

## Input/output rail-to-rail low power operational amplifiers

### Features

- Rail-to-rail input common-mode voltage range
- Rail-to-rail output voltage swing
- Operating from 2.7 V to 12 V
- High-speed (3 MHz, 1 V/μs)
- Low consumption (0.9 mA at 3 V)
- Supply voltage rejection ratio: 80 dB
- Latch-up immunity
- Available in SOT23-5 micropackage

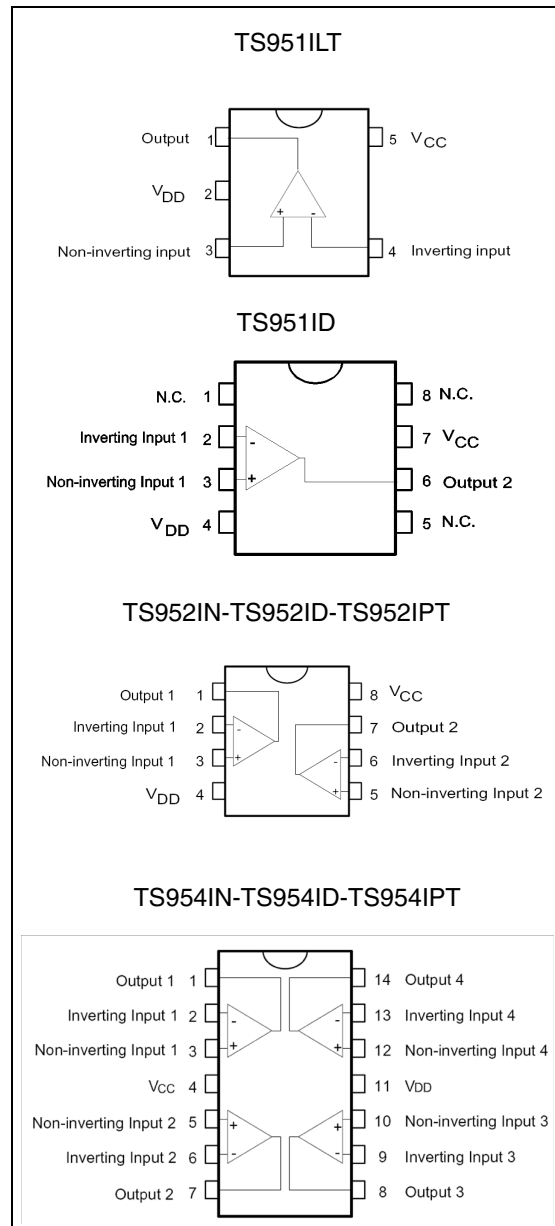
### Applications

- Set-top boxes
- Laptop/notebook computers
- Transformer/line drivers
- Personal entertainment (CD players)
- Portable communications (cell phones, pagers)
- Instrumentation and sensing
- Digital-to-analog converter buffers
- Portable headphone speaker drivers

### Description

The TS951, TS952 and TS954 family of devices are rail-to-rail BiCMOS operational amplifiers optimized and fully specified for 3 V and 5 V operation.

The TS951 is housed in the space-saving 5-pin SOT23 package that makes it well-suited for battery-powered systems. This micropackage simplifies the PC board design because of its ability to be placed in tight spaces (outside dimensions are: 2.8 mm x 2.9 mm).



# 1 Absolute maximum ratings and operating conditions

**Table 1. Absolute maximum ratings**

Symbol	Parameter	Value	Unit
$V_{CC}$	Supply voltage <sup>(1)</sup>	14	V
$V_{id}$	Differential input voltage <sup>(2)</sup>	$\pm 1$	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>		
	SOT23-5	250	°C/W
	SO-8	125	
	SO-14	103	
	TSSOP8	120	
TSSOP14	100		
$R_{thjc}$	Thermal resistance junction to case <sup>(4)</sup>		
	SOT23-5	81	°C/W
	SO-8	40	
	SO-14	31	
	TSSOP8	37	
TSSOP14	32		
ESD	HBM: human body model <sup>(5)</sup>		kV
	TS951	1	
	TS952	2	
	TS954	3	
	MM: machine model <sup>(6)</sup>	100	V
	CDM: charged device model <sup>(7)</sup>		kV
	TS951	1.5	
	TS952	1.5	
	TS954	1	
	Latch-up immunity	200	mA
	Lead temperature (soldering, 10sec)	260	°C

- 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. If  $V_{id} > \pm 1$  V, the maximum input current must not exceed  $\pm 1$  mA. In this case ( $V_{id} > \pm 1$  V), an input series resistor must be added to limit input current.
- Do not exceed 14 V.
- Short-circuits can cause excessive heating and destructive dissipation.  $R_{th}$  are typical values.
- Human body model: a 100 pF capacitor is charged to the specified voltage, then discharged through a 1.5 k $\Omega$  resistor between two pins of the device. This is done for all couples of connected pin combinations while the other pins are 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  $\Omega$ ). This is done for all couples of connected pin combinations while the other pins are floating.
- 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.

**Table 2. Operating conditions**

Symbol	Parameter	Value	Unit
$V_{CC}$	Supply voltage	2.7 to 12	V
$V_{ICM}$	Common mode input voltage range	$V_{DD} - 0.2$ to $V_{CC} + 0.2$	V
$T_{oper}$	Operating free air temperature range	-40 to +125	°C

## 2 Electrical characteristics

**Table 3.**  $V_{CC} = +3\text{ V}$ ,  $V_{DD} = 0\text{ V}$ ,  $R_L$  connected to  $V_{CC}/2$ ,  $T_{amb} = 25^\circ\text{ C}$   
(unless otherwise specified)

Symbol	Parameter	Min.	Typ.	Max.	Unit
$V_{io}$	Input offset voltage $T_{min} \leq T_{amb} \leq T_{max}$			6 8	mV
$DV_{io}$	Input offset voltage drift		2		$\mu\text{V}/^\circ\text{C}$
$I_{io}$	Input offset current $T_{min} \leq T_{amb} \leq T_{max}$		1	30 80	nA
$I_{ib}$	Input bias current $V_{icm} = V_{CC}/2$ $T_{min} \leq T_{amb} \leq T_{max}$		35	100 200	nA
CMR	Common mode rejection ratio	50	80		dB
SVR	Supply voltage rejection ratio $V_{CC} = 2.7\text{ V to } 3.3\text{ V}$	60	80		dB
$A_{vd}$	Large signal voltage gain $V_o = 2 V_{pk-pk}$ , $R_L = 600\ \Omega$		80		dB
$V_{OH}$	High level output voltage $R_L = 600\ \Omega$	2.8	2.9		V
$V_{OL}$	Low level output voltage $R_L = 600\ \Omega$		80	250	mV
$I_{sc}$	Output short-circuit current	10			mA
$I_{CC}$	Supply current (per amplifier) No load, $V_{icm} = V_{CC}/2$		0.9	1.3	mA
GBP	Gain bandwidth product $R_L = 2\text{ k}\Omega$		3		MHz
SR	Slew rate		1		V/ $\mu\text{s}$
$\phi_m$	Phase margin at unit gain $R_L = 600\ \Omega$ , $C_L = 100\text{ pF}$		60		Degrees
Gm	Gain margin $R_L = 600\ \Omega$ , $C_L = 100\text{ pF}$		10		dB
$e_n$	Equivalent input noise voltage $f = 1\text{ kHz}$		25		$\frac{\text{nV}}{\sqrt{\text{Hz}}}$
THD	Total harmonic distortion $V_{out} = 4 V_{pk-pk}$ , $F = 10\text{ kHz}$ , $A_V = 2$ , $R_L = 10\text{ k}\Omega$		0.01		%

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

Symbol	Parameter	Min.	Typ.	Max.	Unit
$V_{io}$	Input offset voltage $T_{min} \leq T_{amb} \leq T_{max}$			6 8	mV
$DV_{io}$	Input offset voltage drift		2		$\mu\text{V}/^\circ\text{C}$
$I_{io}$	Input offset current $V_{icm} = V_{CC}/2$ $T_{min} \leq T_{amb} \leq T_{max}$		1	30 80	nA
$I_{ib}$	Input bias current $V_{icm} = V_{CC}/2$ $T_{min} \leq T_{amb} \leq T_{max}$		35	100 200	nA
CMR	Common mode rejection ratio	50	80		dB
SVR	Supply voltage rejection ratio $V_{CC} = 2.7\text{ V to } 3.3\text{ V}$	60	80		dB
$A_{vd}$	Large signal voltage gain $V_o = 2 V_{pk-pk}$ , $R_L = 600\ \Omega$		86		dB
$V_{OH}$	High level output voltage $R_L = 600\ \Omega$	4.7	4.8		V
$V_{OL}$	Low level output voltage $R_L = 600\ \Omega$		80	300	mV
$I_{sc}$	Output short-circuit current	10			mA
$I_{CC}$	Supply current (per amplifier) No load, $V_{icm} = V_{CC}/2$		0.95	1.4	mA
GBP	Gain bandwidth product $R_L = 2\text{ k}\Omega$		3		MHz
SR	Slew rate		1		$\text{V}/\mu\text{s}$
$\phi_m$	Phase margin at unit gain $R_L = 600\ \Omega$ , $C_L = 100\ \text{pF}$		60		Degrees
Gm	Gain margin $R_L = 600\ \Omega$ , $C_L = 100\ \text{pF}$		10		dB
$e_n$	Equivalent input noise voltage $f = 1\text{ kHz}$		25		$\frac{\text{nV}}{\sqrt{\text{Hz}}}$
THD	Total harmonic distortion $V_{out} = 4 V_{pk-pk}$ , $F = 10\text{ kHz}$ , $A_V = 2$ , $R_L = 10\text{ k}\Omega$		0.01		%

Figure 1. Supply current vs. supply voltage

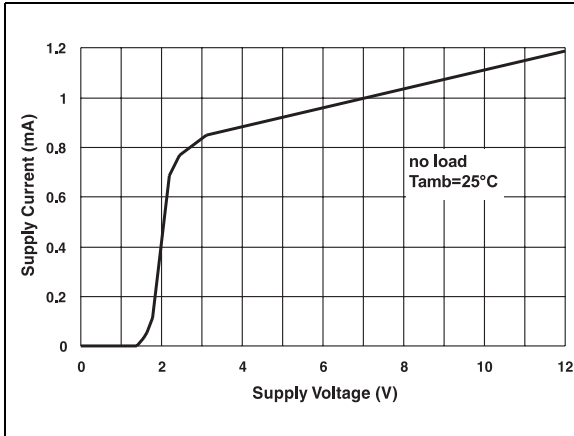


Figure 2. Output short circuit current vs. output voltage

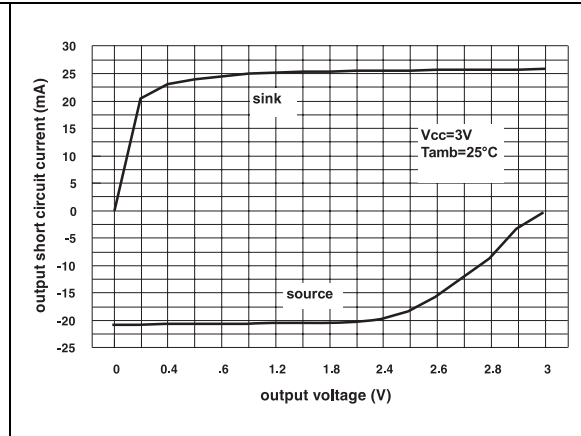


Figure 3. Voltage gain and phase vs. frequency

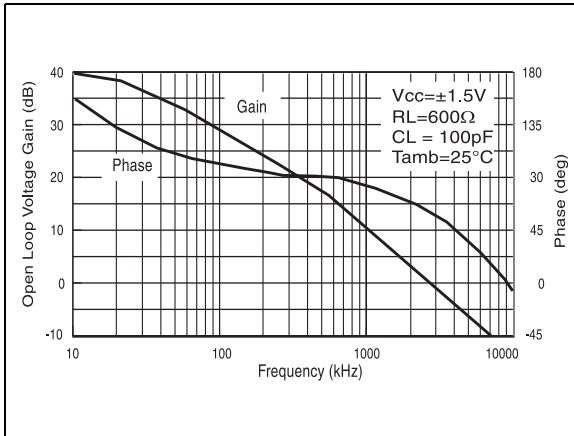


Figure 4. Supply current vs. temperature

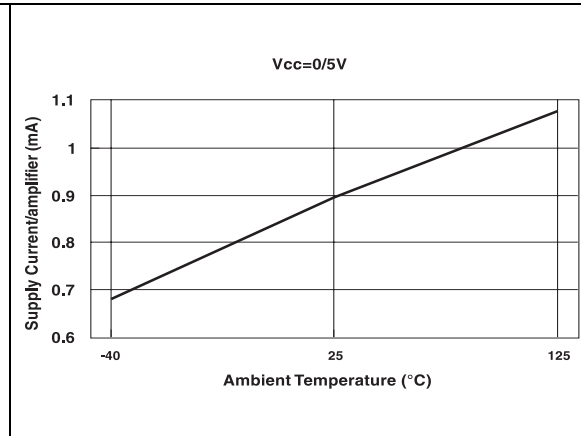


Figure 5. Output short circuit current vs. temperature

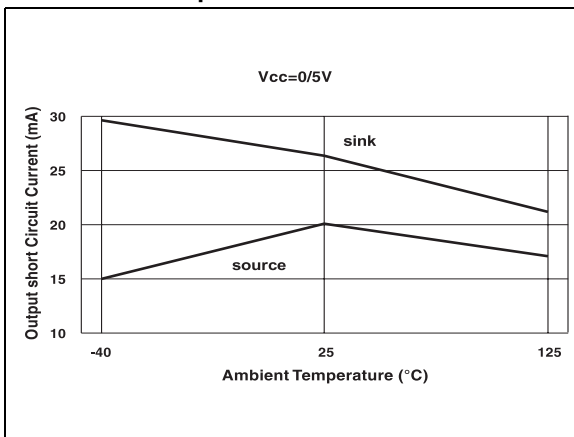


Figure 6. Slew rate vs. temperature

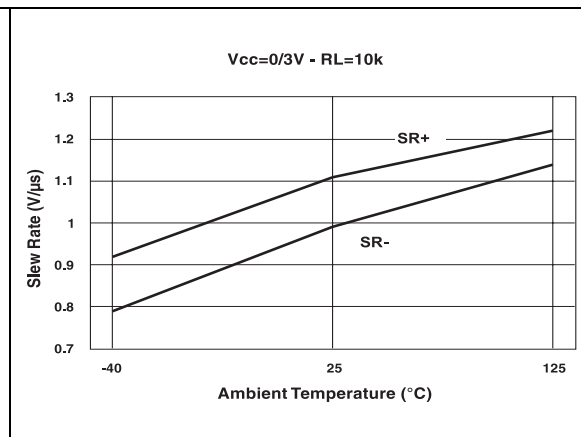


Figure 7. THD + noise vs.  $V_{out}$

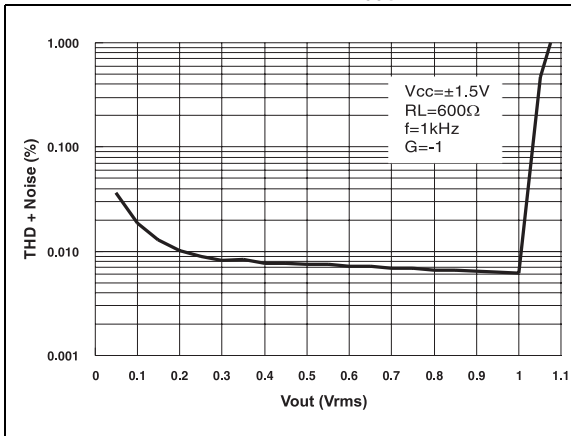


Figure 8. THD + noise vs. frequency

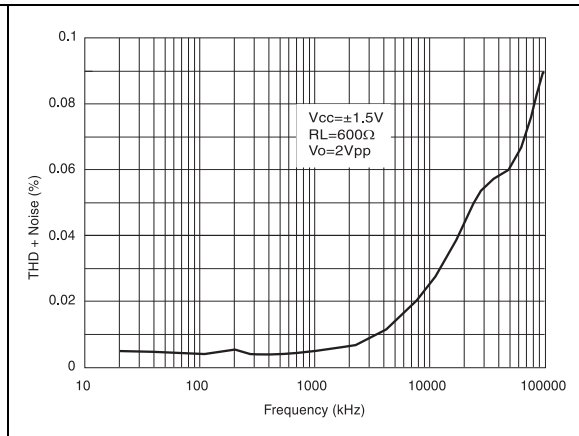


Figure 9. THD + noise vs.  $V_{out}$

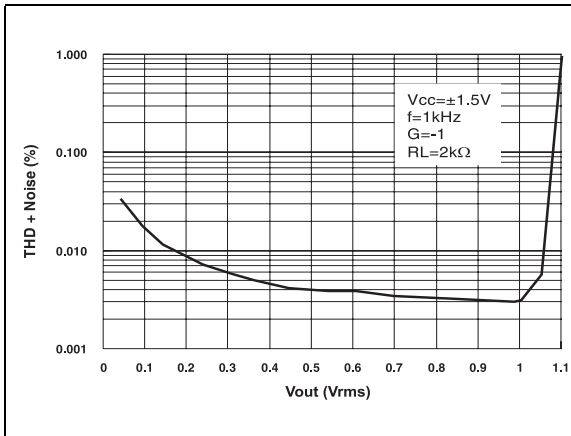
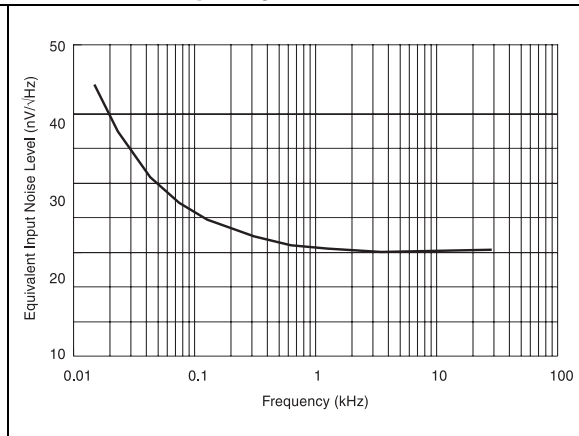


Figure 10. Equivalent input noise voltage vs. frequency



### 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<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.



### 3.1 SOT23-5 package information

Figure 11. SOT23-5 package mechanical drawing

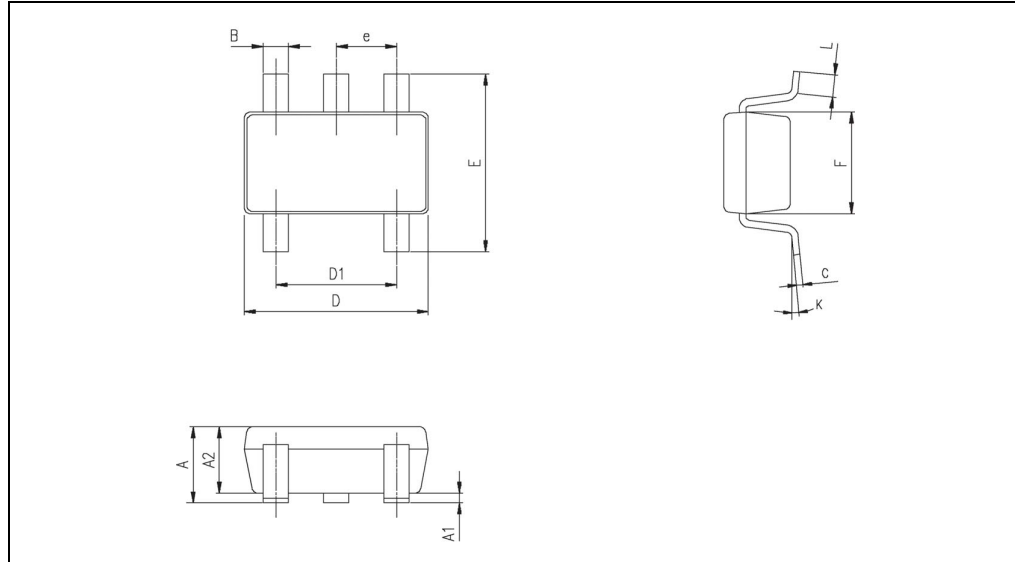


Table 5. SOT23-5 package mechanical data

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			

### 3.2 DIP8 package information

Figure 12. DIP8 package mechanical drawing

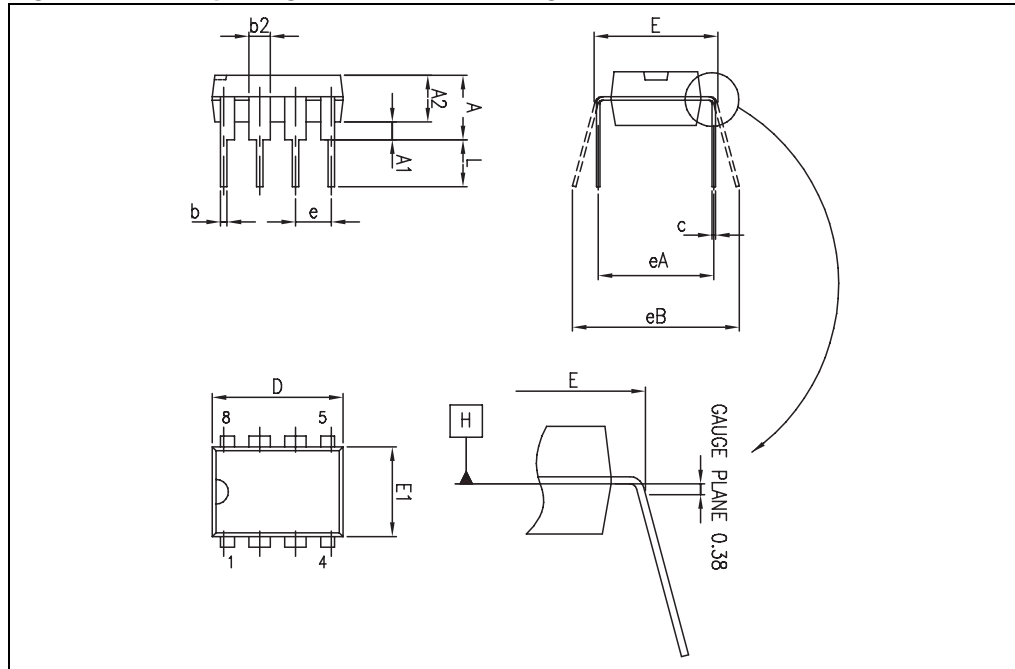


Table 6. DIP8 package mechanical data

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 13. SO-8 package mechanical drawing

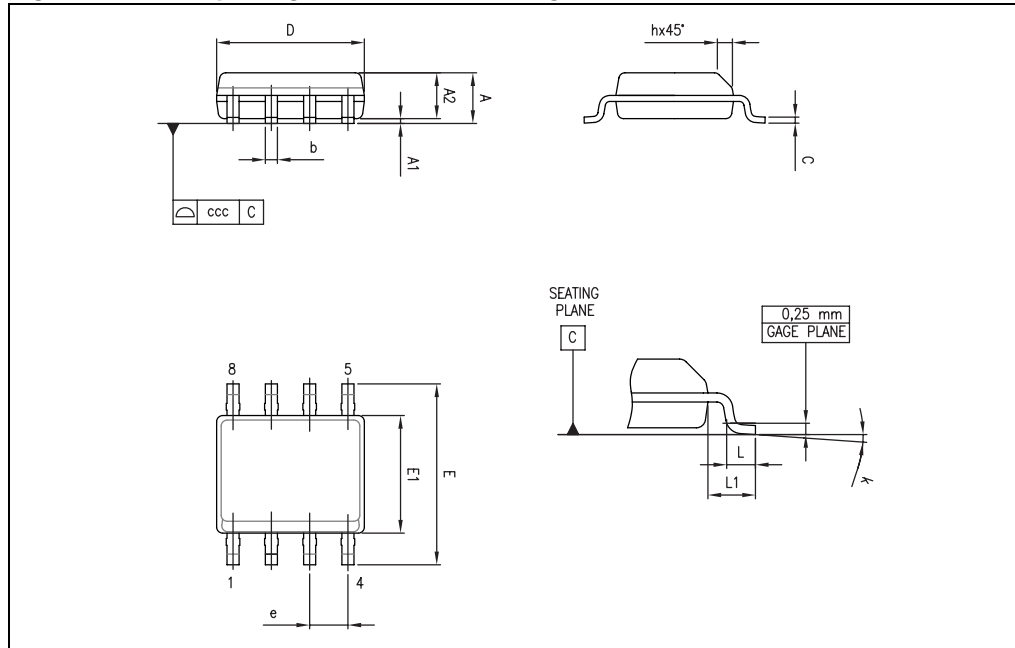


Table 7. SO-8 package mechanical data

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

### 3.4 TSSOP8 package information

Figure 14. TSSOP8 package mechanical drawing

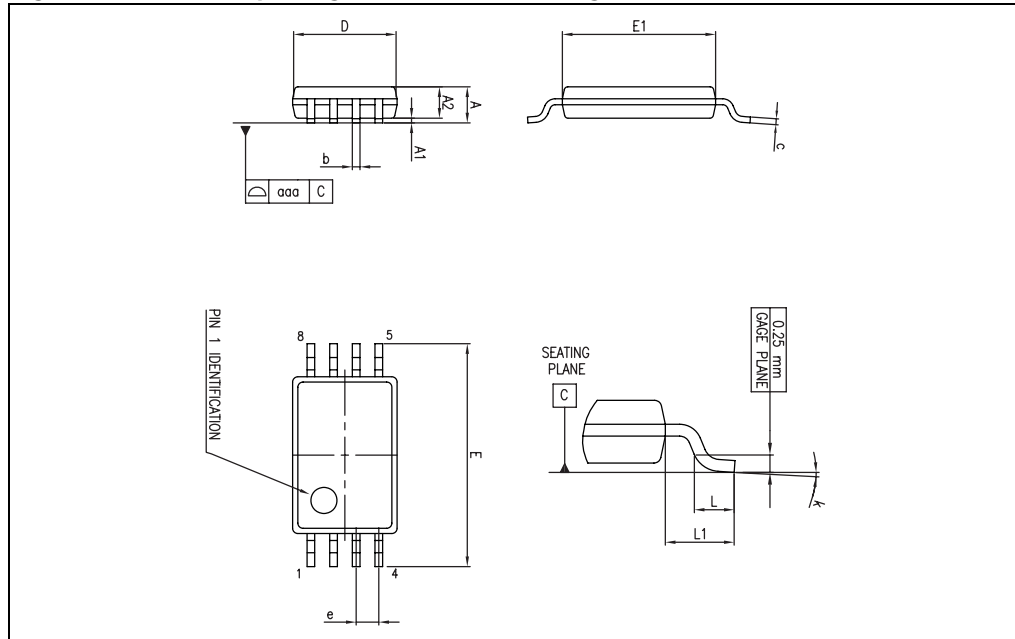


Table 8. TSSOP8 package mechanical data

Ref.	Dimensions					
	Millimeters			Inches		
	Min.	Typ.	Max.	Min.	Typ.	Max.
A			1.20			0.047
A1	0.05		0.15	0.002		0.006
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			0.10			0.004

### 3.5 DIP14 package information

Figure 15. DIP14 package mechanical drawing

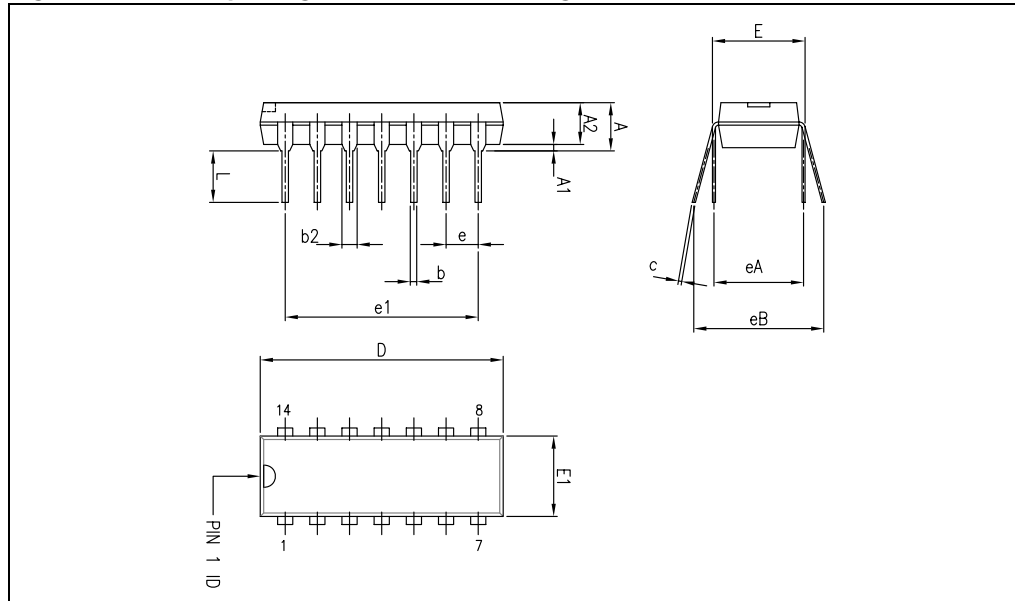


Table 9. DIP14 package mechanical data

Dimensions						
Ref.	Millimeters			Inches		
	Min.	Typ.	Max.	Min.	Typ.	Max.
A			5.33			0.21
A1	0.38			0.015		
A2	2.92	3.30	4.95	0.11	0.13	0.19
b	0.36	0.46	0.56	0.014	0.018	0.022
b2	1.14	1.52	1.78	0.04	0.06	0.07
c	0.20	0.25	0.36	0.007	0.009	0.01
D	18.67	19.05	19.69	0.73	0.75	0.77
E	7.62	7.87	8.26	0.30	0.31	0.32
E1	6.10	6.35	7.11	0.24	0.25	0.28
e		2.54			0.10	
e1		15.24			0.60	
eA		7.62			0.30	
eB			10.92			0.43
L	2.92	3.30	3.81	0.11	0.13	0.15

### 3.6 SO-14 package information

Figure 16. SO-14 package mechanical drawing

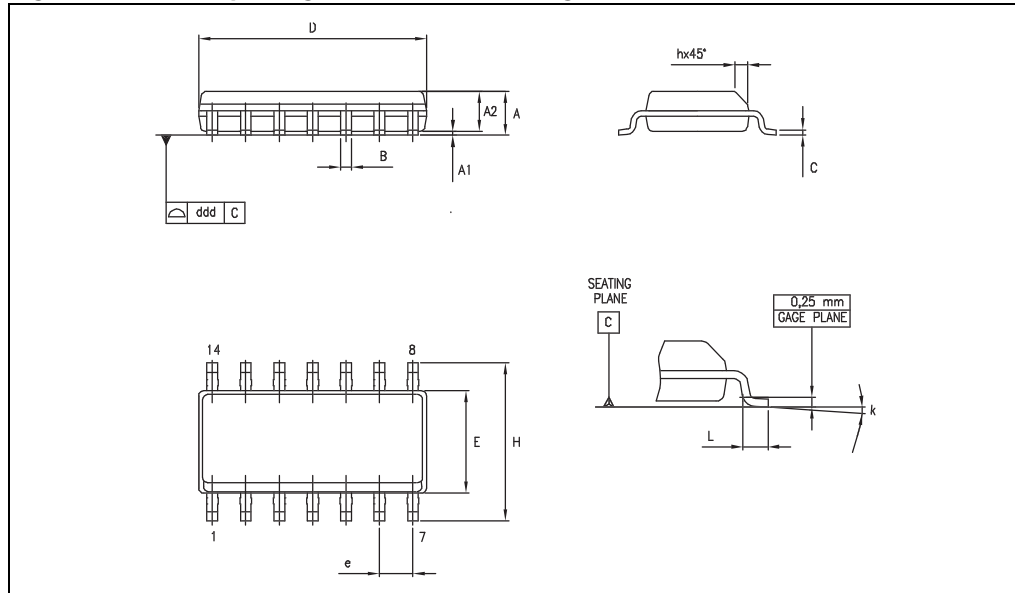


Table 10. SO-14 package mechanical data

Ref.	Dimensions					
	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

### 3.7 TSSOP14 package information

Figure 17. TSSOP14 package mechanical drawing

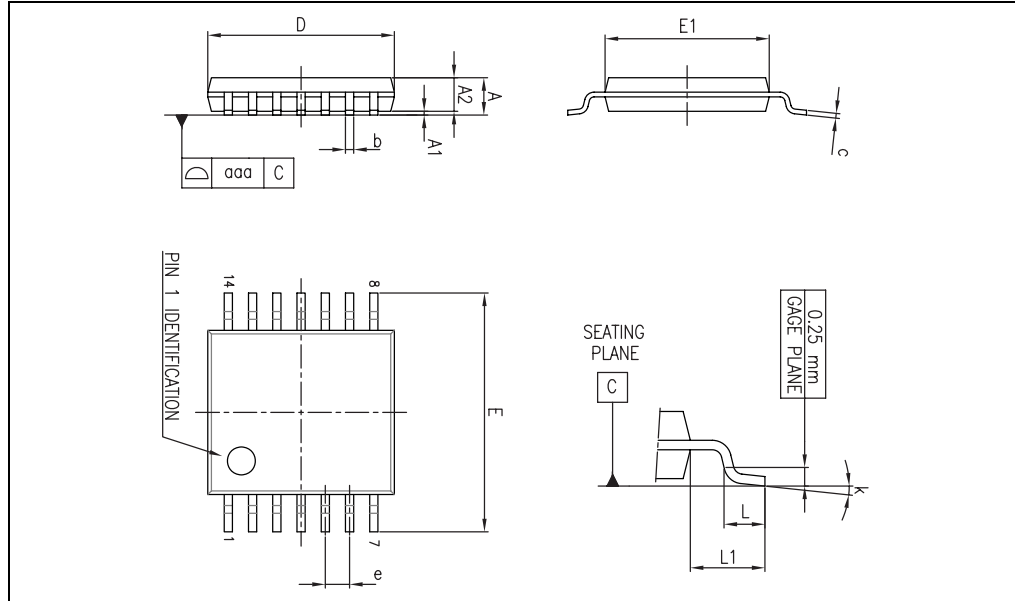


Table 11. TSSOP14 package mechanical data

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

## 4 Ordering information

**Table 12. Order codes**

Order code	Temperature range	Package	Packing	Marking
TS951ID TS951IDT	-40°C to +125°C	SO-8	Tube or Tape & reel	951I
TS951ILT		SOT23-5L	Tape & reel	K10I
TS951IYLT <sup>(1)</sup>		SOT23-5L (Automotive grade)		K1A2
TS952IN		DIP8	Tube	TS952IN
TS952ID TS952IDT		SO-8	Tube or Tape & reel	952I
TS952IYD <sup>(1)</sup> TS952IYDT <sup>(1)</sup>		SO-8 (Automotive grade)		952IY
TS952IPT		TSSOP8	Tape & reel	952I
TS952IYPT <sup>(2)</sup>		TSSOP8 (Automotive grade)		952Y
TS954IN		DIP14	Tube	TS954IN
TS954ID TS954IDT		SO-14	Tube or Tape & reel	954I
TS954IYD <sup>(1)</sup> TS954IYDT <sup>(1)</sup>		SO-14 (Automotive grade)		954IY
TS954IPT		TSSOP14	Tape & reel	954I
TS954IYPT <sup>(2)</sup>		TSSOP14 (Automotive grade)		954Y

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
01-May-2001	1	Initial release.
02-Jan-2005	2	Modifications on AMR <a href="#">Table 1 on page 2</a> (explanation of $V_{id}$ and $V_i$ limits, ESD MM and CDM values added, $R_{thja}$ added).
03-Jul-2005	3	PPAP references inserted in the datasheet see <a href="#">Table 12: Order codes</a> .
04-Aug-2005	4	Table data was badly formatted, see <a href="#">Table 4 on page 5</a> .
15-Dec-2005	5	TS951IYLT PPAP reference added, see <a href="#">Table 12: Order codes</a> .
10-Dec-2007	6	Added missing order codes, and automotive grade status in <a href="#">Table 12: Order codes</a> . Updated footnotes for ESD parameters in <a href="#">Table 1: Absolute maximum ratings</a> . Reformatted package information.
10-Mar-2009	7	Removed TS951IN and TS951IYD/DT from <a href="#">Table 12: Order codes</a> .
24-Feb-2011	8	Changed TS951IYLT marking and updated automotive grade status in <a href="#">Table 12: Order codes</a> .

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