



## TS9222, TS9224

### High precision, high stability dual and quad operational amplifiers

#### Features

- High precision:  $V_{io} = 500 \mu\text{V max}$
- Able to drive capacitive loads up to 500 pF
- Rail-to-rail input and output
- Low noise:  $9 \text{ nV}/\sqrt{\text{Hz}}$
- Low distortion
- High output current: 80 mA
- High speed: 4 MHz, 1.3 V/ $\mu\text{s}$
- Operates from 2.7 V to 12 V
- ESD internal protection: 2 kV
- Latch-up immunity

#### Applications

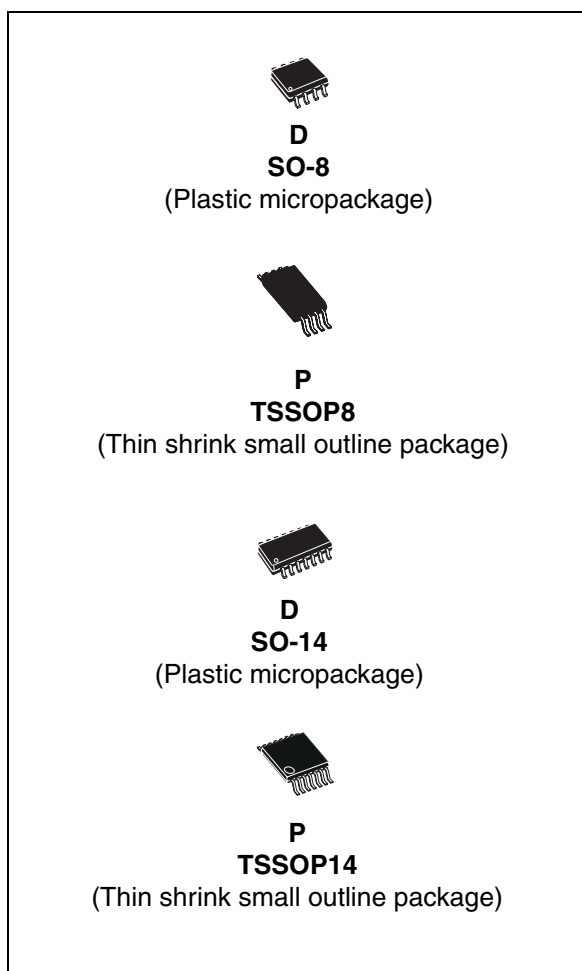
- Signal conditioning
- Automotive applications
- Headphone amplifiers
- Sound cards, multimedia systems
- Line and actuator drivers
- Servo amplifiers

www.DataSheet4U.com

#### Description

The TS9222 and TS9224 are rail-to-rail dual and quad operational amplifiers optimized for precision, noise and stability, which make them suitable for a wide range of automotive and industrial applications.

These devices deliver a high output current that allows low-load impedances to be driven. They are stable for capacitive loads up to 500 pF.



# 1 Absolute maximum ratings and operating conditions

**Table 1. Absolute maximum ratings (AMR)**

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	-65 to +150	°C
$R_{thja}$	Thermal resistance junction to ambient <sup>(4)</sup>		
	SO-8	125	°C/W
	TSSOP8	120	
	SO-14	66	
TSSOP14	100		
$T_j$	Maximum junction temperature	150	°C
ESD	HBM: human body model <sup>(5)</sup>	2000	V
	MM: machine model <sup>(6)</sup>	100	
	CDM: charged device model <sup>(7)</sup>	1500	
	Output short circuit duration	see note <sup>(8)</sup>	
	Latch-up immunity	200	mA
	Soldering temperature (10 sec), unleaded version	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. Destructive dissipation can result from simultaneous short-circuits on all amplifiers. These values are typical.
- Human body model: a 100 pF capacitor is charged to the specified voltage, then discharged through a 1.5k $\Omega$  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.
- There is no short-circuit protection inside the device: short-circuits from the output to  $V_{CC}$  can cause excessive heating. The maximum output current is approximately 80mA, 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	2.7 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. Electrical characteristics measured at  $V_{CC} = +3\text{ V}$ ,  $V_{DD} = 0\text{ V}$ ,  $V_{icm} = V_{CC}/2$ ,  $T_{amb} = 25^\circ\text{ C}$ , and  $R_L$  connected to  $V_{CC}/2$  (unless otherwise specified)**

Symbol	Parameter	Test conditions	Min.	Typ.	Max.	Unit
$V_{io}$	Input offset voltage				500	$\mu\text{V}$
		$T_{min} \leq T_{amb} \leq T_{max}$			900	
$DV_{io}$	Input offset voltage drift			2		$\mu\text{V}/^\circ\text{C}$
$I_{io}$	Input offset current	$V_{out} = V_{CC}/2$ , $T_{min} \leq T_{amb} \leq T_{max}$		1	30	nA
$I_{ib}$	Input bias current	$V_{out} = V_{CC}/2$ $T_{min} \leq T_{amb} \leq T_{max}$		15	55 90	nA
CMR	Common mode rejection ratio	$T_{min} \leq T_{amb} \leq T_{max}$	65 60	85		dB
SVR	Supply voltage rejection ratio	$V_{CC} = 2.7$ to $3.3\text{ V}$ $T_{min} \leq T_{amb} \leq T_{max}$	75 70	90		dB
$A_{vd}$	Large signal voltage gain	$R_L = 10\text{ k}\Omega$ , $V_{out} = 2\text{ V}_{p-p}$ $T_{min} \leq T_{amb} \leq T_{max}$	70	200		V/mV
		$R_L = 600\ \Omega$ , $V_{out} = 2\text{ V}_{p-p}$ $T_{min} \leq T_{amb} \leq T_{max}$	15	35		
$V_{OH}$	High level output voltage	$R_L = 10\text{ k}\Omega$ , $T_{min} \leq T_{amb} \leq T_{max}$	2.90			V
		$R_L = 600\ \Omega$ , $T_{min} \leq T_{amb} \leq T_{max}$	2.87			V
$V_{OL}$	Low level output voltage	$R_L = 10\text{ k}\Omega$ , $T_{min} \leq T_{amb} \leq T_{max}$			50	mV
		$R_L = 600\ \Omega$ , $T_{min} \leq T_{amb} \leq T_{max}$			100	mV
$I_o$	Output short circuit current		50	80		mA
$I_{CC}$	Supply current (per operator)	No load, $V_{out} = V_{CC}/2$ $T_{min} \leq T_{amb} \leq T_{max}$		0.9	1.2 1.3	mA
GBP	Gain bandwidth product	$R_L = 10\text{ k}\Omega$ , $C_L = 100\text{ pF}$		4		MHz
SR	Slew rate	$R_L = 10\text{ k}\Omega$ , $C_L = 100\text{ pF}$		1.3		V/ $\mu\text{s}$
$\phi_m$	Phase margin at unit gain	$R_L = 10\text{ k}\Omega$ , $C_L = 100\text{ pF}$		60		Degrees
$G_m$	Gain margin	$R_L = 10\text{ k}\Omega$ , $C_L = 100\text{ pF}$		8.5		dB
$e_n$	Equivalent input noise voltage	$f = 1\text{ kHz}$		9		$\frac{\text{nV}}{\sqrt{\text{Hz}}}$
THD	Total harmonic distortion	$V_{out} = 2\text{ V}_{p-p}$ , $f = 1\text{ kHz}$ , $A_v = 1$ , $R_L = 600\ \Omega$		0.005		%
$C_s$	Channel separation			120		dB

## Electrical characteristics

TS9222, TS9224

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

Symbol	Parameter	Conditions	Min.	Typ.	Max.	Unit
$V_{io}$	Input offset voltage				500	$\mu\text{V}$
		$T_{min} \leq T_{amb} \leq T_{max}$			900	
$DV_{io}$	Input offset voltage drift			2		$\mu\text{V}/^\circ\text{C}$
$I_{io}$	Input offset current	$V_{out} = V_{CC}/2$ , $T_{min} \leq T_{amb} \leq T_{max}$		1	30	nA
$I_{ib}$	Input bias current	$V_{out} = V_{CC}/2$ $T_{min} \leq T_{amb} \leq T_{max}$		15	55 90	nA
CMR	Common mode rejection ratio	$T_{min} \leq T_{amb} \leq T_{max}$	65 60	85		dB
SVR	Supply voltage rejection ratio	$V_{CC} = 4.5\text{ to }5.5\text{ V}$ $T_{min} \leq T_{amb} \leq T_{max}$	75 70	90		dB
$A_{vd}$	Large signal voltage gain	$R_L = 10\text{ k}\Omega$ , $V_{out} = 2\text{ V}_{p-p}$ $T_{min} \leq T_{amb} \leq T_{max}$	70	200		V/mV
		$R_L = 600\ \Omega$ , $V_{out} = 2\text{ V}_{p-p}$ $T_{min} \leq T_{amb} \leq T_{max}$	20	35		
$V_{OH}$	High level output voltage	$R_L = 10\text{ k}\Omega$ , $T_{min} \leq T_{amb} \leq T_{max}$	4.9			V
		$R_L = 600\ \Omega$ , $T_{min} \leq T_{amb} \leq T_{max}$	4.85			
$V_{OL}$	Low level output voltage	$R_L = 10\text{ k}\Omega$ , $T_{min} \leq T_{amb} \leq T_{max}$			50	mV
		$R_L = 600\ \Omega$ , $T_{min} \leq T_{amb} \leq T_{max}$			120	
$I_o$	Output short circuit current		50	80		mA
$I_{cc}$	Supply current (per operator)	No load, $V_{out} = V_{CC}/2$ $T_{min} \leq T_{amb} \leq T_{max}$		0.9	1.2 1.3	mA
GBP	Gain bandwidth product	$R_L = 10\text{ k}\Omega$ , $C_L = 100\text{ pF}$		4		MHz
SR	Slew rate	$R_L = 10\text{ k}\Omega$ , $C_L = 100\text{ pF}$		1.3		V/ $\mu\text{s}$
$\phi_m$	Phase margin at unit gain	$R_L = 10\text{ k}\Omega$ , $C_L = 100\text{ pF}$		63		Degrees
$G_m$	Gain margin	$R_L = 10\text{ k}\Omega$ , $C_L = 100\text{ pF}$		9.5		dB
$e_n$	Equivalent input noise voltage	$f = 1\text{ kHz}$		9		$\frac{\text{nV}}{\sqrt{\text{Hz}}}$
THD	Total harmonic distortion	$V_{out} = 2\text{ V}_{p-p}$ , $f = 1\text{ kHz}$ , $A_v = 1$ , $R_L = 600\ \Omega$		0.005		%
$C_s$	Channel separation			120		dB

Figure 1. Total supply current vs. supply voltage

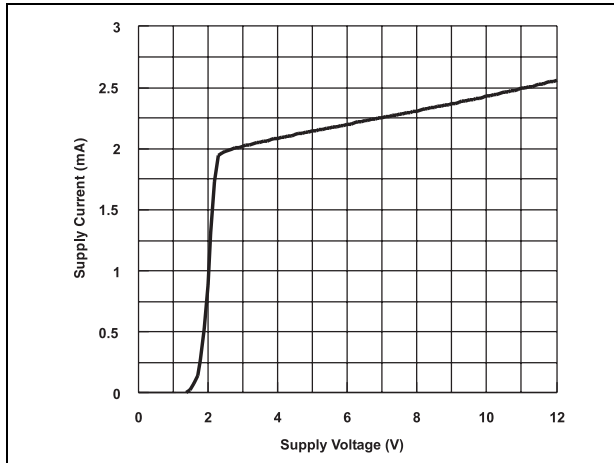


Figure 2. Output short circuit current vs. output voltage

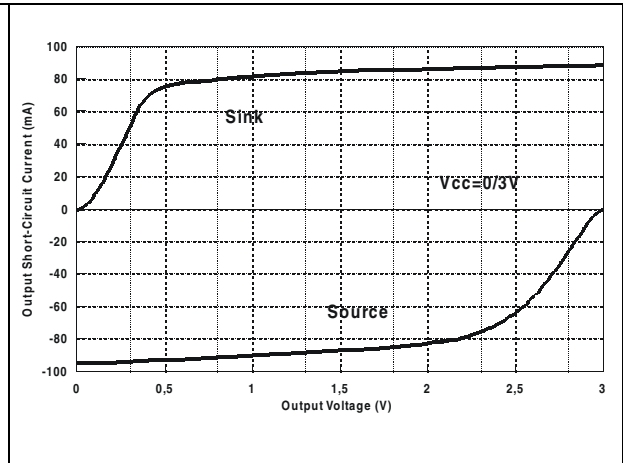


Figure 3. Voltage gain and phase vs. frequency,  $C_L = 100 \text{ pF}$

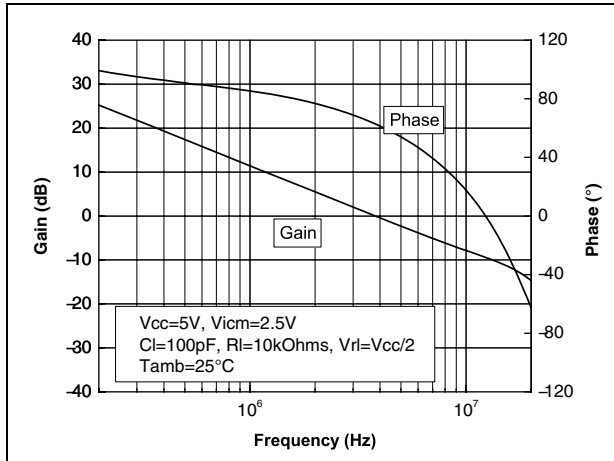
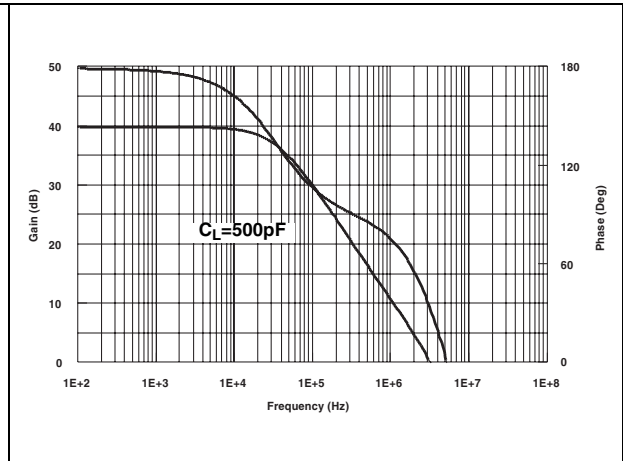


Figure 4. Voltage gain and phase vs. frequency,  $C_L = 500 \text{ pF}$



www.DataSheet4U.com

Figure 5. Equivalent input noise voltage vs. frequency

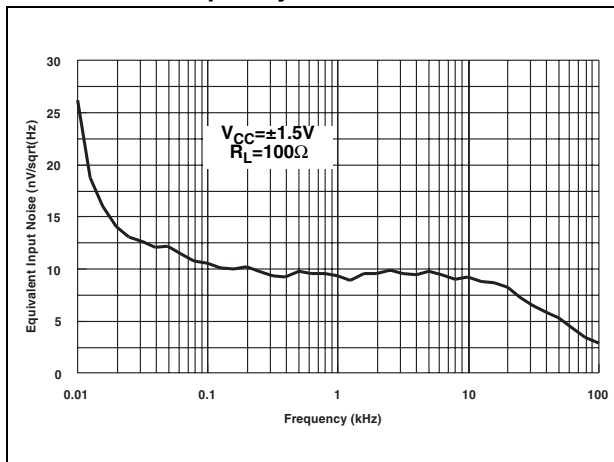
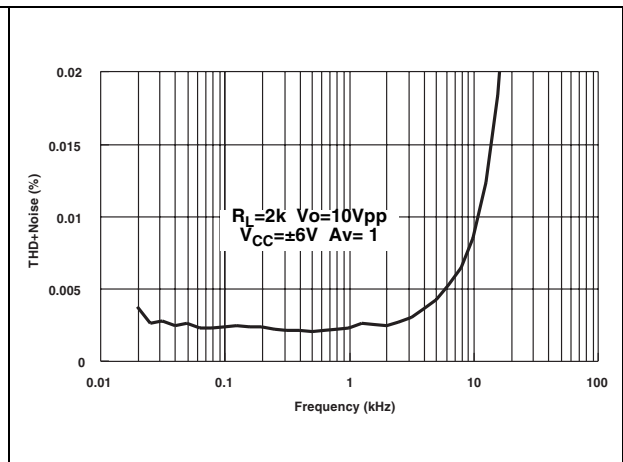


Figure 6. THD + noise vs. frequency



Electrical characteristics

TS9222, TS9224

Figure 7. THD + noise vs. frequency

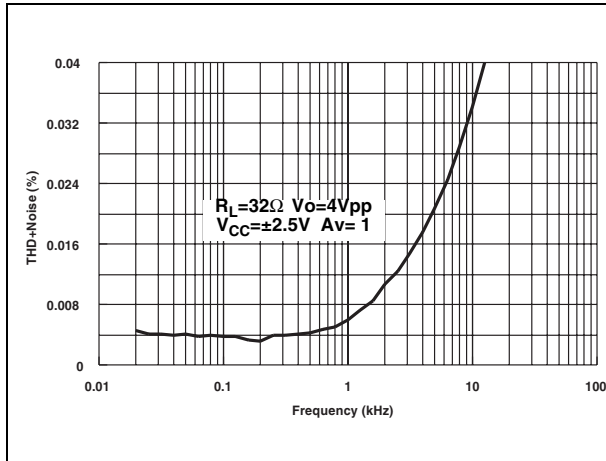


Figure 8. THD + noise vs. frequency

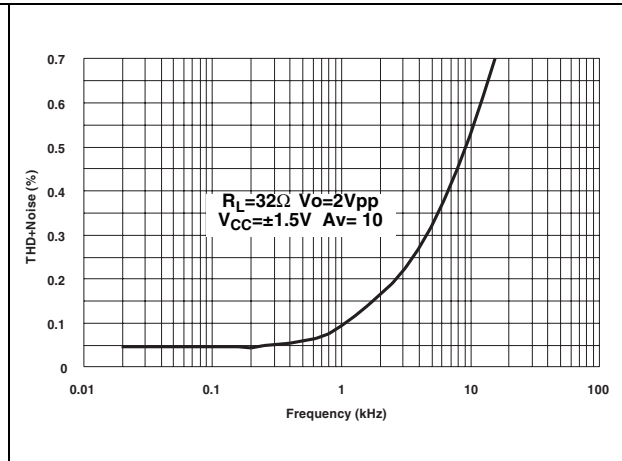


Figure 9. THD + noise vs. output voltage

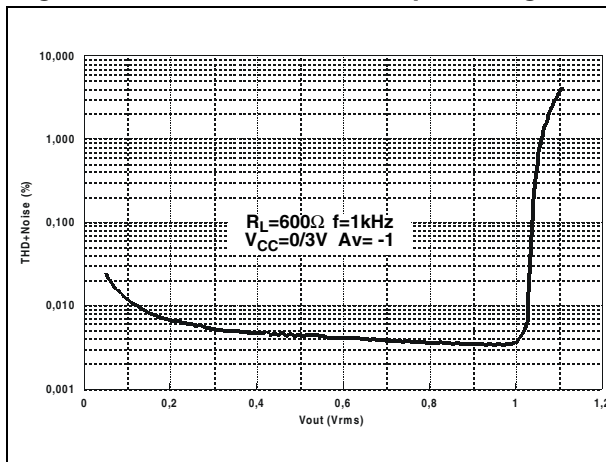


Figure 10. THD + noise vs. output voltage

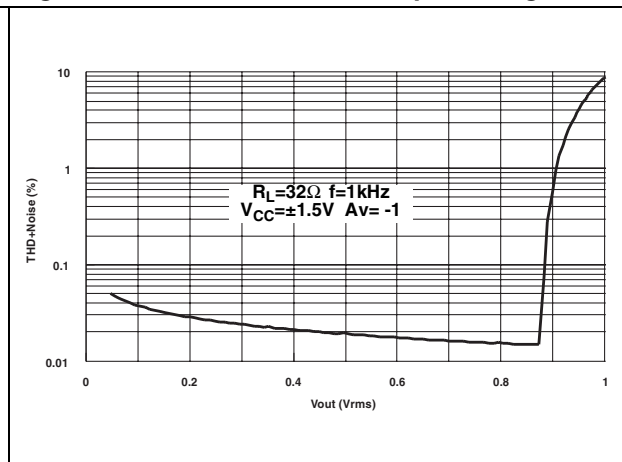
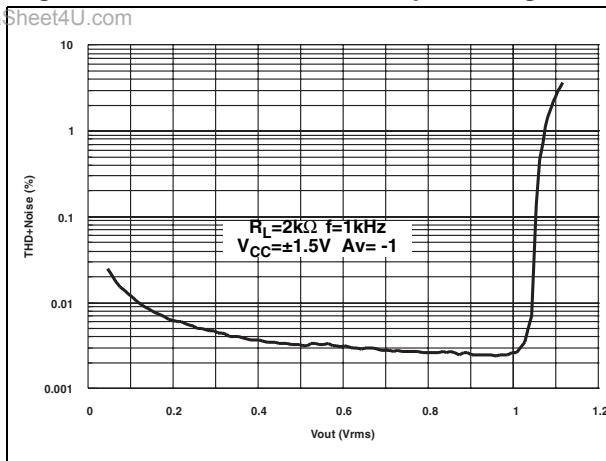


Figure 11. THD + noise vs. output voltage



www.DataSheet4U.com

### 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 SO-8 package information

Figure 12. SO-8 package mechanical drawing

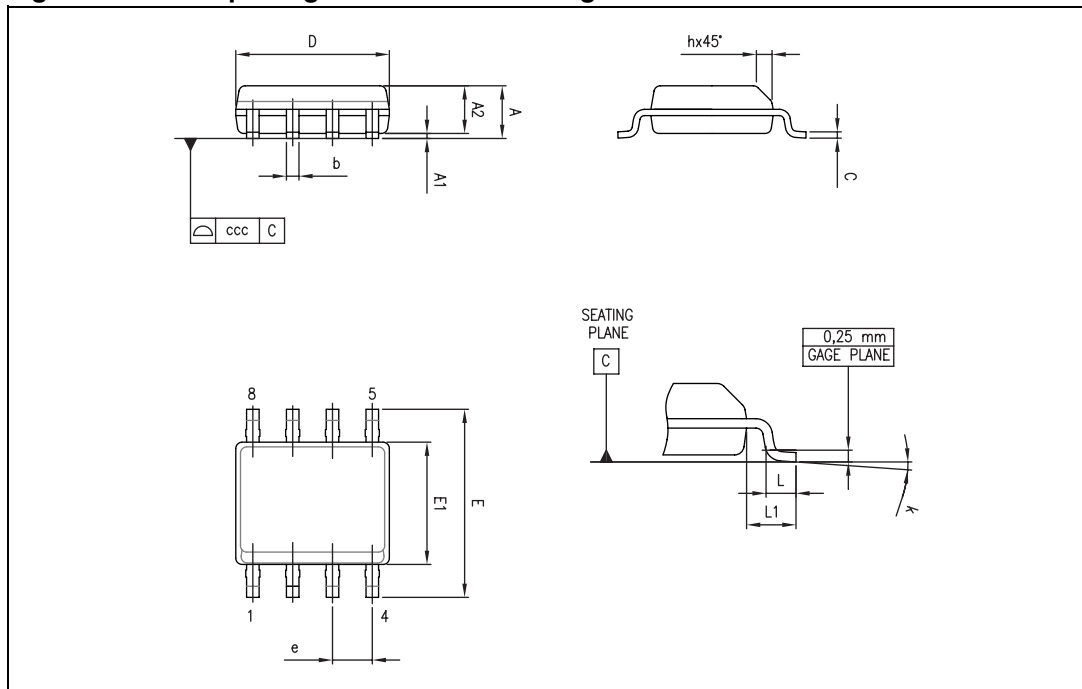


Table 5. SO-8 package mechanical data

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	0		8°	1°		8°
ccc			0.10			0.004



### 3.2 TSSOP8 package information

Figure 13. TSSOP8 package mechanical drawing

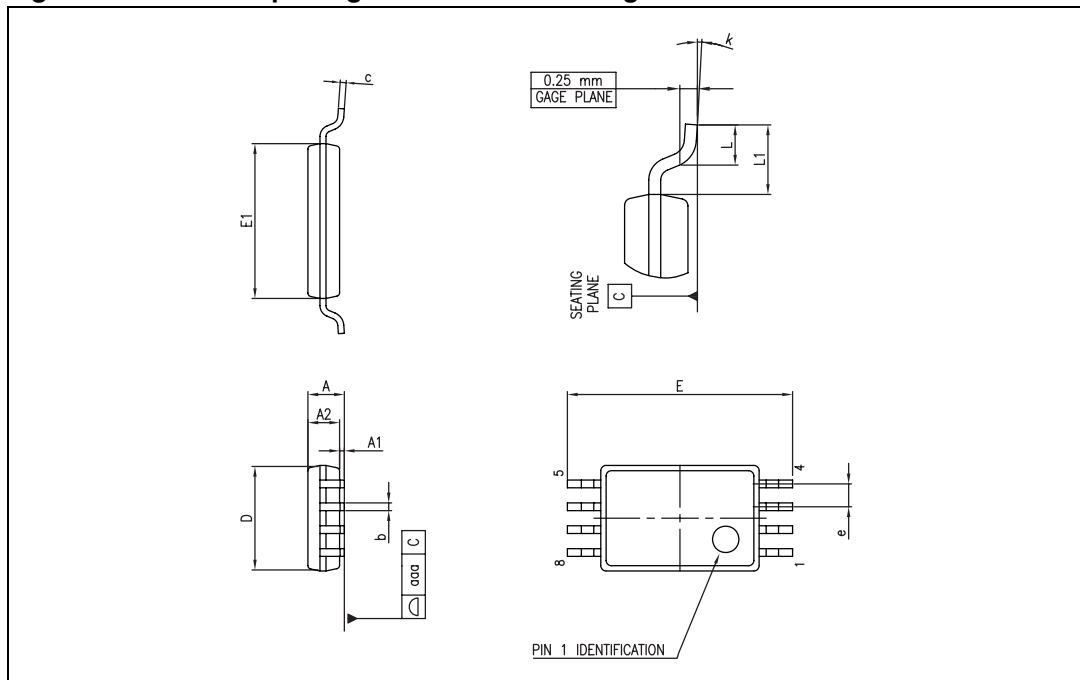


Table 6. TSSOP8 package mechanical data

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

### 3.3 SO-14 package information

Figure 14. SO-14 package mechanical drawing

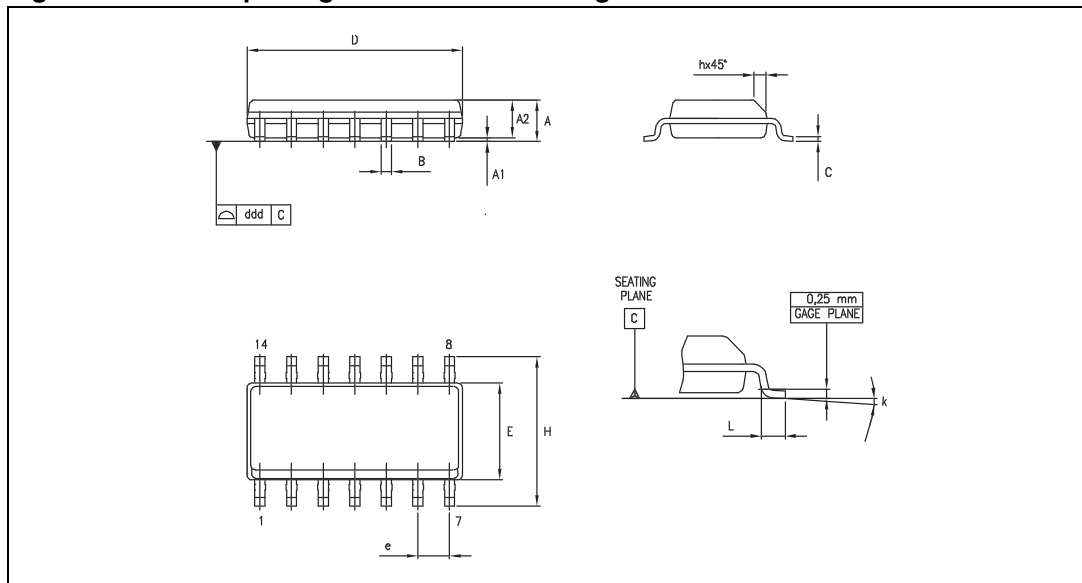


Table 7. SO-14 package mechanical data

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

### 3.4 TSSOP14 package information

Figure 15. TSSOP14 package mechanical drawing

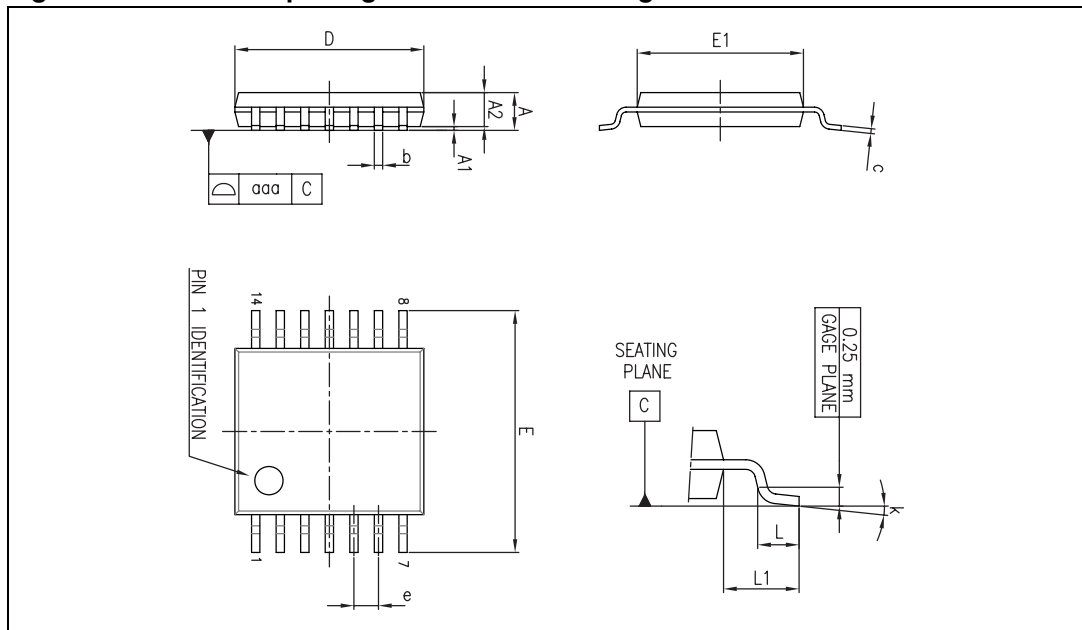


Table 8. TSSOP14 package mechanical data

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

## 4 Ordering information

**Table 9. Order codes**

Order code	Temperature range	Package	Packaging	Marking
TS9222ID TS9222IDT	-40° C, +125° C	SO-8	Tube or Tape & reel	9222
TS9222IPT		TSSOP8	Tape & reel	9222
TS9224ID TS9224IDT		SO-14	Tube or Tape & reel	9224
TS9224IPT		TSSOP14	Tape & reel	9224
TS9222IYDT <sup>(1)</sup>		SO-8 (automotive grade)	Tape & reel	9222Y
TS9222IYPT <sup>(2)</sup>		TSSOP8 (automotive grade)	Tape & reel	9222Y
TS9224IYDT <sup>(1)</sup>		SO-14 (automotive grade)	Tape & reel	9224Y
TS9224IYPT <sup>(1)</sup>		TSSOP14 (automotive grade)	Tape & reel	9224Y

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 10. Document revision history

Date	Revision	Changes
25-Sep-2009	1	Initial release.

**Please Read Carefully:**

Information in this document is provided solely in connection with ST products. STMicroelectronics NV and its subsidiaries ("ST") reserve the right to make changes, corrections, modifications or improvements, to this document, and the products and services described herein at any time, without notice.

All ST products are sold pursuant to ST's terms and conditions of sale.

Purchasers are solely responsible for the choice, selection and use of the ST products and services described herein, and ST assumes no liability whatsoever relating to the choice, selection or use of the ST products and services described herein.

No license, express or implied, by estoppel or otherwise, to any intellectual property rights is granted under this document. If any part of this document refers to any third party products or services it shall not be deemed a license grant by ST for the use of such third party products or services, or any intellectual property contained therein or considered as a warranty covering the use in any manner whatsoever of such third party products or services or any intellectual property contained therein.

**UNLESS OTHERWISE SET FORTH IN ST'S TERMS AND CONDITIONS OF SALE ST DISCLAIMS ANY EXPRESS OR IMPLIED WARRANTY WITH RESPECT TO THE USE AND/OR SALE OF ST PRODUCTS INCLUDING WITHOUT LIMITATION IMPLIED WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE (AND THEIR EQUIVALENTS UNDER THE LAWS OF ANY JURISDICTION), OR INFRINGEMENT OF ANY PATENT, COPYRIGHT OR OTHER INTELLECTUAL PROPERTY RIGHT.**

**UNLESS EXPRESSLY APPROVED IN WRITING BY AN AUTHORIZED ST REPRESENTATIVE, ST PRODUCTS ARE NOT RECOMMENDED, AUTHORIZED OR WARRANTED FOR USE IN MILITARY, AIR CRAFT, SPACE, LIFE SAVING, OR LIFE SUSTAINING APPLICATIONS, NOR IN PRODUCTS OR SYSTEMS WHERE FAILURE OR MALFUNCTION MAY RESULT IN PERSONAL INJURY, DEATH, OR SEVERE PROPERTY OR ENVIRONMENTAL DAMAGE. ST PRODUCTS WHICH ARE NOT SPECIFIED AS "AUTOMOTIVE GRADE" MAY ONLY BE USED IN AUTOMOTIVE APPLICATIONS AT USER'S OWN RISK.**

www.DataSheet4U.com

Resale of ST products with provisions different from the statements and/or technical features set forth in this document shall immediately void any warranty granted by ST for the ST product or service described herein and shall not create or extend in any manner whatsoever, any liability of ST.

ST and the ST logo are trademarks or registered trademarks of ST in various countries.

Information in this document supersedes and replaces all information previously supplied.

The ST logo is a registered trademark of STMicroelectronics. All other names are the property of their respective owners.

© 2009 STMicroelectronics - All rights reserved

STMicroelectronics group of companies

Australia - Belgium - Brazil - Canada - China - Czech Republic - Finland - France - Germany - Hong Kong - India - Israel - Italy - Japan - Malaysia - Malta - Morocco - Philippines - Singapore - Spain - Sweden - Switzerland - United Kingdom - United States of America

[www.st.com](http://www.st.com)