

## 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,  $1.3 \text{ V}/\mu\text{s}$
- Operates from 2.7 V to 12 V
- ESD internal protection: 2 kV
- Latch-up immunity

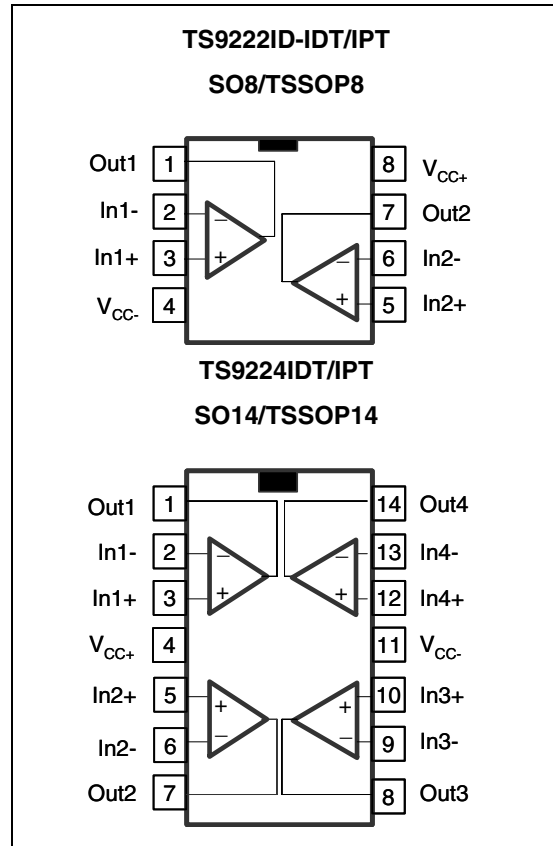
### Applications

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

### 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>	$V_{CC-} - 0.3$ 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	$V_{CC-} - 0.2$ 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  $V_{CC+} = +3\text{ V}$ ,  $V_{CC-} = 0\text{ V}$ ,  $V_{icm} = V_{CC}/2$ ,  $T_{amb} = 25^\circ\text{ C}$ , 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	$R_L = 10\text{ k}\Omega$ , $V_{out} = 2\text{ V}_{p-p}$	70	200		V/mV
		$R_L = 600\ \Omega$ , $V_{out} = 2\text{ V}_{p-p}$ $T_{min} \leq T_{amb} \leq T_{max}$	15 1.8	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		$\frac{nV}{\sqrt{\text{Hz}}}$
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

**Table 4. Electrical characteristics measured at  $V_{CC+} = 5\text{ V}$ ,  $V_{CC-} = 0\text{ V}$ ,  $V_{icm} = V_{CC}/2$ ,  $T_{amb} = 25^\circ\text{ C}$ , 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	$R_L = 10\text{ k}\Omega$ , $V_{out} = 2\text{ V}_{p-p}$	70	200		V/mV
		$R_L = 600\ \Omega$ , $V_{out} = 2\text{ V}_{p-p}$ $T_{min} \leq T_{amb} \leq T_{max}$	24 3	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		$\frac{nV}{\sqrt{\text{Hz}}}$
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

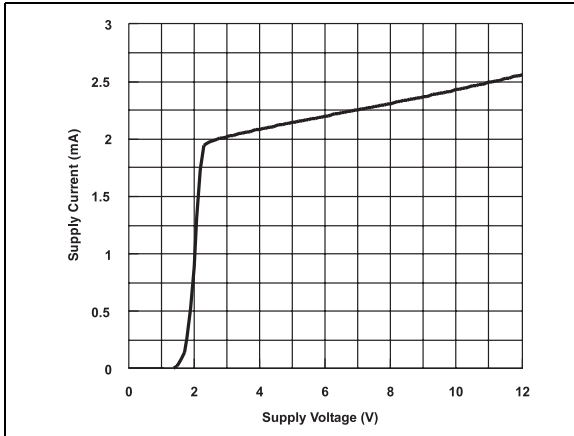


Figure 2. Output short circuit current vs. output voltage

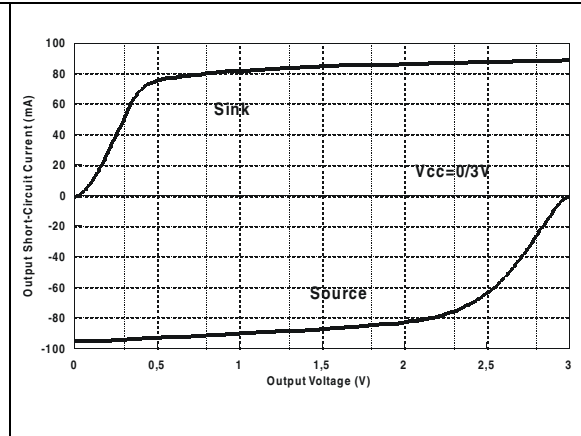


Figure 3. Voltage gain and phase vs. frequency,  $C_L = 100 \text{ pF}$

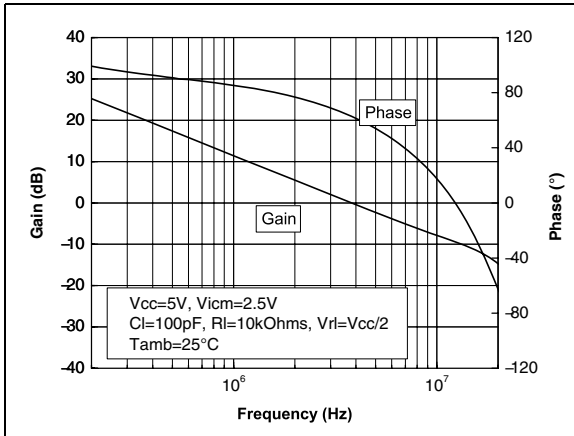


Figure 4. Voltage gain and phase vs. frequency,  $C_L = 500 \text{ pF}$

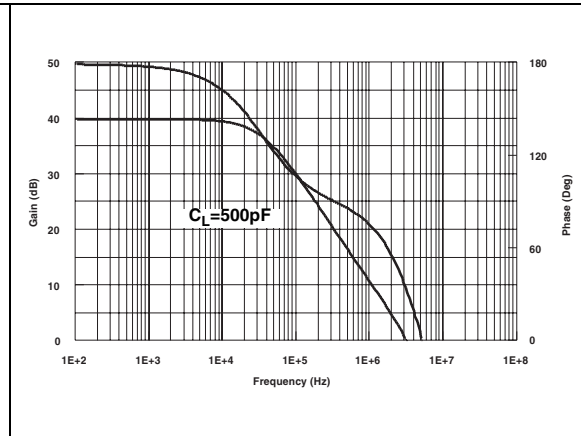


Figure 5. Equivalent input noise voltage vs. frequency

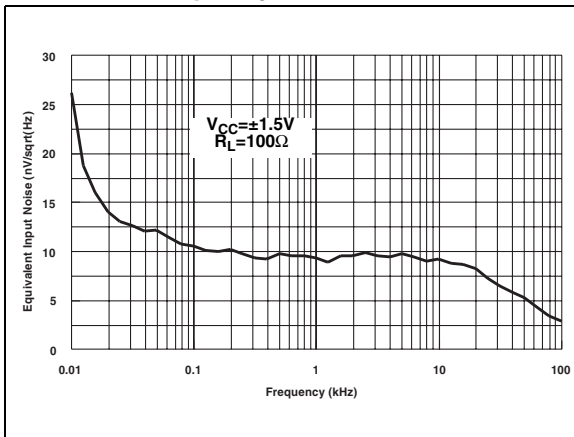


Figure 6. THD + noise vs. frequency,  $R_L = 2 \text{ k}\Omega$ ,  $V_o = 10 \text{ Vpp}$

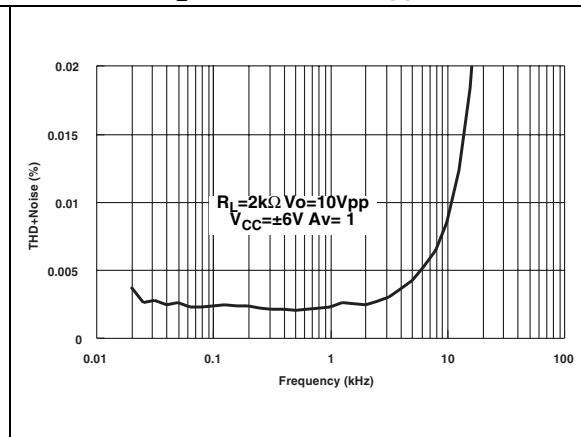


Figure 7. THD + noise vs. frequency,  
 $R_L = 32 \Omega$ ,  $V_o = 4 V_{pp}$

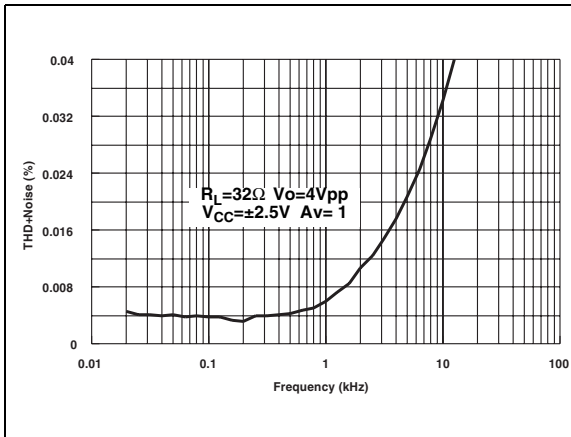


Figure 8. THD + noise vs. frequency,  
 $R_L = 32 \Omega$ ,  $V_o = 2 V_{pp}$

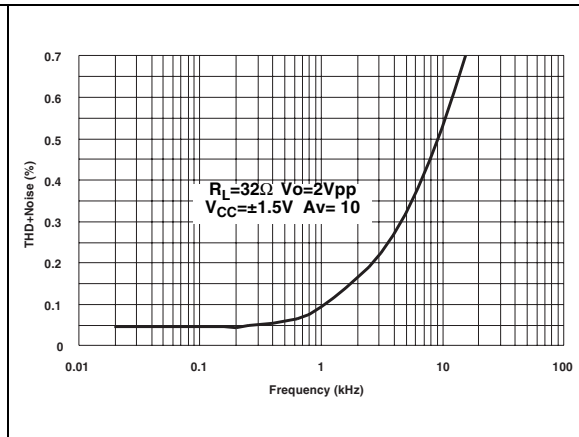


Figure 9. THD + noise vs. output voltage,  
 $R_L = 600 \Omega$ ,  $f = 1 \text{ kHz}$

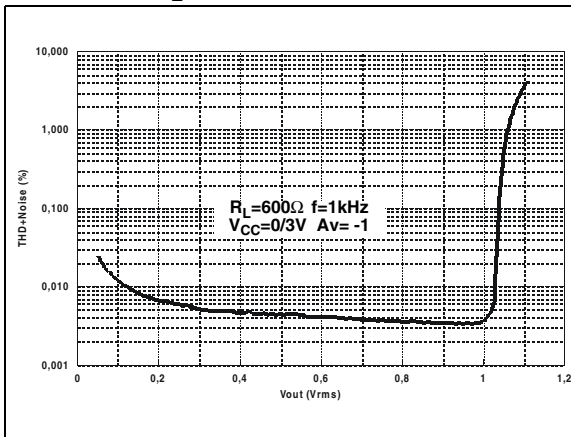


Figure 10. THD + noise vs. output voltage,  
 $R_L = 32 \Omega$ ,  $f = 1 \text{ kHz}$

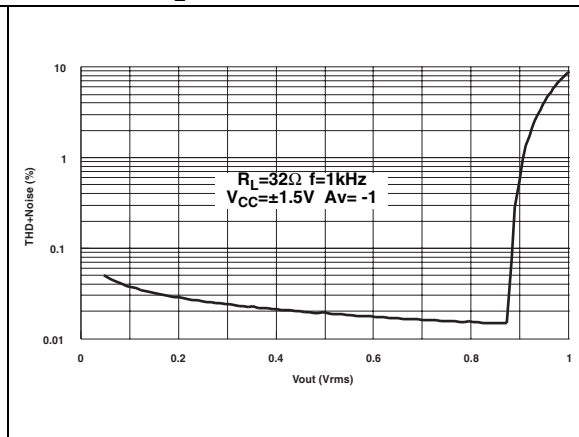
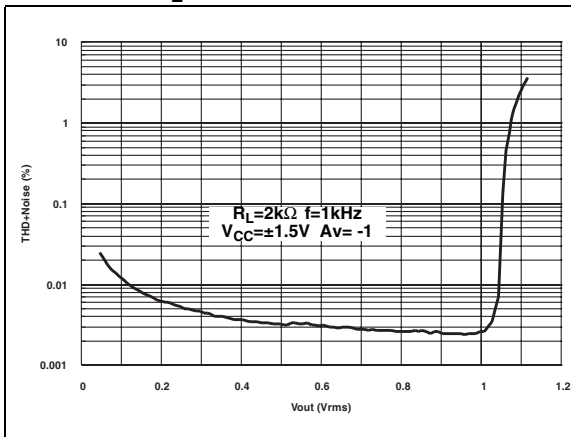


Figure 11. THD + noise vs. output voltage,  
 $R_L = 2 \text{ k}\Omega$ ,  $f = 1 \text{ kHz}$



### 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

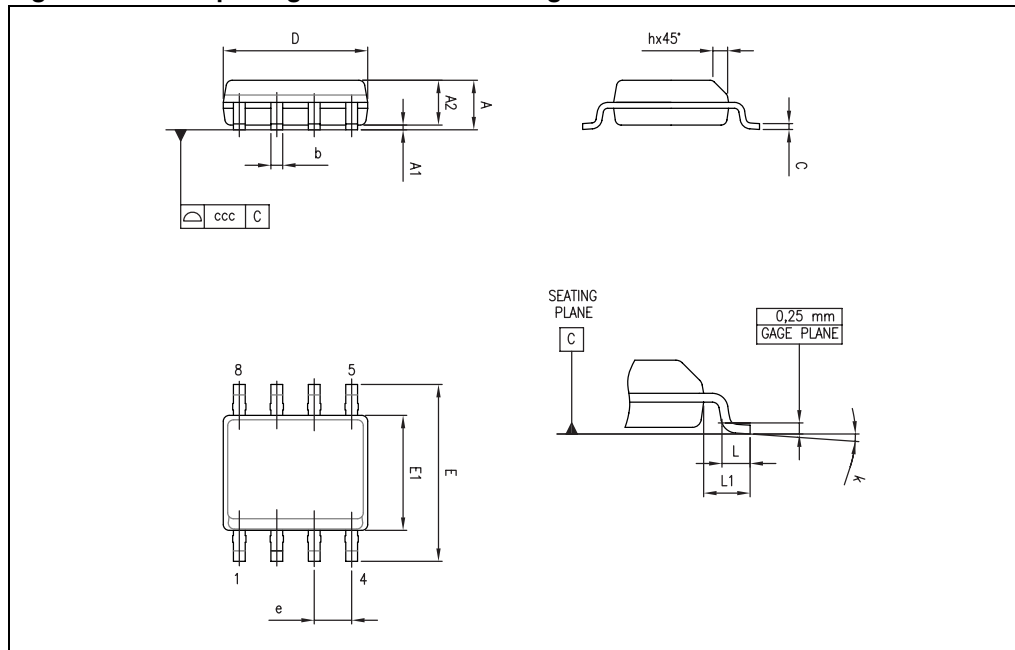


Table 5. SO-8 package mechanical data

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

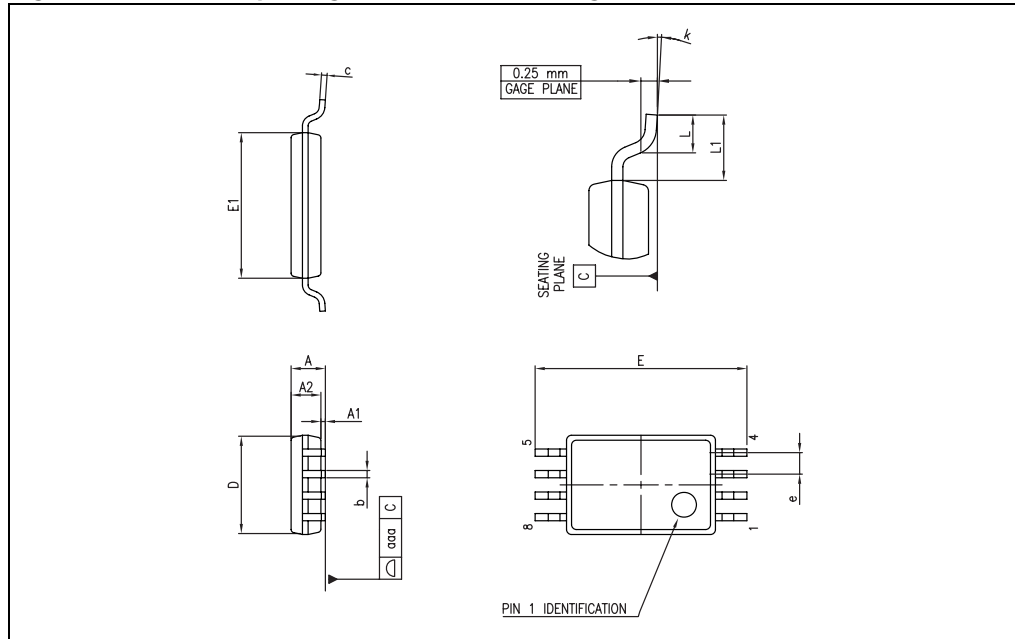


Table 6. TSSOP8 package mechanical data

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

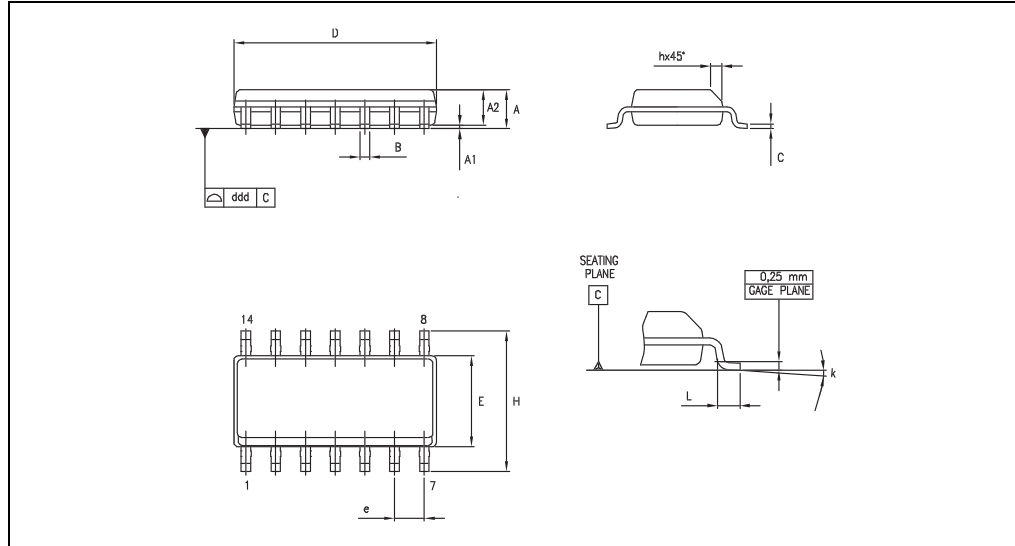


Table 7. SO-14 package mechanical data

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

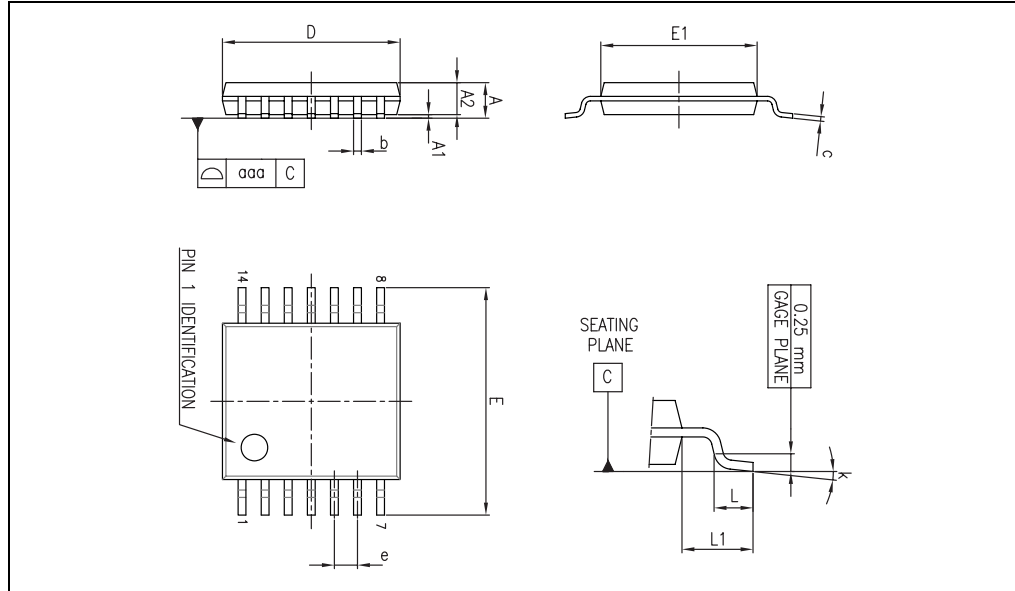


Table 8. TSSOP14 package mechanical data

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.
18-Mar-2010	2	Added pinout of dual and quad versions on cover page. Corrected AVd parameter values in <a href="#">Table 3</a> . and <a href="#">Table 4</a> .

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