

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

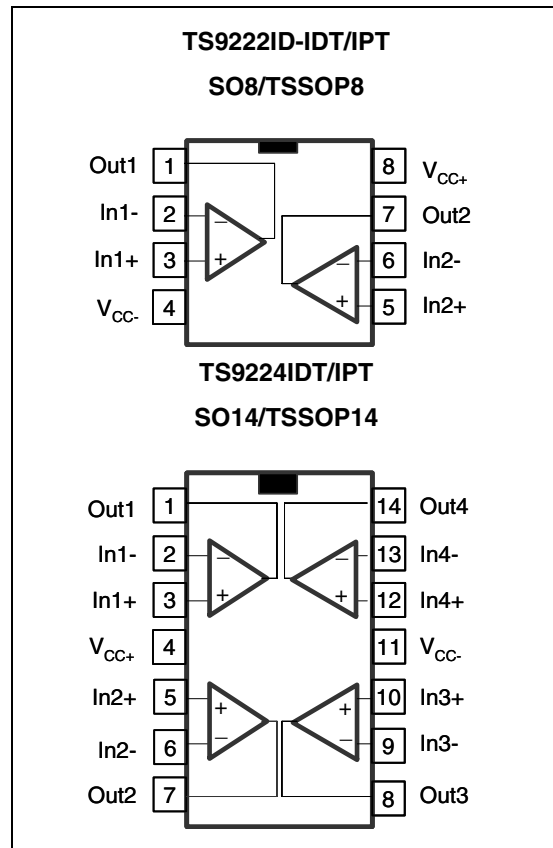
Applications

- 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 ⁽¹⁾	14	V
V_{id}	Differential input voltage ⁽²⁾	± 1	V
V_{in}	Input voltage ⁽³⁾	$V_{CC-} - 0.3$ to $V_{CC+} + 0.3$	V
T_{stg}	Storage temperature	-65 to +150	°C
R_{thja}	Thermal resistance junction to ambient ⁽⁴⁾		
	SO-8	125	°C/W
	TSSOP8	120	
	SO-14	66	
TSSOP14	100		
T_j	Maximum junction temperature	150	°C
ESD	HBM: human body model ⁽⁵⁾	2000	V
	MM: machine model ⁽⁶⁾	100	
	CDM: charged device model ⁽⁷⁾	1500	
	Output short circuit duration	see note ⁽⁸⁾	
	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 ± 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 Ω 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 Ω). 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	μV
		$T_{min} \leq T_{amb} \leq T_{max}$			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	V_{icm} from 0 to 3 V $T_{min} \leq T_{amb} \leq T_{max}$	65 60	85		dB
SVR	Supply voltage rejection ratio	$V_{CC} = 2.7$ to 3.3 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/ μs
ϕ_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	Test conditions	Min.	Typ.	Max.	Unit
V_{io}	Input offset voltage				500	μV
		$T_{min} \leq T_{amb} \leq T_{max}$			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	V_{icm} from 0 to 5 V $T_{min} \leq T_{amb} \leq T_{max}$	65 60	85		dB
SVR	Supply voltage rejection ratio	$V_{CC} = 4.5$ to 5.5 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/ μs
ϕ_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		$\frac{nV}{\sqrt{Hz}}$
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

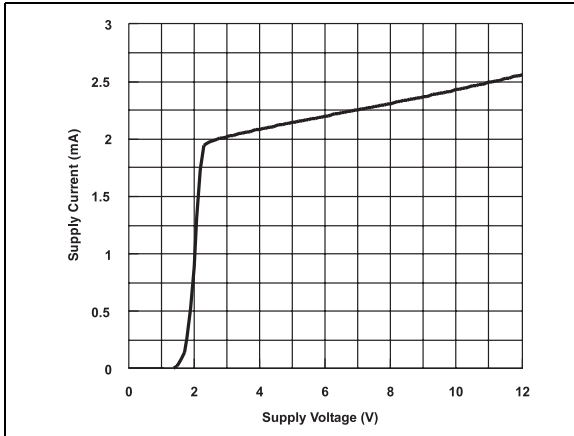


Figure 2. Output short circuit current vs. output voltage

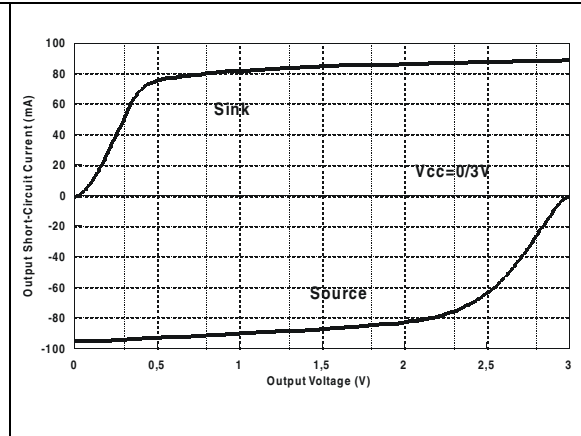


Figure 3. Voltage gain and phase vs. frequency, $C_L = 100 \text{ pF}$

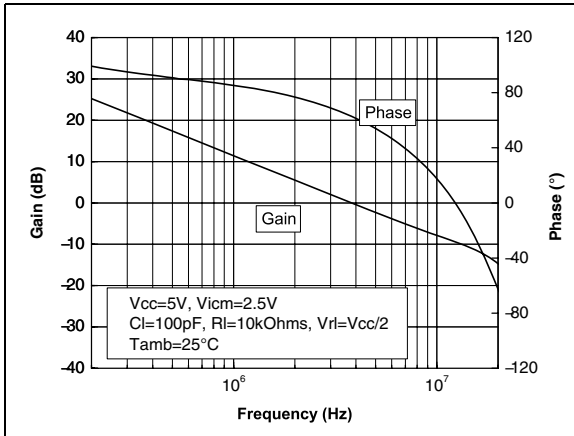


Figure 4. Voltage gain and phase vs. frequency, $C_L = 500 \text{ pF}$

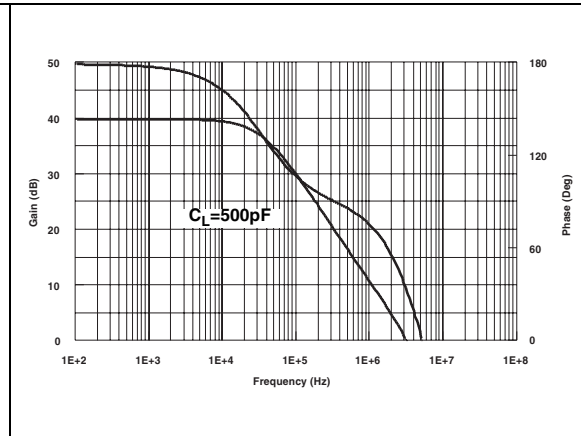


Figure 5. Equivalent input noise voltage vs. frequency

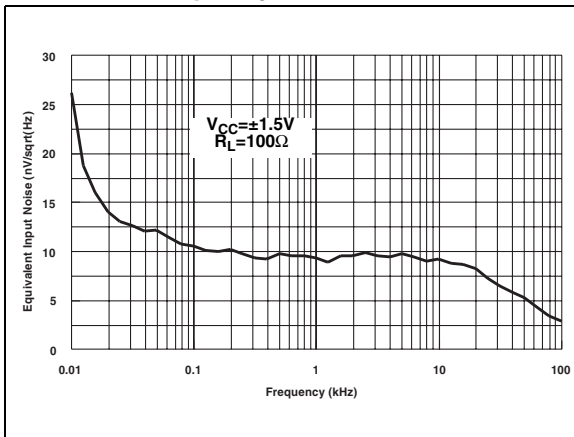


Figure 6. THD + noise vs. frequency, $R_L = 2 \text{ k}\Omega$, $V_o = 10 \text{ Vpp}$

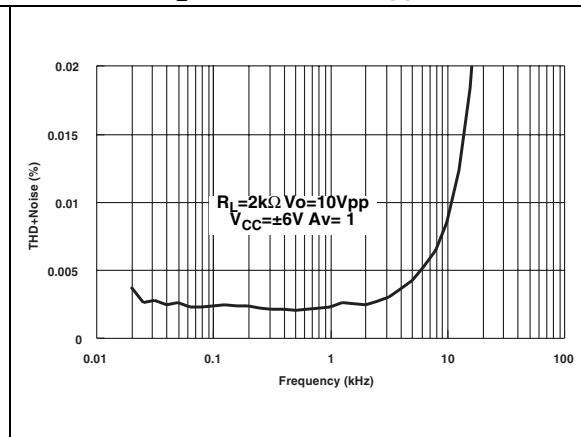


Figure 7. THD + noise vs. frequency,
 $R_L = 32 \Omega$, $V_o = 4 V_{pp}$

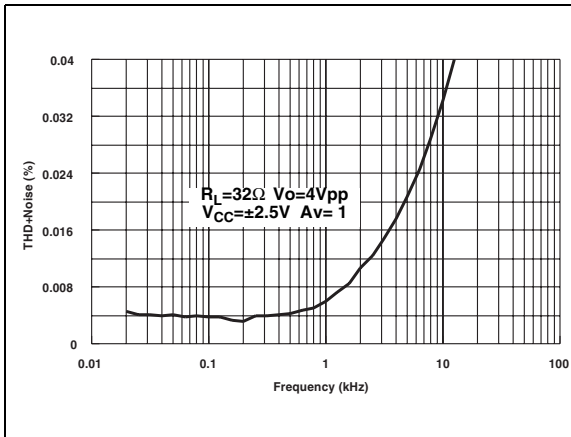


Figure 8. THD + noise vs. frequency,
 $R_L = 32 \Omega$, $V_o = 2 V_{pp}$

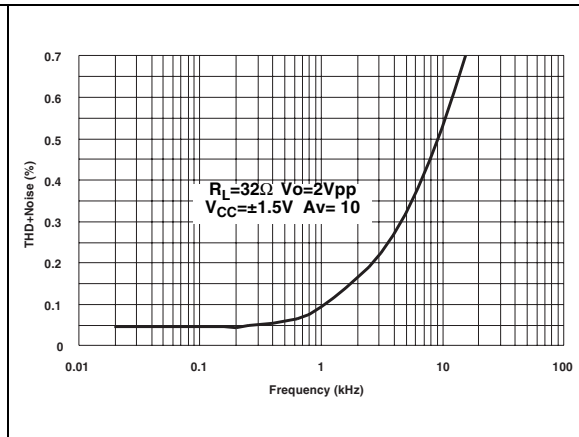


Figure 9. THD + noise vs. output voltage,
 $R_L = 600 \Omega$, $f = 1 \text{ kHz}$

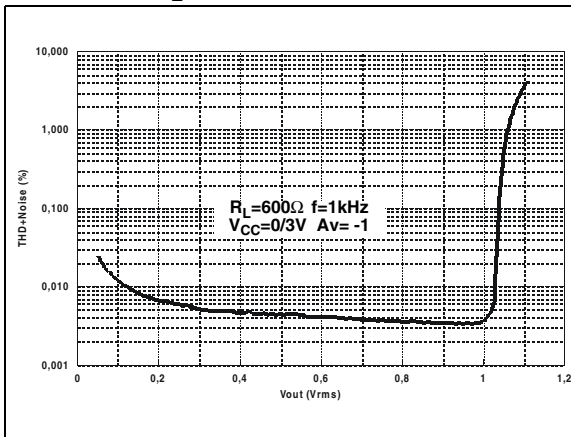


Figure 10. THD + noise vs. output voltage,
 $R_L = 32 \Omega$, $f = 1 \text{ kHz}$

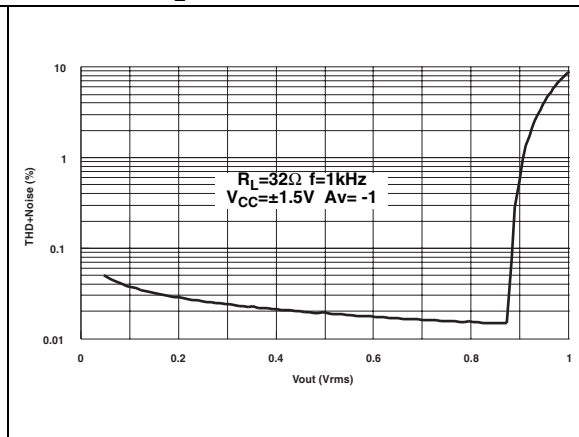
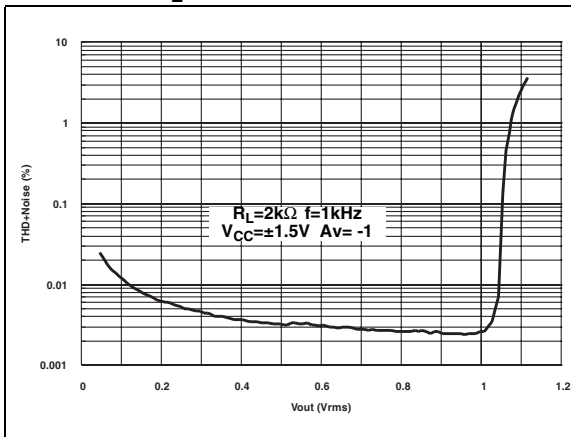


Figure 11. THD + noise vs. output voltage,
 $R_L = 2 \text{ k}\Omega$, $f = 1 \text{ kHz}$



3 Package information

In order to meet environmental requirements, ST offers these devices in different grades of ECOPACK[®] packages, depending on their level of environmental compliance. ECOPACK[®] specifications, grade definitions and product status are available at: www.st.com. ECOPACK[®] is an ST trademark.

3.1 SO-8 package information

Figure 12. SO-8 package mechanical drawing

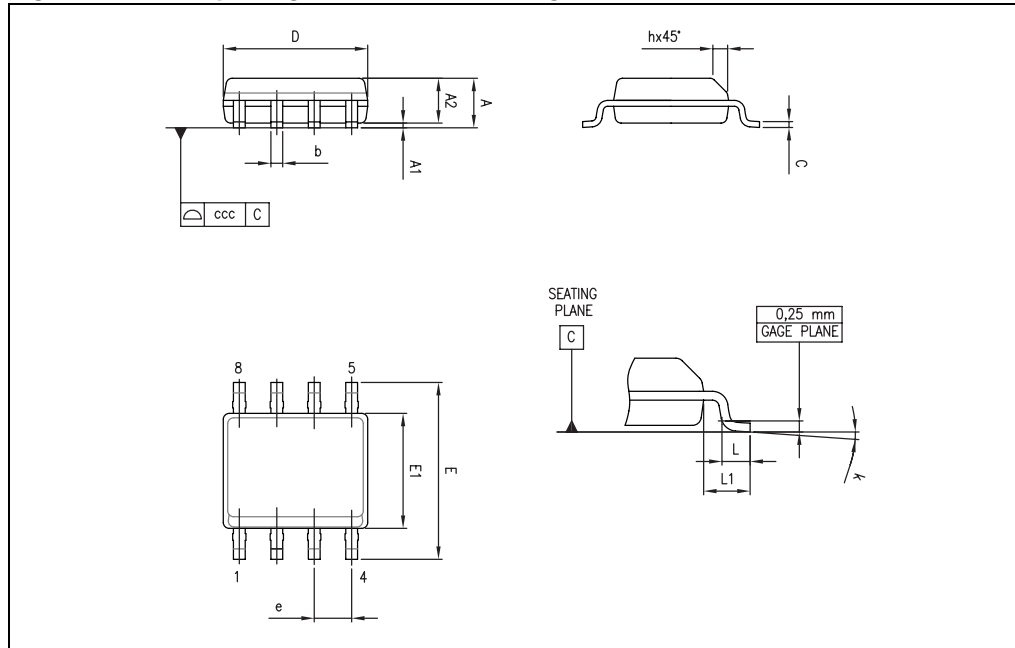


Table 5. SO-8 package mechanical data

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

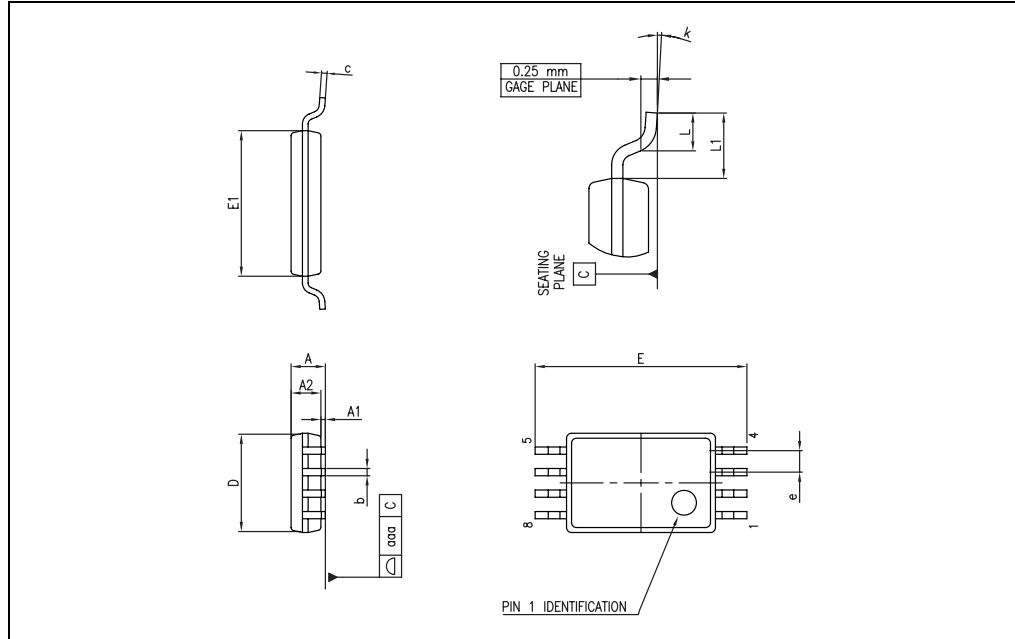


Table 6. TSSOP8 package mechanical data

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

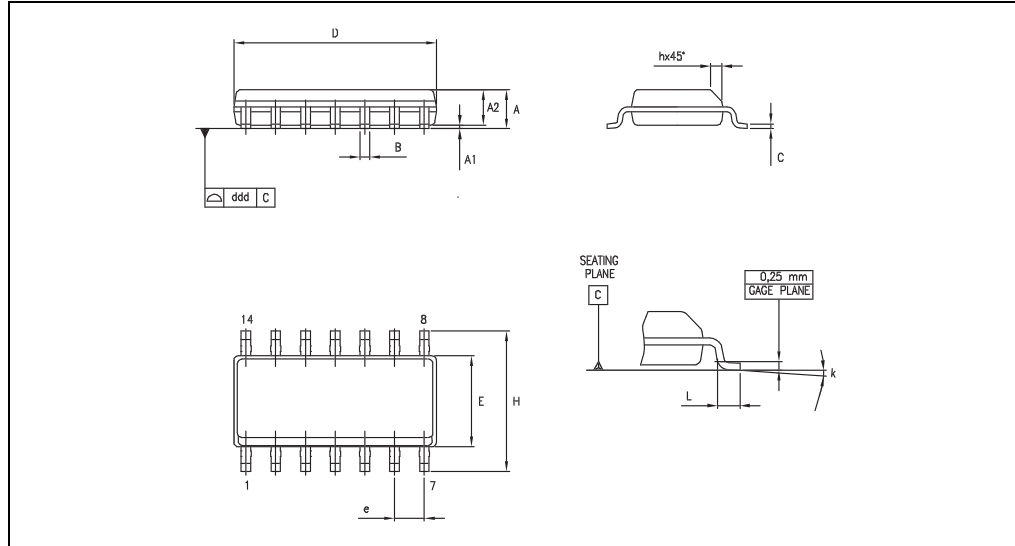


Table 7. SO-14 package mechanical data

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

3.4 TSSOP14 package information

Figure 15. TSSOP14 package mechanical drawing

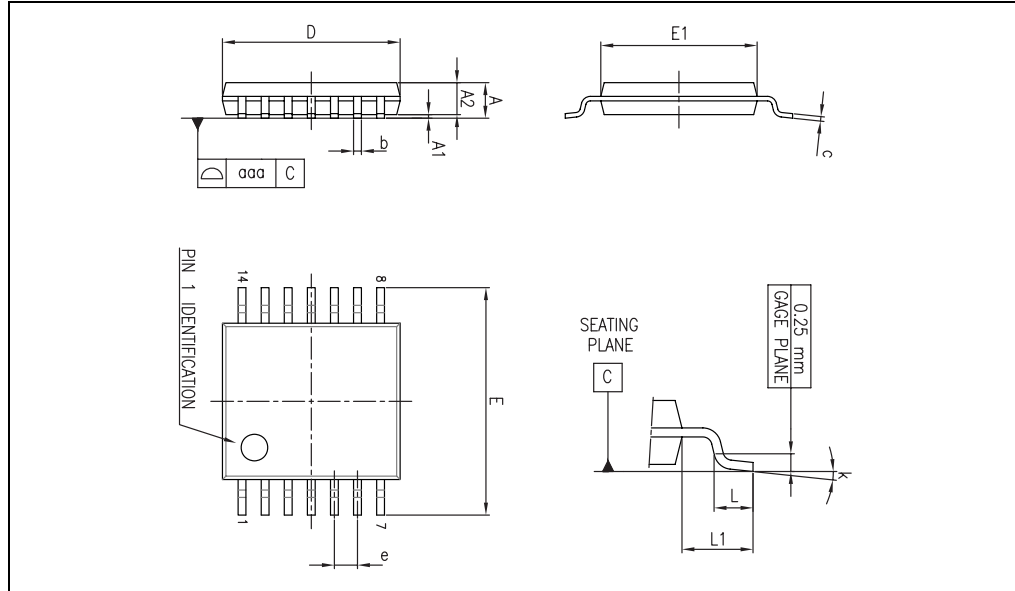


Table 8. TSSOP14 package mechanical data

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 ⁽¹⁾		SO-8 (automotive grade)	Tape & reel	9222Y
TS9222IYPT ⁽²⁾		TSSOP8 (automotive grade)	Tape & reel	9222Y
TS9224IYDT ⁽¹⁾		SO-14 (automotive grade)	Tape & reel	9224Y
TS9224IYPT ⁽¹⁾		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 Table 3 . and Table 4 .
13-Apr-2011	3	Updated test conditions for CMR in Table 3 . and Table 4 .

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