

## Rail-to-rail input/output 20 MHz GBP operational amplifiers

### Features

- Low input offset voltage: 1.5 mV max
- Rail-to-rail input and output
- Wide bandwidth 20 MHz, stable for gain  $\geq 3$
- Low power consumption: 1.1 mA maximum
- High output current: 35 mA
- Operating from 2.5 V to 5.5 V
- Low input bias current, 1 pA typ
- ESD internal protection  $\geq 5$  kV
- Latch-up immunity

### Applications

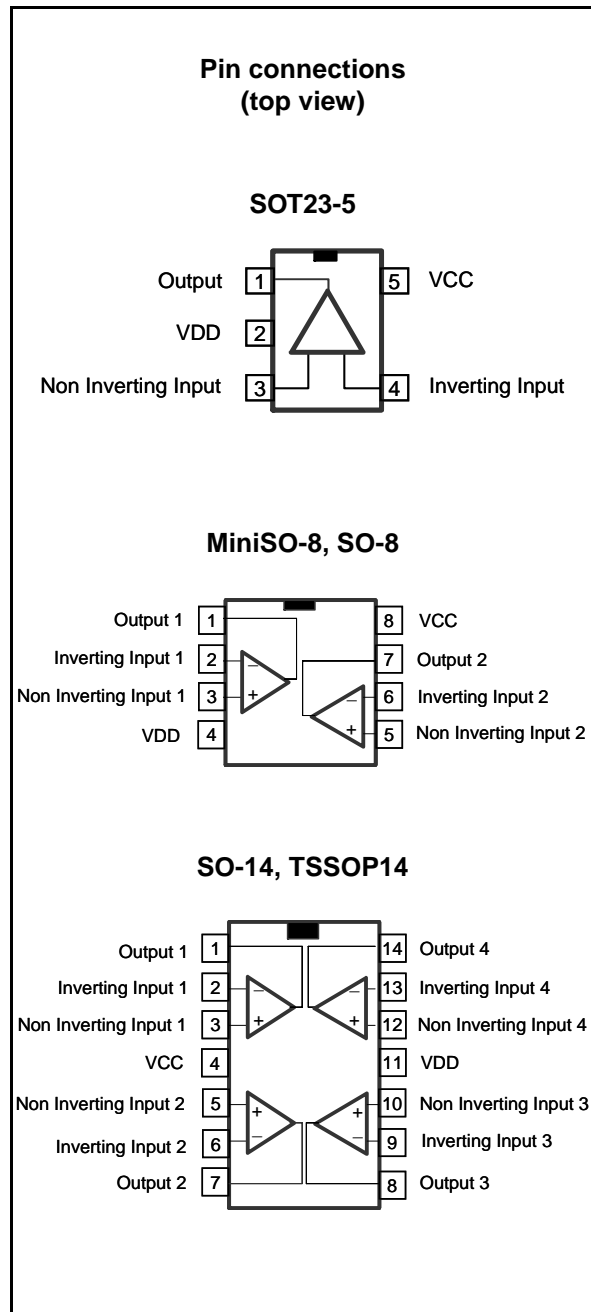
- Battery-powered applications
- Portable devices
- Signal conditioning
- Active filtering
- Medical instrumentation
- Automotive

### Description

The TSV991/2/4 family of single, dual and quad operational amplifiers offers low voltage operation and rail-to-rail input and output.

This family features an excellent speed/power consumption ratio, offering a 20 MHz gain-bandwidth, stable for gain above 3 (100 pF capacitive load), while consuming only 1.1 mA max at 5 V supply voltage. It also features an ultra-low input bias current.

These characteristics make the TSV991/2/4 family ideal for sensor interfaces, battery-supplied and portable applications, as well as active filtering.



# 1 Absolute maximum ratings and operating conditions

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

Symbol	Parameter	Value	Unit	
$V_{CC}$	Supply voltage <sup>(1)</sup>	6	V	
$V_{id}$	Differential input voltage <sup>(2)</sup>	$\pm V_{CC}$	V	
$V_{in}$	Input voltage <sup>(3)</sup>	$V_{DD}-0.2$ to $V_{CC}+0.2$	V	
$T_{stg}$	Storage temperature	-65 to +150	°C	
$R_{thja}$	Thermal resistance junction to ambient <sup>(4) (5)</sup>			
	SOT23-5	250	°C/W	
	SO-8	125		
	MiniSO-8	190		
	SO-14	103		
TSSOP14	100			
$R_{thjc}$	Thermal resistance junction to case			
	SOT23-5	81	°C/W	
	SO-8	40		
	MiniSO-8	39		
	SO-14	31		
TSSOP14	32			
$T_j$	Maximum junction temperature	150	°C	
ESD	HBM: human body model <sup>(6)</sup>	5	kV	
	MM: machine model <sup>(7)</sup>	400	V	
	CDM: charged device model <sup>(8)</sup>	SOT23-5, SO-8, MiniSO-8	1500	V
		TSSOP14	750	
SO-14		500		
	Latch-up immunity	200	mA	

1. Value with respect to  $V_{DD}$  pin.
2. Differential voltages are the non-inverting input terminal with respect to the inverting input terminal.
3.  $V_{CC}-V_{in}$  must not exceed 6V.
4. Short-circuits can cause excessive heating and destructive dissipation.
5.  $R_{th}$  are typical values.
6. Human body model: 100pF discharged through a 1.5kΩ resistor between two pins of the device, done for all couples of pin combinations with other pins floating.
7. Machine model: 200pF is charged to the specified voltage, then discharged directly between two pins of the device with no external series resistor (internal resistor < 5Ω), done for all couples of pin combinations with other pins floating.
8. Charged device model: all pins plus package are charged together to the specified voltage and then discharged directly to the ground.

**Table 2. Operating conditions**

Symbol	Parameter	Value	Unit
$V_{CC}$	Supply voltage	2.5 to 5.5	V
$V_{icm}$	Common mode input voltage range	$V_{DD} - 0.1$ to $V_{CC} + 0.1$	V
$T_{oper}$	Operating free air temperature range	-40 to +125	°C

## 2 Electrical characteristics

**Table 3. Electrical characteristics at  $V_{CC} = +2.5V$ ,  $V_{DD} = 0V$ ,  $V_{icm} = V_{CC}/2$ , with  $R_L$  connected to  $V_{CC}/2$ , full temperature range (unless otherwise specified)<sup>(1)</sup>**

Symbol	Parameter	Conditions	Min.	Typ.	Max.	Unit
<b>DC performance</b>						
$V_{io}$	Offset voltage TSV99x	$T = 25^\circ C$ $T_{min} < T_{op} < T_{max}$	-	0.1	4.5	mV
	TSV99xA	$T = 25^\circ C$ $T_{min} < T_{op} < T_{max}$	-	-	7.5	
$DV_{io}$	Input offset voltage drift		-	2	-	$\mu V/^\circ C$
$I_{io}$	Input offset current <sup>(2)</sup> ( $V_{out} = V_{CC}/2$ )	$T = 25^\circ C$ $T_{min} < T_{op} < T_{max}$	-	1	10	pA
$I_{ib}$	Input bias current <sup>(2)</sup> ( $V_{out} = V_{CC}/2$ )	$T = 25^\circ C$ $T_{min} < T_{op} < T_{max}$	-	1	10	pA
CMR	Common mode rejection ratio $20 \log (\Delta V_{ic}/\Delta V_{io})$	$0V$ to $2.5V$ , $V_{out} = 1.25V$	58	75	-	dB
$A_{vd}$	Large signal voltage gain	$R_L = 10k\Omega$ , $V_{out} = 0.5V$ to $2V$ , $T = 25^\circ C$ $T_{min} < T_{op} < T_{max}$	80	89	-	dB
$V_{CC}-V_{OH}$	High level output voltage	$R_L = 10k\Omega$ $R_L = 600\Omega$		15	40	mV
$V_{OL}$	Low level output voltage	$R_L = 10k\Omega$ $R_L = 600\Omega$	-	15	40	mV
$I_{out}$	$I_{sink}$	$V_o = 2.5V$ , $T = 25^\circ C$ $T_{min} < T_{amb} < T_{max}$	18	32	-	mA
	$I_{source}$	$V_o = 0V$ , $T = 25^\circ C$ $T_{min} < T_{amb} < T_{max}$	18	35	-	
$I_{CC}$	Supply current (per operator)	No load, $V_{out} = V_{CC}/2$	-	0.78	1.1	mA
<b>AC performance</b>						
GBP	Gain bandwidth product	$R_L = 2k\Omega$ , $C_L = 100pF$ , $f = 100kHz$ , $T = 25^\circ C$	-	20	-	MHz
$\phi_m$	Phase margin	$R_L = 2k\Omega$ , $C_L = 100pF$ , $G = 5$ , $f = 100kHz$ , $T = 25^\circ C$	-	60	-	Degrees
$G_m$	Gain margin	$R_L = 2k\Omega$ , $C_L = 100pF$ , $\phi_m = 40^\circ$ , $T = 25^\circ C$	-	2.5	-	dB
SR	Slew rate	$R_L = 2k\Omega$ , $C_L = 100pF$ , $T = 25^\circ C$	-	10	-	$V/\mu s$
$e_n$	Equivalent input noise voltage	$f = 10kHz$ , $T = 25^\circ C$	-	21	-	$\frac{nV}{\sqrt{Hz}}$
THD+ $e_n$	Total harmonic distortion	$G = 1$ , $f = 1kHz$ , $R_L = 2k\Omega$ , $Bw = 22kHz$ , $V_{icm} = (V_{CC} + 1)/2$ , $V_{out} = 1.1V_{pp}$ , $T = 25^\circ C$	-	0.0017	-	%

1. All parameter limits at temperatures other than  $25^\circ C$  are guaranteed by correlation.

2. Guaranteed by design.

**Table 4. Electrical characteristics at  $V_{CC} = +3.3V$ ,  $V_{DD} = 0V$ ,  $V_{icm} = V_{CC}/2$ , with  $R_L$  connected to  $V_{CC}/2$ , full temperature range (unless otherwise specified)<sup>(1)</sup>**

Symbol	Parameter	Conditions	Min.	Typ.	Max.	Unit
<b>DC performance</b>						
$V_{io}$	Offset voltage TSV99x	$T = 25^{\circ}C$ $T_{min} < T_{op} < T_{max}$	-	0.1	4.5	mV
	TSV99xA	$T = 25^{\circ}C$ $T_{min} < T_{op} < T_{max}$	-	-	7.5	
$DV_{io}$	Input offset voltage drift		-	2	-	$\mu V/^{\circ}C$
$I_{io}$	Input offset current <sup>(2)</sup> ( $V_{out} = V_{CC}/2$ )	$T = 25^{\circ}C$ $T_{min} < T_{op} < T_{max}$	-	1	10	pA
$I_{ib}$	Input bias current <sup>(2)</sup> ( $V_{out} = V_{CC}/2$ )	$T = 25^{\circ}C$ $T_{min} < T_{op} < T_{max}$	-	-	100	pA
CMR	Common mode rejection ratio $20 \log (\Delta V_{ic}/\Delta V_{io})$	$0V$ to $3.3V$ , $V_{out} = 1.65V$	60	78	-	dB
$A_{vd}$	Large signal voltage gain	$R_L = 10k\Omega$ , $V_{out} = 0.5V$ to $2.8V$ , $T = 25^{\circ}C$ $T_{min} < T_{op} < T_{max}$	80	90	-	dB
$V_{CC}-V_{OH}$	High level output voltage	$R_L = 10k\Omega$ $R_L = 600\Omega$		15	40	mV
$V_{OL}$	Low level output voltage	$R_L = 10k\Omega$ $R_L = 600\Omega$	-	15	40	mV
$I_{out}$	$I_{sink}$	$V_o = 3.3V$ , $T = 25^{\circ}C$ $T_{min} < T_{amb} < T_{max}$	18	32	-	mA
	$I_{source}$	$V_o = 0V$ , $T = 25^{\circ}C$ $T_{min} < T_{amb} < T_{max}$	16	-	-	
$I_{CC}$	Supply current (per operator)	No load, $V_{out} = V_{CC}/2$	-	0.8	1.1	mA
<b>AC performance</b>						
GBP	Gain bandwidth product	$R_L = 2k\Omega$ , $C_L = 100pF$ , $f = 100kHz$ , $T = 25^{\circ}C$	-	20	-	MHz
$\phi_m$	Phase margin	$R_L = 2k\Omega$ , $C_L = 100pF$ , $G = 5$ , $T = 25^{\circ}C$	-	60	-	Degrees
$G_m$	Gain margin	$R_L = 2k\Omega$ , $C_L = 100pF$ , $f = 100kHz$ , $\phi_m = 40^{\circ}$ , $T = 25^{\circ}C$	-	2.5	-	dB
SR	Slew rate	$R_L = 2k\Omega$ , $C_L = 100pF$ , $f = 100kHz$ , $T = 25^{\circ}C$	-	10	-	$V/\mu s$
$e_n$	Equivalent input noise voltage	$f = 10kHz$ , $T = 25^{\circ}C$	-	21	-	$\frac{nV}{\sqrt{Hz}}$
THD+ $e_n$	Total harmonic distortion	$G = 1$ , $f = 1kHz$ , $R_L = 2k\Omega$ , $Bw = 22kHz$ , $V_{icm} = (V_{CC} + 1)/2$ , $V_{out} = 1.9V_{pp}$ , $T = 25^{\circ}C$	-	0.001	-	%

1. All parameter limits at temperatures other than  $25^{\circ}C$  are guaranteed by correlation.
2. Guaranteed by design.

**Table 5. Electrical characteristics at  $V_{CC} = +5V$ ,  $V_{DD} = 0V$ ,  $V_{icm} = V_{CC}/2$ ,  $R_L$  connected to  $V_{CC}/2$ , full temperature range (unless otherwise specified)<sup>(1)</sup>**

Symbol	Parameter	Conditions	Min.	Typ.	Max.	Unit
<b>DC performance</b>						
$V_{io}$	Offset voltage TSV99x	$T = 25^\circ C$ $T_{min} < T_{op} < T_{max}$	-	0.1	4.5	mV
	TSV99xA	$T = 25^\circ C$ $T_{min} < T_{op} < T_{max}$	-	-	7.5	
$DV_{io}$	Input offset voltage drift		-	2	-	$\mu V/^\circ C$
$I_{io}$	Input offset current <sup>(2)</sup> ( $V_{out} = V_{CC}/2$ )	$T = 25^\circ C$ $T_{min} < T_{op} < T_{max}$	-	1	10	pA
			-	-	100	
$I_{ib}$	Input bias current <sup>(2)</sup> ( $V_{out} = V_{CC}/2$ )	$T = 25^\circ C$ $T_{min} < T_{op} < T_{max}$	-	1	10	pA
			-	-	100	
CMR	Common mode rejection ratio $20 \log (\Delta V_{ic}/\Delta V_{io})$	0V to 5V, $V_{out} = 2.5V$	62	82	-	dB
SVR	Supply voltage rejection ratio $20 \log (\Delta V_{cc}/\Delta V_{io})$	$V_{CC} = 2.5$ to $5V$	70	86	-	dB
$A_{vd}$	Large signal voltage gain	$R_L = 10k\Omega$ , $V_{out} = 0.5V$ to $4.5V$ , $T = 25^\circ C$ $T_{min} < T_{op} < T_{max}$	80	91	-	dB
			75	-	-	dB
$V_{CC}-V_{OH}$	High level output voltage	$R_L = 10k\Omega$ $R_L = 600\Omega$		15 45	40 150	mV
$V_{OL}$	Low level output voltage	$R_L = 10k\Omega$ $R_L = 600\Omega$	-	15 45	40 150	
$I_{out}$	$I_{sink}$	$V_o = 5V$ , $T = 25^\circ C$ $T_{min} < T_{amb} < T_{max}$	18 16	32 -	- -	mA
	$I_{source}$	$V_o = 0V$ , $T = 25^\circ C$ $T_{min} < T_{amb} < T_{max}$	18 16	35 -	- -	
$I_{CC}$	Supply current (per operator)	No load, $V_{out} = 2.5V$	-	0.82	1.1	mA
<b>AC performance</b>						
GBP	Gain bandwidth product	$R_L = 2k\Omega$ , $C_L = 100pF$ , $f = 100kHz$ , $T = 25^\circ C$	-	20	-	MHz
$\phi_m$	Phase margin	$R_L = 2k\Omega$ , $C_L = 100pF$ , $G=5$ , $T = 25^\circ C$	-	60	-	Degrees
$G_m$	Gain margin	$R_L = 2k\Omega$ , $C_L = 100pF$ , $\phi_m = 40^\circ$ , $T = 25^\circ C$	-	2.5	-	dB
SR	Slew rate	$R_L = 2k\Omega$ , $C_L = 100pF$ , $T = 25^\circ C$	-	10	-	V/ $\mu s$
$e_n$	Equivalent input noise voltage	$f = 10kHz$ , $T = 25^\circ C$	-	21	-	$\frac{nV}{\sqrt{Hz}}$
THD+ $e_n$	Total harmonic distortion	$G=1$ , $f=1kHz$ , $R_L=2k\Omega$ , $Bw=22kHz$ , $V_{icm}=(V_{CC}+1)/2$ , $V_{out}=3.6V_{pp}$ , $T=25^\circ C$	-	0.0007	-	%

1. All parameter limits at temperatures other than  $25^\circ C$  are guaranteed by correlation.

2. Guaranteed by design.

Figure 1. Input offset voltage distribution at T = 25°C

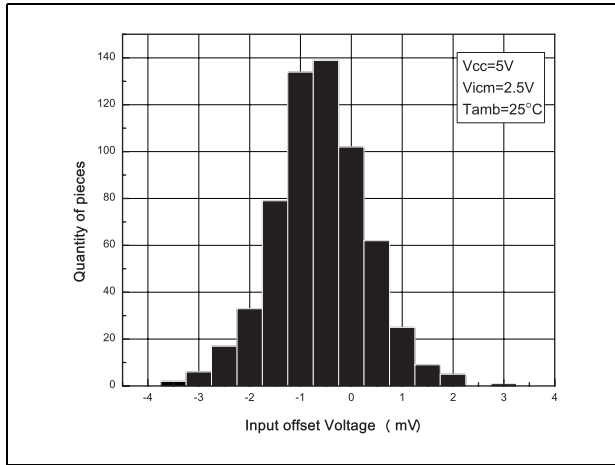


Figure 2. Input offset voltage distribution at T = 125°C

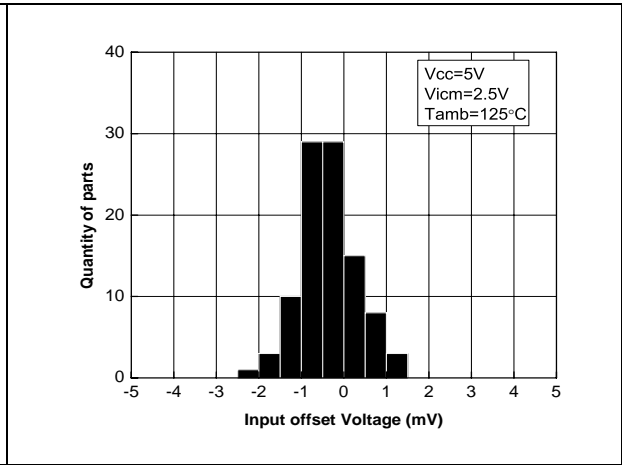


Figure 3. Supply current vs. input common mode voltage at V<sub>CC</sub> = 2.5V

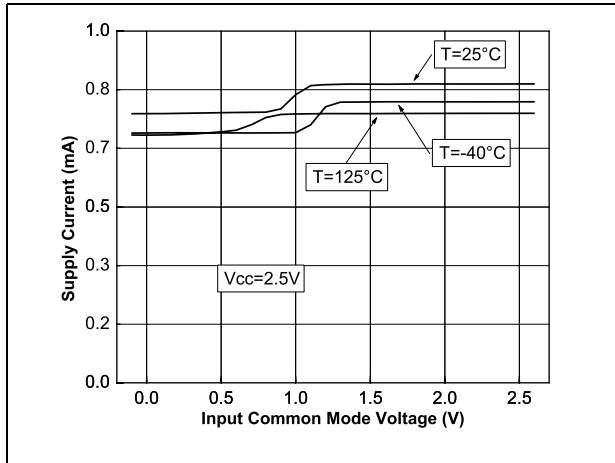


Figure 4. Supply current vs. input common mode voltage at V<sub>CC</sub> = 5V

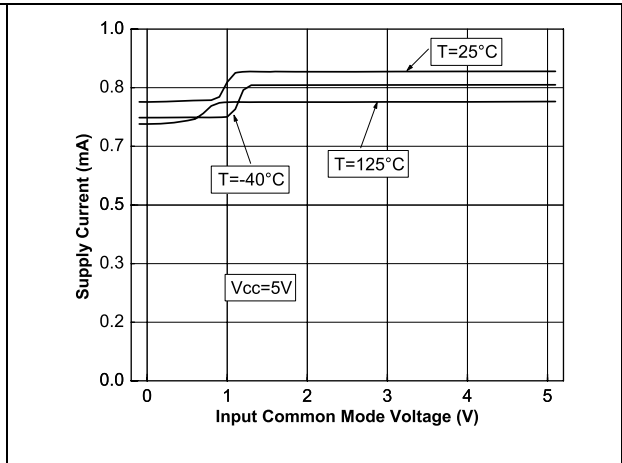


Figure 5. Output current vs. output voltage at V<sub>CC</sub> = 2.5V

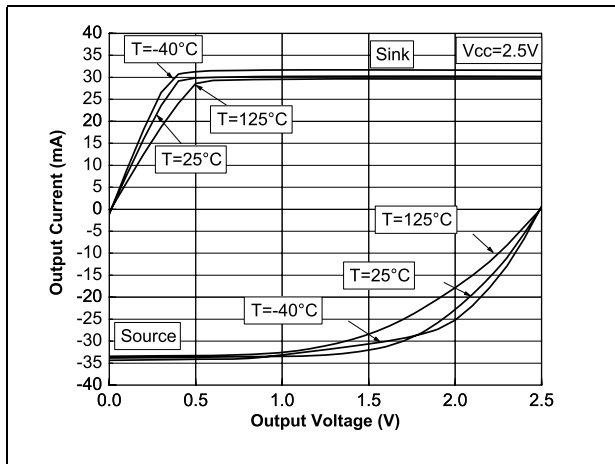


Figure 6. Output current vs. output voltage at V<sub>CC</sub> = 5V

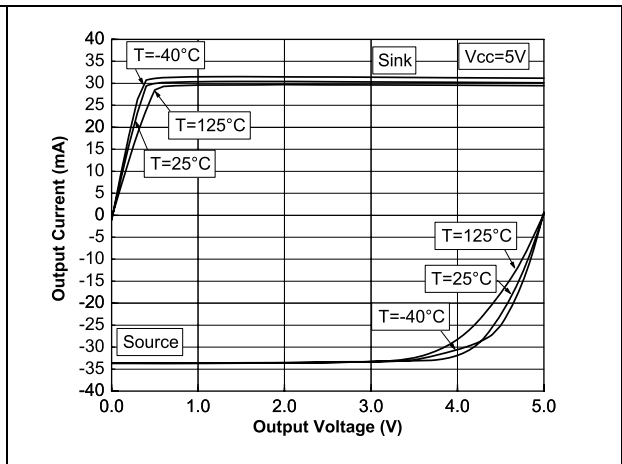


Figure 7. Voltage gain and phase vs frequency at  $V_{CC}=5V$  and  $V_{icm}=0.5V$

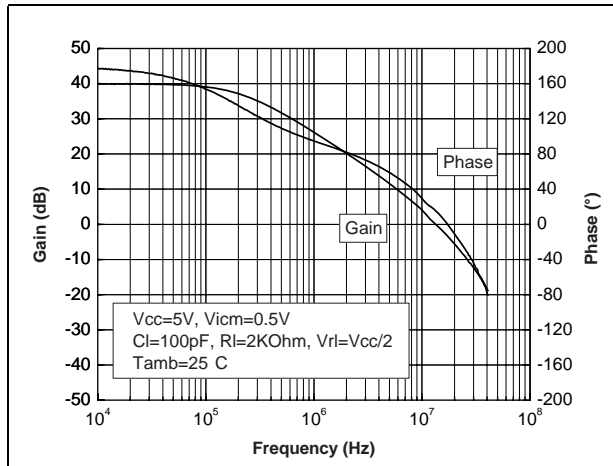


Figure 8. Voltage gain and phase vs frequency at  $V_{CC}=5V$  and  $V_{icm}=2.5V$

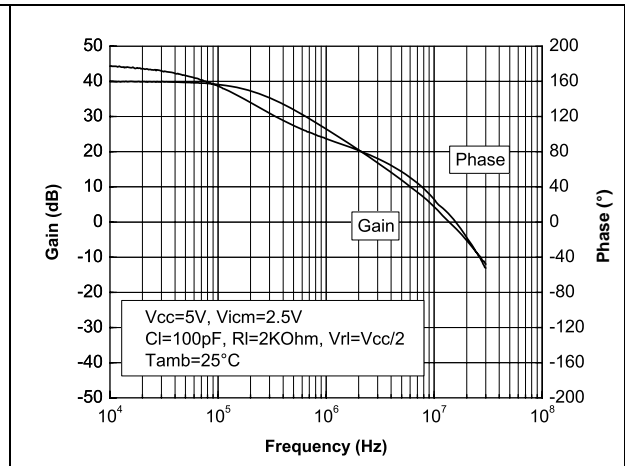


Figure 9. Positive slew rate

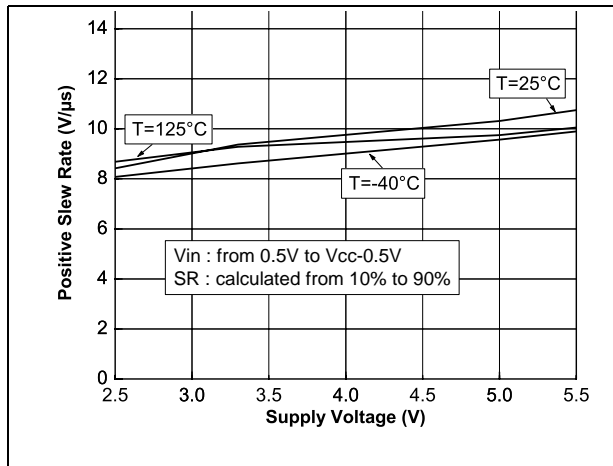


Figure 10. Negative slew rate

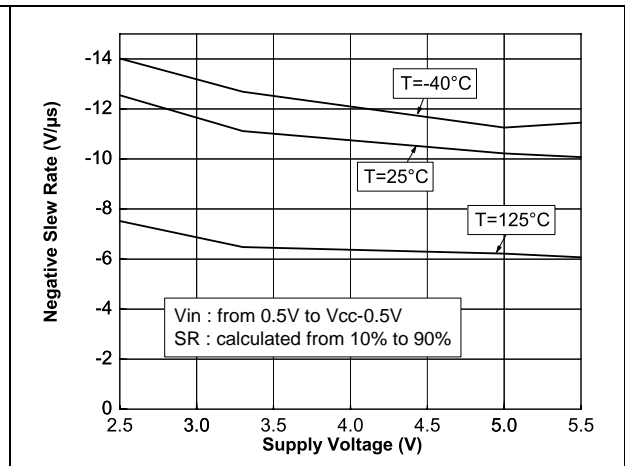


Figure 11. Distortion + noise vs. frequency

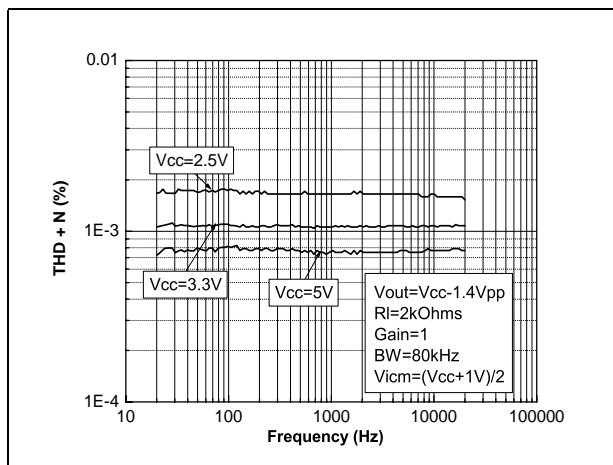


Figure 12. Distortion + noise vs. output voltage

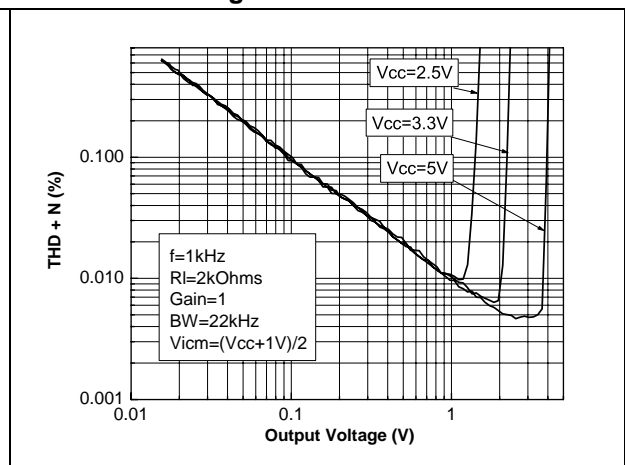
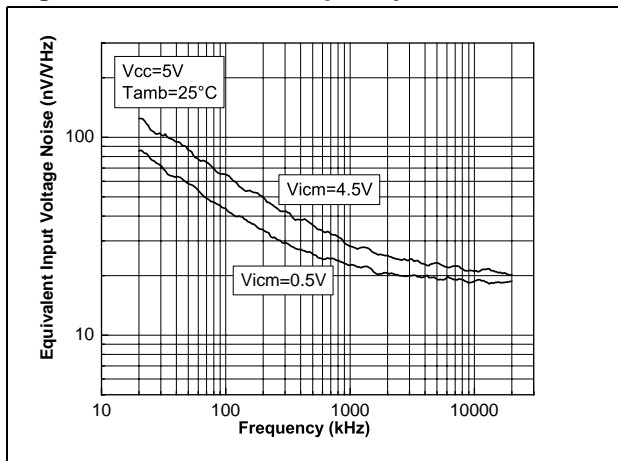




Figure 13. Noise vs. frequency



### 3 Package information

In order to meet environmental requirements, STMicroelectronics offers these devices in ECOPACK® 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 STMicroelectronics trademark. ECOPACK specifications are available at: [www.st.com](http://www.st.com).

*Note: All packages are Moisture Sensitivity Level 1 as per Jedec J-STD-020-C, except SO-14 which is Jedec level 3.*

### 3.1 SOT23-5 package information

Figure 14. SOT23-5 package mechanical drawing

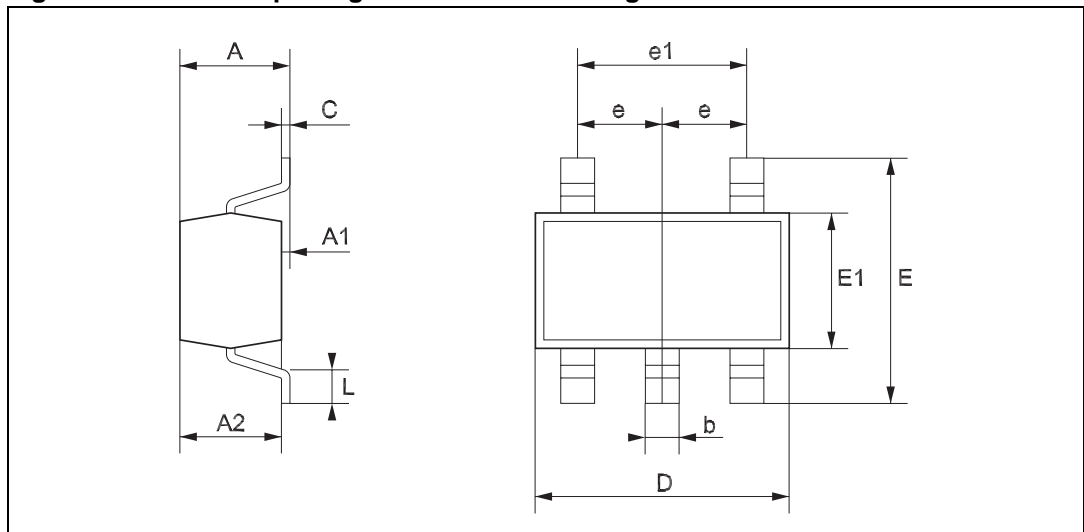


Table 6. SOT23-5 package mechanical data

Ref.	Dimensions					
	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 MiniSO-8 package information

Figure 15. MiniSO-8 package mechanical drawing

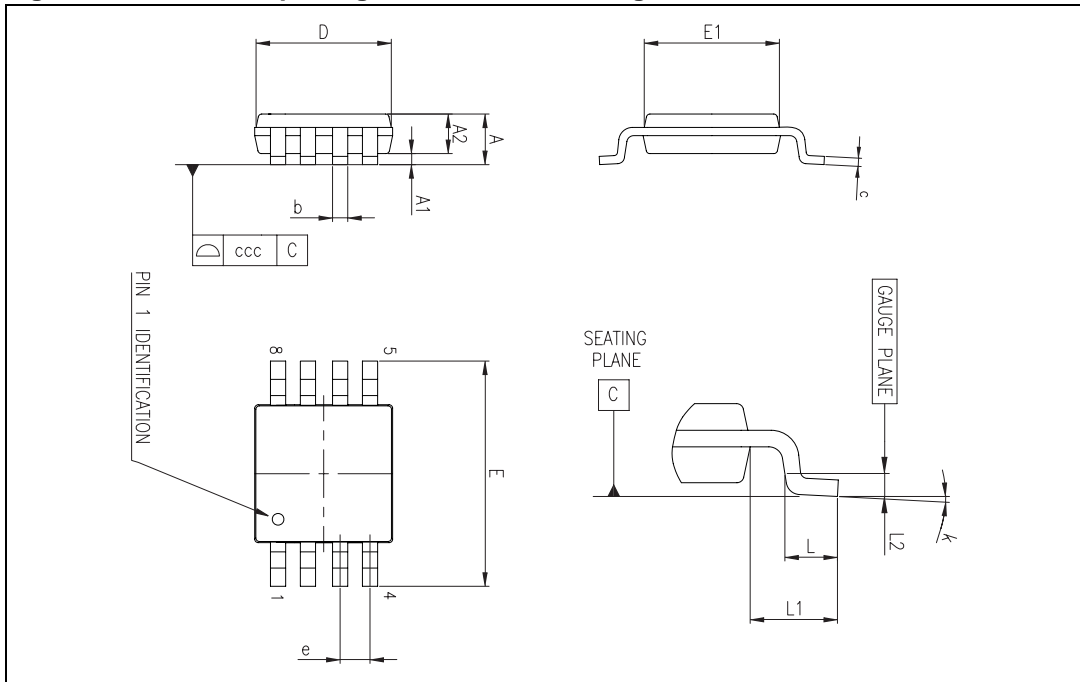
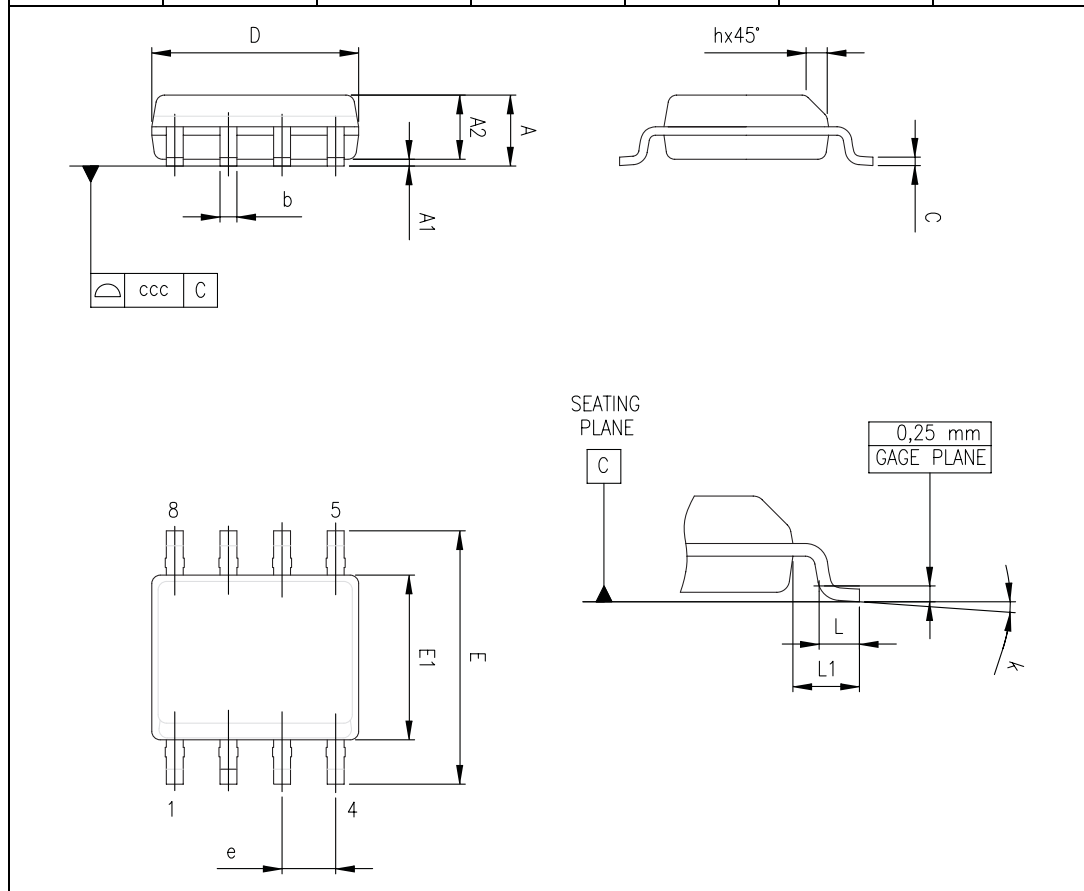


Table 7. MiniSO-8 package mechanical data

Ref.	Dimensions					
	Millimeters			Inches		
	Min.	Typ.	Max.	Min.	Typ.	Max.
A			1.1			0.043
A1	0		0.15	0		0.006
A2	0.75	0.85	0.95	0.030	0.033	0.037
b	0.22		0.40	0.009		0.016
c	0.08		0.23	0.003		0.009
D	2.80	3.00	3.20	0.11	0.118	0.126
E	4.65	4.90	5.15	0.183	0.193	0.203
E1	2.80	3.00	3.10	0.11	0.118	0.122
e		0.65			0.026	
L	0.40	0.60	0.80	0.016	0.024	0.031
L1		0.95			0.037	
L2		0.25			0.010	
k	0°		8°	0°		8°
ccc			0.10			0.004

Figure 16. 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



### 3.3 TSSOP14 package information

Figure 17. TSSOP14 package mechanical drawing

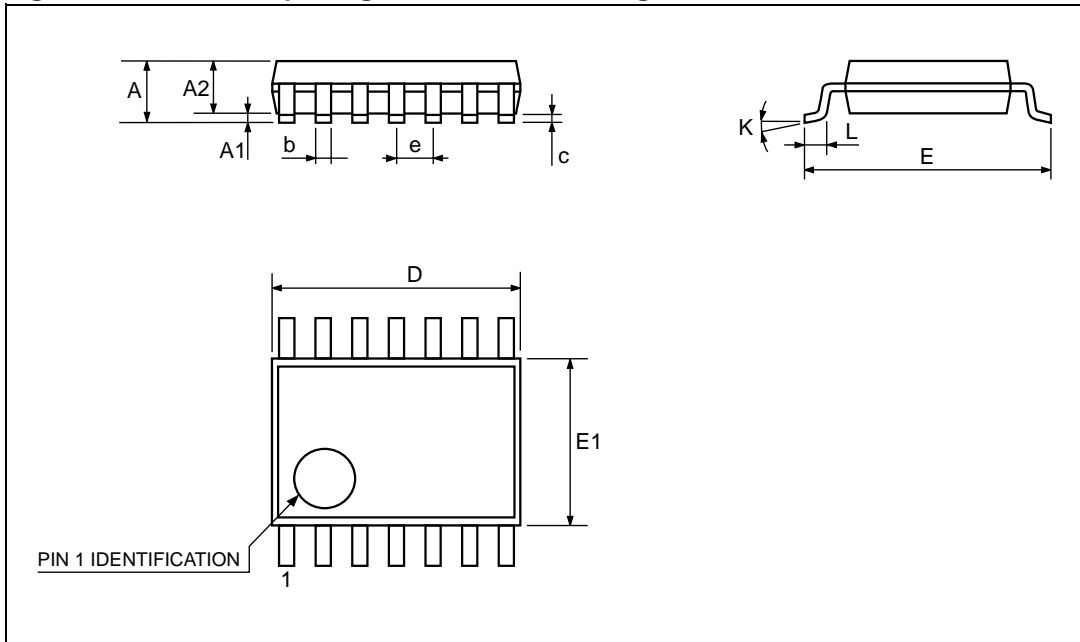
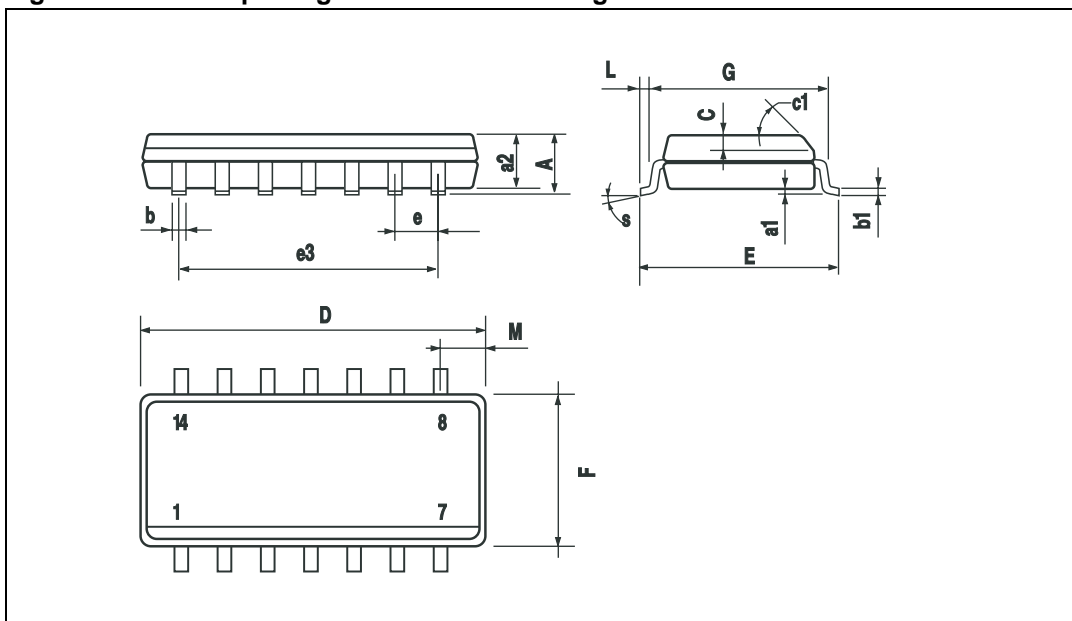


Table 8. TSSOP14 package mechanical data

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°
L1	0.45	0.60	0.75	0.018	0.024	0.030

### 3.4 SO-14 package information

Figure 18. SO-14 package mechanical drawing



## 4 Ordering information

**Table 9. Order codes<sup>(1)</sup>**

Order code	Temperature range	Package	Packing	Marking
TSV991ILT	-40°C to +125°C	SOT23-5	Tape & reel	K130
TSV991AILT				K129
TSV992IST		MiniSO-8		K132
TSV992AIST				K135
TSV992ID		SO-8	Tube or tape & reel	V992I
TSV992IDT				V992AI
TSV992AID		TSSOP14	Tape & reel	V994I
TSV992AIDT				V994AI
TSV994IPT		SO-14 <sup>(1)</sup>	Tube or tape & reel	V994I
TSV994IPT				V994AI
TSV994ID		SO-8 Automotive grade	Tube or tape & reel	V991IY
TSV994IDT				V991AY
TSV994AID		V992IY		
TSV994AIDT		V992AY		
TSV994IYD <sup>(2)</sup>		SO-14 <sup>(1)</sup> Automotive grade		V994IY
TSV994IYDT <sup>(2)</sup>				V994AY
TSV994AIYD <sup>(2)</sup>				
TSV994AIYDT <sup>(2)</sup>				

- All packages are Moisture Sensitivity Level 1 as per Jecdec J-STD-020-C, except SO-14 which is Jecdec level 3.
- 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

Date	Revision	Changes
31-Jul-2006	1	Preliminary data release for product under development.
07-Nov-2006	2	Final version of datasheet.
12-Dec-2006	3	Noise and distortion figures added.
07-Jun-2007	4	ESD tolerance modified for SO-14, CDM in <a href="#">Table 1: Absolute maximum ratings (AMR)</a> . Automotive grade commercial products added in <a href="#">Table 9: Order codes</a> . Note about SO-14 added in <a href="#">Table 9: Order codes</a> . Limits in temperature added in <a href="#">Section 2: Electrical characteristics</a> .
11-Feb-2008	5	Corrected MiniSO-8 package information. Corrected footnote for automotive grade order codes in order code table. Improved presentation of package information.

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