



# TSV991, TSV992, TSV994, TSV991A, TSV992A, TSV994A

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

Datasheet – production data

## Features

- Low input offset voltage: 1.5 mV max (A grade)
- Rail-to-rail input and output
- Wide bandwidth 20 MHz
- Stable for gain  $\geq 4$  or  $\leq -3$
- Low power consumption: 820  $\mu\text{A}$  typ
- 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

## Related products

- See TSV91 series for unity-gain stable amplifiers

## Applications

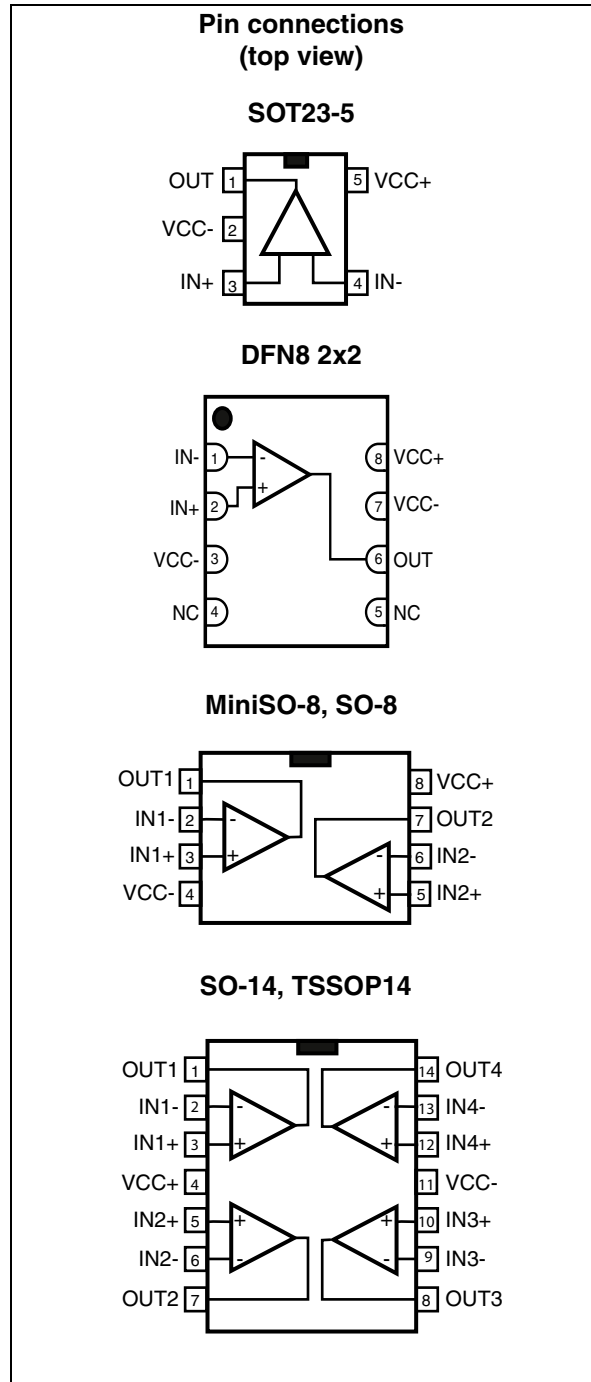
- Battery-powered applications
- Portable devices
- Signal conditioning and active filtering
- Medical instrumentation
- Automotive applications

## Description

The TSV991, TSV992 and TSV994 family of single, dual, and quad operational amplifiers offers low voltage operation and rail-to-rail input and output.

These devices feature an excellent speed/power consumption ratio, offering a 20 MHz gain-bandwidth, stable for gains above 4 (100 pF capacitive load), while consuming only 1.1 mA maximum at 5 V. They also feature an ultra-low input bias current.

These characteristics make the TSV99x family ideal for sensor interfaces, battery-supplied and portable applications, as well as active filtering.



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# 1 Absolute maximum ratings and operating conditions

**Table 1. Absolute maximum ratings**

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>	$V_{CC-} - 0.2$ to $V_{CC+} + 0.2$	V
$I_{in}$	Input current <sup>(4)</sup>	10	mA
$T_{stg}$	Storage temperature	-65 to +150	°C
$R_{thja}$	Thermal resistance junction to ambient <sup>(5)(6)</sup>		°C/W
	DFN8 2x2	57	
	SOT23-5	250	
	SO-8	125	
	MiniSO-8	190	
	SO-14	103	
$R_{thjc}$	Thermal resistance junction to case		°C/W
	SOT23-5	81	
	SO-8	40	
	MiniSO-8	39	
	SO-14	31	
$T_j$	Maximum junction temperature	150	°C
ESD	HBM: Human body model <sup>(7)</sup>	5	kV
	MM: Machine model <sup>(8)</sup>	400	V
	CDM: Charged device model <sup>(9)</sup>		V
	SOT23-5, SO-8, MiniSO-8	1500	
	DFN8 2x2	1500	
TSSOP14	750		
	SO-14	500	
	Latch-up immunity	200	mA

- Value with respect to  $V_{DD}$  pin.
- Differential voltages are the non-inverting input terminal with respect to the inverting input terminal.
- $V_{CC-} - V_{in}$  must not exceed 6 V.
- Input current must be limited by a resistor in series with the inputs.
- Short-circuits can cause excessive heating and destructive dissipation.
- $R_{th}$  are typical values.
- Human body model: 100 pF discharged through a 1.5 k $\Omega$  resistor between two pins of the device, done for all couples of pin combinations with other pins floating.
- Machine model: 200 pF charged to the specified voltage, then discharged directly between two pins of the device with no external series resistor (internal resistor < 5  $\Omega$ ), done for all couples of pin combinations with other pins floating.
- 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	$V_{CC-} - 0.1$ to $V_{CC+} + 0.1$	V
$T_{op}$	Operating free air temperature range	-40 to +125	°C

## 2 Electrical characteristics

**Table 3. Electrical characteristics at  $V_{CC+} = +2.5\text{ V}$ ,  $V_{CC-} = 0\text{ V}$ ,  $V_{icm} = V_{CC}/2$ , 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	$T_{op} = 25^\circ\text{ C}$		0.1	4.5	mV
		$T_{min} < T_{op} < T_{max}$			7.5	
	Offset voltage TSV99xA	$T_{op} = 25^\circ\text{ C}$			1.5	
		$T_{min} < T_{op} < T_{max}$			3	
$\Delta V_{io}/\Delta T$	Input offset voltage drift			2		$\mu\text{V}/^\circ\text{C}$
$I_{io}$	Input offset current <sup>(2)</sup> ( $V_{out} = V_{CC}/2$ )	$T_{op} = 25^\circ\text{ C}$		1	10	pA
		$T_{min} < T_{op} < T_{max}$			100	
$I_{ib}$	Input bias current <sup>(2)</sup> ( $V_{out} = V_{CC}/2$ )	$T_{op} = 25^\circ\text{ C}$		1	10	pA
		$T_{min} < T_{op} < T_{max}$			100	
CMR	Common mode rejection ratio $20 \log(\Delta V_{ic}/\Delta V_{io})$	$0\text{ V to } 2.5\text{ V}$ , $V_{out} = 1.25\text{ V}$ , $T_{op} = 25^\circ\text{ C}$	58	75		dB
		$T_{min} < T_{op} < T_{max}$	53			
$A_{vd}$	Large signal voltage gain	$R_L = 10\text{ k}\Omega$ , $V_{out} = 0.5\text{ V to } 2\text{ V}$ , $T_{op} = 25^\circ\text{ C}$	80	89		dB
		$T_{min} < T_{op} < T_{max}$	75			
$V_{CC-}$ $V_{OH}$	High level output voltage	$R_L = 10\text{ k}\Omega$ , $T_{min} < T_{op} < T_{max}$		15	40	mV
		$R_L = 600\ \Omega$ , $T_{min} < T_{op} < T_{max}$		45	150	
$V_{OL}$	Low level output voltage	$R_L = 10\text{ k}\Omega$ , $T_{min} < T_{op} < T_{max}$		15	40	mV
		$R_L = 600\ \Omega$ , $T_{min} < T_{op} < T_{max}$		45	150	
$I_{out}$	$I_{sink}$	$V_o = 2.5\text{ V}$ , $T_{op} = 25^\circ\text{ C}$	18	32		mA
		$T_{min} < T_{op} < T_{max}$	16			
	$I_{source}$	$V_o = 0\text{ V}$ , $T = 25^\circ\text{ C}$	18	35		
		$T_{min} < T_{op} < T_{max}$	16			
$I_{CC}$	Supply current (per operator)	No load, $V_{out} = V_{CC}/2$ , $T_{min} < T_{op} < T_{max}$		0.78	1.1	
<b>AC performance</b>						
GBP	Gain bandwidth product	$R_L = 2\text{ k}\Omega$ , $C_L = 100\text{ pF}$ , $f = 100\text{ kHz}$ , $T_{op} = 25^\circ\text{ C}$		20		MHz
Gain	Minimum gain for stability	Phase margin = $45^\circ$ , $R_f = 10\text{ k}\Omega$ , $R_L = 2\text{ k}\Omega$ , $C_L = 100\text{ pF}$ , $T_{op} = 25^\circ\text{ C}$ Positive gain configuration		4		V/V
			Negative gain configuration		-3	
SR	Slew rate	$R_L = 2\text{ k}\Omega$ , $C_L = 100\text{ pF}$ , $T_{op} = 25^\circ\text{ C}$		10		V/ $\mu\text{s}$

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

Symbol	Parameter	Conditions	Min.	Typ.	Max.	Unit
$e_n$	Equivalent input noise voltage	$f = 10\text{ kHz}$ , $T_{op} = 25^\circ\text{ C}$		21		$\frac{nV}{\sqrt{Hz}}$
THD+N	Total harmonic distortion	$G = -3$ , $f = 1\text{ kHz}$ , $R_L = 2\text{ k}\Omega$ , $Bw = 22\text{ kHz}$ , $V_{icm} = V_{CC}/2$ , $V_{out} = 2\text{ V}_{pp}$ , $T_{op} = 25^\circ\text{ C}$		0.0025		%

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

**Table 4. Electrical characteristics at  $V_{CC+} = +3.3\text{ V}$ ,  $V_{CC-} = 0\text{ V}$ ,  $V_{icm} = V_{CC}/2$ , 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	$T_{op} = 25^\circ\text{ C}$		0.1	4.5	mV
		$T_{min} < T_{op} < T_{max}$			7.5	
	Offset voltage TSV99xA	$T_{op} = 25^\circ\text{ C}$			1.5	
		$T_{min} < T_{op} < T_{max}$			3	
$\Delta V_{io}/\Delta T$	Input offset voltage drift		-	2	-	$\mu V/^\circ C$
$I_{io}$	Input offset current <sup>(2)</sup> ( $V_{out} = V_{CC}/2$ )	$T_{op} = 25^\circ\text{ C}$		1	10	pA
		$T_{min} < T_{op} < T_{max}$			100	
$I_{ib}$	Input bias current <sup>(2)</sup> ( $V_{out} = V_{CC}/2$ )	$T_{op} = 25^\circ\text{ C}$		1	10	
		$T_{min} < T_{op} < T_{max}$			100	
CMR	Common mode rejection ratio $20\log(\Delta V_{ic}/\Delta V_{io})$	$0\text{ V to }3.3\text{ V}$ , $V_{out} = 1.65\text{ V}$ , $T_{op} = 25^\circ\text{ C}$	60	78		dB
		$T_{min} < T_{op} < T_{max}$	55			
$A_{vd}$	Large signal voltage gain	$R_L = 10\text{ k}\Omega$ , $V_{out} = 0.5\text{ V to }2.8\text{ V}$ , $T=25^\circ\text{ C}$	80	90		
		$T_{min} < T_{op} < T_{max}$	75			
$V_{CC-}$ $V_{OH}$	High level output voltage	$R_L = 10\text{ k}\Omega$ , $T_{min} < T_{op} < T_{max}$		15	40	mV
		$R_L = 600\ \Omega$ , $T_{min} < T_{op} < T_{max}$		45	150	
$V_{OL}$	Low level output voltage	$R_L = 10\text{ k}\Omega$ , $T_{min} < T_{op} < T_{max}$	-	15	40	
		$R_L = 600\ \Omega$ , $T_{min} < T_{op} < T_{max}$		45	150	
$I_{out}$	$I_{sink}$	$V_o = 3.3\text{ V}$ , $T_{op} = 25^\circ\text{ C}$	18	32		mA
		$T_{min} < T_{op} < T_{max}$	16			
	$I_{source}$	$V_o = 0\text{ V}$ , $T_{op} = 25^\circ\text{ C}$	18	35		
		$T_{min} < T_{op} < T_{max}$	16			
$I_{CC}$	Supply current (per operator)	No load, $V_{out} = V_{CC}/2$ , $T_{min} < T_{op} < T_{max}$		0.8	1.1	

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

Symbol	Parameter	Conditions	Min.	Typ.	Max.	Unit
<b>AC performance</b>						
GBP	Gain bandwidth product	$R_L = 2\text{ k}\Omega$ , $C_L = 100\text{ pF}$ , $f = 100\text{ kHz}$ , $T_{op} = 25^\circ\text{ C}$		20		MHz
Gain	Minimum gain for stability	Phase margin = $45^\circ$ , $R_f = 10\text{ k}\Omega$ , $R_L = 2\text{ k}\Omega$ , $C_L = 100\text{ pF}$ , $T_{op} = 25^\circ\text{ C}$ Positive gain configuration Negative gain configuration		4 -3		V/V
SR	Slew rate	$R_L = 2\text{ k}\Omega$ , $C_L = 100\text{ pF}$ , $f = 100\text{ kHz}$ , $T_{op} = 25^\circ\text{ C}$		10		V/ $\mu\text{s}$
$e_n$	Equivalent input noise voltage	$f = 10\text{ kHz}$ , $T_{op} = 25^\circ\text{ C}$		21		$\frac{\text{nV}}{\sqrt{\text{Hz}}}$
THD+N	Total harmonic distortion	$G = -3$ , $f = 1\text{ kHz}$ , $R_L = 2\text{ k}\Omega$ , $Bw = 22\text{ kHz}$ , $V_{icm} = V_{CC}/2$ , $V_{out} = 2.8\text{ V}_{pp}$ , $T_{op} = 25^\circ\text{ C}$		0.0018		%

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

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

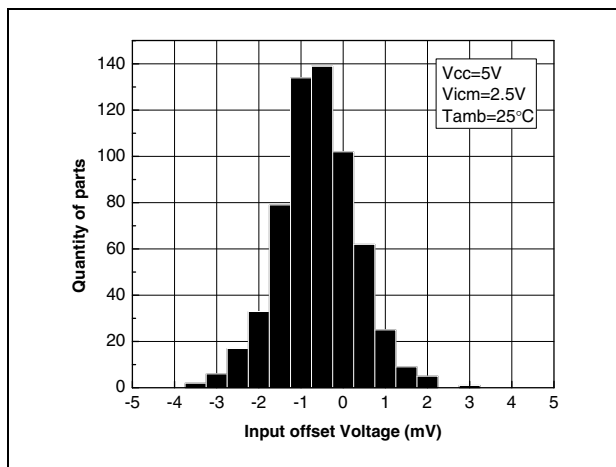
Symbol	Parameter	Conditions	Min.	Typ.	Max.	Unit
<b>DC performance</b>						
$V_{io}$	Offset voltage TSV99x	$T_{op} = 25^\circ\text{ C}$		0.1	4.5	mV
		$T_{min} < T_{op} < T_{max}$			7.5	
	Offset voltage TSV99xA	$T_{op} = 25^\circ\text{ C}$			1.5	
		$T_{min} < T_{op} < T_{max}$			3	
$\Delta V_{io}/\Delta T$	Input offset voltage drift		-	2	-	$\mu\text{V}/^\circ\text{C}$
$I_{io}$	Input offset current <sup>(2)</sup> ( $V_{out} = V_{CC}/2$ )	$T_{op} = 25^\circ\text{ C}$		1	10	pA
		$T_{min} < T_{op} < T_{max}$			100	
$I_{ib}$	Input bias current <sup>(2)</sup> ( $V_{out} = V_{CC}/2$ )	$T_{op} = 25^\circ\text{ C}$		1	10	pA
		$T_{min} < T_{op} < T_{max}$			100	
CMR	Common mode rejection ratio, $20\text{ log}(\Delta V_{ic}/\Delta V_{io})$	0 V to 5 V, $V_{out} = 2.5\text{ V}$ , $T_{op} = 25^\circ\text{ C}$	62	82		dB
		$T_{min} < T_{op} < T_{max}$	57			
SVR	Supply voltage rejection ratio, $20\text{ log}(\Delta V_{cc}/\Delta V_{io})$	$V_{CC} = 2.5\text{ to }5\text{ V}$	70	86		dB
$A_{vd}$	Large signal voltage gain	$R_L = 10\text{ k}\Omega$ , $V_{out} = 0.5\text{ V to }4.5\text{ V}$ , $T = 25^\circ\text{ C}$	80	91		
		$T_{min} < T_{op} < T_{max}$	75			

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

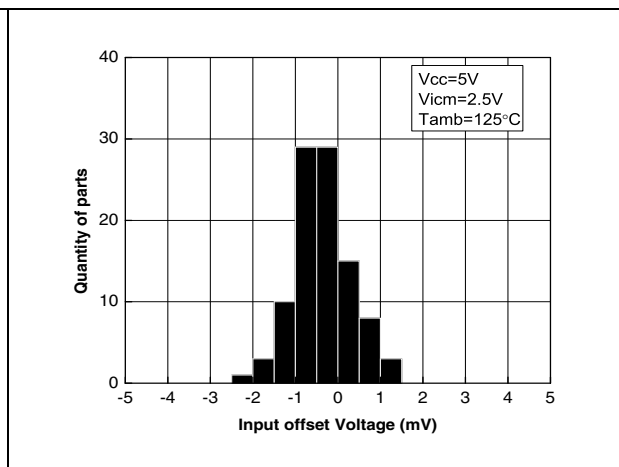
Symbol	Parameter	Conditions	Min.	Typ.	Max.	Unit
$V_{CC-}$ $V_{OH}$	High level output voltage	$R_L = 10\text{ k}\Omega$ , $T_{min} < T_{op} < T_{max}$		15	40	mV
		$R_L = 600\ \Omega$ , $T_{min} < T_{op} < T_{max}$		45	150	
$V_{OL}$	Low level output voltage	$R_L = 10\text{ k}\Omega$ , $T_{min} < T_{op} < T_{max}$		15	40	
		$R_L = 600\ \Omega$ , $T_{min} < T_{op} < T_{max}$		45	150	
$I_{out}$	$I_{sink}$	$V_o = 5\text{ V}$ , $T_{op} = 25^\circ\text{ C}$	18	32	mA	
		$T_{min} < T_{amb} < T_{max}$	16			
	$I_{source}$	$V_o = 0\text{ V}$ , $T_{op} = 25^\circ\text{ C}$	18	35		
		$T_{min} < T_{amb} < T_{max}$	16			
$I_{CC}$	Supply current (per operator)	No load, $V_{out} = 2.5\text{ V}$ , $T_{min} < T_{op} < T_{max}$		0.82	1.1	mA
<b>AC performance</b>						
GBP	Gain bandwidth product	$R_L = 2\text{ k}\Omega$ , $C_L = 100\text{ pF}$ , $f = 100\text{ kHz}$ , $T_{op} = 25^\circ\text{ C}$		20		MHz
Gain	Minimum gain for stability	Phase margin = $45^\circ$ , $R_f = 10\text{ k}\Omega$ , $R_L = 2\text{ k}\Omega$ , $C_L = 100\text{ pF}$ , $T_{op} = 25^\circ\text{ C}$ Positive gain configuration Negative gain configuration		4 -3		V/V
SR	Slew rate	$R_L = 2\text{ k}\Omega$ , $C_L = 100\text{ pF}$ , $T_{op} = 25^\circ\text{ C}$		10		V/ $\mu\text{s}$
$e_n$	Equivalent input noise voltage	$f = 10\text{ kHz}$ , $T_{op} = 25^\circ\text{ C}$		21		$\frac{\text{nV}}{\sqrt{\text{Hz}}}$
THD+N	Total harmonic distortion	$G = -3$ , $f = 1\text{ kHz}$ , $R_L = 2\text{ k}\Omega$ , $Bw = 22\text{ kHz}$ , $V_{icm} = V_{CC}/2$ , $V_{out} = 4.4\text{ V}_{pp}$ , $T_{op} = 25^\circ\text{ C}$		0.0014		%

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

**Figure 1. Input offset voltage distribution at  $T = 25^\circ\text{ C}$**

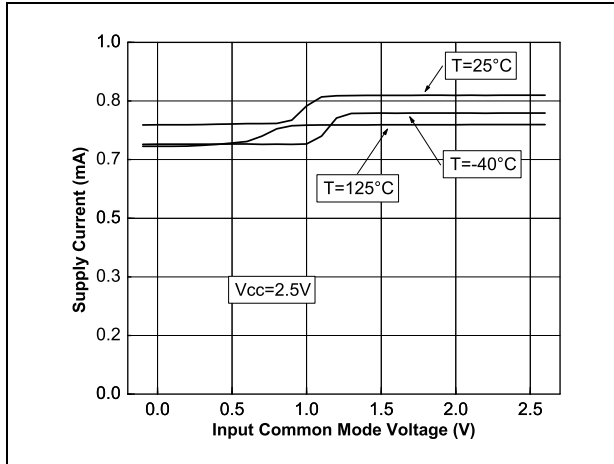


**Figure 2. Input offset voltage distribution at  $T = 125^\circ\text{ C}$**

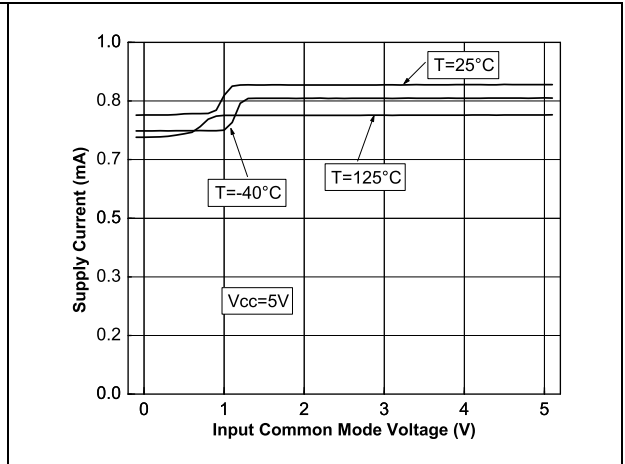




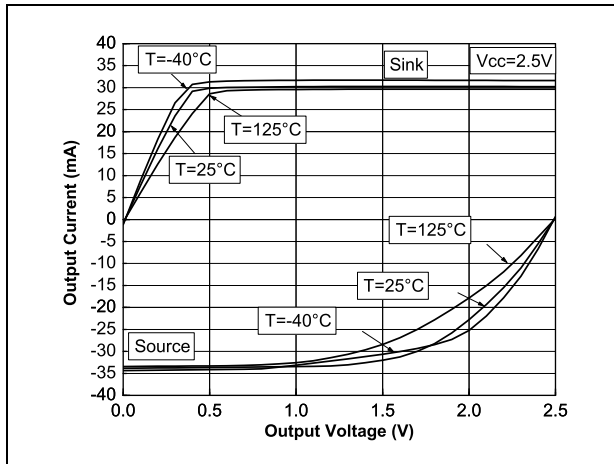
**Figure 3. Supply current vs. input common mode voltage at  $V_{CC} = 2.5\text{ V}$**



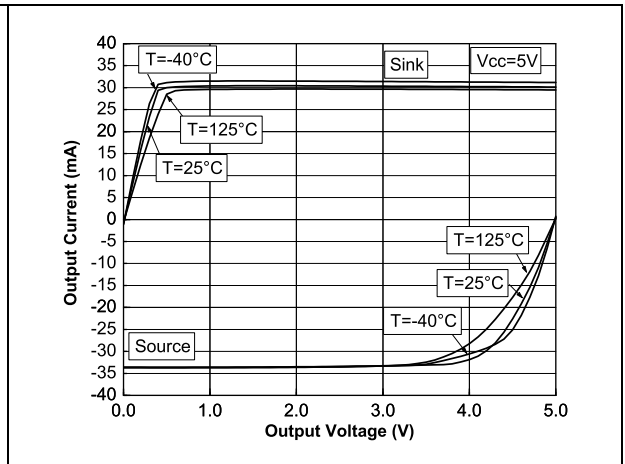
**Figure 4. Supply current vs. input common mode voltage at  $V_{CC} = 5\text{ V}$**



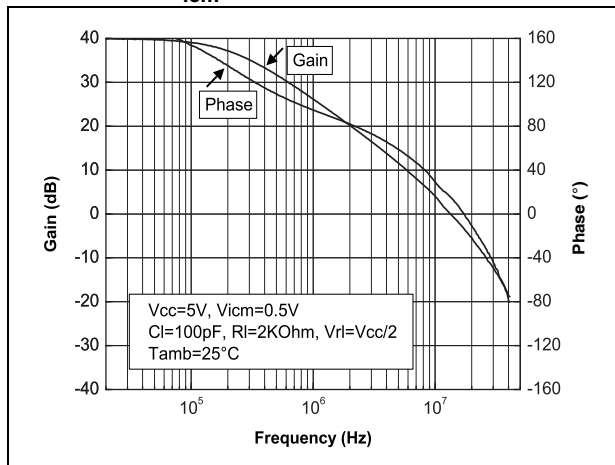
**Figure 5. Output current vs. output voltage at  $V_{CC} = 2.5\text{ V}$**



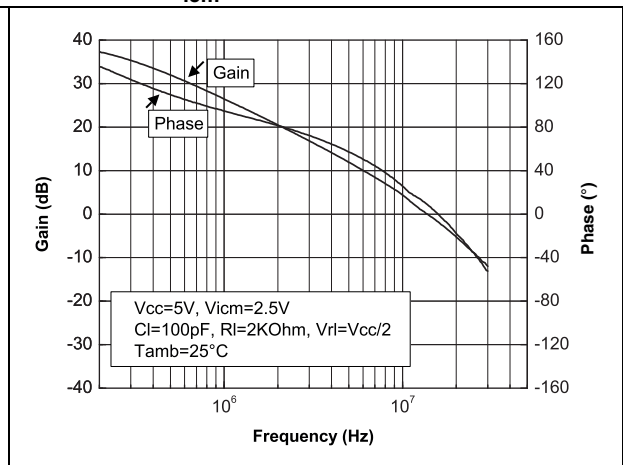
**Figure 6. Output current vs. output voltage at  $V_{CC} = 5\text{ V}$**



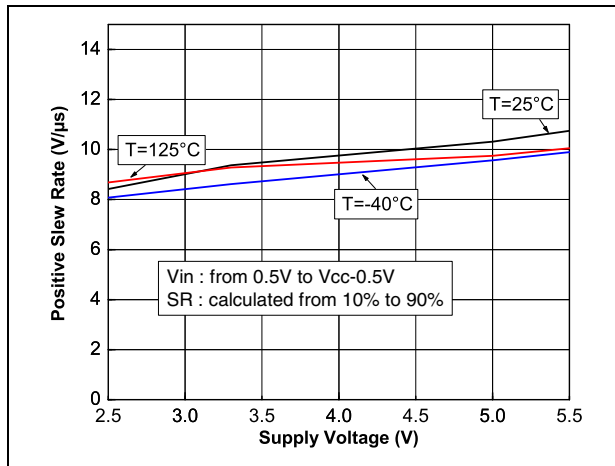
**Figure 7. Voltage gain and phase vs frequency at  $V_{CC} = 5\text{ V}$  and  $V_{icm} = 0.5\text{ V}$**



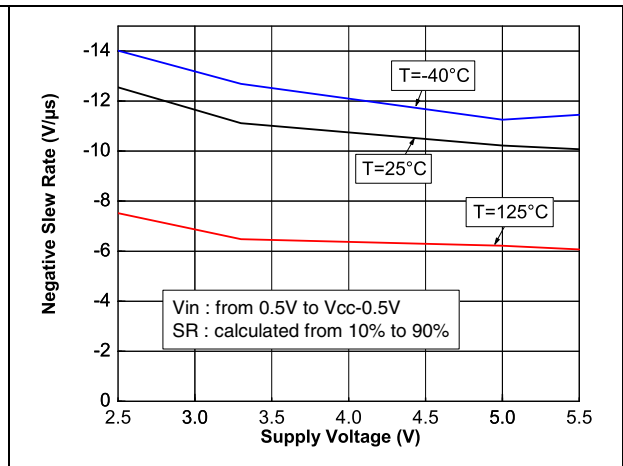
**Figure 8. Voltage gain and phase vs frequency at  $V_{CC} = 5\text{ V}$  and  $V_{icm} = 2.5\text{ V}$**



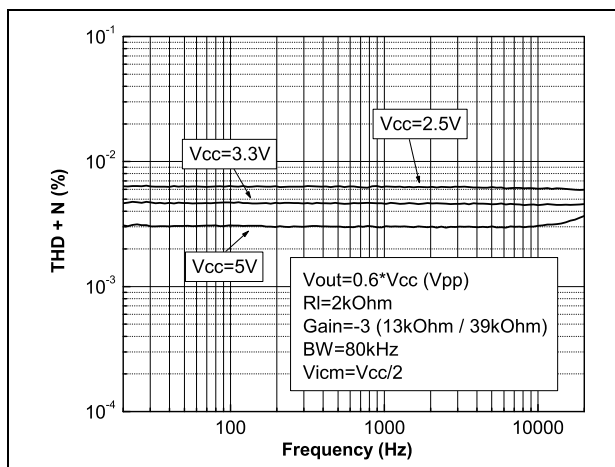
**Figure 9. Positive slew rate**



**Figure 10. Negative slew rate**



**Figure 11. Distortion + noise vs. frequency**



**Figure 12. Distortion + noise vs. output voltage**

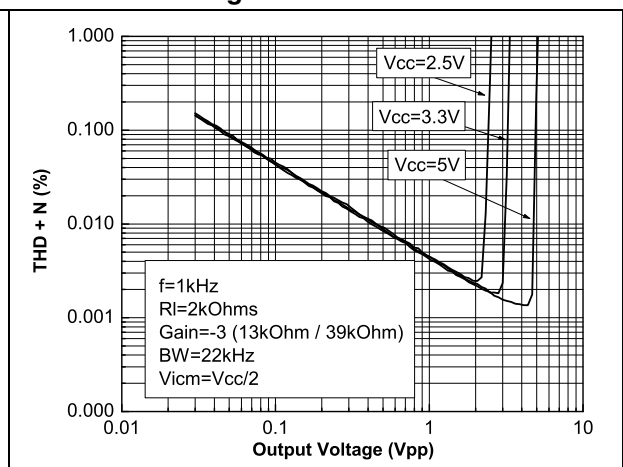


Figure 13. Noise vs. frequency

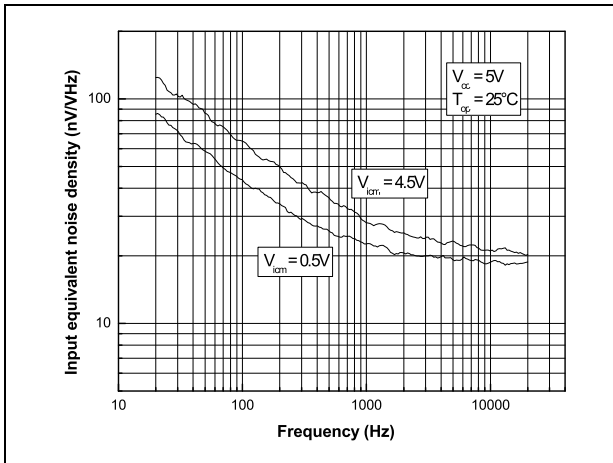
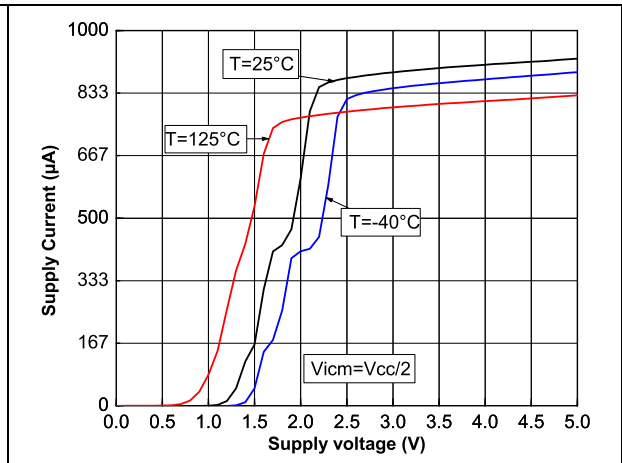


Figure 14. Supply current vs. supply voltage



### 3 Application information

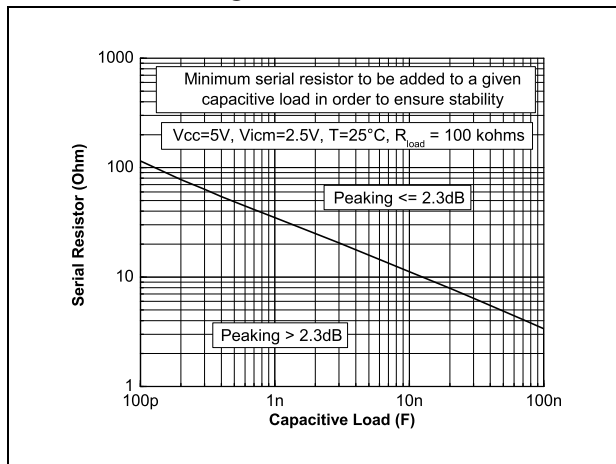
#### 3.1 Driving resistive and capacitive loads

These products are low-voltage, low-power operational amplifiers optimized to drive rather large resistive loads above 2 kΩ.

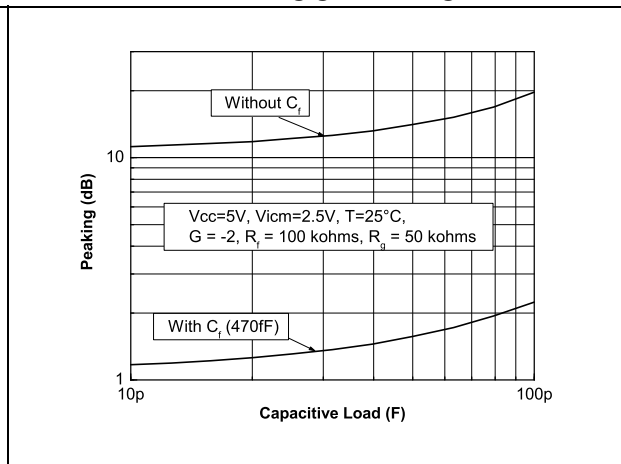
TSV99x products are not unity gain stable. To ensure proper stability they must be used in a gain configuration, with a minimum gain of -3 or +4.

However, they can be used in a “follower“ configuration by adding a small, in-series resistor at the output, which drastically improves the stability of the device (Figure 15 shows the recommended in-series resistor values). Once the in-series resistor value has been selected, the stability of the circuit should be tested on the bench and simulated with the simulation model.

**Figure 15. In-series resistor vs. capacitive load when TSV99x used in follower configuration**



**Figure 16. Peaking versus capacitive load, with or without feedback capacitor in inverting gain configuration**



Another way to improve stability and reduce peaking is to add a capacitor in parallel with the feedback resistor. As shown in Figure 16, the feedback capacitor drastically reduces the peaking versus capacitive load (inverting gain configuration, gain = -2).

#### 3.2 PCB layouts

For correct operation, it is advised to add 10 nF decoupling capacitors as close as possible to the power supply pins.

### 3.3 Macromodel

An accurate macromodel of the TSV99x is available on STMicroelectronics' web site at [www.st.com](http://www.st.com). This model is a trade-off between accuracy and complexity (that is, time simulation) of the TSV99x operational amplifiers. It emulates the nominal performances of a typical device within the specified operating conditions mentioned in the datasheet. It helps to validate a design approach and to select the right operational amplifier, *however, it does not replace on-board measurements.*

## 4 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.

### 4.1 SOT23-5 package information

Figure 17. SOT23-5 package mechanical drawing

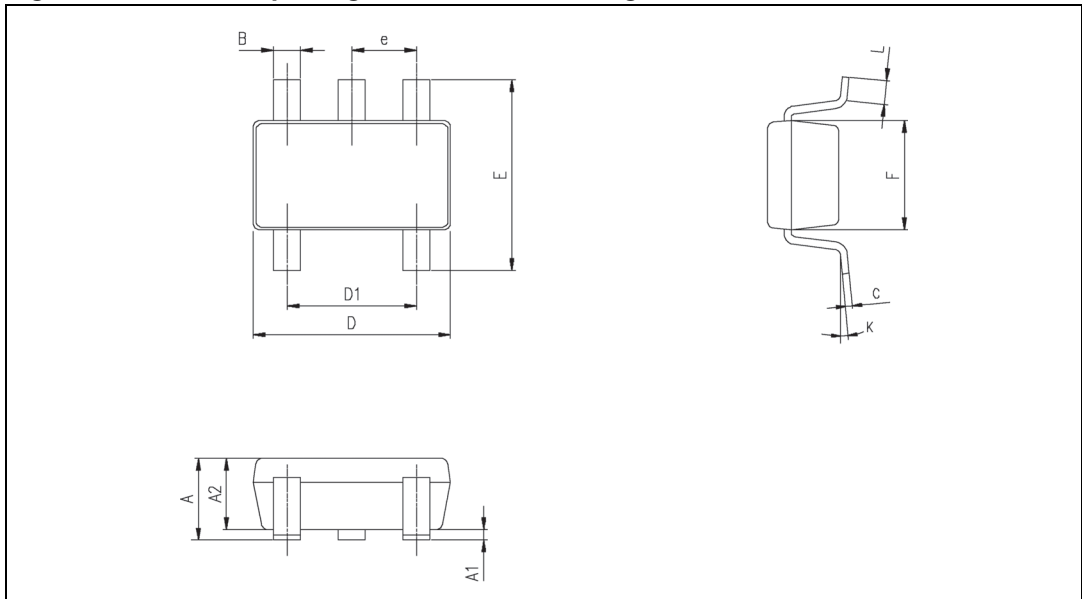
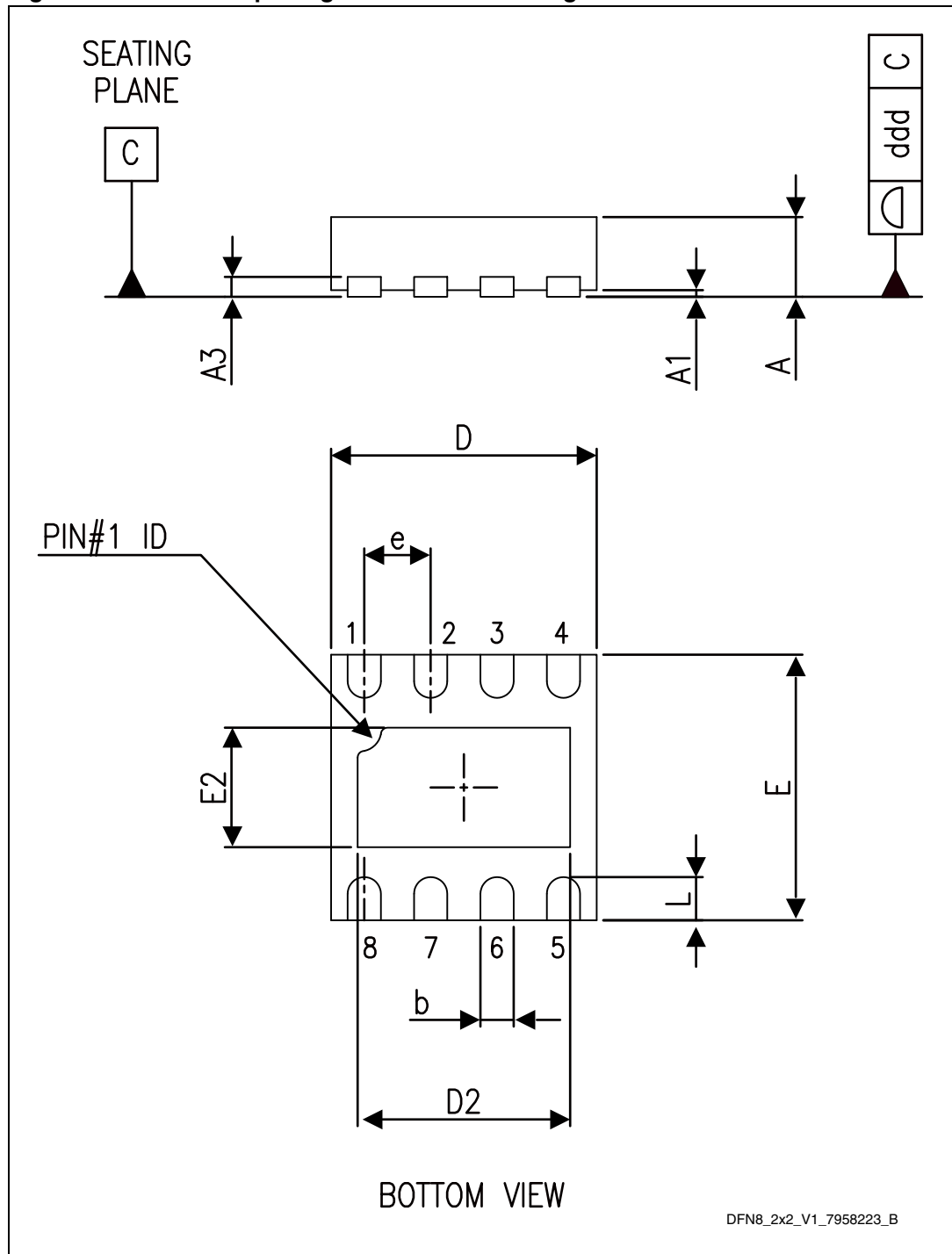


Table 6. SOT23-5 package mechanical data

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			

### 4.2 DFN8 2x2 package information

Figure 18. DFN8 2x2 package mechanical drawing



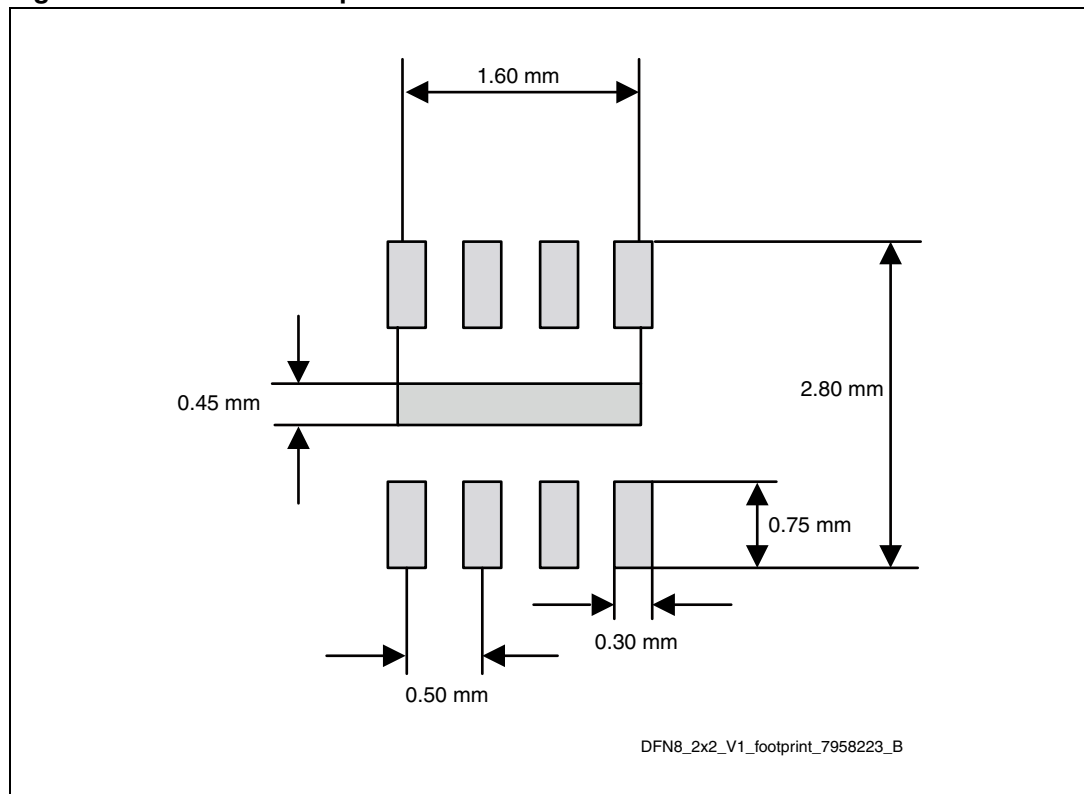


**Table 7. DFN8 2x2 package mechanical data**

Ref.	Dimensions					
	Millimeters			Inches <sup>(1)</sup>		
	Min.	Typ.	Max.	Min.	Typ.	Max.
A	0.51	0.55	0.60	0.020	0.022	0.024
A1			0.05			0.002
A3		0.15			0.006	
b	0.18	0.25	0.30	0.007	0.010	0.012
D	1.85	2.00	2.15	0.073	0.079	0.085
D2	1.45	1.60	1.70	0.057	0.063	0.067
E	1.85	2.00	2.15	0.073	0.079	0.085
E2	0.75	0.90	1.00	0.030	0.035	0.039
e		0.50			0.020	
L			0.50			0.020
ddd			0.08			0.003

1. Values in inches are rounded to three decimal digits.

**Figure 19. DFN8 2x2 footprint recommendation**



### 4.3 MiniSO-8 package information

Figure 20. MiniSO-8 package mechanical drawing

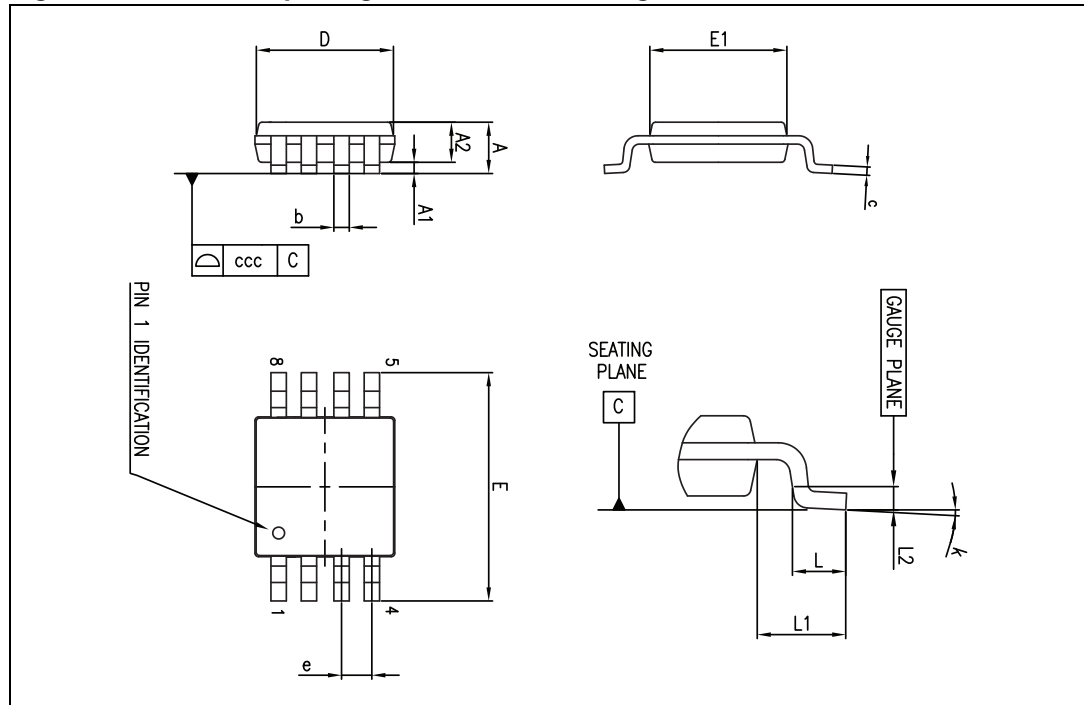


Table 8. MiniSO-8 package mechanical data

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

### 4.4 SO-8 package information

Figure 21. SO-8 package mechanical drawing

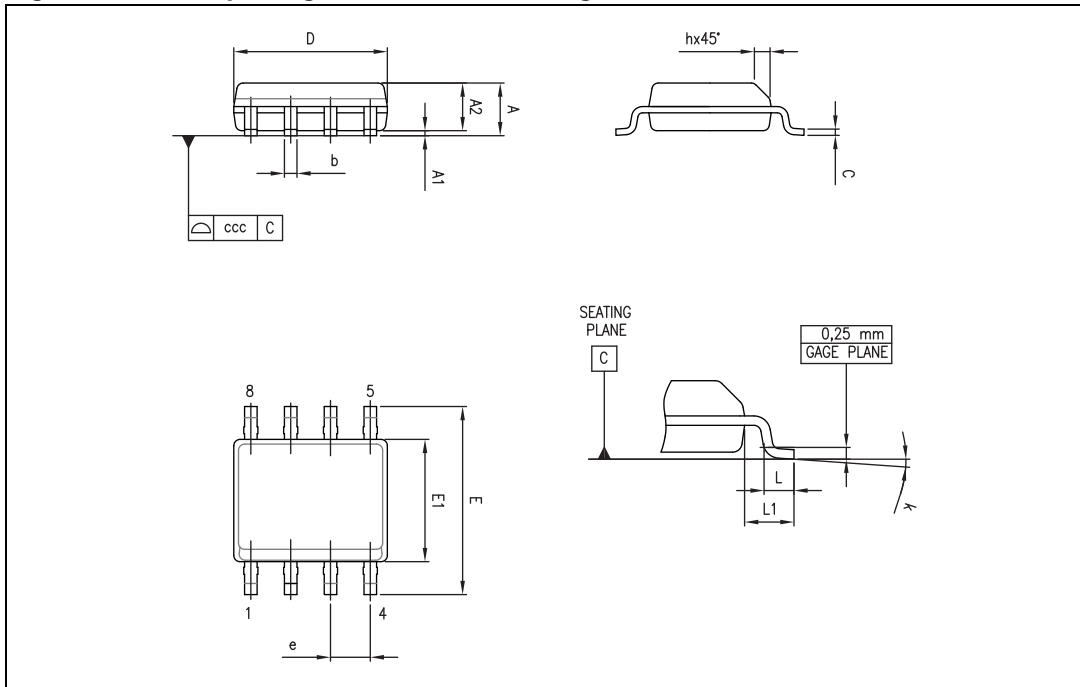


Table 9. SO-8 package mechanical data

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

### 4.5 TSSOP14 package information

Figure 22. TSSOP14 package mechanical drawing

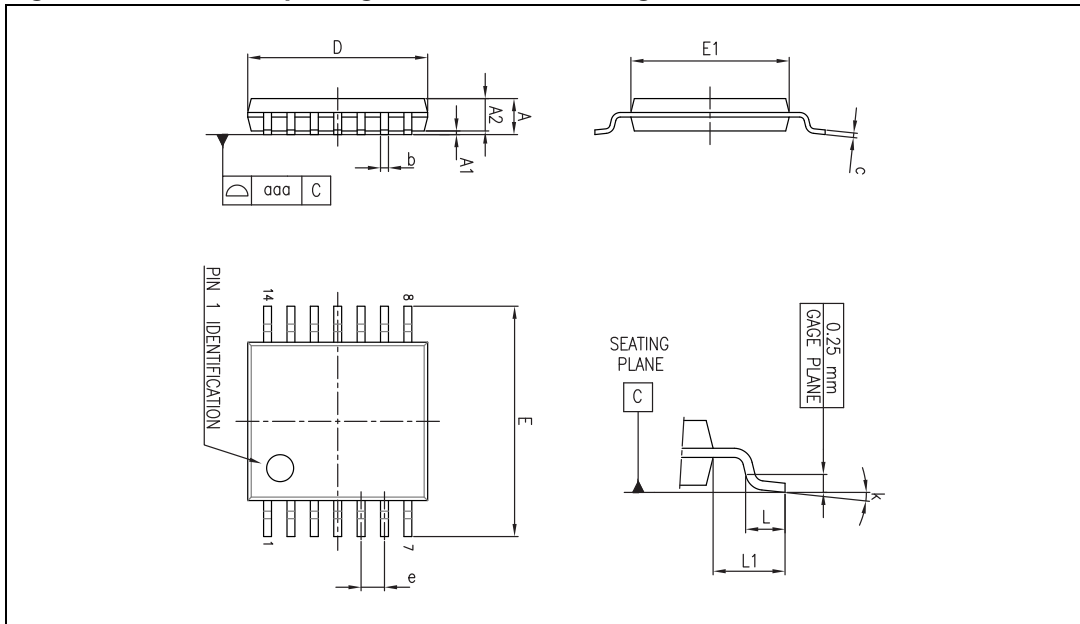


Table 10. TSSOP14 package mechanical data

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

### 4.6 SO-14 package information

Figure 23. SO-14 package mechanical drawing

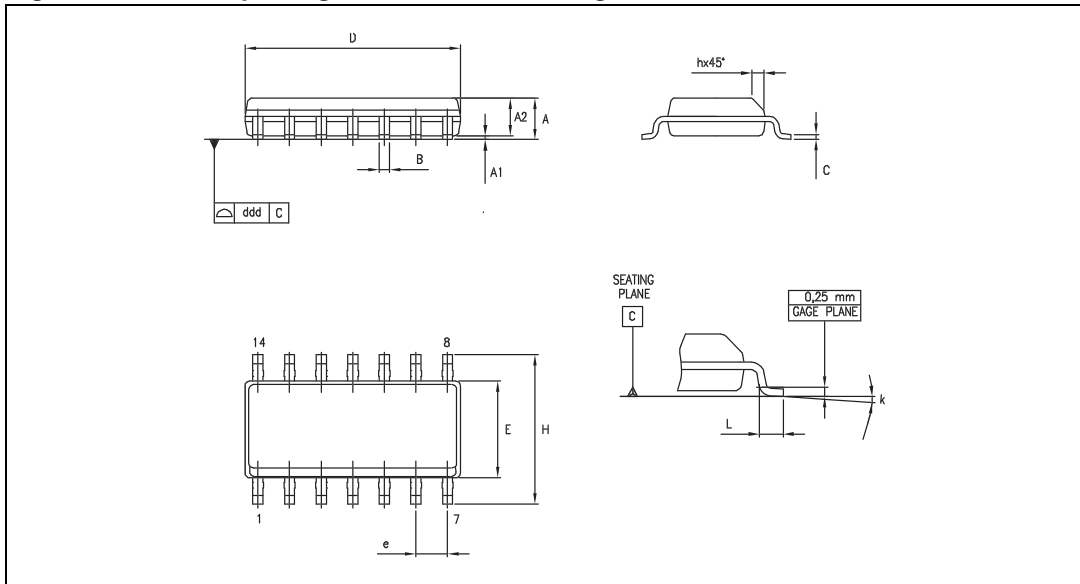


Table 11. SO-14 package mechanical data

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

## 5 Ordering information

Table 12. 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
TSV991IQ2T		DFN8 2x2		K1E
TSV992IST		MiniSO-8		K132
TSV992AIST				K135
TSV992ID TSV992IDT		SO-8	Tube Tape & reel	V992I
TSV992AID TSV992AIDT			Tube Tape & reel	V992AI
TSV994IPT		TSSOP14	Tape & reel	V994I
TSV994AIPT				V994AI
TSV994ID TSV994IDT		SO-14 <sup>(1)</sup>	Tube Tape & reel	V994I
TSV994AID TSV994AIDT			Tube Tape & reel	V994AI
TSV991IYLT <sup>(2)</sup>		-40° C to +125° C Automotive grade	SOT23-5	Tape & reel
TSV991AIYLT <sup>(2)</sup>	K150			
TSV992IYDT <sup>(2)</sup>	SO-8		Tape & reel	V992IY
TSV992AIYDT <sup>(2)</sup>			Tape & reel	V992AY
TSV992IYST <sup>(2)</sup>	MiniSO-8		Tape & reel	K149
TSV992AIYST <sup>(2)</sup>				K150
TSV994IYDT <sup>(2)</sup>	SO-14 <sup>(1)</sup>		Tape & reel	V994IY
TSV994AIYDT <sup>(2)</sup>			Tape & reel	V994AY
TSV994IYPT <sup>(2)</sup>	TSSOP14		Tape & reel	V994IY
TSV994AIYPT <sup>(2)</sup>				V994AY

1. All packages are Moisture Sensitivity Level 1 as per Jedec J-STD-020-C, except SO-14 which is Jedec level 3.
2. Qualified and characterized according to AEC Q100 and Q003 or equivalent, advanced screening according to AEC Q001 & Q 002 or equivalent.

## 6 Revision history

**Table 13. Document 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</a> . Automotive grade commercial products added in <a href="#">Table 12: Order codes</a> . Note about SO-14 added in <a href="#">Table 12: 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.
25-May-2009	6	Added input current information in table <a href="#">Table 1: Absolute maximum ratings</a> . Added <a href="#">Chapter 3: Application information</a> . Updated all packages in <a href="#">Chapter 4: Package information</a> . Added new order codes: TSV991IYLT, TSV991AIYLT, TSV992IYST, TSV992AIYST, TSV994IYPT, TSV994AIYPT in <a href="#">Table 12: Order codes</a> .
19-Oct-2009	7	Added A versions of devices in title on cover page. Added parameters for full temperature range in <a href="#">Table 3</a> , <a href="#">Table 4</a> , <a href="#">Table 5</a> . Removed <i>gain margin</i> and <i>phase margin</i> parameters in <a href="#">Table 3</a> , <a href="#">Table 4</a> and <a href="#">Table 5</a> . These parameters have been replaced by the <i>gain</i> parameter (minimum gain for stability). Added <a href="#">Figure 14</a> and <a href="#">Figure 16</a> .
14-Jan-2010	8	Added parameters for full temperature range in <a href="#">Table 3</a> , <a href="#">Table 4</a> and <a href="#">Table 5</a> . Modified <a href="#">Note 2</a> relative to automotive grade in <a href="#">Table 12: Order codes</a> .
22-Oct-2012	9	Document status changed to production data. Modified gain value in <a href="#">Features</a> and <a href="#">Description</a> . Added DFN8 2x2 pin connection diagram. <a href="#">Table 1: Absolute maximum ratings</a> : added package DFN8 2x2 to rows R <sub>thja</sub> and ESD. <a href="#">Table 3</a> , <a href="#">Table 4</a> , and <a href="#">Table 5</a> : replaced “DV <sub>io</sub> ” with $\Delta V_{io}/\Delta T$ ; modified “Gain” and “THD+N” conditions and typical values. <a href="#">Figure 7</a> and <a href="#">Figure 8</a> : added arrows indicating “Gain” and “Phase”.

Table 13. Document revision history

Date	Revision	Changes
22-Oct-2012	9 cont'd	<i>Figure 11</i> and <i>Figure 12</i> : updated. Added <i>Figure 18: DFN8 2x2 package mechanical drawing</i> and <i>Figure 19: DFN8 2x2 footprint recommendation</i> . <i>Table 12: Order codes</i> : updated automotive grade qualification and added order code of DFN8 package.



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