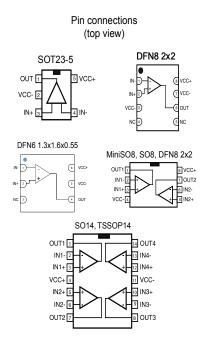


# TSV991, TSV992, TSV994 TSV991A TSV992A, TSV994A

**Datasheet** 

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



#### **Features**

- Low input offset voltage: 1.5 mV max. (A grade)
- · Rail-to-rail input and output
- · Wide bandwidth 20 MHz
- Stable for gain ≥ 4 or ≤ -3
- Low power consumption: 820 μA 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 ≥ 5 kV

#### **Applications**

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

#### **Description**

The TSV99x and TSV99xA 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. These characteristics make the TSV99x, TSV99xA family ideal for sensor interfaces, battery-supplied and portable applications, as well as active filtering.

#### Product status link

TSV991, TSV992, TSV994, TSV991A, TSV992A, TSV994A

#### Related products

See TSV991,TSV992, TSV994

For unity-gain stable amplifiers



### 1 Absolute maximum ratings and operating conditions

Table 1. Absolute maximum ratings (AMR)

Symbol	Parameter		Value	Unit	
V <sub>CC</sub>	Supply voltage (1)		6		
V <sub>id</sub>	Differential input voltage (2)		±V <sub>CC</sub>	V	
V <sub>in</sub>	Input voltage (3)		(V <sub>CC-</sub> ) - 0.2 to (V <sub>CC+</sub> ) + 0.2		
l <sub>in</sub>	Input current (4)		10	mA	
T <sub>stg</sub>	Storage temperature		-65 to 150		
T <sub>j</sub>	Maximum junction temperature		150	°C	
		DFN8 2x2	57		
		DFN6 1.3x1.6x0.55	230		
		SOT23-5	250		
R <sub>thja</sub>	Thermal resistance junction to ambient (5) (6)	SO8	125	°C/W	
		MiniSO8	190		
		SO14	103		
		TSSOP14	100		
		SOT23-5	81		
		SO8	40		
$R_{\text{thjc}}$	Thermal resistance junction to case	MiniSO8	39		
		SO14	31		
		TSSOP14	32		
	HBM: human body model (7)		5	kV	
	MM: machine model (8)		400		
ESD		SOT23-5, SO8, MiniSO8, DFN8 2x2	1500		
	CDM: charged device model (9)	DFN6 1.3x1.6x0.55	TBD	mA °C	
		TSSOP14	750		
		SO14	500		
	Latch-up immunity		200	mA	

- 1. Value is with respect to the  $V_{CC}$  pin.
- 2. Differential voltages are the non-inverting input terminal with respect to the inverting input terminal.
- 3. V<sub>CC</sub> V<sub>IN</sub> must not exceed 6 V.
- 4. Input current must be limited by a resistor in series with the inputs.
- 5. Short-circuits can cause excessive heating and destructive dissipation.
- 6. Rth are typical values.
- Human body model: 100 pF discharged through a 1.5 kΩ resistor between two pins of the device, done for all couples of pin combinations with other pins floating.
- 8. 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.
- 9. Charged device model: all pins plus packages are charged together to the specified voltage and then discharged directly to the ground.

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Absolute maximum ratings and operating conditions

#### **Table 2. Operating conditions**

Symbol	Parameter	Value	Unit
V <sub>CC</sub>	Supply voltage	2.5 to 5.5	V
V <sub>icm</sub>	Common mode input voltage range	(V <sub>CC-</sub> ) - 0.1 to (V <sub>CC+</sub> ) + 0.1	V
T <sub>op</sub>	Operating free air temperature range	-40 to 125	°C

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### 2 Electrical characteristics

Note: In the electrical characteristic tables below, all parameter limits at temperatures other than 25 °C are guaranteed by correlation

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)

Symbol	Parameter	Conditions	Min.	Тур.	Max.	Unit
		DC performance				
	O#==1=H==== T0\/00:	T <sub>op</sub> = 25 °C		0.1	4.5	
V	Offset voltage, TSV99x	$T_{min} < T_{op} < T_{max}$			7.5	
$V_{io}$	Off. 1 11 TO 100 A	T <sub>op</sub> = 25 °C			1.5	mV
	Offset voltage, TSV99xA	T <sub>min</sub> < T <sub>op</sub> < T <sub>max</sub>			3	
$\Delta V_{io}/\Delta T$	Input offset voltage drift			2		μV/°C
	Input offset current,	T <sub>op</sub> = 25 °C		1	10	
l <sub>io</sub>	$V_{out} = V_{CC}/2$ (1)	T <sub>min</sub> < T <sub>op</sub> < T <sub>max</sub>			100	
	Input bias current, V <sub>out</sub> = V <sub>CC</sub> /2	T <sub>op</sub> = 25 °C		1	10	pA
l <sub>ib</sub>	Section 2 Electrical characteristics	T <sub>min</sub> < T <sub>op</sub> < T <sub>max</sub>			100	
	Common mode rejection ratio,	0 V to 2.5 V, V <sub>out</sub> = 1.25 V, T <sub>op</sub> = 25 °C	58	75		
CMR	20 log ( $\Delta V_{ic}/\Delta V_{io}$ )	T <sub>min</sub> < T <sub>op</sub> < T <sub>max</sub>	53			
		$R_L = 10 \text{ k}\Omega, V_{out} = 0.5 \text{ V to 2 V},$	80	89		dB
A <sub>vd</sub>	Large signal voltage gain	T <sub>op</sub> = 25 °C				
		T <sub>min</sub> < T <sub>op</sub> < T <sub>max</sub>	75			
., .,		$R_L = 10 \text{ k}\Omega$ , $T_{min} < T_{op} < T_{max}$		15	40	
V <sub>CC</sub> - V <sub>OH</sub>	High-level output voltage	$R_L = 600 \Omega$ , $T_{min} < T_{op} < T_{max}$		45	150	\
		$R_L = 10 \text{ k}\Omega$ , $T_{min} < T_{op} < T_{max}$		15	40	mV
$V_{OL}$	Low-level output voltage	$R_L = 600 \Omega$ , $T_{min} < T_{op} < T_{max}$		45	150	
		V <sub>o</sub> = 2.5 V, T <sub>op</sub> = 25 °C	18	32		
	l <sub>sink</sub>	T <sub>min</sub> < T <sub>op</sub> < T <sub>max</sub>	16			
l <sub>out</sub>		V <sub>o</sub> = 0 V, T <sub>op</sub> = 25 °C	18	35		mA
	I <sub>source</sub>	T <sub>min</sub> < T <sub>op</sub> < T <sub>max</sub>	16			- 111/4
I <sub>CC</sub>	Supply current (per channel)	No load, $V_{out} = V_{CC}/2$ , $T_{min} < T_{op} < T_{max}$		0.78	1.1	_
		AC performance		1		
GBP	Gain bandwidth product	$R_L = 2 \text{ k}\Omega, C_L = 100 \text{ pF, f} = 100 \text{ kHz,}$ $T_{op} = 25 \text{ °C}$		20		MHz
Gain	Minimum gain for stability	Phase margin = 45 °, $R_f$ = 10 k $\Omega$ , $R_L$ = 2 k $\Omega$ , $C_L$ = 100 pF, $T_{op}$ = 25 °C, positive gain configuration		4		V/V
Gain	Minimum gain for stability	Phase margin = 45 °, $R_f$ = 10 k $\Omega$ , $R_L$ = 2 k $\Omega$ , $C_L$ = 100 pF, $T_{op}$ = 25 °C, negative gain configuration		-3		V/V
SR	Slew rate	$R_L = 2 k\Omega$ , $C_L = 100 pF$ , $T_{op} = 25 °C$		10		V/µs

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Symbol	Parameter	Conditions	Min.	Тур.	Max.	Unit
e <sub>n</sub>	Equivalent input noise voltage	f = 10 kHz, T <sub>op</sub> = 25 °C		21		nV/√Hz
THD+N	Total harmonic distortion	$G = -3, f = 1 \text{ kHz}, R_L = 2 \text{ k}\Omega, Bw = 22$ kHz, $V_{\text{icm}} = V_{\text{CC}}/2, V_{\text{out}} = 2 \text{ V}_{pp},$ $T_{op} = 25 \text{ °C}$		0.0025		%

<sup>1.</sup> 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)

Symbol	Parameter	Conditions	Min.	Тур.	Max.	Unit
		DC performance				
	Off 1   TOV /00	T <sub>op</sub> = 25 °C		0.1	4.5	
\ <u>/</u>	Offset voltage, TSV99x	T <sub>min</sub> < T <sub>op</sub> < T <sub>max</sub>			7.5	
$V_{io}$	Office traditions TCV/00vA	T <sub>op</sub> = 25 °C			1.5	mV
	Offset voltage, TSV99xA	$T_{min} < T_{op} < T_{max}$			3	
$\Delta V_{io}/\Delta T$	Input offset voltage drift			2		μV/°C
	Input offset current,	T <sub>op</sub> = 25 °C		1	10	
l <sub>io</sub>	$V_{\text{out}} = V_{\text{CC}}/2^{(1)}$	T <sub>min</sub> < T <sub>op</sub> < T <sub>max</sub>			100	
	Input bias current, V <sub>out</sub> = V <sub>CC</sub> /2	T <sub>op</sub> = 25 °C		1	10	pA
l <sub>ib</sub>	Section 2 Electrical characteristics	T <sub>min</sub> < T <sub>op</sub> < T <sub>max</sub>			100	
0115	Common mode rejection ratio,	0 V to 3.3 V, V <sub>out</sub> = 1.65 V, T <sub>op</sub> = 25 °C	60	78		
CMR	20 log ( $\Delta V_{ic}/\Delta V_{io}$ )	T <sub>min</sub> < T <sub>op</sub> < T <sub>max</sub>	55			
		$R_L = 10 \text{ k}\Omega$ , $V_{out} = 0.5 \text{ V to } 2.8 \text{ V}$ ,	80	89		μV/°C pA dB
$A_{vd}$	Large signal voltage gain	T <sub>op</sub> = 25 °C				
		T <sub>min</sub> < T <sub>op</sub> < T <sub>max</sub>	75			
	I limb land a start with a	$R_L = 10 \text{ k}\Omega, T_{min} < T_{op} < T_{max}$		15	40	
V <sub>CC</sub> - V <sub>OH</sub>	High-level output voltage	$R_L = 600 \Omega$ , $T_{min} < T_{op} < T_{max}$		45	150	
\/		$R_L = 10 \text{ k}\Omega$ , $T_{min} < T_{op} < T_{max}$		15	40	– mv
V <sub>OL</sub>	Low-level output voltage	$R_L = 600 \Omega$ , $T_{min} < T_{op} < T_{max}$		45	150	
		V <sub>o</sub> = 3.3 V, T <sub>op</sub> = 25 °C	18	32		
	l <sub>sink</sub>	T <sub>min</sub> < T <sub>op</sub> < T <sub>max</sub>	16			
l <sub>out</sub>		V <sub>o</sub> = 0 V, T <sub>op</sub> = 25 °C	18	35		mA
	I <sub>source</sub>	T <sub>min</sub> < T <sub>op</sub> < T <sub>max</sub>	16			
I <sub>CC</sub>	Supply current (per channel)	No load, $V_{out} = V_{CC}/2$ , $T_{min} < T_{op} < T_{max}$		0.8	1.1	
		AC performance				1
GBP	Gain bandwidth product	$R_L = 2 \text{ k}\Omega$ , $C_L = 100 \text{ pF}$ , $f = 100 \text{ kHz}$ , $T_{op} = 25 \text{ °C}$		20		MHz

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Symbol	Parameter	Conditions	Min.	Тур.	Max.	Unit
Gain	Minimum gain for stability	Phase margin = 45 °, $R_f$ = 10 $k\Omega$ , $R_L$ = 2 $k\Omega$ , $C_L$ = 100 pF, $T_{op}$ = 25 °C, positive gain configuration		4		V/V
Gain Minimum gain for stat	Will influin gain for Stability	Phase margin = 45 °, $R_f$ = 10 $k\Omega$ , $R_L$ = 2 $k\Omega$ , $C_L$ = 100 pF, $T_{op}$ = 25 °C, negative gain configuration		-3		V/V
SR	Slew rate	$R_L$ = 2 k $\Omega$ , $C_L$ = 100 pF, f = 100 kHz, $T_{op}$ = 25 °C		10		V/µs
e <sub>n</sub>	Equivalent input noise voltage	f = 10 kHz, T <sub>op</sub> = 25 °C		21		nV/√Hz
THD+N	Total harmonic distortion	$G = -3$ , $f = 1$ kHz, $R_L = 2$ k $\Omega$ , $Bw = 22$ kHz, $V_{icm} = V_{CC}/2$ , $V_{out} = 2.8$ $V_{pp}$ , $V_{op} = 25$ °C		0.0018		%

<sup>1.</sup> Guaranteed by design.

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

Symbol	Parameter	Conditions	Min.	Тур.	Max.	Unit
		DC performance				
	Office to the sea TCV (00)	T <sub>op</sub> = 25 °C		0.1	4.5	
	Offset voltage, TSV99x	$T_{min} < T_{op} < T_{max}$			7.5	
$V_{io}$	Official could be a TOV (OO) A	T <sub>op</sub> = 25 °C			1.5	mV μV/°C pA dB
	Offset voltage, TSV99xA	$T_{min} < T_{op} < T_{max}$			3	
$\Delta V_{io}/\Delta T$	Input offset voltage drift			2		μV/°C
	Input offset current,	T <sub>op</sub> = 25 °C		1	10	
l <sub>io</sub>	$V_{out} = V_{CC}/2$ (1)	$T_{min} < T_{op} < T_{max}$			100	
	Input bias current, V <sub>out</sub> = V <sub>CC</sub> /2	T <sub>op</sub> = 25 °C		1	10	pA
l <sub>ib</sub>	Section 2 Electrical characteristics	$T_{min} < T_{op} < T_{max}$			100	
		0 V to 5 V, V <sub>out</sub> = 2.5 V,	62	82		
CMR	Common mode rejection ratio, 20 log ( $\Delta V_{ic}/\Delta V_{io}$ )	$T_{op}$ = 25 °C				
	2 20 ( 10 10)	$T_{min} < T_{op} < T_{max}$	57			
SVR	Supply voltage rejection ratio, 20 log (ΔV <sub>cc</sub> /ΔV <sub>io</sub> )	V <sub>CC</sub> = 2.5 V to 5 V	70	86		dB
		$R_L = 10 \text{ k}\Omega, V_{out} = 0.5 \text{ V to } 4.5 \text{ V},$	80	91		
$A_{vd}$	Large signal voltage gain	$T_{op}$ = 25 °C				
		$T_{min} < T_{op} < T_{max}$	75			
\/ \/	High lavel astronomy to the	$R_L = 10 \text{ k}\Omega$ , $T_{min} < T_{op} < T_{max}$		15	40	
V <sub>CC</sub> - V <sub>OH</sub>	High-level output voltage	$R_L = 600 \Omega$ , $T_{min} < T_{op} < T_{max}$		45	150	
V	1 1	$R_L = 10 \text{ k}\Omega$ , $T_{min} < T_{op} < T_{max}$		15	40	mv mv
$V_{OL}$	Low-level output voltage	$R_L = 600 \Omega$ , $T_{min} < T_{op} < T_{max}$		45	150	

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Symbol	Parameter	Conditions	Min.	Тур.	Max.	Unit	
		V <sub>o</sub> = 5 V, T <sub>op</sub> = 25 °C	18	32			
	I <sub>sink</sub>	T <sub>min</sub> < T <sub>op</sub> < T <sub>max</sub>	16				
l <sub>out</sub>	1	V <sub>o</sub> = 0 V, T <sub>op</sub> = 25 °C	18	35		mA	
	I <sub>source</sub>	T <sub>min</sub> < T <sub>op</sub> < T <sub>max</sub>	16				
Icc	Supply current (per channel)	No load, $V_{out}$ = 2.5 V, $T_{min}$ < $T_{op}$ < $T_{max}$		0.82	1.1		
		AC performance					
CDD	Gain bandwidth product	$R_L = 2 k\Omega$ , $C_L = 100 pF$ , $f = 100 kHz$ ,		20		MHz	
GBP	GBP	T <sub>op</sub> = 25 °C					
0-1-	Minimum and for Al-Hills	Phase margin = 45 °, $R_f$ = 10 $k\Omega$ , $R_L$ = 2 $k\Omega$ , $C_L$ = 100 pF, $T_{op}$ = 25 °C, positive gain configuration		4			
Gain	Minimum gain for stability	Phase margin = 45 $^{\circ}$ , R <sub>f</sub> = 10 k $\Omega$ , R <sub>L</sub> = 2 k $\Omega$ , C <sub>L</sub> = 100 pF, T <sub>op</sub> =25 $^{\circ}$ C, negative gain configuration		-3		V/V	
SR	Slew rate	$R_L = 2 \text{ k}\Omega$ , $C_L = 100 \text{ pF}$ , $f = 100 \text{ kHz}$ , $T_{op} = 25 \text{ °C}$		10		V/µs	
en	Equivalent input noise voltage	f = 10 kHz, T <sub>op</sub> = 25 °C		21		nV/√Hz	
THD+N	Total harmonic distortion	$G = -3$ , $f = 1$ kHz, $R_L = 2$ kΩ, $Bw = 22$ kHz, $V_{icm} = V_{CC}/2$ , $V_{out} = 4.4$ $V_{pp}$ , $V_{op} = 25$ °C		0.0014		%	

<sup>1.</sup> Guaranteed by design.

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#### **Electrical characteristic curves** 3

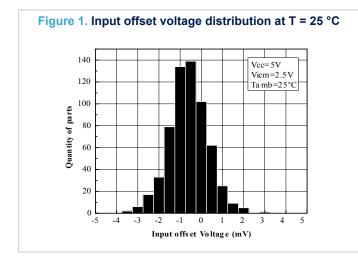


Figure 2. Input offset voltage distribution at T = 125 °C Vcc=5V Vicm=2.5V Tamb=125°C 30 Quantity of parts 10 Input offs et Voltage (mV)

Figure 3. Supply current vs. input common-mode voltage at  $V_{CC} = 2.5 \text{ V}$ 1.0 T=25°C 0.8 Supply Current (mA) 0.5 0.3 T=-40°C T=125°C

at  $V_{CC} = 5 V$ 1.0 T=25°C 0.8 Supply Current (mA) 0.2 0.3 T=125°C T=-40°C 0.5 Vcc=5V 0.2 0.0 1 2 3 4 Input Common Mode Voltage (V)

Figure 4. Supply current vs. input common-mode voltage

0.5 1.0 1.5 2.0 Input Common Mode Voltage (V) Figure 5. Output current vs. output voltage at  $V_{CC} = 2.5 \text{ V}$ 

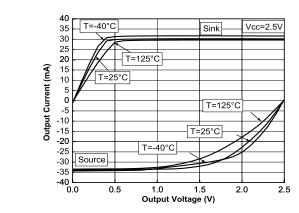
2.5

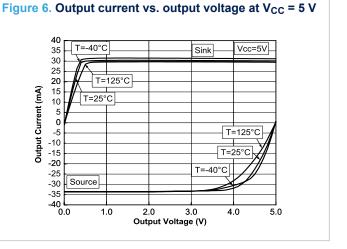
Vcc=2.5V

0.2

0.0

0.0





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Figure 7. Voltage gain and phase vs. frequency at  $V_{CC} = 5$  | Figure 8. Voltage gain and phase vs. frequency at  $V_{CC} = 5$ V and V<sub>icm</sub> = 0.5 V 160 Gain 30 120 Phase 20 80 40 Gain (dB) 0 0 40 -20 -80 Vcc=5V, Vicm=0.5V CI=100pF, RI=2KOhm, VrI=Vcc/2 Tamb=25°C -30 -120

10

Frequency (Hz)

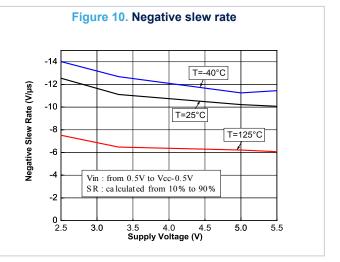
-160

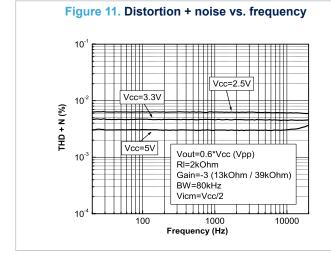
10

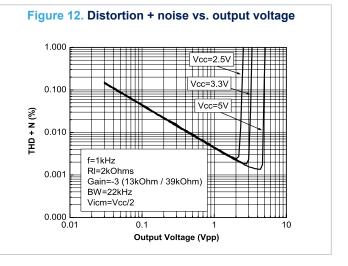
V and V<sub>icm</sub> = 2.5 V 40 160 30 120 20 80 10 40 Gain (dB) 0 0 -10 -40 -20 -80 Vcc=5V, Vicm=2.5V CI=100pF, RI=2KOhm, VrI=Vcc/2 -30 -120 Tamb=25°C -40 10 Frequency (Hz)

Figure 9. Positive slew rate 14 T=25°C Positive Slew Rate (V/µs) T=125°C T=-40°C Vin: from 0.5V to Vcc-0.5V  $S\,R$  : calculated from 10% to 90% 2 0 L 2.5 3.0 4.0 5.5 Supply Voltage (V)

10<sup>5</sup>

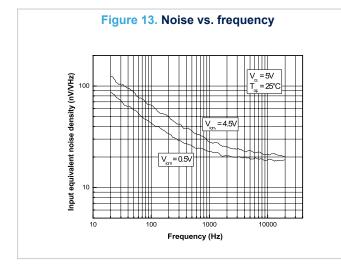


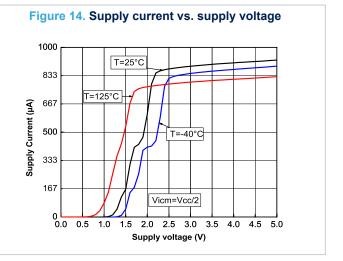




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### 4 Application information

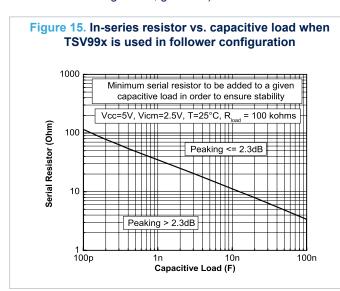
#### 4.1 Driving resistive and capacitive loads

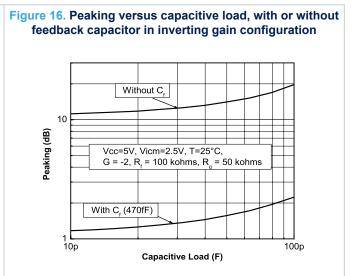
These products are low-voltage, low-power operational amplifiers optimized to drive rather large resistive loads above  $2 \text{ k}\Omega$ .

The 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. In-series resistor vs. capacitive load when TSV99x is used in follower configuration 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.

Another way to improve stability and reduce peaking is to add a capacitor in parallel with the feedback resistor. As shown in Figure 16. Peaking versus capacitive load, with or without feedback capacitor in inverting gain configuration, the feedback capacitor drastically reduces the peaking versus capacitive load (inverting gain configuration, gain = -2).





#### 4.2 PCB layouts

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

#### 4.3 Macromodel

An accurate macromodel of the TSV99x is available on STMicroelectronics' web site at 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 performance 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.

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## 5 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.

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## 5.1 SOT23-5 package information

Figure 17. SOT23-5 package outline

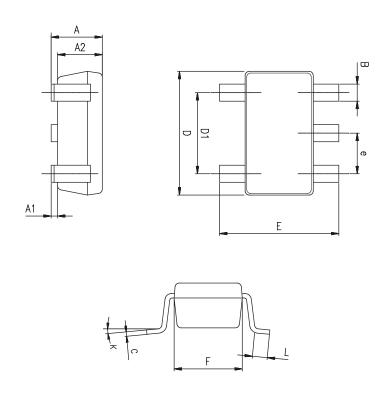


Table 6. SOT23-5 mechanical data

			Dimer	nsions		
Ref.		Millimeters			Inches	
	Min.	Тур.	Max.	Min.	Тур.	Max.
Α	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
В	0.35	0.40	0.50	0.014	0.016	0.020
С	0.09	0.15	0.20	0.004	0.006	0.008
D	2.80	2.90	3.00	0.110	0.114	0.118
D1		1.90			0.075	
е		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	0.014	0.024
K	0 degrees		10 degrees	0 degrees		10 degrees

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## 5.2 DFN8 2 x 2 package information

SEATING PLANE

C

PIN#1 ID

e

1

2

3

4

BOTTOM VIEW

Figure 18. DFN8 2 x 2 package outline

Table 7. DFN8 2 x 2 mechanical data

			Dime	nsions		
Ref.		Millimeters			Inches	
	Min.	Тур.	Max.	Min.	Тур.	Max.
Α	0.51	0.55	0.60	0.020	0.022	0.024
A1			0.05			0.002
А3		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
е		0.50			0.020	
L			0.425			0.017
ddd			0.08			0.003

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0.45mm 0.75mm 2.80mm

Figure 19. DFN8 2 x 2 recommended footprint

Note: The exposed pad of the DFN8 2x2 package is not internally connected. It can be set to ground or left floating.

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### 5.3 DFN6 1.3 x 1.6 x 0.55 package information

D PIN #1 INDEX AREA ia) ge ( △ aaa C 2x TOP VIEW // ccc C PLANE eee C SIDE VIEW PIN #1 ID 3 bbb(M) C Terminal BOTTOM VIEW Tip

Figure 20. DFN6 1.3 x 1.6 x 0.55 package outline

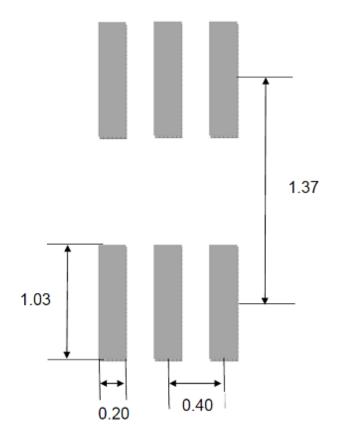
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Table 8. DFN6 1.3 x 1.6 x 0.55 mechanical data

			Dime	nsions		
Ref.		Millimeters			Inches	
	Min.	Тур.	Max.	Min.	Тур.	Max.
Α	0.50	0.55	0.60	0.020	0.022	0.024
A1	0.00	0.02	0.05	0.000	0.001	0.002
А3		0.15			0.006	
В	0.15	0.20	0.25	0.006	0.008	0.010
D		1.30			0.051	
E		1.60			0.063	
е		0.40			0.016	
L	0.453	0.553	0.653	0.018	0.022	0.026
N		6			0.236	
aaa		0.05			0.002	
bbb		0.07			0.003	
ccc		0.10			0.004	
ddd		0.05			0.002	
eee		0.08			0.003	

Figure 21. DFN6 1.3 x 1.6 x 0.55 recommended footprint



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### 5.4 MiniSO8 package information

Figure 22. MiniSO8 package outline

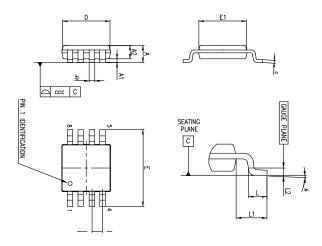


Table 9. MiniSO8 package mechanical data

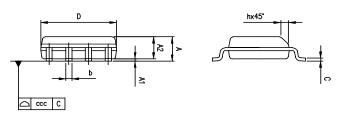
			Dimer	nsions		
Ref.		Millimeters			Inches	
	Min.	Тур.	Max.	Min.	Тур.	Max.
А			1.1			0.043
A1	0		0.15	0		0.0006
A2	0.75	0.85	0.95	0.030	0.033	0.037
b	0.22		0.40	0.009		0.016
С	0.08		0.23	0.003		0.009
D	2.80	3.00	3.20	0.11	0.118	0.126
E	4.65	4.90	5.15	0.183	0.193	0.203
E1	2.80	3.00	3.10	0.11	0.118	0.122
е		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

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## 5.5 SO8 package information

Figure 23. SO8 package outline



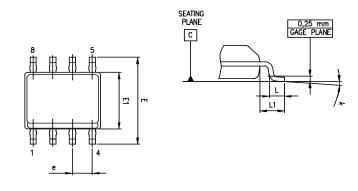


Table 10. SO8 package mechanical data

	Dimensions						
Ref.	Millimeters			Inches			
	Min.	Тур.	Max.	Min.	Тур.	Max.	
Α			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	
С	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	
е		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°	0°		8°	
ccc			0.10			0.004	

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## 5.6 SO14 package information

Figure 24. SO14 package outline

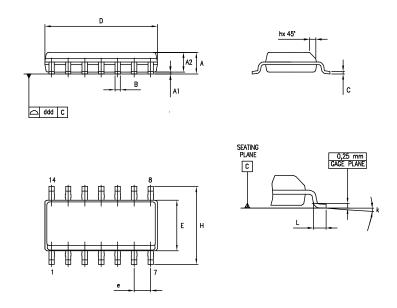


Table 11. SO14 package mechanical data

	Dimensions					
Ref.	Millimeters			Inches		
	Min.	Тур.	Max.	Min.	Тур.	Max.
			1.75			0.069
А	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
В	0.33		0.51	0.01		0.02
С	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
е		1.27			0.05	
Н	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

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## 5.7 TSSOP14 package information

Figure 25. TSSOP14 package outline

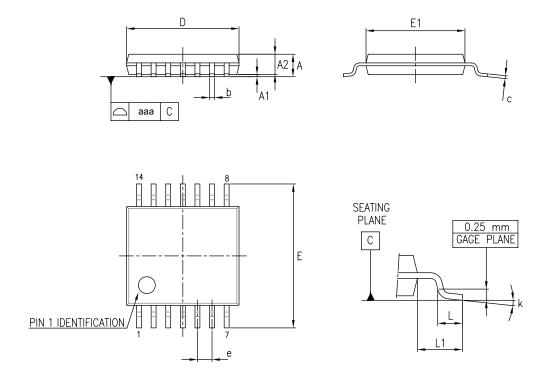


Table 12. TSSOP14 package mechanical data

	Dimensions						
Ref.	Millimeters			Inches			
	Min.	Тур.	Max.	Min.	Тур.	Max.	
А			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	
С	0.09		0.20	0.004		0.0089	
D	4.90	5.00	5.10	0.193	0.197	0.201	
Е	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	
е		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	

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## 6 Ordering information

Table 13. Order code

Order code	Temperature range	Package	Packing	Marking
TSV991ILT		SOT23-5		K130
TSV991AILT		30123-3		K129
TSV991IQ2T		DFN8 2x2		K1F
TSV991AIQ2T		DFN6 2X2		K1E
TSV991AIQ1T		DFN6 1.3x1.6x0.55		K5
TSV992IST		MiniSO8		K132
TSV992AIST	-40 °C to 125 °C	IVIIIIISO6		K135
TSV992IDT	-40 C to 125 C	SO8		V992I
TSV992AIDT		506	Tape and reel	V992AI
TSV992IQ2T		DFN8 2x2		K38
TSV994IPT		TSSOP14		V994I
TSV994AIPT		SO14		V994AI
TSV994IDT				V994I
TSV994AIDT		3014		V994AI
TSV991IYLT (1)		SOT23-5		K149
TSV991AIYLT (1)				K150
TSV992IYDT (1)	-	200		V992IY
TSV992AIYDT (1)	-	SO8		V992AY
TSV992IYST (1)	-40 °C to 125 °C	M: 1000		K149
TSV992AIYST (1)	automotive grade	MiniSO8		K150
TSV994IYDT (1)	-	2211		V994IY
TSV994AIYDT (1)	-	SO14		V994AY
TSV994IYPT (1)	-			V994IY
TSV994AIYPT (1)	-	TSSOP14		V994AY

Qualified and characterized according to AEC Q100 and Q003 or equivalent, advanced screening according to AEC Q001 & Q 002 or equivalent.

Note:

In the table above, all packages except the SO14 are "moisture sensitivity level 1" as per JEDEC J-STD-020-C. SO14 is JEDEC level 3.

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### **Revision history**

**Table 14. 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 SO14, CDM in Table 1: "Absolute maximum ratings (AMR)".
		Automotive grade commercial products added in Table 13: "Order codes".
		Note about SO14 added in Table 13: "Order codes".
		Limits in temperature added in Section 2: "Electrical characteristics".
11-Feb-2008	5	Corrected MiniSO8 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 1: "Absolute maximum ratings (AMR)".
		Added Section 3: "Application information".
		Updated all packages in Section 4: "Package information".
		Added new order codes: TSV991IYLT, TSV991AIYLT, TSV992IYST, TSV992AIYST, TSV994IYPT, TSV994AIYPT in Table 13: "Order codes".
19-Oct-2009	7	Added A versions of devices in title on cover page.
		Added parameters for full temperature range in Table 3, Table 4, and Table 5.
		Removed gain margin and phase margin parameters in Table 3, Table 4, and Table 5.  These parameters have been replaced by the gain parameter (minimum gain for stability).
		Added Figure 14 and Figure 16.
14-Jan-2010	8	Added parameters for full temperature range in Table 3, Table 4, and Table 5.
		Modified note relative to automotive grade in Table 13: "Order codes".
22-Oct-2012	9	Document status changed to production data.
		Modified gain value in Features and Description.
		Added DFN8 2x2 pin connection diagram.
		Table 1: "Absolute maximum ratings (AMR)": added package DFN8 2x2 to rows R <sub>thja</sub> and ESD.
		Table 3, Table 4, and Table 5: replaced "DV $_{io}$ " with $\Delta V_{io}/\Delta T$ ; modified "Gain" and "THD +N" conditions and typical values.
		Figure 7 and Figure 8: added arrows indicating "Gain" and 'Phase".
22-Oct-2012	9 cont'd	Figure 11 and Figure 12: updated.
		Added Figure 18: "DFN8 2 x 2 mm (NB) package outline" and Figure 19: "DFN8 2 x 2 mm (NB) recommended footprint".
		Table 13: "Order codes": updated automotive grade qualification and added order code of DFN8 package.
10-Mar-2014	10	Table 13: "Order codes": added new commercial product TSV991AIQ2T; corrected "Marking" error for TSV991IQ2T from K1E to K1F.
12-Jun-2015	11	Added DFN6 1.3 x 1.6 x 0.55 package for new order code TSV991AIQ1T.
		Updated "L" dimension of Section 4: "DFN8 2 x 2 mm (NB) package information".
		Updated min "k" value of Section 4.5: "SO8 package information".

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Date	Revision	Changes
27-Nov-2015	12	Table 3, Table 4, and Table 5: modified that $R_L$ = 600 $\Omega$ (not 600 $k\Omega$ ) for the high-level and low-level output voltage parameters.
		Section 5.2: updated name of package and titles of drawings and table; added note about exposed pad.
		Section 5.3: updated name of package.
03-Apr-2018	13	Updated cover image and Table 13. Order code.

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