



# TS951-TS952-TS954

## Input/Output Rail-to-Rail Low Power Operational Amplifier

- Rail-to-rail input common-mode voltage range
- Rail-to-rail output voltage swing
- Operating from 2.7V to 12V
- High-speed (3MHz, 1V/μs)
- Low consumption (0.9mA @ 3V)
- Supply voltage rejection ratio: 80dB
- Latch-up immunity
- Available in SOT23-5 micropackage

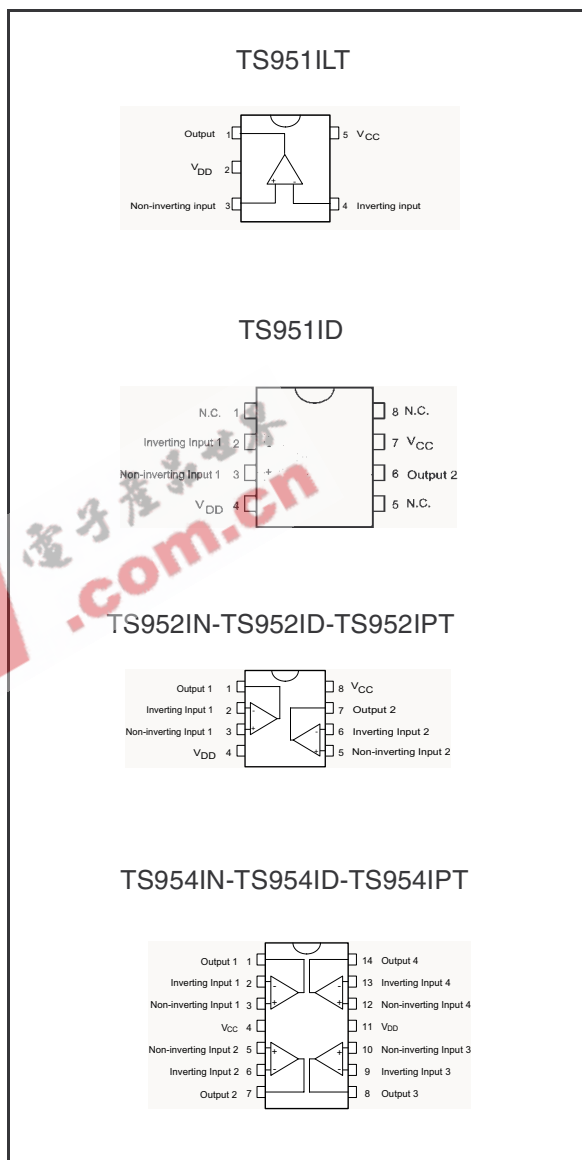
### Description

The TS95x family are rail-to-rail BiCMOS operational amplifiers optimized and fully specified for 3V and 5V operation.

The TS951 is housed in the space-saving 5 pins SOT23 package that makes it well suited for battery-powered systems. This micropackage simplifies the PC board design because of its ability to be placed in tight spaces (outside dimensions are: 2.8mm x 2.9mm)

### Applications

- Set-top boxes
- Laptop/notebook computers
- Transformer/line drivers
- Personal entertainments (CD players)
- Portable communication (cell phones, pagers)
- Instrumentation & sensing
- Digital to analog converter buffers
- Portable headphone speaker drivers



## Order Codes

Part Number	Temperature Range	Package	Packing	Marking
TS951IN	-40°C, +125°C	DIP	Tube	TS951IN
TS951ILT		SOT23-5L	Tape & Reel	K101
TS951IYLT				K102
TS952IN		DIP	Tube	TS952IN
TS952ID/IDT		SO	Tube or Tape & Reel	952I
TS952IPT		TSSOP (Thin Shrink Outline Package)	Tape & Reel	952I
TS954IN		DIP	Tube	TS954IN
TS954ID/IDT		SO	Tube or Tape & Reel	954I
TS954IPT		TSSOP (Thin Shrink Outline Package)	Tape & Reel	954I
TS952IYD/IYDT		SO (automotive grade level)	Tube or Tape & Reel	952IY

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# 1 Absolute Maximum Ratings

**Table 1. Key parameters and their absolute maximum ratings**

Symbol	Parameter	Value	Unit
$V_{CC}$	Supply voltage <sup>(1)</sup>	14	V
$V_{id}$	Differential Input Voltage <sup>(2)</sup>	$\pm 1$	V
$V_{in}$	Input Voltage <sup>(3)</sup>	$V_{DD}-0.3$ to $V_{CC}+0.3$	V
Tstg	Storage Temperature Range	-65 to +150	
$T_j$	Maximum Junction Temperature	150	$^{\circ}\text{C}$
Rthja	Thermal Resistance Junction to Ambient <sup>(4)</sup>		$^{\circ}\text{C/W}$
	SOT23-5	250	
	SO8	125	
	SO14	103	
	TSSOP8 TSSOP14	120 100	
ESD	HBM: Human Body Model <sup>(5)</sup>		kV
	TS951	1	
	TS952 TS954	2 3	
	MM: Machine Model <sup>(6)</sup>	100	V
	CDM: Charged Device Model	1.5	kV
	Latch-up Immunity	200	mA
	Lead Temperature (soldering, 10sec)	260	$^{\circ}\text{C}$

1. All voltage values, except differential voltage are with respect to network ground terminal.
2. Differential voltages are the non-inverting input terminal with respect to the inverting input terminal. If  $V_{id} > \pm 1\text{V}$ , the maximum input current must not exceed  $\pm 1\text{mA}$ . In this case ( $V_{id} > \pm 1\text{V}$ ) an input serie resistor must be added to limit input current.
3. Do not exceed 14V.
4. Short-circuits can cause excessive heating and destructive dissipation.
5. Human body model, 100pF discharged through a 1.5k $\Omega$  resistor into pin of device.
6. Machine model ESD, a 200pF cap is charged to the specified voltage, then discharged directly into the IC with no external series resistor (internal resistor < 5 $\Omega$ ), into pin to pin of device.

**Table 2. Operating conditions**

Symbol	Parameter	Value	Unit
$V_{CC}$	Supply voltage	2.7 to 12	V
$V_{icm}$	Common Mode Input Voltage Range	$V_{DD}-0.2$ to $V_{CC}+0.2$	V
$T_{oper}$	Operating Free Air Temperature Range	-40 to +125	$^{\circ}\text{C}$

## 2 Electrical Characteristics

**Table 3.**  $V_{CC} = +3V$ ,  $V_{DD} = 0V$ ,  $R_L$  connected to  $V_{CC}/2$ ,  $T_{amb} = 25^\circ C$  (unless otherwise specified)

Symbol	Parameter	Min.	Typ.	Max.	Unit
$V_{io}$	Input Offset Voltage $T_{min} \leq T_{amb} \leq T_{max}$			6 8	mV
$DV_{io}$	Input Offset Voltage Drift		2		$\mu V/^\circ C$
$I_{io}$	Input Offset Current $T_{min} \leq T_{amb} \leq T_{max}$		1	30 80	nA
$I_{ib}$	Input Bias Current $V_{icm} = V_{cc}/2$ $T_{min} \leq T_{amb} \leq T_{max}$		35	100 200	nA
CMR	Common Mode Rejection Ratio	50	80		dB
SVR	Supply Voltage Rejection Ratio $V_{cc} = 2.7V$ to $3.3V$	60	80		dB
$A_{vd}$	Large Signal Voltage Gain $V_o = 2V_{pk-pk}$ $R_L = 600\Omega$		80		dB
$V_{OH}$	High Level Output Voltage $R_L = 600\Omega$	2.8	2.9		V
$V_{OL}$	Low Level Output Voltage $R_L = 600\Omega$		80	250	mV
$I_{sc}$	Output Short Circuit Current	10			mA
$I_{cc}$	Supply Current (per Amplifier) No load, $V_{icm} = V_{cc}/2$		0.9	1.3	mA
GBP	Gain Bandwidth Product $R_L = 2k\Omega$		3		MHz
SR	Slew Rate		1		V/ $\mu s$
$\phi_m$	Phase Margin at Unit Gain $=100pF$ $R_L = 600\Omega$ , $C_L$		60		Degrees
Gm	Gain Margin $=100pF$ $R_L = 600\Omega$ , $C_L$		10		dB
$e_n$	Equivalent Input Noise Voltage $f = 1kHz$		25		$\frac{nV}{\sqrt{Hz}}$
THD	Total Harmonic Distortion $V_{out} = 4V_{pk-pk}$ , $F = 10kHz$ , $A_v = 2$ , $R_L = 10k\Omega$		0.01		%

**Table 4.**  $V_{CC} = +5V$ ,  $V_{DD} = 0V$ ,  $R_L$  connected to  $V_{CC}/2$ ,  $T_{amb} = 25^\circ C$  (unless otherwise specified)

Symbol	Parameter	Min.	Typ.	Max.	Unit
$V_{io}$	Input Offset Voltage $T_{min} \leq T_{amb} \leq T_{max}$			6 8	mV
$DV_{io}$	Input Offset Voltage Drift		2		$\mu V/^\circ C$
$I_{io}$	Input Offset Current $V_{icm} = V_{CC}/2$ $T_{min} \leq T_{amb} \leq T_{max}$		1	30 80	nA
$I_{ib}$	Input Bias Current $V_{icm} = V_{CC}/2$ $T_{min} \leq T_{amb} \leq T_{max}$		35	100 200	nA
CMR	Common Mode Rejection Ratio	50	80		dB
SVR	Supply Voltage Rejection Ratio $V_{CC} = 2.7V$ to $3.3V$	60	80		dB
$A_{vd}$	Large Signal Voltage Gain $V_o = 2V_{pk-pk}$ $R_L = 600\Omega$		86		dB
$V_{OH}$	High Level Output Voltage $R_L = 600\Omega$	4.7	4.8		V
$V_{OL}$	Low Level Output Voltage $R_L = 600\Omega$		80	300	mV
$I_{SC}$	Output Short Circuit Current	10			mA
$I_{CC}$	Supply Current (per Amplifier) No load, $V_{icm} = V_{CC}/2$		0.95	1.4	mA
GBP	Gain Bandwidth Product $R_L = 2k\Omega$		3		MHz
SR	Slew Rate		1		$V/\mu s$
$\phi_m$	Phase Margin at Unit Gain $R_L = 600\Omega$ , $C_L = 100pF$		60		Degree s
Gm	Gain Margin $R_L = 600\Omega$ , $C_L = 100pF$		10		dB
$e_n$	Equivalent Input Noise Voltage $f = 1kHz$		25		$\frac{nV}{\sqrt{Hz}}$
THD	Total Harmonic Distortion $V_{out} = 4V_{pk-pk}$ , $F = 10kHz$ , $A_v = 2$ , $R_L = 10k\Omega$		0.01		%

Figure 1. Supply current vs. supply voltage

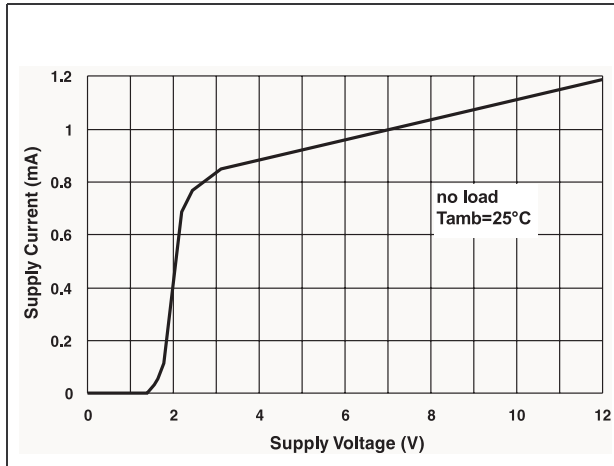


Figure 2. Output short circuit current vs. output voltage

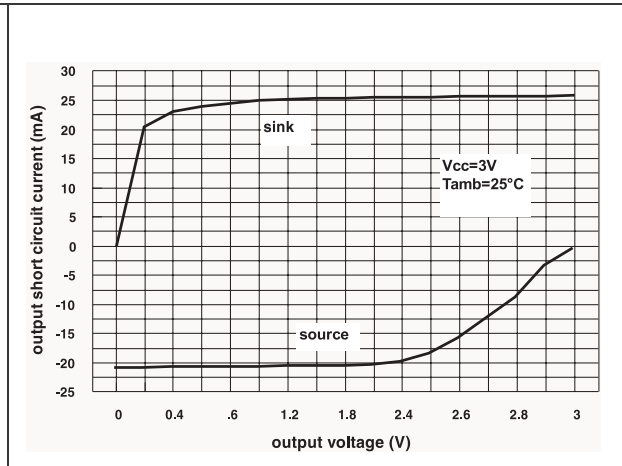


Figure 3. Voltage gain and phase vs. frequency

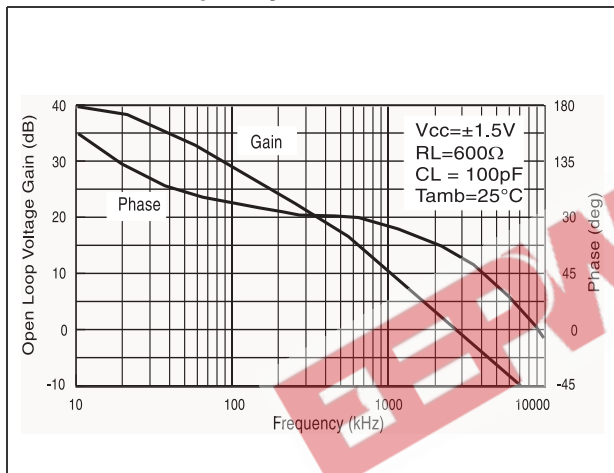


Figure 4. Supply current vs. temperature

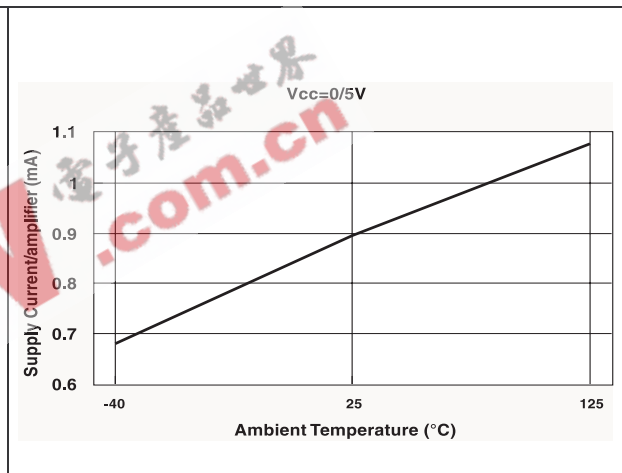


Figure 5. Output short circuit current vs. temperature

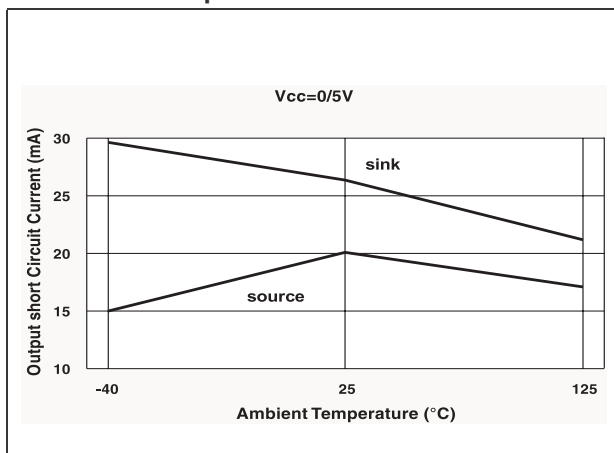


Figure 6. Slew rate vs. temperature

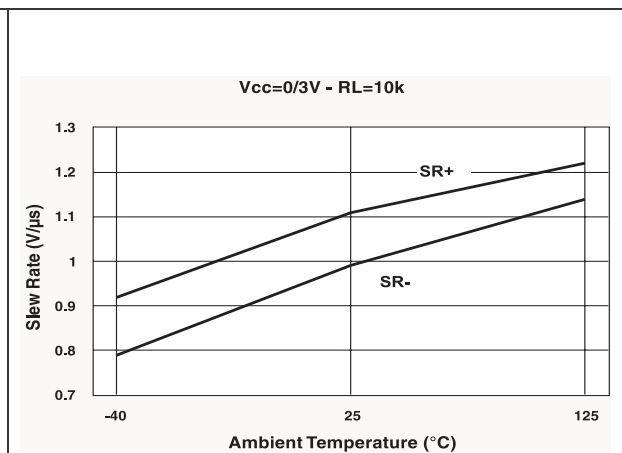


Figure 7. THD + noise vs. Vout

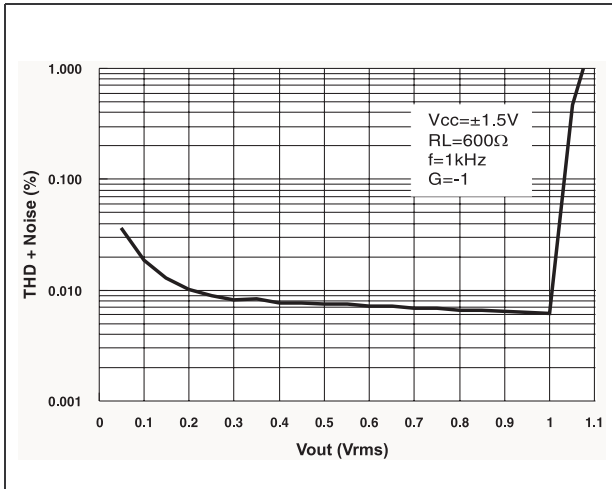


Figure 8. THD + noise vs. frequency

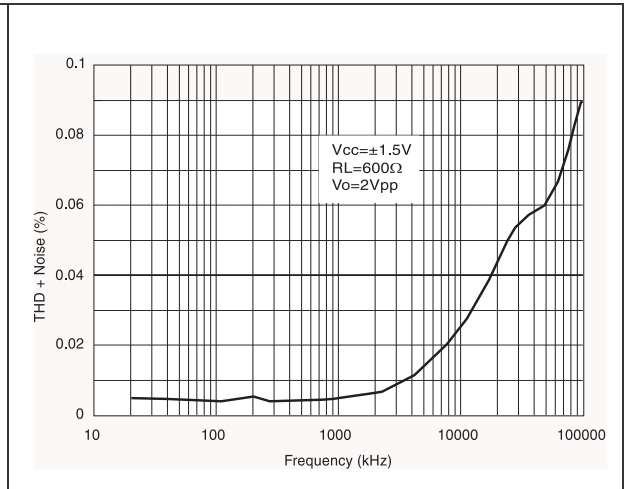


Figure 9. THD + noise vs. Vout

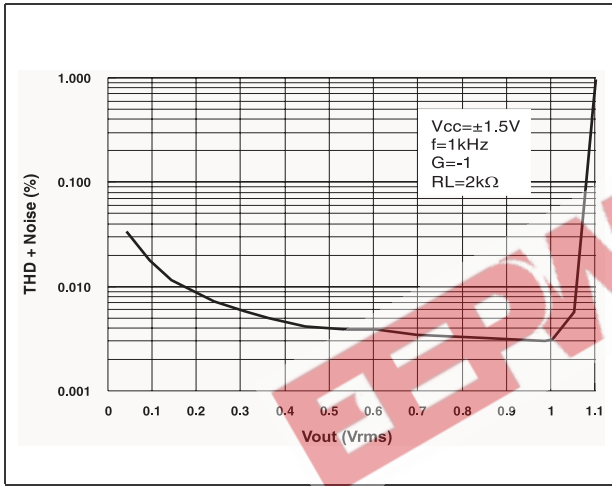
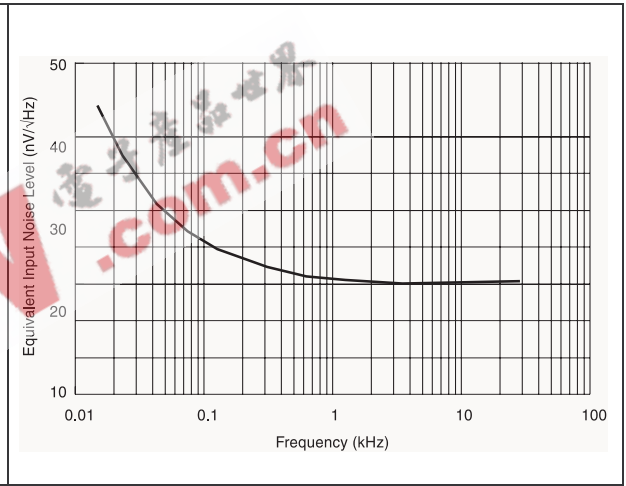


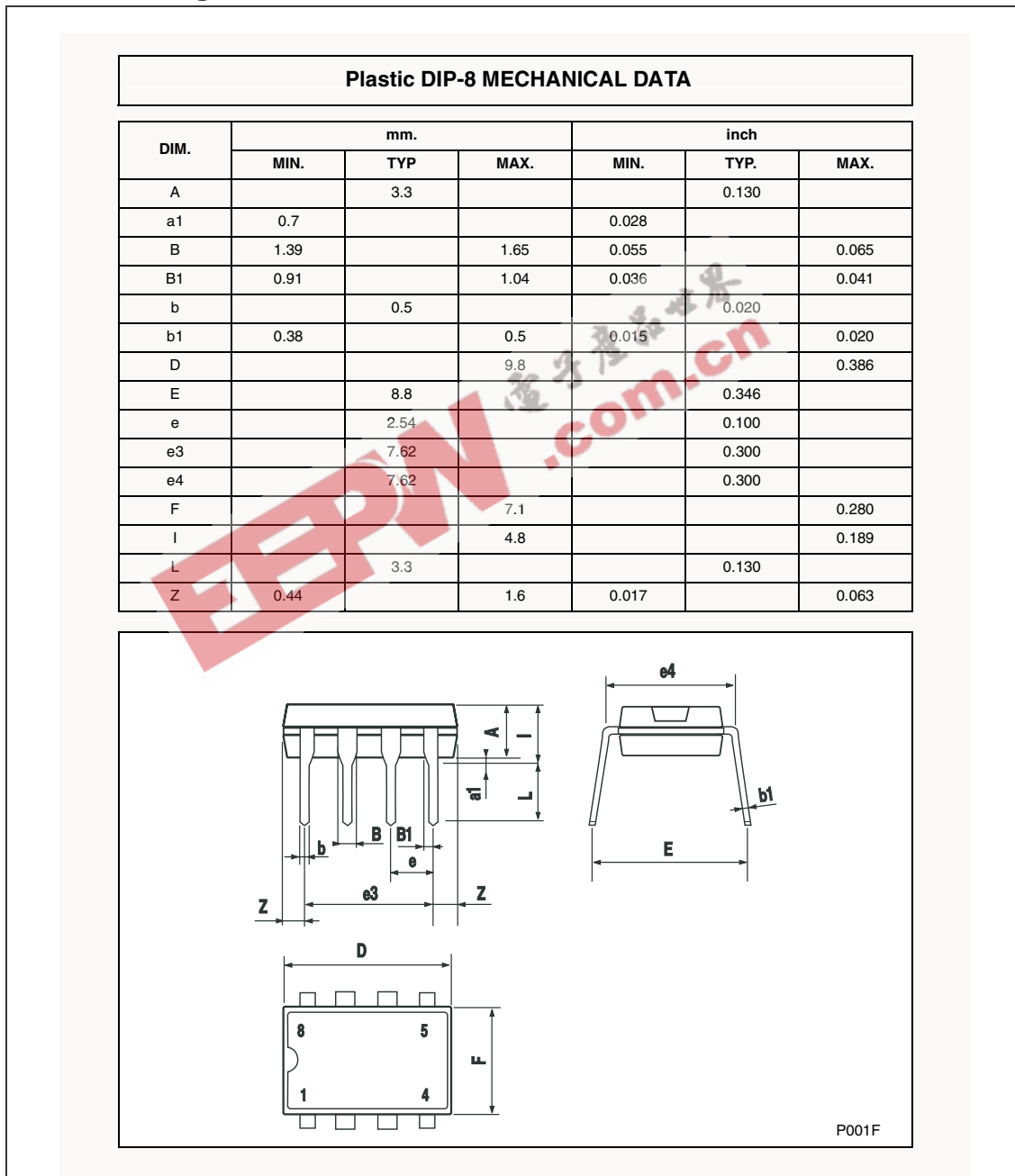
Figure 10. Equivalent input noise voltage vs. frequency



### 3 Package Mechanical Data

In order to meet environmental requirements, ST 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 ST trademark. ECOPACK specifications are available at: [www.st.com](http://www.st.com).

#### 3.1 DIP8 Package

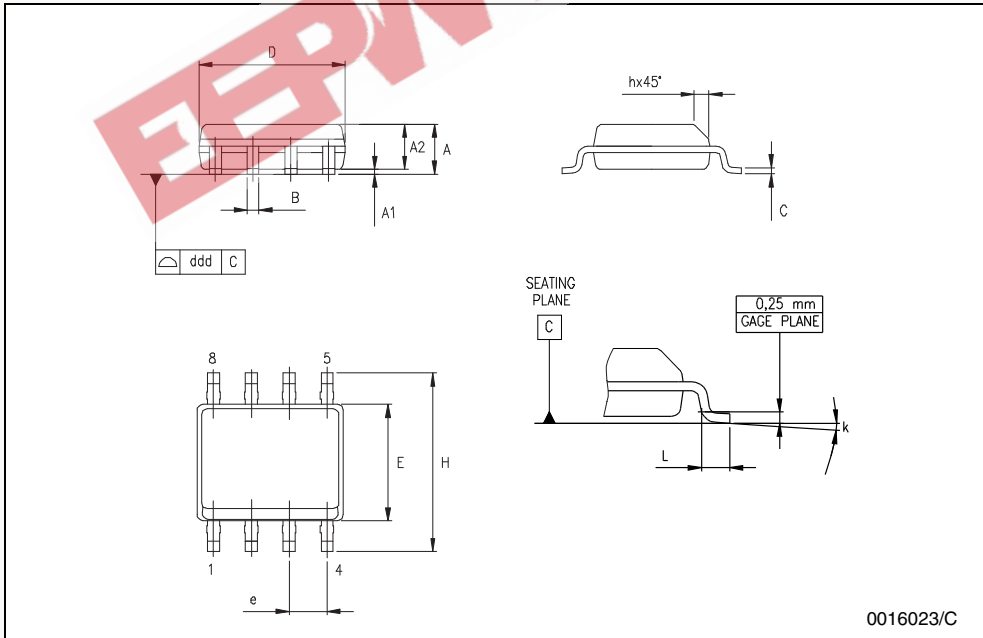




3.2 SO-8 Package

SO-8 MECHANICAL DATA

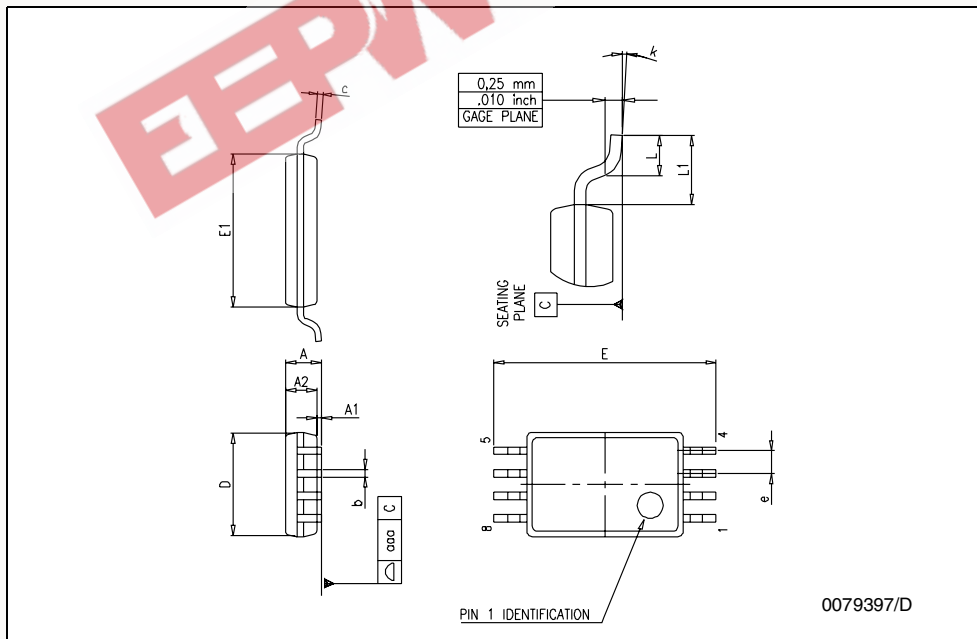
DIM.	mm.			inch		
	MIN.	TYP	MAX.	MIN.	TYP.	MAX.
A	1.35		1.75	0.053		0.069
A1	0.10		0.25	0.04		0.010
A2	1.10		1.65	0.043		0.065
B	0.33		0.51	0.013		0.020
C	0.19		0.25	0.007		0.010
D	4.80		5.00	0.189		0.197
E	3.80		4.00	0.150		0.157
e		1.27			0.050	
H	5.80		6.20	0.228		0.244
h	0.25		0.50	0.010		0.020
L	0.40		1.27	0.016		0.050
k	8° (max.)					
ddd			0.1			0.04



### 3.3 TSSOP8 Package

**TSSOP8 MECHANICAL DATA**

DIM.	mm.			inch		
	MIN.	TYP	MAX.	MIN.	TYP.	MAX.
A			1.2			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	

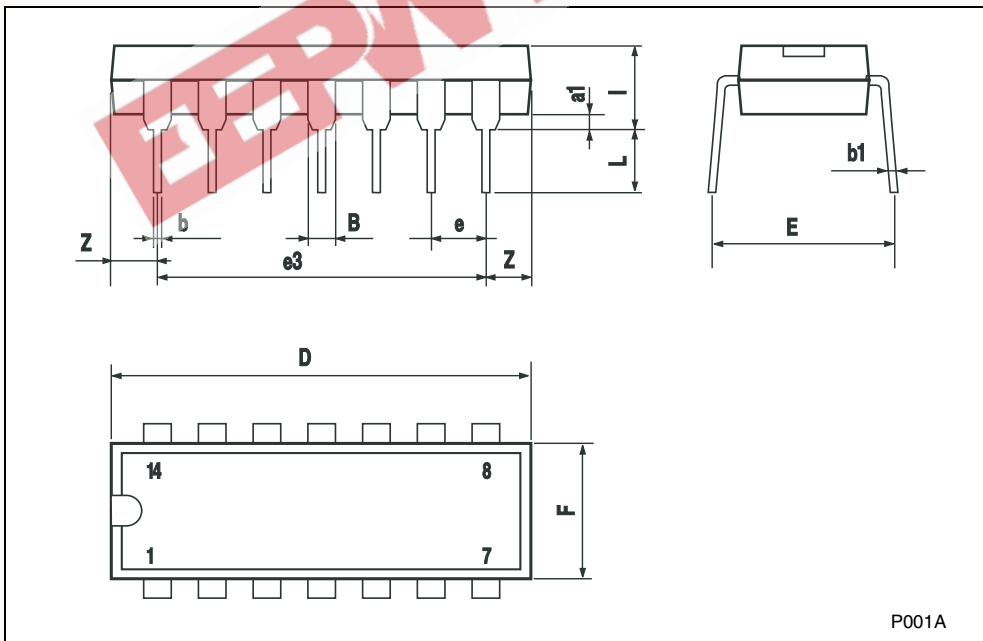


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### 3.4 DIP14 Package

**Plastic DIP-14 MECHANICAL DATA**

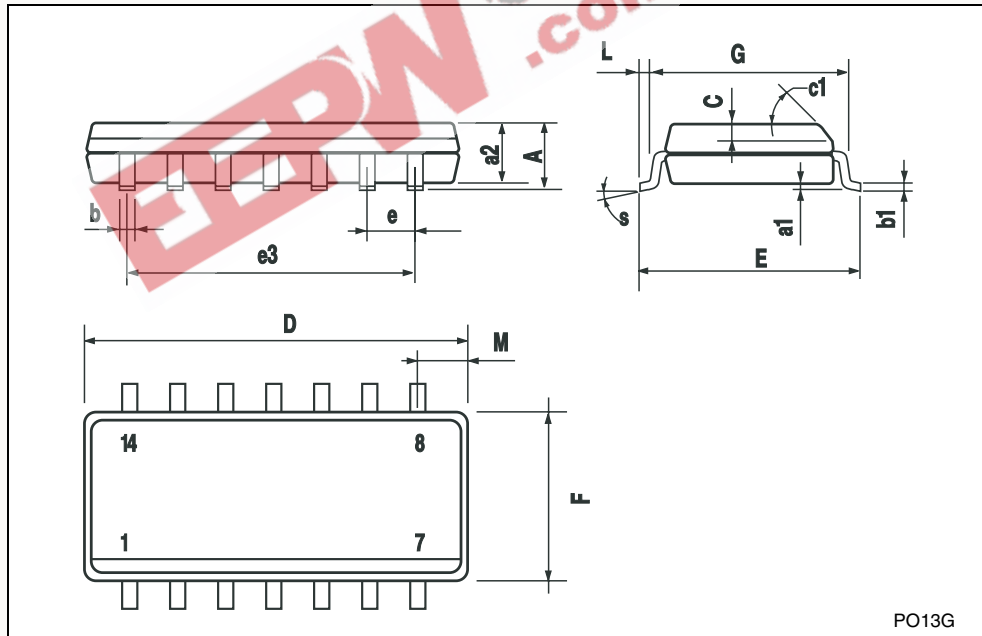
DIM.	mm.			inch		
	MIN.	TYP	MAX.	MIN.	TYP.	MAX.
a1	0.51			0.020		
B	1.39		1.65	0.055		0.065
b		0.5			0.020	
b1		0.25			0.010	
D			20			0.787
E		8.5			0.335	
e		2.54			0.100	
e3		15.24			0.600	
F			7.1			0.280
l			5.1			0.201
L		3.3			0.130	
Z	1.27		2.54	0.050		0.100



### 3.5 SO-14 Package

**SO-14 MECHANICAL DATA**

DIM.	mm.			inch		
	MIN.	TYP	MAX.	MIN.	TYP.	MAX.
A			1.75			0.068
a1	0.1		0.2	0.003		0.007
a2			1.65			0.064
b	0.35		0.46	0.013		0.018
b1	0.19		0.25	0.007		0.010
C		0.5			0.019	
c1	45° (typ.)					
D	8.55		8.75	0.336		0.344
E	5.8		6.2	0.228		0.244
e		1.27			0.050	
e3		7.62			0.300	
F	3.8		4.0	0.149		0.157
G	4.6		5.3	0.181		0.208
L	0.5		1.27	0.019		0.050
M			0.68			0.026
S	8° (max.)					

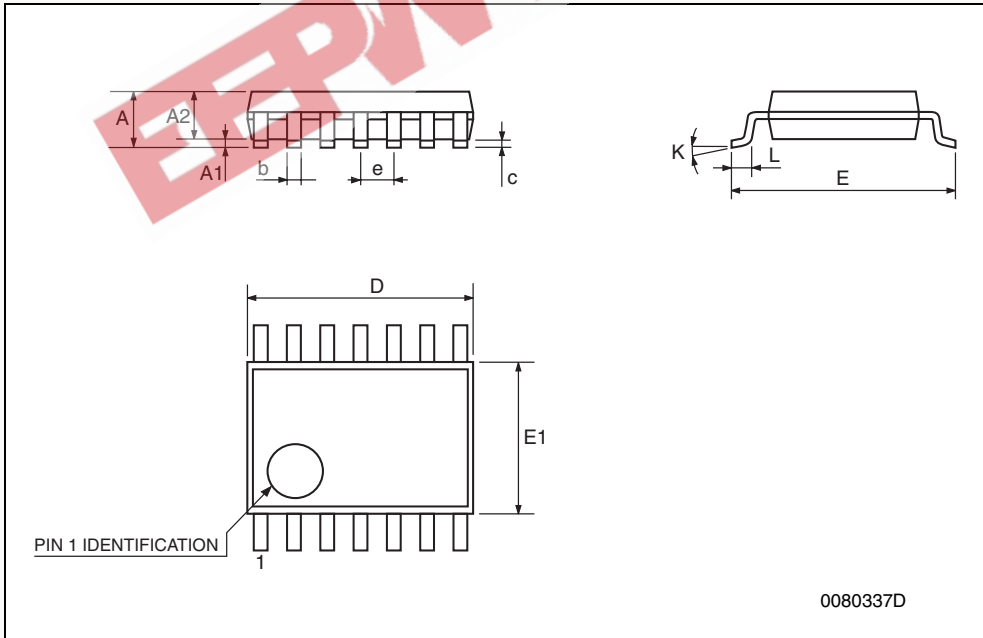


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### 3.6 TSSOP14 Package

**TSSOP14 MECHANICAL DATA**

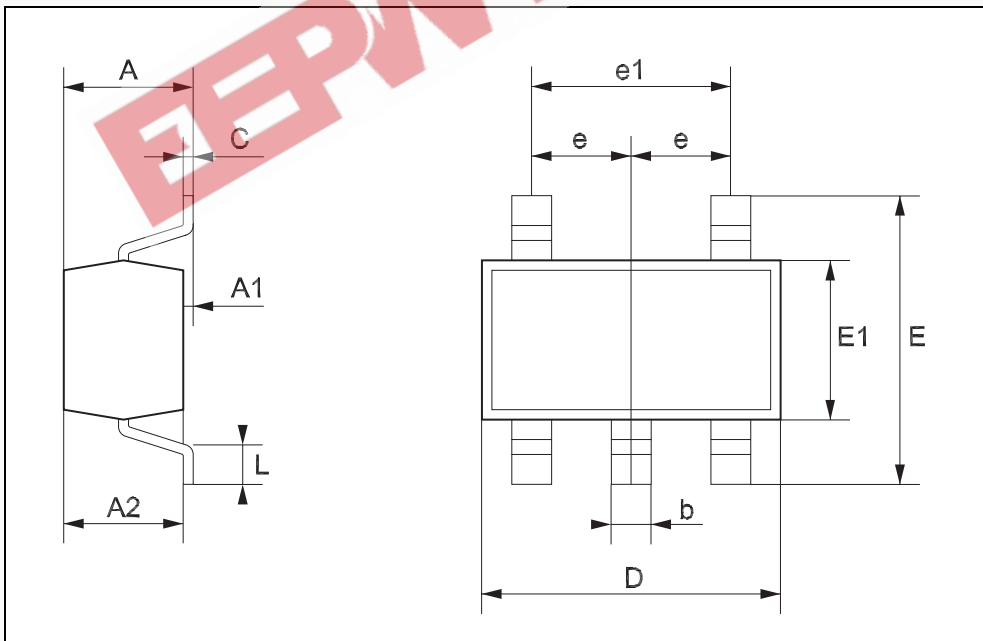
DIM.	mm.			inch		
	MIN.	TYP	MAX.	MIN.	TYP.	MAX.
A			1.2			0.047
A1	0.05		0.15	0.002	0.004	0.006
A2	0.8	1	1.05	0.031	0.039	0.041
b	0.19		0.30	0.007		0.012
c	0.09		0.20	0.004		0.0089
D	4.9	5	5.1	0.193	0.197	0.201
E	6.2	6.4	6.6	0.244	0.252	0.260
E1	4.3	4.4	4.48	0.169	0.173	0.176
e		0.65 BSC			0.0256 BSC	
K	0°		8°	0°		8°
L	0.45	0.60	0.75	0.018	0.024	0.030



### 3.7 SOT23-5 Package

**SOT23-5L MECHANICAL DATA**

DIM.	mm.			mils		
	MIN.	TYP.	MAX.	MIN.	TYP.	MAX.
A	0.90		1.45	35.4		57.1
A1	0.00		0.15	0.0		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



## 4 Revision History

Date	Revision	Changes
May 2001	1	First Release.
Jan. 2005	2	Modifications on AMR <i>Table 1 on page 3</i> (explanation of Vid and Vi limits, ESD MM and CDM values added, Rthja added).
July 2005	3	PPAP references inserted in the datasheet see <i>Table : Order Codes on page 2</i> .
Aug. 2005	4	Table data was badly formatted see <i>Table 4 on page 5</i> .
Dec. 2005	5	TS951IYLT PPAP reference added see <i>Table : Order Codes on page 2</i> .

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