TS93x, TS93xA, TS93xB

Output rail-to-rail micropower operational amplifiers

Features

- Rail-to-rail output voltage swing
- Micropower consumption (20 µA)
- Single supply operation (2.7 to 10 V)
- Low offset (2 mV max. for TS93xB)
- CMOS inputs
- Ultra low input bias current (1 pA)
- ESD protection (2 kV)
- Latch-up immunity (class A)
- Available in SOT23-5 micropackage
- Automotive grade

Applications

- Battery-powered systems
- Portable communication systems
- Alarms, smoke detectors
- Instrumentation and sensoring
- PH meters
- Digital scales
- Automotive

Description

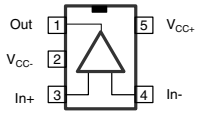
The TS93x (single, dual and quad) series are operational amplifiers that can operate with voltages as low as 2.7 V and reach a 2.9 Vpp output swing with R_L = 100 kΩ when supplied at 3 V.

Offering a typical consumption of only 20 µA, these devices are particularly well-suited to battery-powered applications.

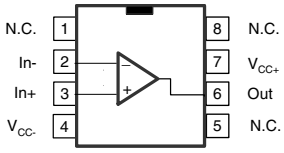
The amplifiers' space-saving 5-pin SOT23-5 package with outer dimensions of 2.8 mm x 2.9 mm make them very easy to implement on a board design.

Pin connections (top view)

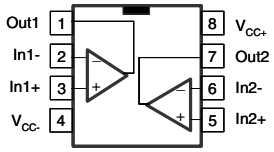
TS931ILT



TS931ID-TS931IDT



TS932ID-TS932IDT



TS934ID-TS934IDT-TS934IPT

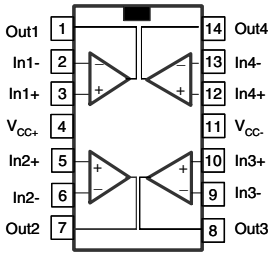


Table 1. Device summary

Reference	Part number
TS93x	TS931, TS932, TS934
TS93xA	TS931A, TS932A, TS934A
TS93xB	TS931B, TS932B, TS934B

1 Absolute maximum ratings and operating conditions

Table 2. Absolute maximum ratings

Symbol	Parameter	Value	Unit
V_{CC}	Supply voltage (1)	12	V
V_{id}	Differential input voltage (2)	$\pm V_{CC}$	V
V_{in}	Input voltage range (3)	V_{CC-} -0.3 to V_{CC+} +0.3	V
I_{in}	Input current range (4)	10	mA
T_{std}	Storage temperature range	-65 to +150	°C
T_j	Maximum junction temperature	150	°C
R_{thja}	Thermal resistance junction to ambient (5) – SOT23-5 – SO8 – SO14 – TSSOP8 – TSSOP14	 250 125 103 120 100	°C/W
ESD	HBM: human body model(6)	2	kV
	MM: machine model(7)	200	V
	CDM: charged device model(8)	2	kV
	Latch-up immunity	200	mA
	Soldering temperature (10 sec), leaded version	250	°C

1. All voltages values, except differential voltage are with respect to network terminal.
2. Differential voltages are non-inverting input terminal with respect to the inverting input terminal.
3. The magnitude of input and output voltages must never exceed V_{CC+} +0.3 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. Human body model: 100 pF discharged through a 1.5 kΩ resistor into pin of device.
7. Machine model ESD: a 200 pF capacitor is charged to the specified voltage, then discharged directly into the IC with no external series resistor (internal resistor < 5 Ω), into pin-to-pin of device.
8. Charged device model: all pins and the package are charged together to the specified voltage and then discharged directly to ground through only one pin. This is done for all pins.

Table 3. Operating conditions

Symbol	Parameter	Value	Unit
V_{CC}	Supply voltage	2.7 to 10	V
V_{icm}	Common mode input voltage range	V_{CC-} -0.2 to V_{CC+} -1.5	V
T_{oper}	Operating free air temperature range	-40 to +105	°C

2 Electrical characteristics

Table 4 and *Table 5* give the electrical characteristics at each V_{CC} value.

Table 4. V_{CC}+ = +3 V, V_{CC}- = 0 V, T_{amb} = 25° C (unless otherwise specified)

Symbol	Parameter	Min.	Typ.	Max.	Unit
V_{io}	Input offset voltage TS931/2/4 TS931/2/4A TS931/2/4B			 10 5 2	mV
	$T_{min} < T_{op} < T_{max}$ TS931/2/4 TS931/2/4A TS931/2/4B			 15 10 6	
ΔV_{io}	Input offset voltage drift		3		µV/°C
I_{io}	Input offset current (1) $T_{min} < T_{op} < T_{max}$		1	100 200	pA
I_{ib}	Input bias current (1) $T_{min} < T_{op} < T_{max}$		1	150 300	pA
CMR	Common mode rejection ratio, $0 \leq V_{icm} \leq V_{CC+}$ -1.7 $T_{min} < T_{op} < T_{max}$	55 55	85 85		dB
SVR	Supply voltage rejection ratio (2) $T_{min} < T_{op} < T_{max}$	55 55	85 85		dB
A_{vd}	Large signal voltage gain V_O = 2 Vpp, R_L = 1 MΩ R_L = 100 kΩ		 120 106		dB
V_{OH}	High level output voltage, V_{ID} = 100 mV, R_L = 100 kΩ $T_{min} < T_{op} < T_{max}$	2.95 2.95	2.99		V
V_{OL}	Low level output voltage, V_{ID} = -100 mV, R_L = 100 kΩ $T_{min} < T_{op} < T_{max}$		10	50 50	mV
I_o	Output source current V_{ID} = 100mV, V_O = V_{CC-} Output sink current V_{ID} = -100 mV, V_O = V_{CC+}		 1.5 1.5		mA
I_{CC}	Supply current (per amplifier), A_{VCL} = 1, no load $T_{min} < T_{op} < T_{max}$		20	31 33	µA
GBP	Gain bandwidth product R_L = 100 kΩ, C_L = 50 pF		 100		kHz
SR	Slew rate R_L = 100 kΩ, C_L = 50 pF		 50		V/ms

Table 4. V_{CC}+ = +3 V, V_{CC}- = 0 V, T_{amb} = 25° C (unless otherwise specified) (continued)

Symbol	Parameter	Min.	Typ.	Max.	Unit
ϕm	Phase margin C_L = 50 pF		 65		Degrees
en	Input voltage noise		75		nV/√Hz

1. Maximum values including unavoidable inaccuracies of the industrial test.
2. V_{CC} has a 0.2 V variation.

Table 5. V_{CC}+ = +5 V, V_{CC}- = 0 V, T_{amb} = 25° C (unless otherwise specified)

Symbol	Parameter	Min.	Typ.	Max.	Unit
V_{io}	Input offset voltage TS931/2/4 TS931/2/4A TS931/2/4B			 10 5 2	mV
	$T_{min} < T_{op} < T_{max}$ TS931/2/4 TS931/2/4A TS931/2/4B			 15 10 6	
ΔV_{io}	Input offset voltage drift		3		µV/°C
I_{io}	Input offset current (1) $T_{min} < T_{op} < T_{max}$		1	100 200	pA
I_{ib}	Input bias current (1) $T_{min} < T_{op} < T_{max}$		1	150 300	pA
CMR	Common mode rejection ratio, 0 ≤V_{icm} ≤V_{CC+} - 1.7 $T_{min} < T_{op} < T_{max}$	55 55	85 85		dB
SVR	Supply voltage rejection ratio (2) $T_{min} < T_{op} < T_{max}$	55 55	85 85		dB
A_{vd}	Large signal voltage gain V_O = 4 Vpp, R_L = 1 MΩ R_L = 100 kΩ		 120 112		dB
V_{OH}	High level output voltage, V_{ID} = 100 mV, R_L = 100 kΩ $T_{min} < T_{op} < T_{max}$	4.95 4.95	4.99		V
V_{OL}	Low level output voltage, V_{ID} = -100 mV, R_L = 100 kΩ $T_{min} < T_{op} < T_{max}$		10	50 50	mV
I_o	Output source current V_{ID} = 100 mV, V_O = V_{DD} Output sink current V_{ID} = -100 mV, V_O = V_{CC}		 5 5		mA
I_{CC}	Supply current (per amplifier), A_{VCL} = 1, no load $T_{min} < T_{op} < T_{max}$		20	33 35	µA

Table 5. V_{CC}+ = +5 V, V_{CC}- = 0 V, T_{amb} = 25° C (unless otherwise specified) (continued)

Symbol	Parameter	Min.	Typ.	Max.	Unit
GBP	Gain bandwidth product R_L = 100 KΩ, C_L = 50 pF		100		kHz
SR	Slew rate R_L = 100 KΩ, C_L = 50 pF		50		V/ms
ϕm	Phase margin C_L = 50 pF		65		Degrees
en	Input voltage noise		76		nV/√Hz

1. Maximum values including unavoidable inaccuracies of the industrial test.
2. V_{CC} has a 0.2 V variation.

Figure 1. Input offset voltage vs. temperature

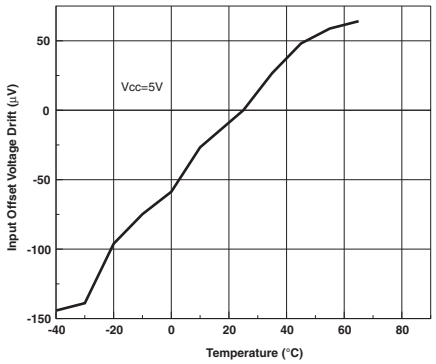


Figure 2. Supply current vs. supply voltage, in open loop configuration.

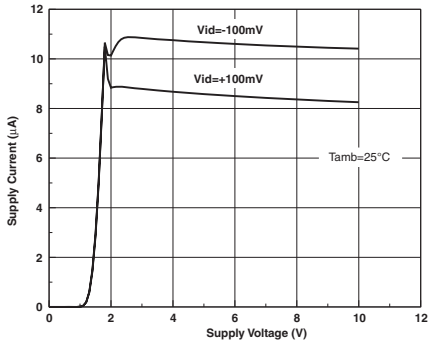


Figure 3. Supply current vs. supply voltage in follower configuration, $V_{icm} = V_{cc}/2$

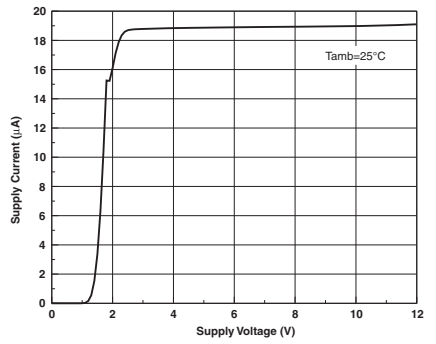


Figure 4. Supply current vs. temperature

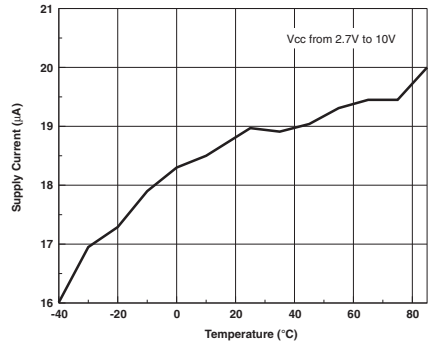


Figure 5. Output short circuit current vs. temperature

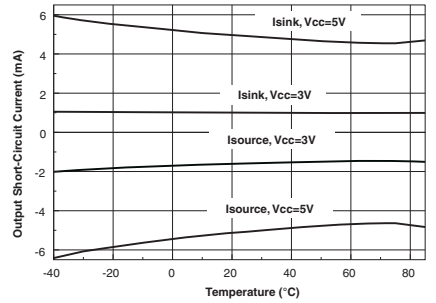


Figure 6. Output short circuit current vs. supply voltage

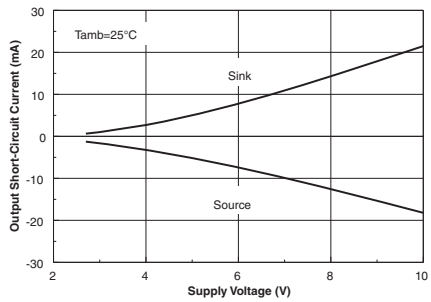


Figure 7. Output short circuit current vs. output voltage at V_{CC}+ = 2.7 V

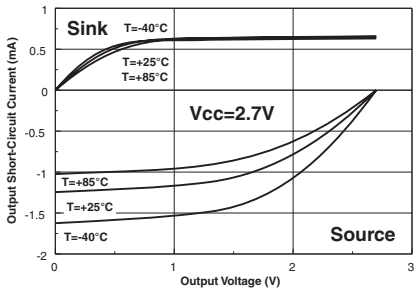


Figure 8. Output short circuit current vs. output voltage at V_{CC}+ = 3 V

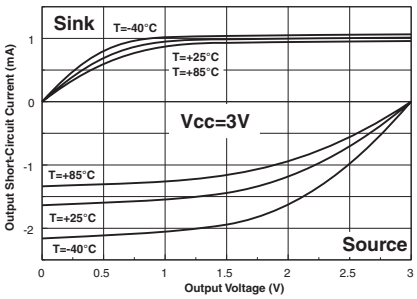


Figure 9. Output short circuit current vs. output voltage at V_{CC}+ = 5 V

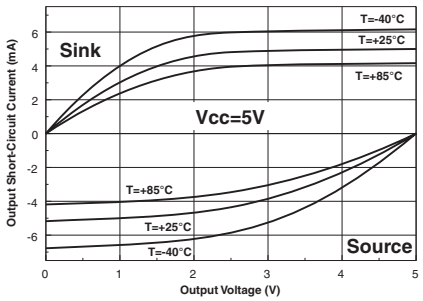


Figure 10. Output short circuit current vs. output voltage at V_{CC}+ = 10 V

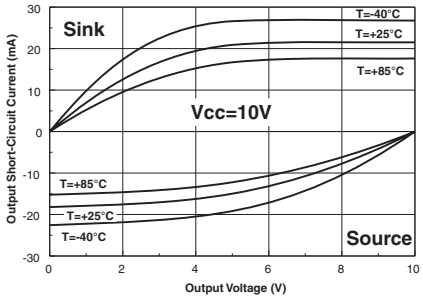


Figure 11. High level output voltage drop vs. supply voltage

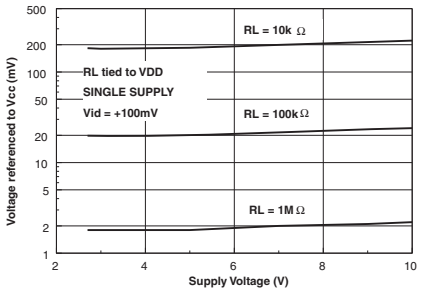


Figure 12. Low level output voltage drop vs. supply voltage

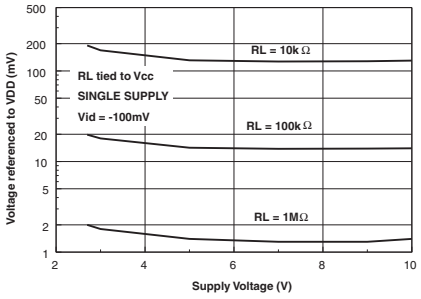


Figure 13. Voltage gain and phase vs. frequency for C_L = 50 pF

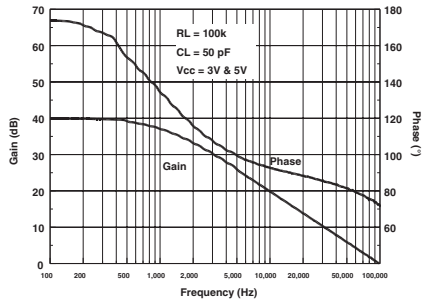


Figure 14. Voltage gain and phase vs. frequency for C_L = 100 pF

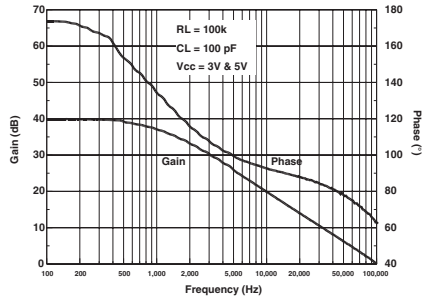


Figure 15. Distortion vs. frequency

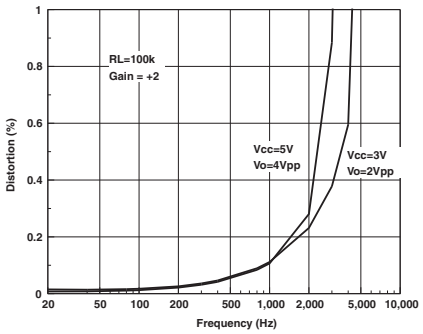


Figure 16. Equivalent input noise voltage vs. frequency

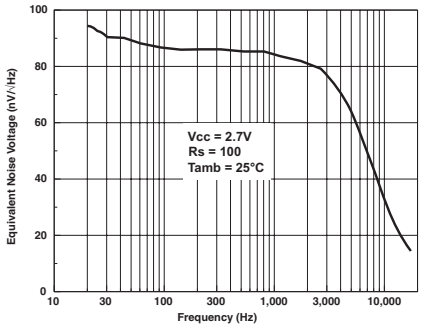


Figure 17. Distortion vs. output voltage

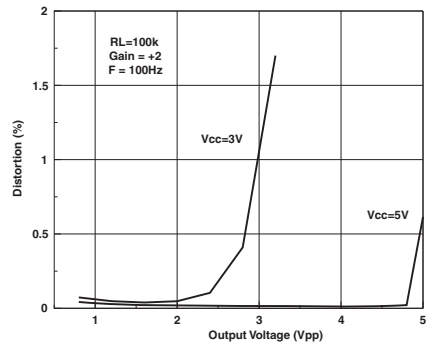


Figure 18. Supply voltage rejection vs. frequency

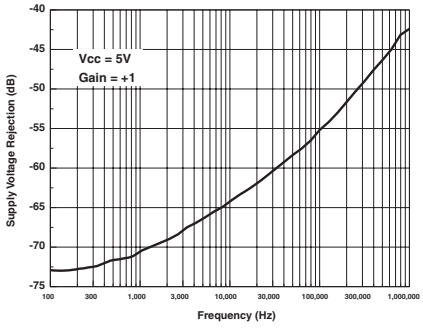


Figure 19. Slew rate vs. time for small input voltage signal

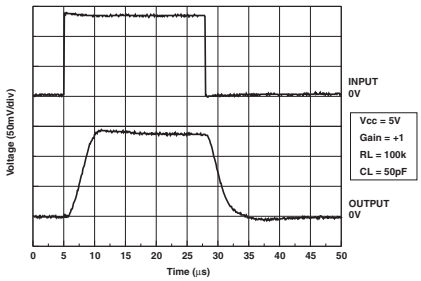
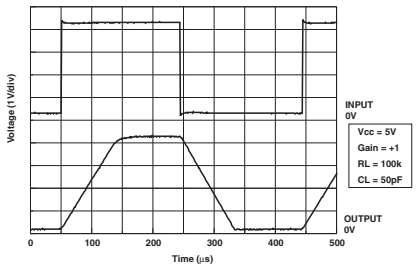


Figure 20. Slew rate vs. time for large input voltage signal



3 Package information

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

3.1 SO-8 package information

Figure 21. SO-8 package mechanical drawing

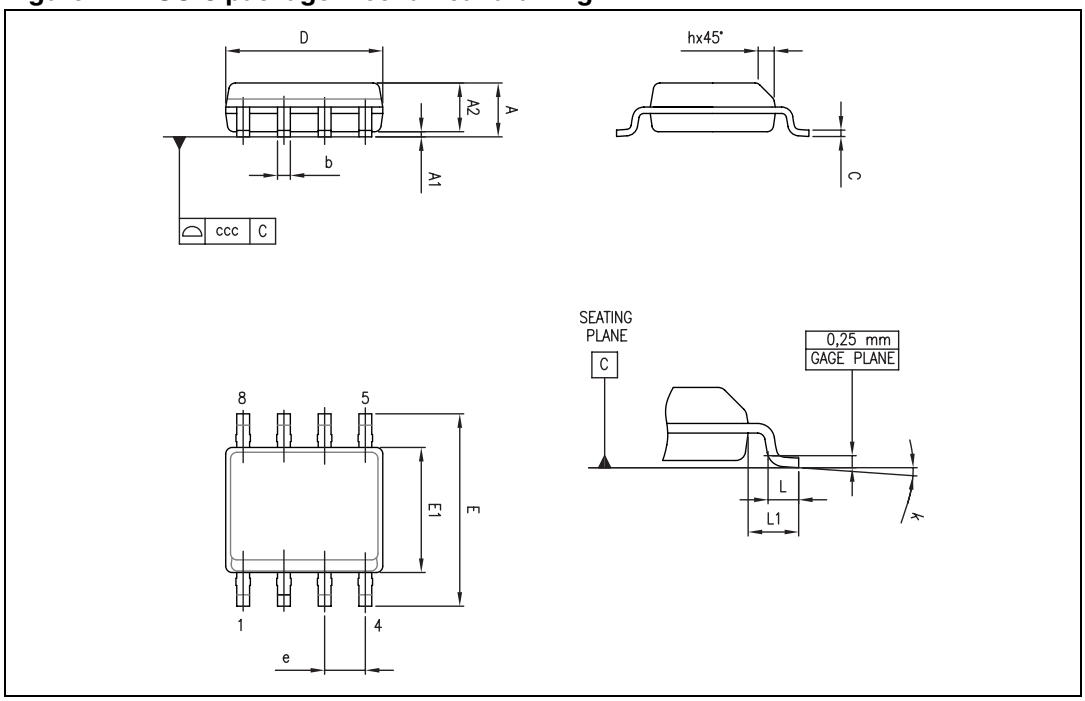


Table 6. SO-8 package mechanical data

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	1°		8°	1°		8°
ccc			0.10			0.004

3.2 SO-14 package information

Figure 22. SO-14 package mechanical drawing

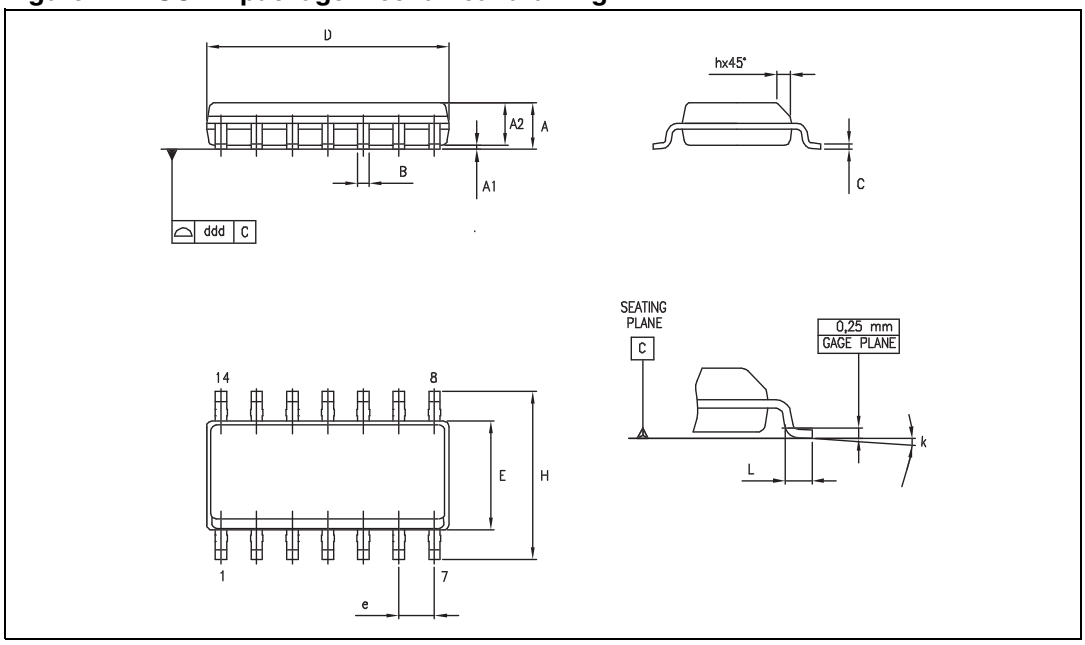


Table 7. SO-14 package mechanical data

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

3.3 TSSOP14 package information

Figure 23. TSSOP14 package mechanical drawing

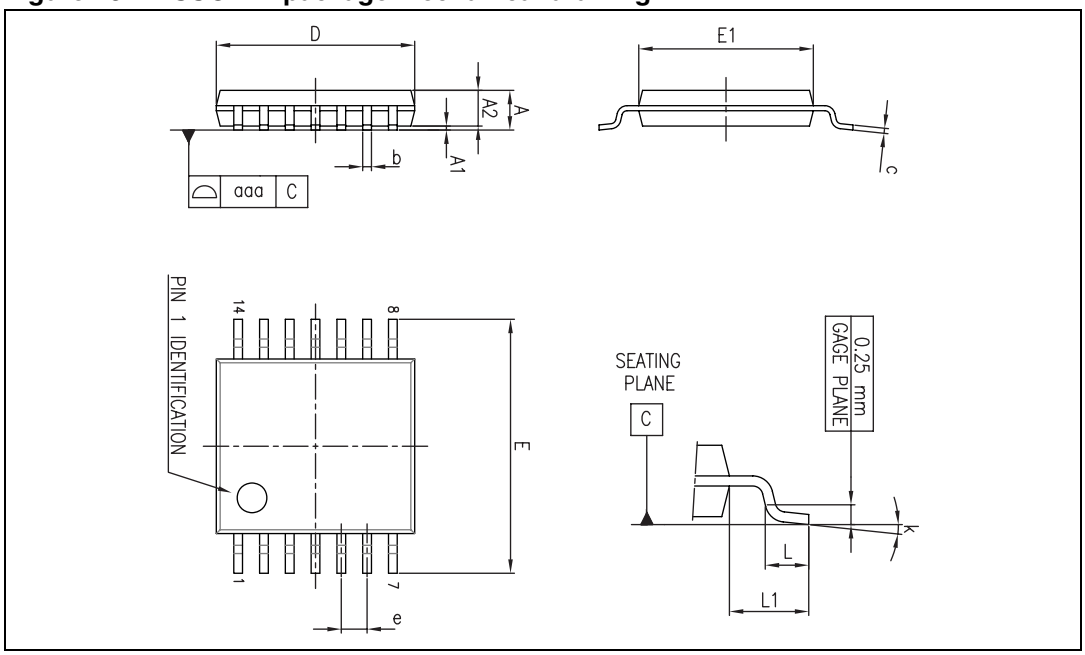


Table 8. TSSOP14 package mechanical data

Ref.	Dimensions					
	Millimeters			Inches		
	Min.	Typ.	Max.	Min.	Typ.	Max.
A			1.20			0.047
A1	0.05		0.15	0.002	0.004	0.006
A2	0.80	1.00	1.05	0.031	0.039	0.041
b	0.19		0.30	0.007		0.012
c	0.09		0.20	0.004		0.0089
D	4.90	5.00	5.10	0.193	0.197	0.201
E	6.20	6.40	6.60	0.244	0.252	0.260
E1	4.30	4.40	4.50	0.169	0.173	0.176
e		0.65			0.0256	
L	0.45	0.60	0.75	0.018	0.024	0.030
L1		1.00			0.039	
k	0°		8°	0°		8°
aaa			0.10			0.004

3.4 SOT23-5 package information

Figure 24. SOT23-5 package mechanical drawing

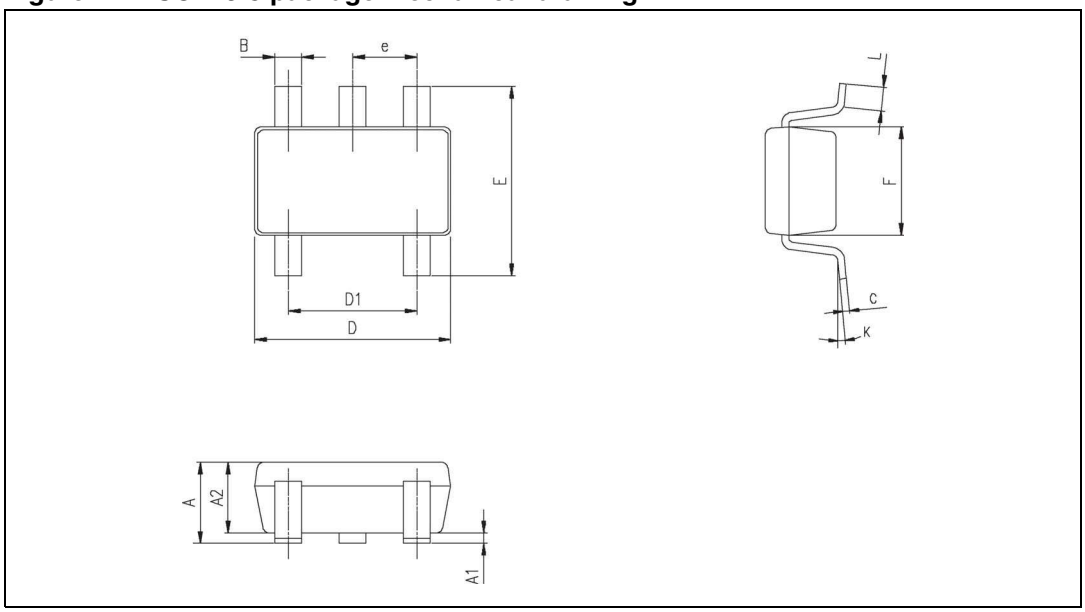


Table 9. SOT23-5 package mechanical data

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 Ordering information

Table 10. Order codes

Order code	Temperature range	Package	Packing	Marking
TS931ID	-40°C, +105°C	SO-8	Tube	931I
TS931IDT			Tape & reel	931I
TS931AID			Tube	931AI
TS931AIDT			Tape & reel	931AI
TS931BID			Tube	931BI
TS931BIDT			Tape & reel	931BI
TS931ILT		SOT23-5L	Tape & reel	K205
TS931AILT				K206
TS931BILT				K207
TS932ID		SO-8	Tube	932I
TS932IDT			Tape & reel	932I
TS932AID			Tube	932AI
TS932AIDT			Tape & reel	932AI
TS932BID			Tube	932BI
TS932BIDT			Tape & reel	932BI
TS934ID		SO-14	Tube	934I
TS934IDT			Tape & reel	934I
TS934AID			Tube	934AI
TS934AIDT			Tape & reel	934AI
TS934BIDT			Tube	934BI
TS934BIDT			Tape & reel	934BI
TS934IPT		TSSOP-14 (Thin shrink outline package)	Tape & reel	934I
TS934AIPT				934AI
TS934BIPT				934BI
TS934IYD(1)		SO-14 (automotive grade)	Tube	934IY
TS934IYDT(1)			Tape & reel	934IY
TS934AIYD(1)			Tube	934AIY
TS934AIYDT(1)			Tape & reel	934AIY

1. Qualification and characterization according to AEC Q100 and Q003 or equivalent, advanced screening according to AEC Q001 & Q 002 or equivalent are on-going.

5 Revision history

Table 11. Document revision history

Date	Revision	Changes
01-Nov-2001	1	Initial release.
01-Dec-2004	2	Modified AMR values in *Table 2* (explanation of Vid and Vi limits).
04-May-2009	3	Document reformatted. Removed DIP package information and order codes from *Chapter 3*. Modified temperature range: extended to -40 to +105° C in *Table 10: Order codes*. Added automotive grade products in *Table 10*.
07-Sep-2009	4	Added root part numbers (TS93xA, TS93xB) and *Table 1: Device summary* on cover page. Added parameters for full temperature range in *Table 4* and in *Table 5*.

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