TS94x, TS94xA, TS94xB

Output rail-to-rail micropower operational amplifiers

Features

- Rail-to-rail output voltage swing
- Micropower consumption (1.2 µA)
- Single supply operation (2.5 V to 10 V)
- CMOS inputs
- Ultra low input bias current (1 pA)
- ESD protection (2 kV)
- Latch-up immunity (class A)
- Available in SOT23-5 micropackage

Applications

- Battery-powered systems (alarm)
- Portable communication systems (pagers)
- Smoke/gas/fire detectors
- Instrumentation and sensoring
- PH meter

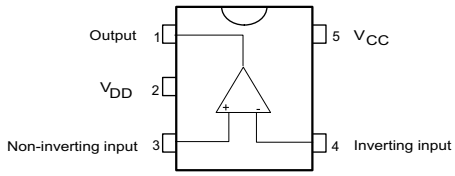
Description

The TS94x (single, dual and quad) series are operational amplifiers characterized for 2.5 V to 10 V operation over a -40° C to +85° C temperature range.

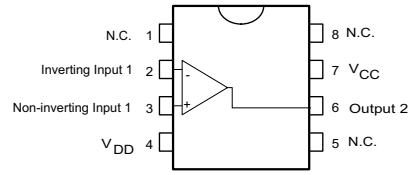
They exhibit excellent consumption -1.2 µA, while featuring 10 kHz gain bandwidth product, 1.5 mA output capability and output rail-to-rail operation - 2.85 V typical at 3 V with R_L=10 kΩ

The TS94x op-amps are ideal for battery-powered systems, where very low supply current and output rail-to-rail are required. Their very low - 1 pA typical input bias current and constant supply current over supply voltage enhance the devices' performance near the end of the battery charge or battery life.

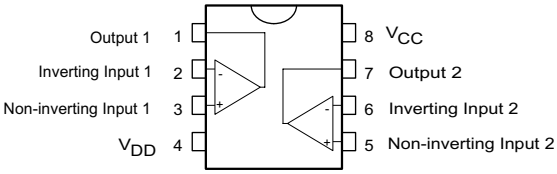
TS941ILT



TS941ID-TS941IDT



TS942ID-TS942IDT-TS942IPT



TS944ID-TS944IDT-TS944IPT

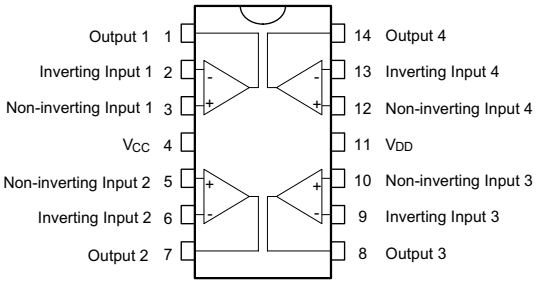


Table 1. Device summary

Reference	Selection on offset voltage
TS94x	TS941, TS942, TS944
TS94xA	TS941A, TS942A, TS944A
TS94xB	TS941B, TS942B, TS944B

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)	± V_{CC}	V
V_{in}	Input voltage range (3)	V_{DD}-0.3 to V_{CC}+0.3	V
T_{stg}	Storage temperature range	-65 to +150	°C
T_j	Maximum junction temperature	150	°C
R_{thja}	Thermal resistance junction to ambient (4) SOT23-5 SO-8 SO-14 TSSOP8 TSSOP14	 250 125 103 120 100	°C/W
R_{thjc}	Thermal resistance junction to case (4) SOT23-5 SO-8 SO-14 TSSOP8 TSSOP14	 81 40 31 37 32	°C/W
ESD	HBM: human body model (5)	2	kV
	MM: machine model (6) (TS941, TS942)	200	V
	CDM: charged device model (7) TS941 - TS944IDT TS942 - TS944IPT	 1.5 1	kV
	Latch-up immunity	200	mA
	Lead temperature (soldering, 10sec)	250	°C

1. All voltage values, except differential voltage are with respect to network terminal.
2. Differential voltages are the 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. Short-circuits can cause excessive heating and destructive dissipation. R_{th} are typical values.
5. Human body model: a 100 pF capacitor is charged to the specified voltage, then discharged through a 1.5 kΩ resistor between two pins of the device. This is done for all couples of connected pin combinations while the other pins are floating.
6. Machine model: a 200 pF capacitor is charged to the specified voltage, then discharged directly between two pins of the device with no external series resistor (internal resistor < 5 Ω). This is done for all couples of connected pin combinations while the other pins are floating.
7. Charged device model: all pins and the package are charged together to the specified voltage and then discharged directly to the ground through only one pin. This is done for all pins.

Table 3. Operating conditions

Symbol	Parameter	Value	Unit
V_{CC}	Supply voltage	2.5 to 10	V
V_{icm}	Common mode input voltage range	V_{DD} -0.2 to V_{CC} -1.3	V
T_{oper}	Operating free air temperature range	-40 to + 85	°C

2 Electrical characteristics

Table 4. V_{CC} = +2.5 V, V_{DD} = 0 V, R_L connected to $V_{CC}/2$, T_{amb} = 25° C (unless otherwise specified)

Symbol	Parameter	Min.	Typ.	Max.	Unit
V_{io}	Input offset voltage TS941/2/4 TS941/2/4A TS941/2/4B			 10 5 2	mV
ΔV_{io}	Input offset voltage drift		7		µV/°C
I_{io}	Input offset current (1)		1	100	pA
I_{ib}	Input bias current (1)		1	150	pA
CMR	Common mode rejection ratio	60	85		dB
SVR	Supply voltage rejection ratio	50	78		dB
A_{vd}	Large signal voltage gain V_O = 2 V_{pp}, R_L = 1 MΩ		100		dB
V_{OH}	High level output voltage V_{ID} = 100 mV, R_L = 1 MΩ R_L = 10 kΩ	 2.45 2.3	 2.49 2.4		V
V_{OL}	Low level output voltage V_{ID} = -100 mV, R_L = 1 MΩ R_L = 10 kΩ		 1 100	 5 200	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}	 350 280	 650 500		µA
I_{CC}	Supply current (per amplifier), A_{VCL} = 1, no load		1.2	1.8	µA
GBP	Gain bandwidth product, R_L = 1 MΩ, C_L = 50 pF		10		kHz
SR	Slew rate, R_L = 1 MΩ, C_L = 50 pF	3	4.5		V/ms
ϕm	Phase margin, C_L = 50 pF		65		Degrees

1. Maximum values include unavoidable inaccuracies of the industrial tests.

Table 5. V_{CC} = +3 V, V_{DD} = 0 V, R_L connected to $V_{CC}/2$,T_{amb} = 25° C (unless otherwise specified) (1)

Symbol	Parameter	Min.	Typ.	Max.	Unit
V_{io}	Input offset voltage TS941/2/4 TS941/2/4A TS941/2/4B			 10 5 2	mV
ΔV_{io}	Input offset voltage drift		7		µV/°C
I_{io}	Input offset current (2)		1	100	pA
I_{ib}	Input bias current (2)		1	150	pA
CMR	Common mode rejection ratio	60	85		dB
SVR	Supply voltage rejection ratio	50	85		dB
A_{vd}	Large signal voltage gain V_O = 2 V_{pp},R_L = 1 MΩ		100		dB
V_{OH}	High level output voltage V_{ID} = 100 mV, R_L = 1 MΩ R_L = 10 kΩ	 2.9 2.8	 2.99 2.85		V
V_{OL}	Low level output voltage V_{ID} = -100 mV, R_L = 1 MΩ R_L = 10 kΩ		 1 100	 5 200	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}	 680 650	 1500 1300		µA
I_{CC}	Supply current (per amplifier), A_{VCL} = 1, no load		1.2	1.8	µA
GBP	Gain bandwidth product, R_L = 1 MΩ, C_L = 50 pF		10		kHz
SR	Slew rate, R_L = 1 MΩ, C_L = 50 pF	3	4.5		V/ms
ϕm	Phase margin, C_L = 50 pF		65		Degrees

1. All electrical values are guaranteed with correlation measurements at 2.5 V and 5 V.
2. Maximum values include unavoidable inaccuracies of the industrial tests.

Table 6. V_{CC} = +5 V, V_{DD} = 0 V, R_L connected to $V_{CC}/2$, T_{amb} = 25° C (unless otherwise specified)

Symbol	Parameter	Min.	Typ.	Max.	Unit
V_{io}	Input offset voltage TS941/2/4 TS941/2/4A TS941/2/4B			 10 5 2	mV
ΔV_{io}	Input offset voltage drift		7		µV/°C
I_{io}	Input offset current (1)		1	100	pA
I_{ib}	Input bias current (1)		1	150	pA
CMR	Common mode rejection ratio	60	85		dB
SVR	Supply voltage rejection ratio	50	85		dB
A_{vd}	Large signal voltage gain V_O = 2 V_{pp}, R_L = 1 MΩ		100		dB
V_{OH}	High level output voltage V_{ID} = 100 mV, R_L = 1 MΩ R_L = 10 kΩ	 4.9 4.8	 4.99 4.85		V
V_{OL}	Low level output voltage V_{ID} = -100 mV, R_L = 1 MΩ R_L = 10 kΩ		 1 100	 5 150	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}	 3 3.7	 4.5 5		mA
I_{CC}	Supply current (per amplifier), A_{VCL} = 1, no load		1.2	1.85	µA
GBP	Gain bandwidth product, R_L = 1 MΩ, C_L = 50 pF		10		kHz
SR	Slew rate, R_L = 1 MΩ, C_L = 50 pF	3	4.5		V/ms
ϕm	Phase margin, C_L = 50 pF		65		Degrees

1. Maximum values include unavoidable inaccuracies of the industrial tests.

Figure 1. Supply current per amplifier vs. supply voltage in overdrive

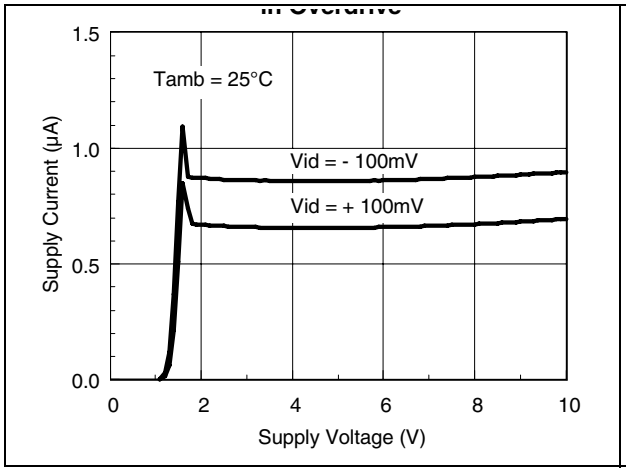


Figure 2. Supply current per amplifier vs. supply voltage

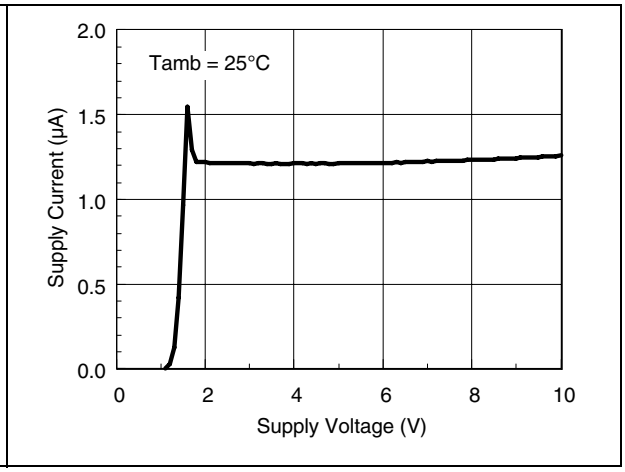


Figure 3. Output short-circuit current vs. temperature

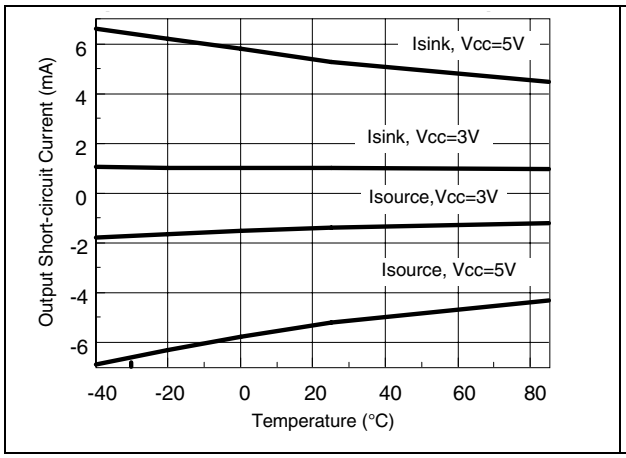


Figure 4. Supply current per amplifier vs. temperature

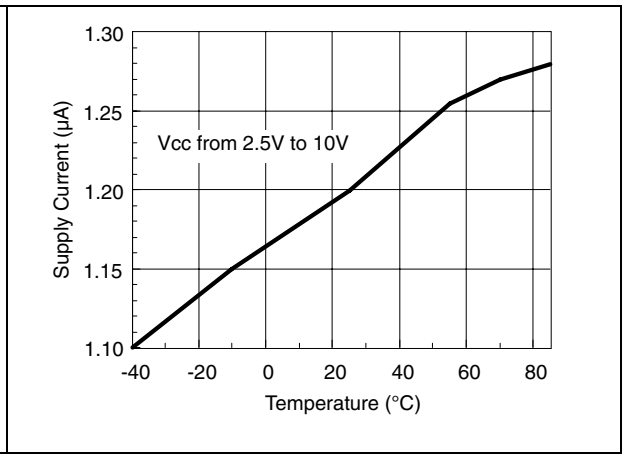


Figure 5. Output short-circuit current vs. supply voltage

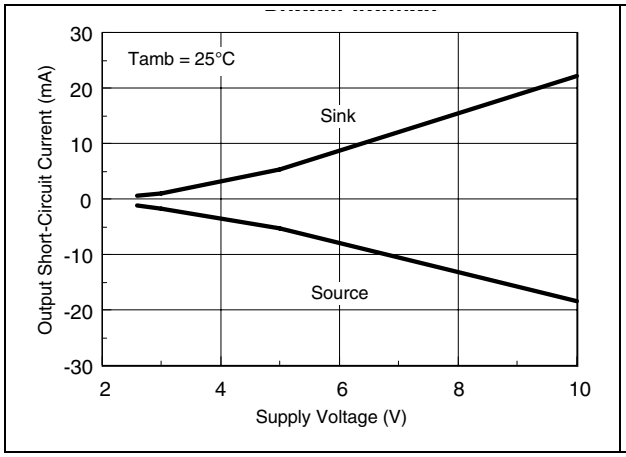


Figure 6. Output short-circuit current vs. output voltage

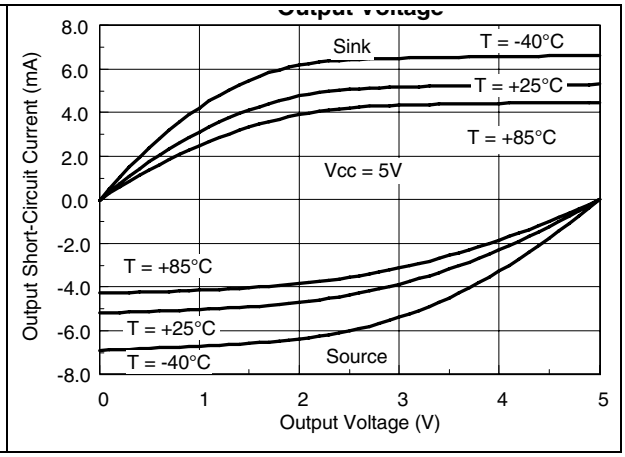


Figure 7. Output short-circuit current vs. output voltage

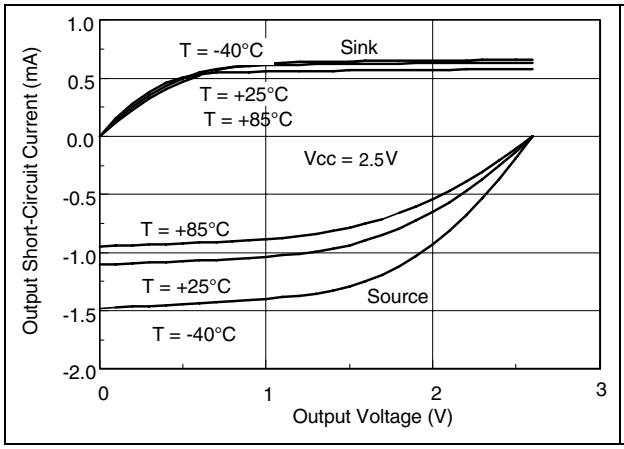


Figure 8. High level output voltage vs. supply voltage

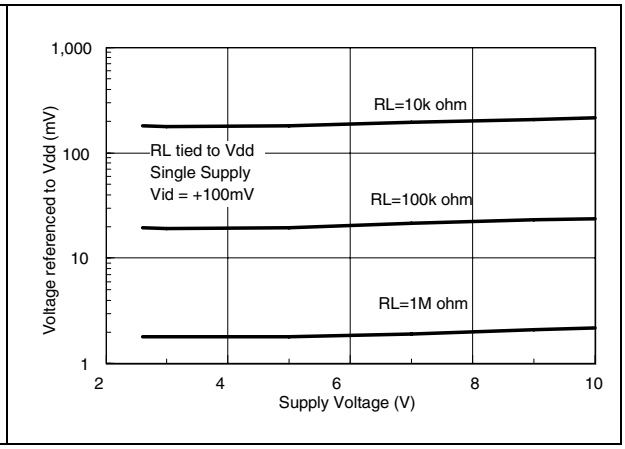


Figure 9. Output short-circuit current vs. output voltage

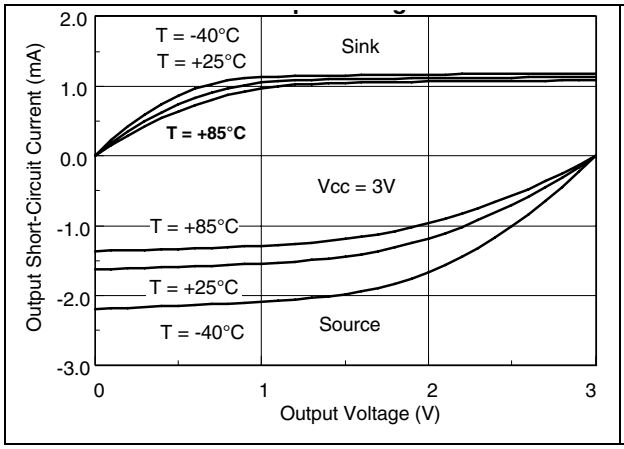


Figure 10. Low level output voltage vs. supply voltage

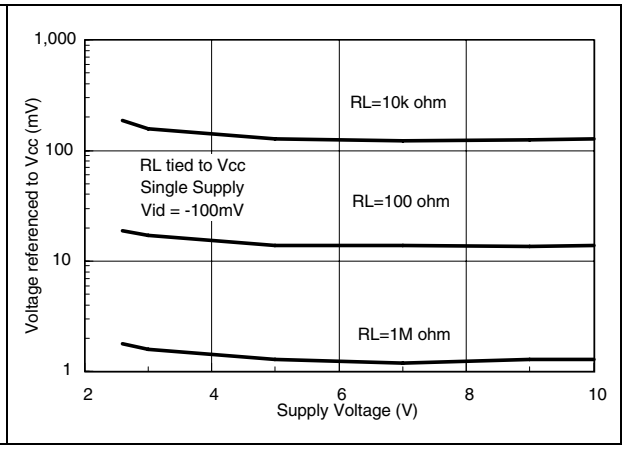


Figure 11. Output short-circuit current vs. output voltage

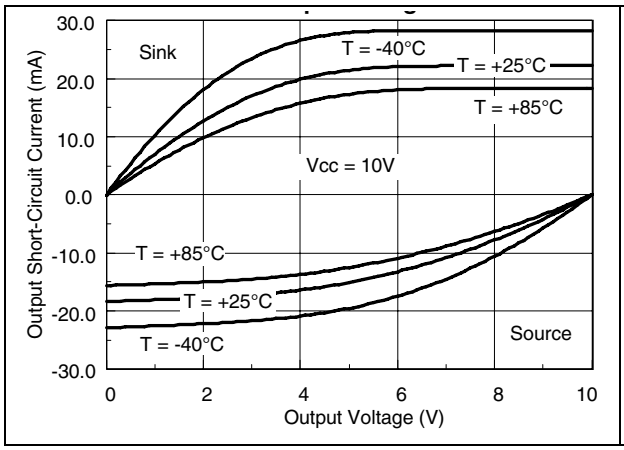


Figure 12. Gain and phase vs. frequency

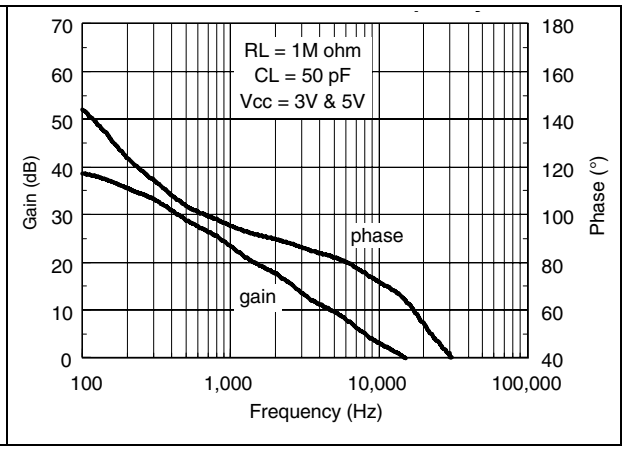


Figure 13. Small signal transient response

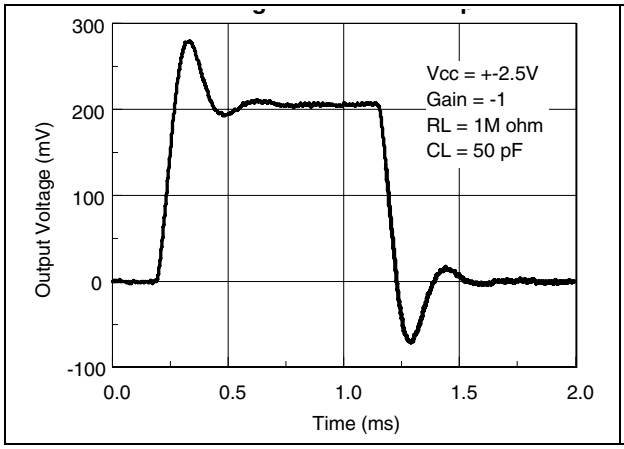


Figure 14. Gain and phase versus frequency

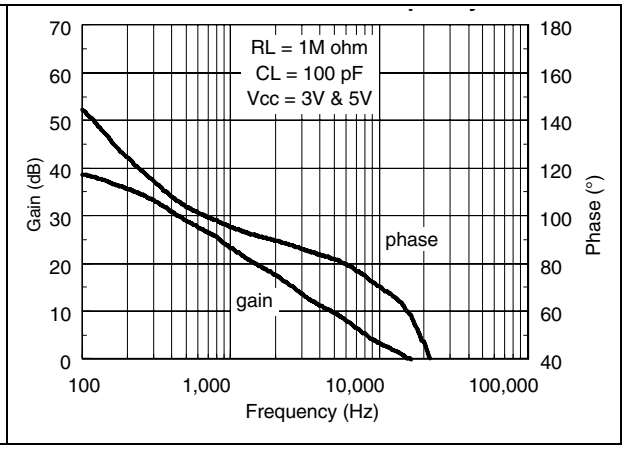


Figure 15. Slew rate positive and negative vs. temperature

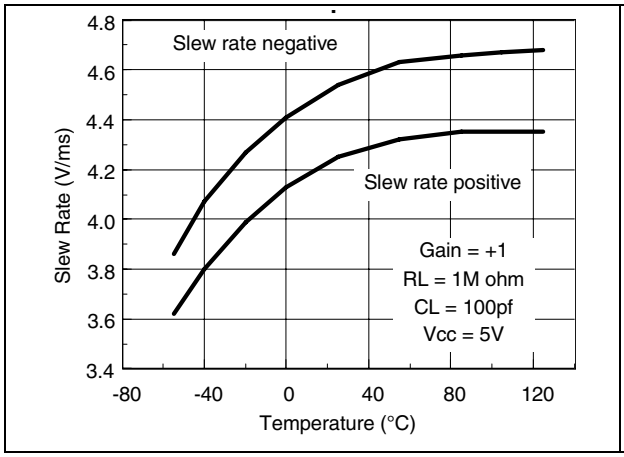
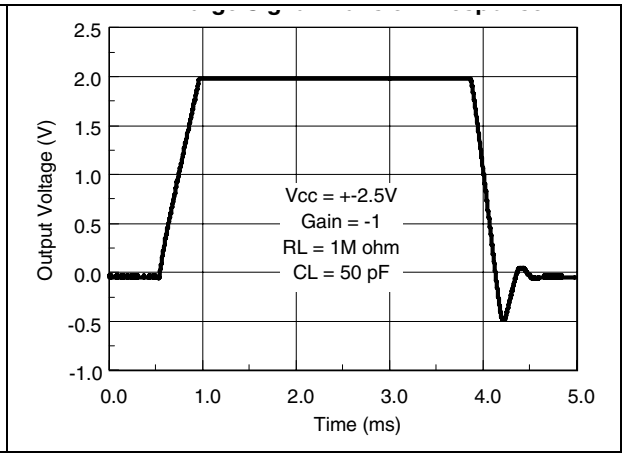


Figure 16. Large signal transient response



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 SOT23-5 package information

Figure 17. SOT23-5 package mechanical drawing

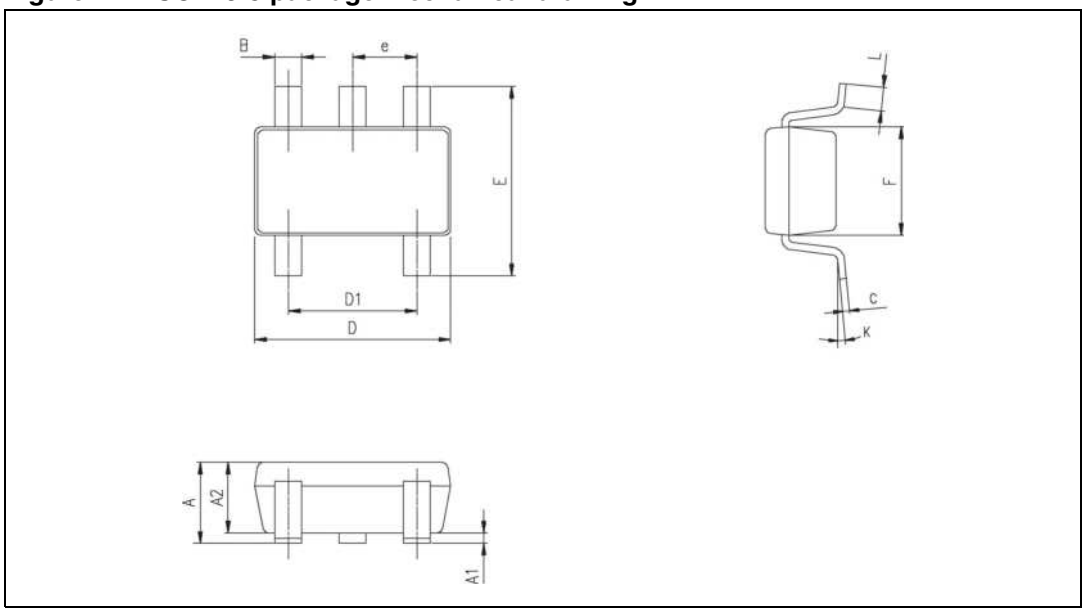


Table 7. SOT23-5 package mechanical data

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			

3.2 SO-8 package information

Figure 18. SO-8 package mechanical drawing

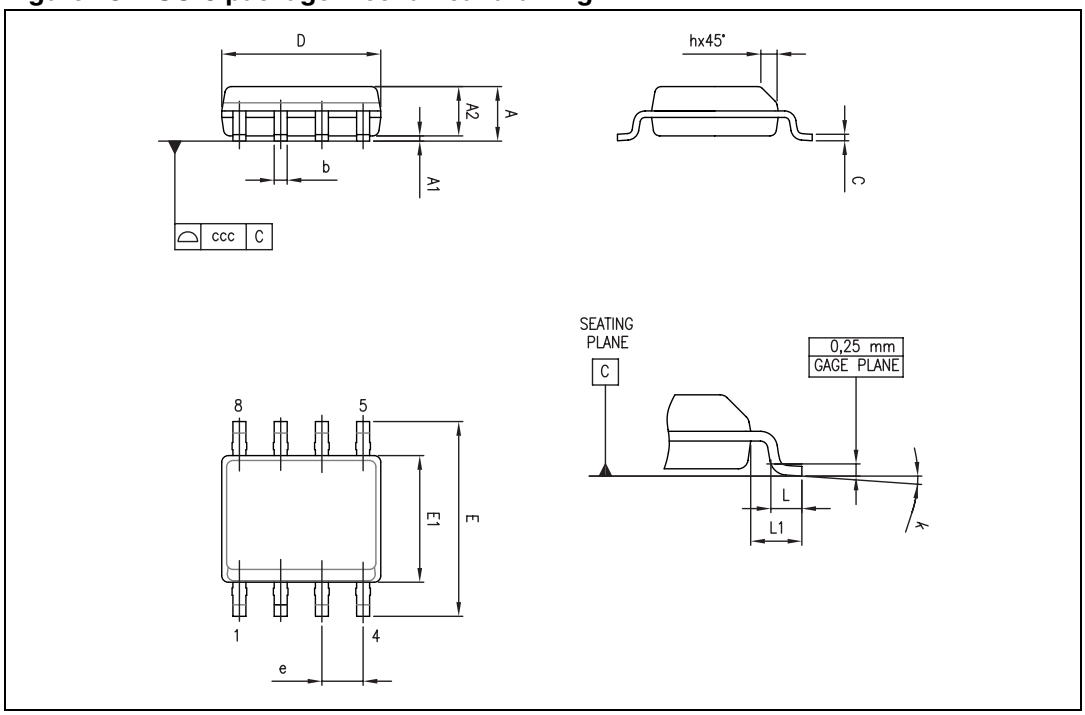


Table 8. SO-8 package mechanical data

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

3.3 TSSOP8 package information

Figure 19. TSSOP8 package mechanical drawing

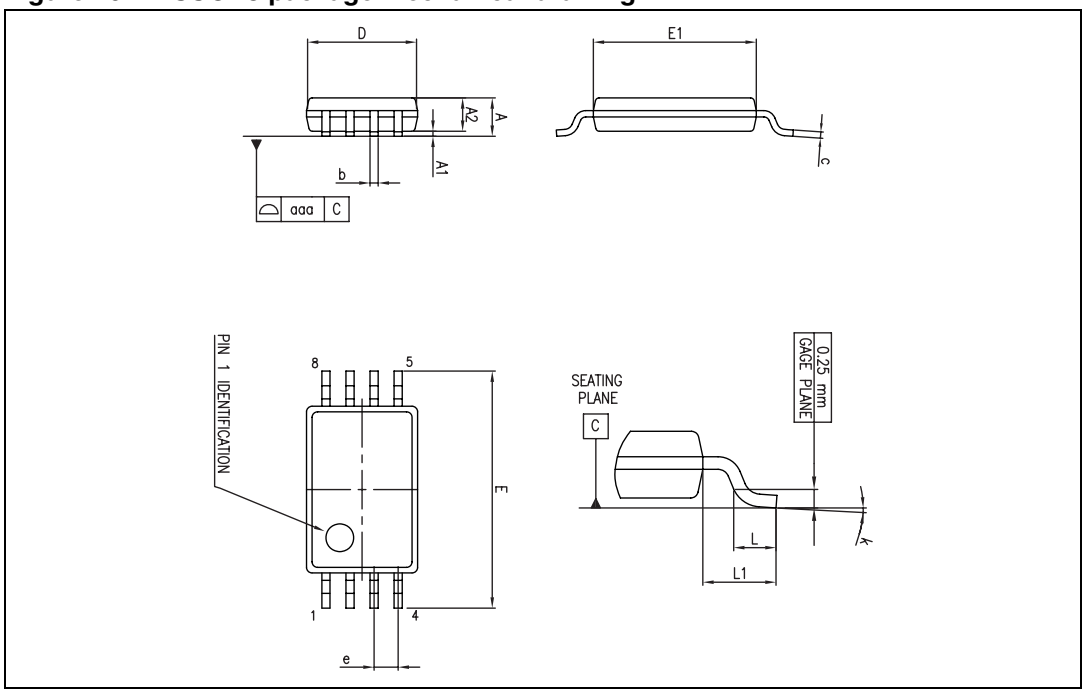


Table 9. TSSOP8 package mechanical data

Ref.	Dimensions					
	Millimeters			Inches		
	Min.	Typ.	Max.	Min.	Typ.	Max.
A			1.20			0.047
A1	0.05		0.15	0.002		0.006
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	
aaa			0.10			0.004

3.4 SO-14 package information

Figure 20. SO-14 package mechanical drawing

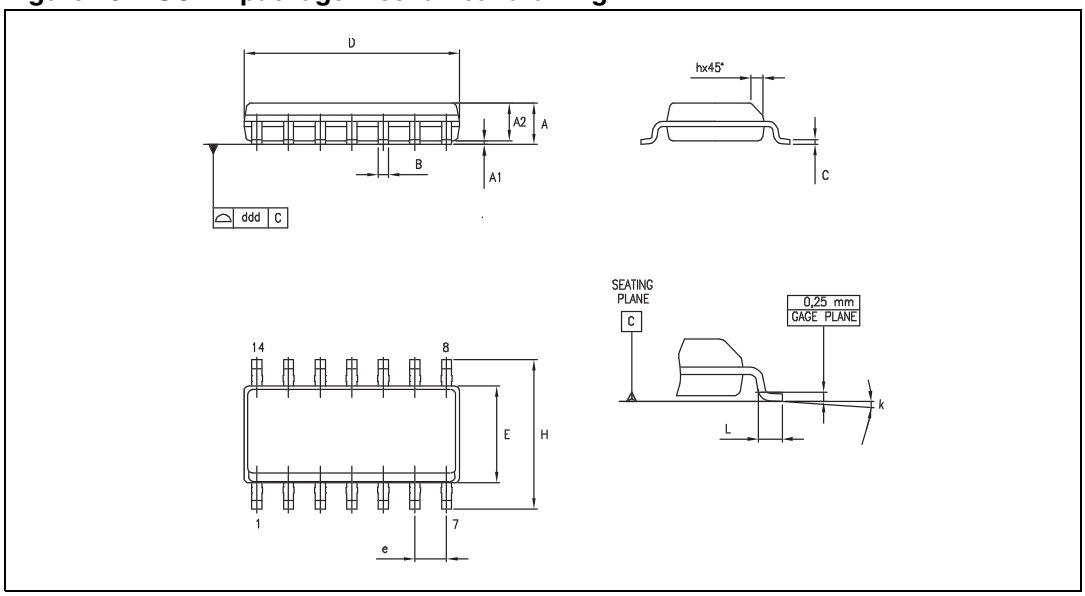


Table 10. SO-14 package mechanical data

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

3.5 TSSOP14 package information

Figure 21. TSSOP14 package mechanical drawing

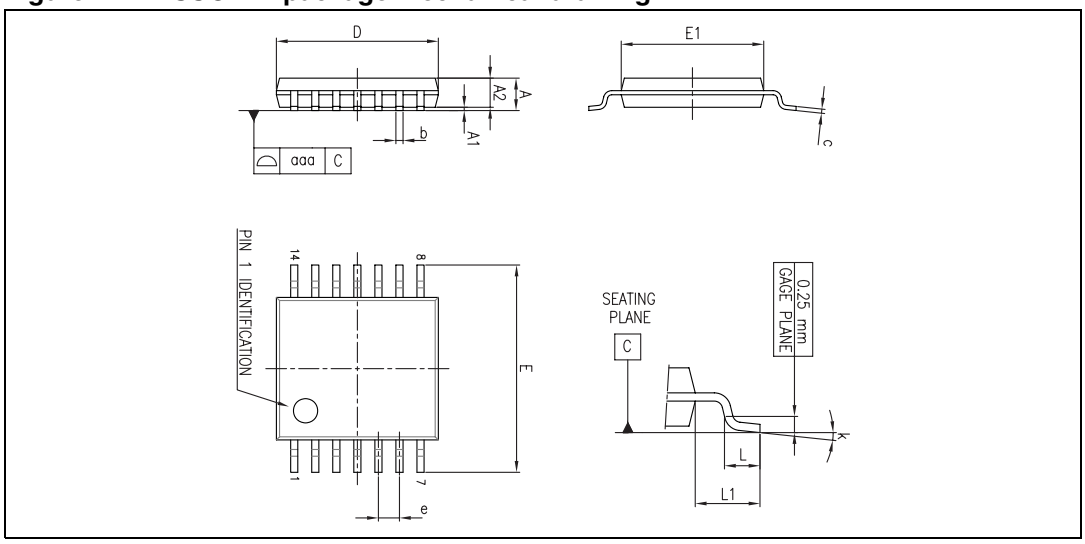


Table 11. TSSOP14 package mechanical data

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 Ordering information

Table 12. Order codes

Order code	Temperature range	Package	Packaging	Marking
TS941ID TS941IDT	-40°C to +85°C	SO-8	Tube or Tape & reel	TS941ID TS941IDT
TS941AID TS941AIDT				TS941AID
TS941BID TS941BIDT				TS941BID
TS941ILT		SOT23-5L	Tape & reel	K201
TS941AILT				K202
TS941BILT				K203
TS942ID TS942IDT		SO-8	Tube or Tape & reel	TS942ID TS942IDT
TS942AID TS942AIDT				TS942AID
TS942BID TS942BIDT				TS942BID
TS942IPT		TSSOP8	Tape & reel	TS942
TS942AIPT				942AI
TS942BIPT				942BI
TS944ID TS944IDT		SO-14	Tube or Tape & reel	TS944ID TS944IDT
TS944AID TS944AIDT				TS944AID TS944AIDT
TS944BID TS944BIDT				TS944BID TS944BIDT
TS944IPT		TSSOP14	Tape & reel	TS944IPT
TS944AIPT				TS944AI
TS944BIPT				TS944BI

5 Revision history

Table 13. Document revision history

Date	Revision	Changes
01-Dec-2001	1	Initial release.
01-Dec-2004	2	Modifications on AMR table (explanation of V_{id} and V_{in} limits).
13-Mar-2008	3	CDM values added for TS944 in SO and TSSOP packages. Document reformatted.
09-Apr-2008	4	Corrected error in power consumption on cover page (1.2µA, not 1.2mA).
05-Mar-2009	5	Removed DIP package information and order codes in *Chapter 3* and *Chapter 4*. Updated all other package mechanical drawings and data in *Chapter 3*.
06-Oct-2009	6	Added root part numbers (TS94xA, TS94xB) and *Table 1: Device summary* on cover page.

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