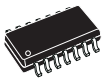
TS924, TS924A

Rail-to-rail output current quad operational amplifier

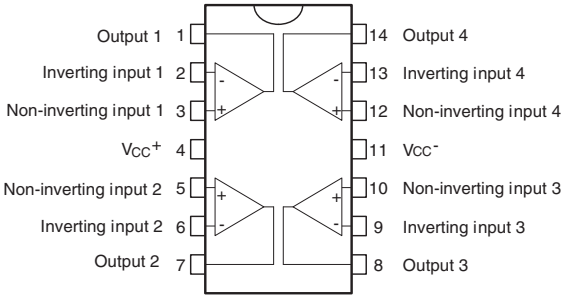
Datasheet - production data



D
SO14
(plastic micropackage)

P
TSSOP14
(thin shrink small outline package)

Pin connections (top view)



Features

- Rail-to-rail input and output
- Low noise: 9 nV/√Hz
- Low distortion
- High output current: 80 mA (able to drive 32 Ω loads)
- High-speed: 4 MHz, 1.3 V/µs
- Operating range from 2.7 V to 12 V
- Low input offset voltage: 900 µV max. (TS924A)
- ESD internal protection: 3 kV
- Latch-up immunity
- Macromodel included in this specification

Related products

- See the TS921 device for the single version and the TS922 device for the dual version
- See the TSX56x series for smaller packages

Applications

- Headphone amplifiers
- Piezoelectric speaker drivers
- Sound cards
- MPEG boards, multimedia systems
- Line drivers, buffers
- Cordless telephones and portable communication equipment
- Instrumentation with low noise as key factor

Description

The TS924 and TS924A devices are rail-to-rail quad BiCMOS operational amplifiers optimized and fully specified for 3 V and 5 V operation.

High output current allows low load impedances to be driven.

The TS924 and TS924A devices exhibit a very low noise, low distortion, low offset, and high output current capability, making these devices an excellent choice for high-quality, low-voltage, and battery-operated audio systems.

The devices are stable for capacitive loads up to 500 pF.

This is information on a product in full production. www.st.com

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1 Absolute maximum ratings and operating conditions

Table 1. Absolute maximum ratings

Symbol	Parameter	Value	Unit
V_{CC}	Supply voltage(1)	14	V
V_{id}	Differential input voltage(2)	±1	
V_{in}	Input voltage(3)	V_{CC-} -0.3 to V_{CC+} +0.3	
T_{stg}	Storage temperature	-65 to +150	°C
T_j	Maximum junction temperature	150	
R_{thja}	Thermal resistance junction-to-ambient(4) SO14 TSSOP14	 66 100	°C/W
ESD	HBM: human body model(5)	3	kV
	MM: machine model(6)	100	V
	CDM: charged device model(7) SO14 TSSOP14	 1.5 1	kV
	Output short-circuit duration	See footnote(8)	
	Latch-up immunity	200	mA
	Soldering temperature (10 sec.), leaded version	250	°C
	Soldering temperature (10 sec.), unleaded version	260	

1. All voltage values, except the differential voltage, are with respect to network ground terminal.
2. The differential voltage is the non-inverting input terminal with respect to the inverting input terminal. If V_{id} > ±1 V, the maximum input current must not exceed ±1 mA. In this case (V_{id} > ±1 V), an input series resistor must be added to limit input current.
3. Do not exceed 14 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 ground through only one pin. This is done for all pins.
8. There is no short-circuit protection inside the device: short-circuits from the output to V_{CC} can cause excessive heating. The maximum output current is approximately 80 mA, independent of the magnitude of V_{CC}. Destructive dissipation can result from simultaneous short-circuits on all amplifiers.

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_{CC-} -0.2 to V_{CC+} +0.2	
T_{oper}	Operating free air temperature range	-40 to +125	°C

2 Electrical characteristics

Table 3. Electrical characteristics at V_{CC+} = +3 V with V_{CC-} = 0 V, V_{icm} = V_{CC+}/2, T_{amb} = 25 °C, and R_L connected to V_{CC+}/2 (unless otherwise specified)

Symbol	Parameter	Min.	Typ.	Max.	Unit
DC performance					
V_{io}	Input offset voltage TS924 TS924A $T_{min} \le T_{amb} \le T_{max}$ TS924 TS924A			 3 0.9 5 1.8	mV
DV_{io}	Input offset voltage drift		2		µV/°C
I_{io}	Input offset current - $T_{min} \le T_{amb} \le T_{max}$		1	30	nA
I_{ib}	Input bias current - $T_{min} \le T_{amb} \le T_{max}$		15	100	
CMR	V_{icm} from 0 to 3 V $T_{min} \le T_{amb} \le T_{max}$	60 56	80		dB
SVR	Supply voltage rejection ratio - V_{CC+} = 2.7 to 3.3 V $T_{min} \le T_{amb} \le T_{max}$	60 60	85		
A_{vd}	Large signal voltage gain (V_{out} = 2 V_{pk-pk}) R_L= 10 kΩ, $T_{min} \le T_{amb} \le T_{max}$ R_L = 600 Ω, $T_{min} \le T_{amb} \le T_{max}$ R_L = 32 Ω	 70 15	 200 35 16		V/mV
V_{OH}	High level output voltage R_L= 10 kΩ, $T_{min} \le T_{amb} \le T_{max}$ R_L = 600 Ω, $T_{min} \le T_{amb} \le T_{max}$ R_L = 32 Ω	 2.90 2.87	 2.63		V
V_{OL}	Low level output voltage R_L= 10 kΩ, $T_{min} \le T_{amb} \le T_{max}$ R_L = 600 Ω, $T_{min} \le T_{amb} \le T_{max}$ R_L = 32 Ω		 180	 50 100	mV
I_o	Output short-circuit current	50	80		mA
I_{CC}	Supply current /operator - no load, V_{out} = V_{CC+}/2 $T_{min} \le T_{amb} \le T_{max}$		1	1.5 1.6	
AC performance					
GBP	Gain bandwidth product - R_L = 600 Ω		4		MHz
ϕ_m	Phase margin at unit gain - R_L = 600 Ω, C_L =100 pF		68		Degrees
G_m	Gain margin - R_L = 600 Ω, C_L =100 pF		12		dB
SR	Slew rate	0.7	1.3		V/µs
e_n	Equivalent input noise voltage - f = 1 kHz		9		$\frac{nV}{\sqrt{Hz}}$

Table 3. Electrical characteristics at V_{CC+} = +3 V with V_{CC-} = 0 V, V_{icm} = V_{CC+}/2, T_{amb} = 25 °C, and R_L connected to V_{CC+}/2 (unless otherwise specified) (continued)

Symbol	Parameter	Min.	Typ.	Max.	Unit
THD	Total harmonic distortion V_{out} = 2 V_{pk-pk}, F = 1 kHz, A_v = 1, R_L = 600 Ω		0.005		%
C_s	Channel separation		120		dB

Table 4. V_{CC+} = +5 V, V_{CC-} = 0 V, V_{icm} = V_{CC}/2, T_{amb} = 25 °C, R_L connected to V_{CC}/2 (unless otherwise specified)

Symbol	Parameter	Min.	Typ.	Max.	Unit
DC performance					
V_{io}	Input offset voltage TS924 TS924A $T_{min} \le T_{amb} \le T_{max}$ TS924 TS924A			 3 0.9 5 1.8	mV
DV_{io}	Input offset voltage drift		2		µV/°C
I_{io}	Input offset current - $T_{min} \le T_{amb} \le T_{max}$		1	30	nA
I_{ib}	Input bias current - $T_{min} \le T_{amb} \le T_{max}$		15	100	
CMR	V_{icm} from 0 to 5 V $T_{min} \le T_{amb} \le T_{max}$	60 56	80		dB
SVR	Supply voltage rejection ratio - V_{CC+} = 3 V to 5 V $T_{min} \le T_{amb} \le T_{max}$	60 60	85		
A_{vd}	Large signal voltage gain (V_{out} = $2V_{pk-pk}$) R_L= 10 kΩ, $T_{min} \le T_{amb} \le T_{max}$ R_L = 600 Ω, $T_{min} \le T_{amb} \le T_{max}$ R_L = 32 Ω	 70 20	 200 40 17		V/mV
V_{OH}	High level output voltage R_L= 10 kΩ, $T_{min} \le T_{amb} \le T_{max}$ R_L = 600 Ω, $T_{min} \le T_{amb} \le T_{max}$ R_L = 32 Ω	 4.90 4.85	 4.4		V
V_{OL}	Low level output voltage R_L= 10 kΩ, $T_{min} \le T_{amb} \le T_{max}$ R_L = 600 Ω, $T_{min} \le T_{amb} \le T_{max}$ R_L = 32 Ω		 300	 50 120	mV
I_o	Output short-circuit current	50	80		mA
I_{CC}	Supply current / operator - no load, V_{out} = V_{CC+}/2 $T_{min} \le T_{amb} \le T_{max}$		1	1.5 1.6	
AC performance					
GBP	Gain bandwidth product - R_L = 600 Ω		4		MHz
ϕm	Phase margin at unit gain - R_L = 600 Ω, C_L =100 pF		68		Degrees
G_m	Gain margin -R_L = 600 Ω, C_L =100 pF		12		dB
SR	Slew rate	0.7	1.3		V/µs
e_n	Equivalent input noise voltage - f = 1 kHz		9		$\frac{nV}{\sqrt{Hz}}$
THD	Total harmonic distortion V_{out} = 2 V_{pk-pk}, F = 1 kHz, A_v = 1, R_L = 600 Ω		0.005		%
C_s	Channel separation		120		dB

Figure 1. Output short-circuit current vs. output voltage (V_{CC} = 0/12 V)

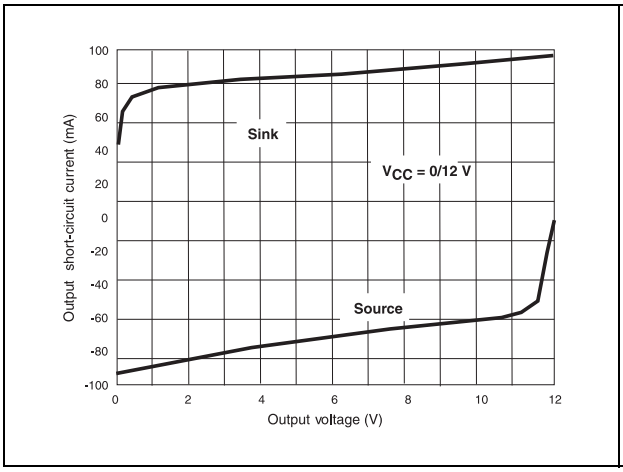


Figure 2. Output short-circuit current vs. output voltage (V_{CC} = 0/3 V)

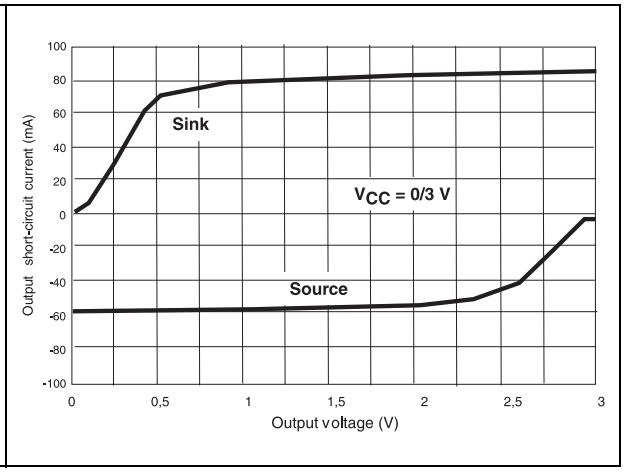


Figure 3. Voltage gain and phase vs. frequency (C_L = 500 pF, V_{CC} = ±1.5 V)

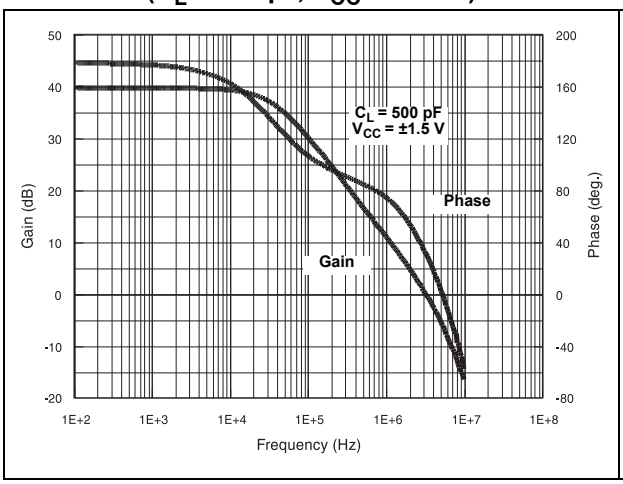


Figure 4. Output short-circuit current vs. output voltage (V_{CC} = 0/5 V)

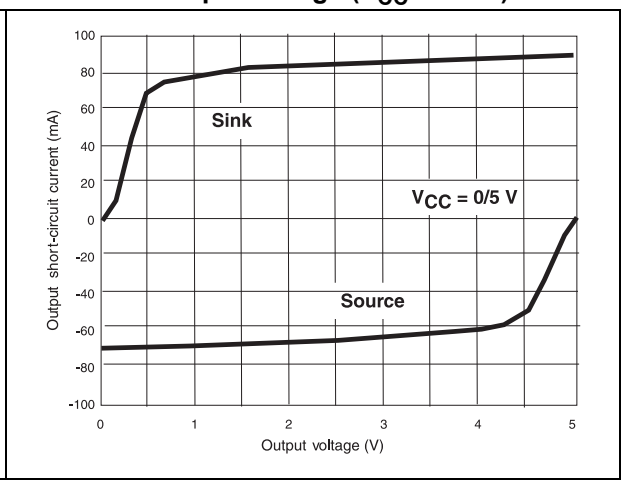


Figure 5. Voltage gain and phase vs. frequency (R_L = 10 kΩ, C_L = 100 pF, V_{CC} = ±1.5 V)

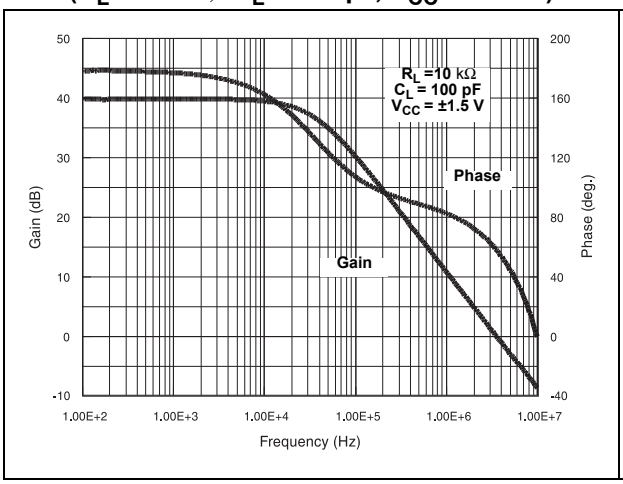


Figure 6. THD + noise vs. frequency (R_L = 2 kΩ, V_O = 10 Vpp, V_{CC} = ±6 V, A_v = -1)

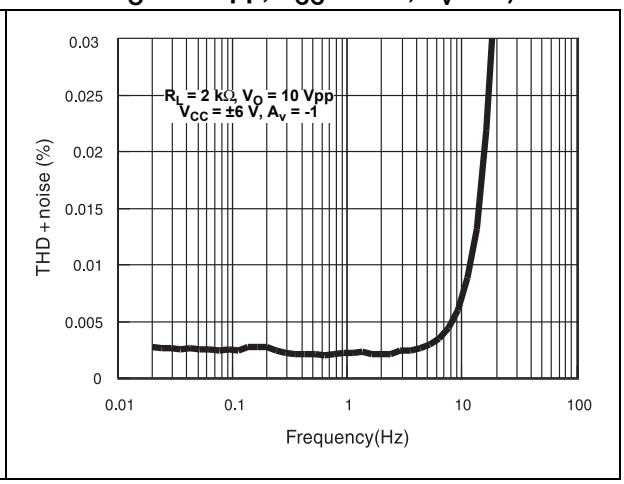


Figure 7. THD + noise vs. frequency (R_L = 2 kΩ, V_O = 10 Vpp, V_{CC} = ±6 V, A_v = 1)

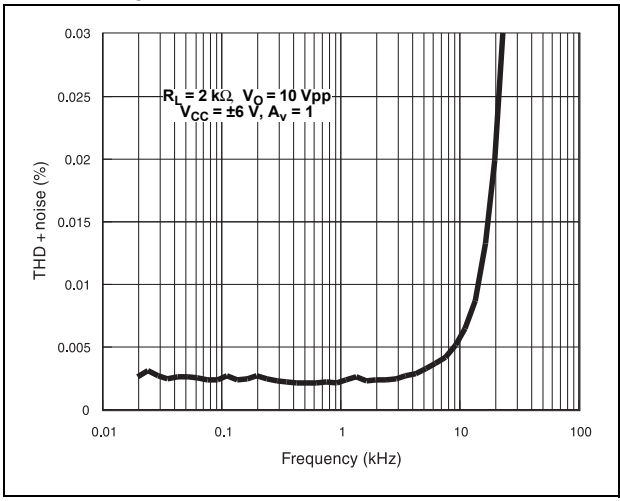


Figure 8. THD + noise vs. frequency (R_L = 32 Ω, V_O = 2 Vpp, V_{CC} = ±1.5 V, A_v = 10)

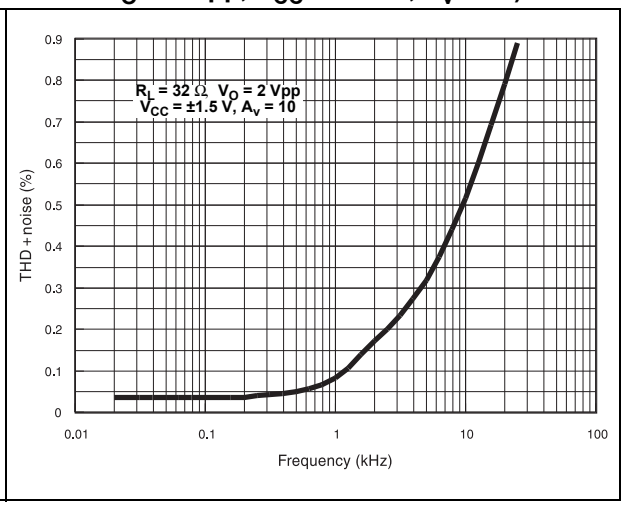


Figure 9. THD + noise vs. V_{out} (R_L = 32 Ω, f = 1 kHz, V_{CC} = ±1.5 V, A_v = -1)

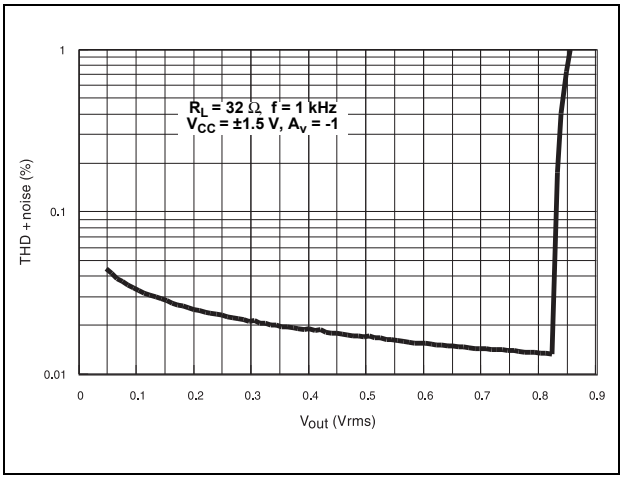


Figure 10. THD + noise vs. frequency (R_L = 32 Ω, V_O = 4 Vpp, V_{CC} = ±2.5 V, A_v = 1)

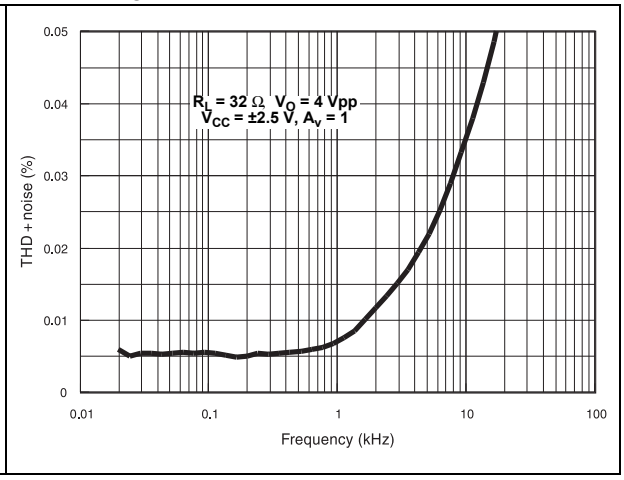


Figure 11. THD + noise vs. V_{out} (R_L = 600 Ω, f = 1 kHz, V_{CC} = ±1.5 V , A_v = -1)

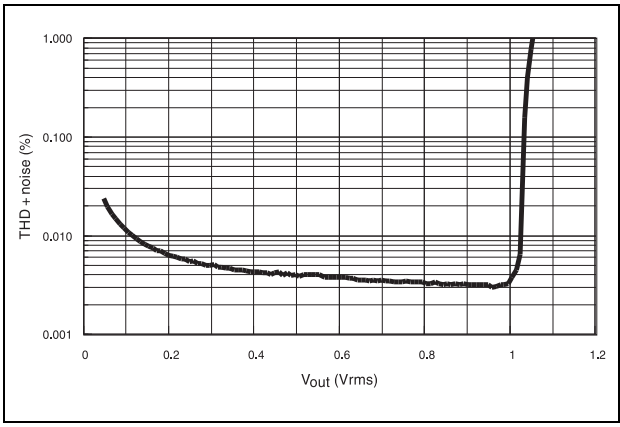


Figure 12. THD + noise vs. V_{out} (R_L = 2 kΩ, f = 1 kHz, V_{CC} = ±1.5 V, A_v = -1)

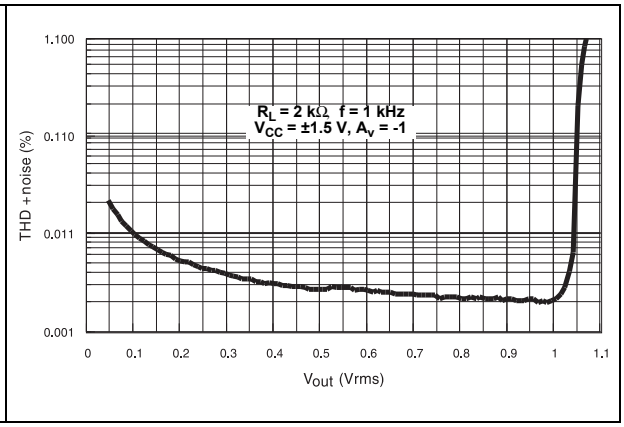
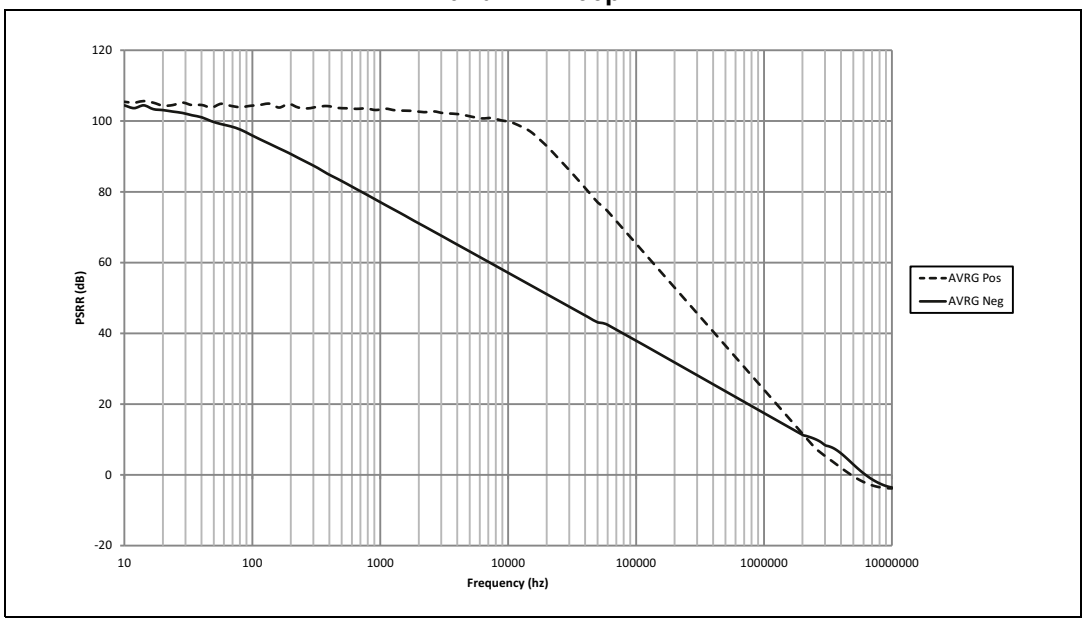


Figure 13. PSRR for TS924/TS924A at V_{CC} = 5 V, V_{icm} = 2.5 V, T = 25 °C, RI = 100 kΩ, and CI = 100pF



3 Macromodel

3.1 Important note concerning this macromodel

Note the following remarks before using this macromodel:

- All models are a trade-off between accuracy and complexity (that is, simulation time).
- Macromodels are not a substitute to breadboarding; rather, they confirm the validity of a design approach and help to select surrounding component values.
- A macromodel emulates the **nominal** performance of a **typical** device within **specified operating conditions** (for example, temperature, supply voltage). Thus, the macromodel is often not as exhaustive as the datasheet, its purpose is to illustrate the main parameters of the product.

Data derived from macromodels used outside of the specified conditions (such as V_{CC} and temperature) or worse, outside of the device operating conditions (such as V_{CC} and V_{icm}), are not reliable in any way.

Section 3.2 presents the electrical characteristics resulting from the use of these macromodels.

3.2 Electrical characteristics from macromodelization

Table 5. Macromodel simulation at V_{CC+} = 3 V, V_{CC-} = 0 V, R_L, C_L connected to V_{CC}/2, and T_{amb} = 25 °C (unless otherwise specified)

Symbol	Conditions	Value	Unit
V_{io}		0	mV
A_{vd}	R_L = 10 kΩ	200	V/mV
I_{CC}	No load, per operator	1.2	mA
V_{icm}		-0.2 to 3.2	V
V_{OH}	R_L = 10 kΩ	2.95	
V_{OL}	R_L = 10 kΩ	25	mV
I_{sink}	V_O = 3 V	80	mA
I_{source}	V_O = 0 V	80	
GBP	R_L = 600 kΩ	4	MHz
SR	R_L = 10 kΩ, C_L = 100 pF	1	V/µs
ϕm	R_L = 600 kΩ	68	Degrees

3.3 Macromodel code

```
** Standard Linear Ics Macromodels, 1996.
** CONNECTIONS:
* 1 INVERTING INPUT
* 2 NON-INVERTING INPUT
* 3 OUTPUT
* 4 POSITIVE POWER SUPPLY
* 5 NEGATIVE POWER SUPPLY

.SUBCKT TS92X 1 2 3 4 5
*
.MODEL MDTH D IS=1E-8 KF=2.664234E-16 CJO=10F
*
* INPUT STAGE
CIP 2 5 1.000000E-12
CIN 1 5 1.000000E-12
EIP 10 5 2 5 1
EIN 16 5 1 5 1
RIP 10 11 8.125000E+00
RIN 15 16 8.125000E+00
RIS 11 15 2.238465E+02
DIP 11 12 MDTH 400E-12
DIN 15 14 MDTH 400E-12
VOFP 12 13 DC 153.5u
VOFN 13 14 DC 0
IPOL 13 5 3.200000E-05
CPS 11 15 1e-9
DINN 17 13 MDTH 400E-12
VIN 17 5 -0.100000e+00
DINR 15 18 MDTH 400E-12
VIP 4 18 0.400000E+00
FCP 4 5 VOFP 1.865000E+02
FCN 5 4 VOFN 1.865000E+02
FIBP 2 5 VOFP 6.250000E-03
FIBN 5 1 VOFN 6.250000E-03
* GM1 STAGE ***************
FGM1P 119 5 VOFP 1.1
FGM1N 119 5 VOFN 1.1
RAP 119 4 2.6E+06
RAN 119 5 2.6E+06
* GM2 STAGE ***************
G2P 19 5 119 5 1.92E-02
G2N 19 5 119 4 1.92E-02
R2P 19 4 1E+07
```

```
R2N 19 5 1E+07
*************************
VINT1 500 0 5
GCONVP 500 501 119 4 19.38
VP 501 0 0
GCONVN 500 502 119 5 19.38
VN 502 0 0
********* orientation isink isource *******
VINT2 503 0 5
FCOPY 503 504 VOUT 1
DCOPYP 504 505 MDTH 400E-9
VCOPYP 505 0 0
DCOPYN 506 504 MDTH 400E-9
VCOPYN 0 506 0
***************************
F2PP 19 5 poly(2) VCOPYP VP 0 0 0 0 0.5
F2PN 19 5 poly(2) VCOPYP VN 0 0 0 0 0.5
F2NP 19 5 poly(2) VCOPYN VP 0 0 0 0 1.75
F2NN 19 5 poly(2) VCOPYN VN 0 0 0 0 1.75
* COMPENSATION ************
CC 19 119 25p
* OUTPUT ***********
DOPM 19 22 MDTH 400E-12
DONM 21 19 MDTH 400E-12
HOPM 22 28 VOUT 6.250000E+02
VIPM 28 4 5.000000E+01
HONM 21 27 VOUT 6.250000E+02
VINM 5 27 5.000000E+01
VOUT 3 23 0
ROUT 23 19 6
COUT 3 5 1.300000E-10
DOP 19 25 MDTH 400E-12
VOP 4 25 1.052
DON 24 19 MDTH 400E-12
VON 24 5 1.052
.ENDS ;TS92X
```

4 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.

4.1 SO14 package information

Figure 14. SO14 package outline

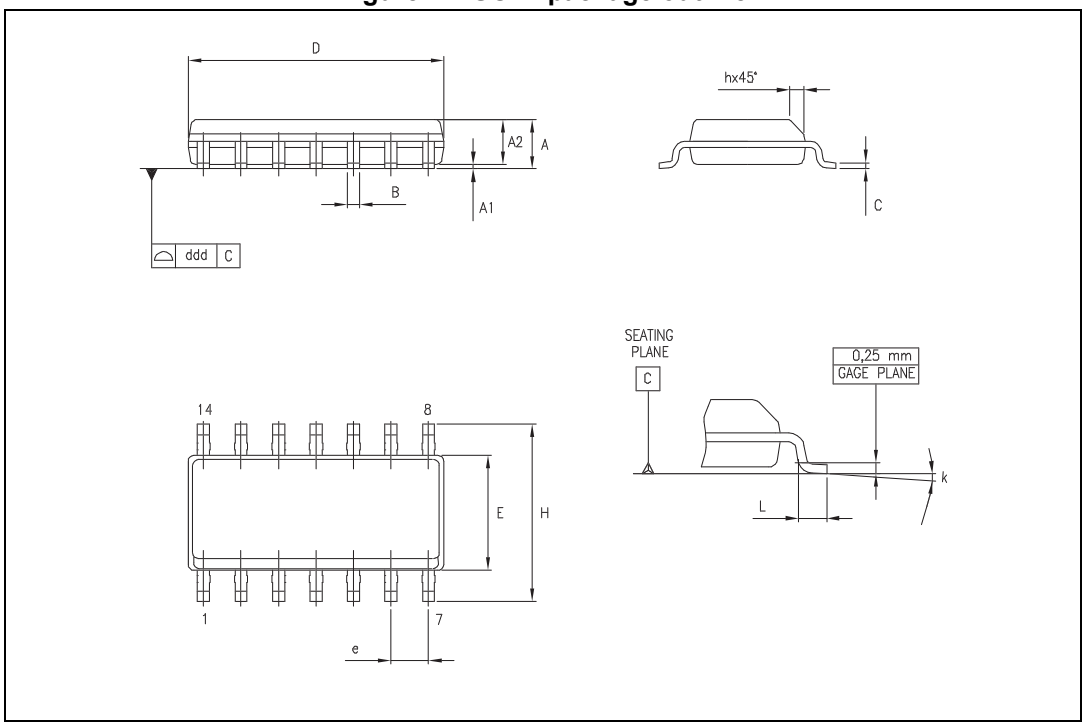


Table 6. SO14 package mechanical data

Symbol	Dimensions					
	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

4.2 TSSOP14 package information

Figure 15. TSSOP14 package outline

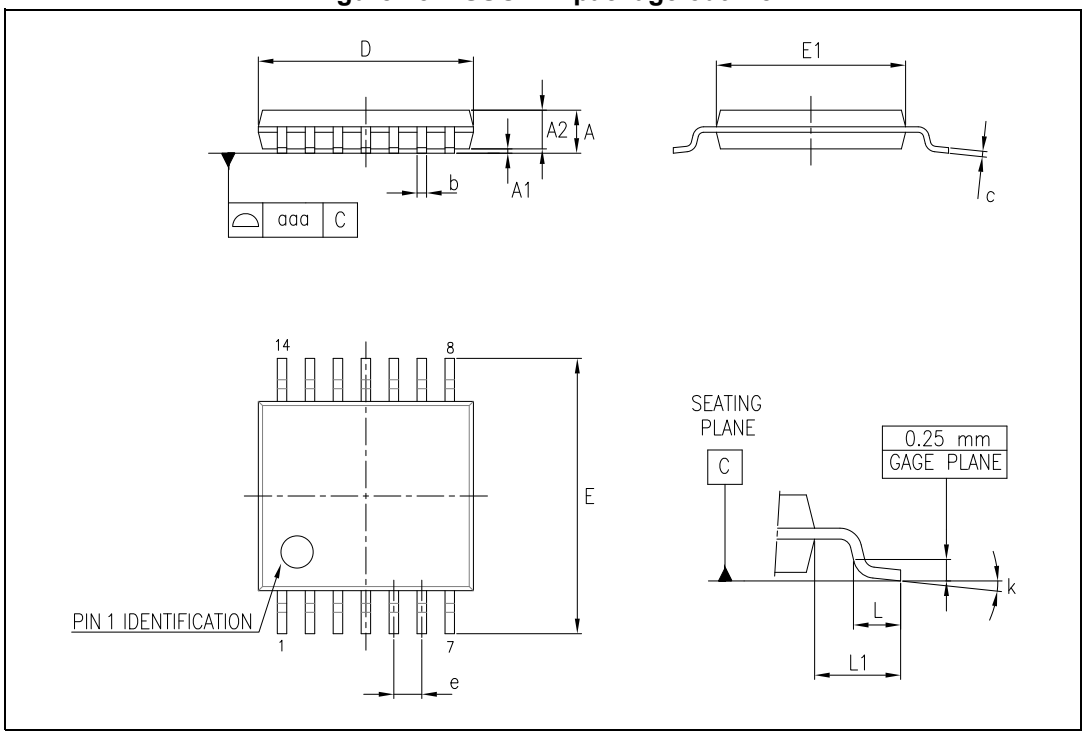


Table 7. TSSOP14 package mechanical data

Symbol	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

5 Ordering information

Table 8. Order codes

Order code	Temperature range	Package	Packaging	Marking
TS924ID TS924IDT	-40 °C, 125 °C	SO14	Tube or tape and reel	924I
TS924AID TS924AIDT				924AI
TS924IYDT(1)		SO14 (automotive grade)	Tape and reel	924IY
TS924AIYDT(1)				924AIY
TS924IPT		TSSOP14		924I
TS924AIPT				924AI
TS924IYPT(1)		TSSOP14 (automotive grade)		924IY
TS924AIYPT(1)				924AIY

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

6 Revision history

Table 9. Document revision history

Date	Revision	Changes
28-May-2001	1	First release.
12-May-2005	2	Modifications on AMR *Table on page 3* (explanation of V_{id} and V_{in} limits, ESD MM and CDM values added, R_{thja} added).
31-Jul-2005	3	PPAP references inserted in the datasheet, see order codes table.
30-Nov-2005	4	Package mechanical data modified. TS924IYPT/TS924AYIPT PPAP reference inserted in order code table. Macromodel modified.
11-Mar-2008	5	Added footnotes for automotive grade order codes in *Table 8: Order codes*. Updated document format.
19-Dec-2008	6	ESD tolerance improved for machine model in *Table 1: Absolute maximum ratings*. Removed TS914AIN order code and corrected footnotes in *Table 8: Order codes*.
08-Oct-2009	7	Added part number TS924A on cover page. Added limits on full temperature range in *Table 3* and *Table 4*. Removed order codes TS924IYD and TS924AIYD from *Table 8*.
15-Apr-2011	8	Modified CMR parameter values in *Table 3* and *Table 4*.
19-May-2011	9	Added A version in title and header.
04-Dec-2012	10	Added DIP14 package to Figure on page 1. Added *Related products* to *Features*. Added DIP14 with value for R_{thja} in *Table 1*. Added conditions to titles of *Figure 1* to *Figure 12*. Replaced V_{CC} by V_{CC+} and V_{DD} by V_{CC-} in title of *Table 5*. Qualified status of TS924IYPT and TS924AIYPT order codes in *Table 8*. Minor corrections throughout document.
05-Jun-2014	11	Removed DIP14 package and order code pertaining to it Added *Figure 13*

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