

# High-speed low-power quad operational amplifier with dual standby position

Datasheet – production data

## Features

- Low supply current: 4.5 mA
- High speed: 150 MHz - 110 V/ $\mu$ s
- Unity gain stability
- Low offset voltage: 4 mV
- Low noise 4.2 nV/ $\sqrt$ Hz
- Specified for 600  $\Omega$  and 150  $\Omega$  loads
- High video performances
  - Differential gain: 0.03%
  - Differential phase: 0.07°
  - Gain flatness: 6 MHz, 0.1 dB max. at 10 db gain

## Applications

- Video buffers
- A/D converter drivers

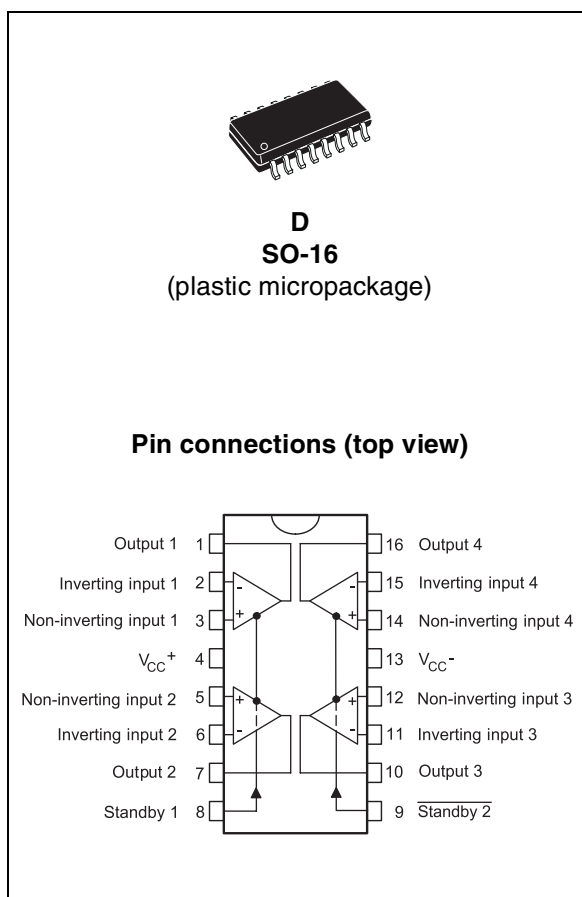
## Description

The TSH95 device is a low-power, high frequency quad operational amplifier designated for high-quality video processing. The device offers an excellent speed consumption ratio with 4.5 mA per amplifier for a 150 MHz bandwidth.

A high slew rate and low noise also make it suitable for high-quality audio applications.

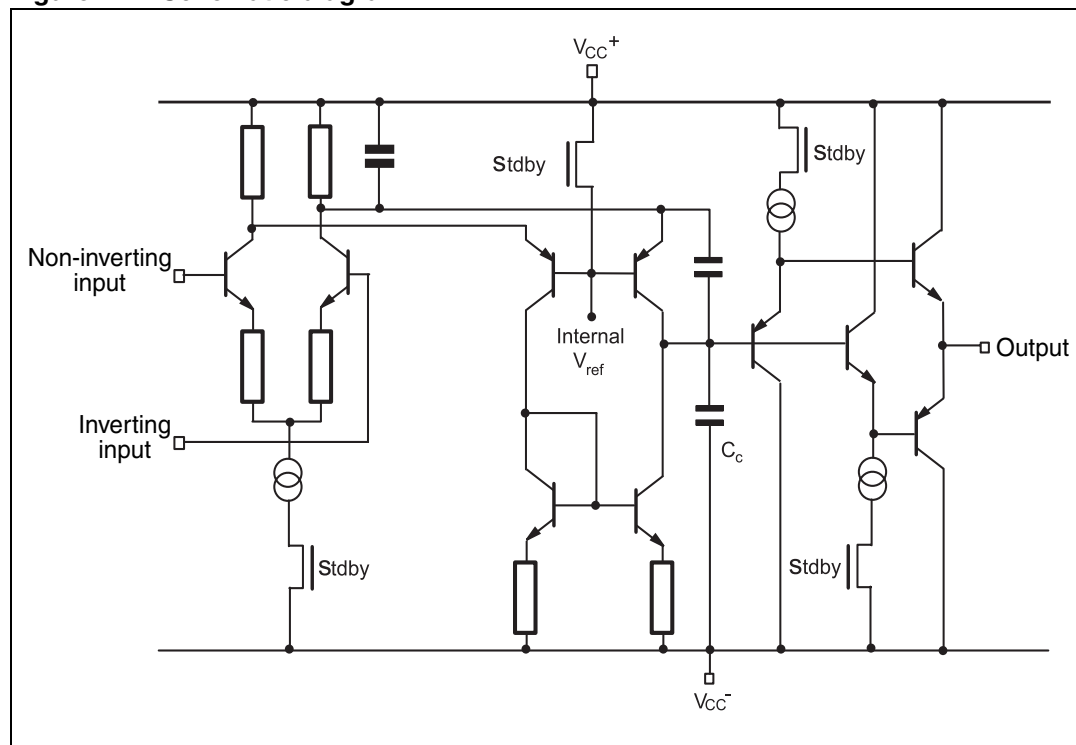
The TSH95 device offers two separate complementary standby pins: “Standby 1” acting on operators 1 and 2, and “Standby 2” acting on operators 3 and 4.

These pins reduce the consumption of the corresponding operators and put the output in a high impedance state.



# 1 Schematic diagram

Figure 1. Schematic diagram



## 2 Absolute maximum ratings and operating conditions

**Table 1. Absolute maximum ratings**

Symbol	Parameter	Value	Unit
$V_{CC}$	Supply voltage <sup>(1)</sup>	14	V
$V_{id}$	Differential input voltage <sup>(2)</sup>	±5	V
$V_i$	Input voltage <sup>(3)</sup>	-0.3 to 12	V
$T_{oper}$	Operating free air temperature range	-40 to +125	°C
$T_{stg}$	Storage temperature range	-65 to +150	°C
ESD	CDM: charged device model <sup>(4)</sup>	1.5	kV
	HBM: human body model <sup>(5)</sup>	2	kV
	MM: machine model <sup>(6)</sup>	200	V

1. All voltages 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.
3. The magnitude of input and output voltages must never exceed  $V_{CC}^+ + 0.3$  V.
4. 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.
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.

**Table 2. Operating conditions**

Symbol	Parameter	Value	Unit
$V_{CC}$	Supply voltage	7 to 12	V
$V_{ic}$	Common mode input voltage range	$V_{CC}^- + 2$ to $V_{CC}^+ - 1$	V

### 3 Electrical characteristics

**Table 3. Electrical characteristics at  $V_{CC+} = 5\text{ V}$ ,  $V_{CC-} = -5\text{ V}$ , pin 8 connected to 0 V, pin 9 connected to  $V_{CC+}$ ,  $T_{amb} = 25\text{ °C}$  (unless otherwise specified)**

Symbol	Parameter	Min.	Typ.	Max.	Unit
$V_{io}$	Input offset voltage $V_{ic} = V_o = 0\text{ V}$ $T_{min.} \leq T_{amb} \leq T_{max.}$			4 6	mV
$I_{io}$	Input offset current $T_{min.} \leq T_{amb} \leq T_{max.}$		1	2 5	$\mu\text{A}$
$I_{ib}$	Input bias current $T_{min.} \leq T_{amb} \leq T_{max.}$		5	15 20	$\mu\text{A}$
$I_{CC}$	Supply current (per amplifier, no load) $T_{min.} \leq T_{amb} \leq T_{max.}$		4.5	6 8	mA
CMR	Common-mode rejection ratio $V_{ic} = -3\text{ V to } +4\text{ V}$ , $V_o = 0\text{ V}$ $T_{min.} \leq T_{amb} \leq T_{max.}$	80 70	100		dB
SVR	Supply voltage rejection ratio $V_{CC} = \pm 5\text{ V to } \pm 3\text{ V}$ $T_{min.} \leq T_{amb} \leq T_{max.}$	60 50	75		dB
$A_{vd}$	Large signal voltage gain $R_L = 10\text{ k}\Omega$ , $V_o = \pm 2.5\text{ V}$ $T_{min.} \leq T_{amb} \leq T_{max.}$	57 54	70		dB
$V_{OH}$	High level output voltage $V_{id} = 1\text{ V}$ $R_L = 600\ \Omega$ $R_L = 150\ \Omega$ $T_{min.} \leq T_{amb} \leq T_{max.}$ $R_L = 150\ \Omega$	3 2.5 2.4	3.5 3		V
$V_{OL}$	Low level output voltage $V_{id} = 11\text{ V}$ $R_L = 600\ \Omega$ $R_L = 150\ \Omega$ $T_{min.} \leq T_{amb} \leq T_{max.}$ $R_L = 150\ \Omega$		-3.5 -2.8	-3 -2.5 -2.4	V
$I_o$	Output short-circuit current $V_{id} = \pm 1\text{ V}$ source sink $T_{min.} \leq T_{amb} \leq T_{max.}$ source sink	20 20 15 15	36 40		mA
GBP	Gain bandwidth product $A_{VCL} = 100$ , $R_L = 600\ \Omega$ , $C_L = 15\text{ pF}$ , $f = 7.5\text{ MHz}$	90	150		MHz
$f_T$	Transition frequency		90		MHz
SR	Slew rate $V_{in} = -2\text{ to } +2\text{ V}$ , $R_L = 600\ \Omega$ , $C_L = 15\text{ pF}$	62	110		V/ $\mu\text{s}$
$e_n$	Equivalent input voltage noise $R_s = 50\ \Omega$ , $f = 1\text{ kHz}$		4.2		nV/ $\sqrt{\text{Hz}}$
$\phi_m$	Phase margin $A_{VM} = +1$		35		Degrees
$V_{O1}/V_{O2}$	Channel separation $f = 1\text{ MHz to } 10\text{ MHz}$		65		dB
Gf	Gain flatness $f = \text{DC to } 6\text{ MHz}$ , $A_{VCL} = 10\text{ dB}$			0.1	dB
THD	Total harmonic distortion $f = 1\text{ kHz}$ , $V_o = \pm 2.5\text{ V}$ , $R_L = 600\ \Omega$		0.01		%

**Table 3. Electrical characteristics at  $V_{CC+} = 5\text{ V}$ ,  $V_{CC-} = -5\text{ V}$ , pin 8 connected to 0 V, pin 9 connected to  $V_{CC+}$ ,  $T_{amb} = 25\text{ °C}$  (unless otherwise specified) (continued)**

Symbol	Parameter	Min.	Typ.	Max.	Unit
$\Delta G$	Differential gain $f = 3.58\text{ MHz}$ , $A_{VCL} = +2$ , $R_L = 150\ \Omega$		0.03		%
$\Delta\phi$	Differential phase $f = 3.58\text{ MHz}$ , $A_{VCL} = +2$ , $R_L = 150\ \Omega$		0.07		Degrees

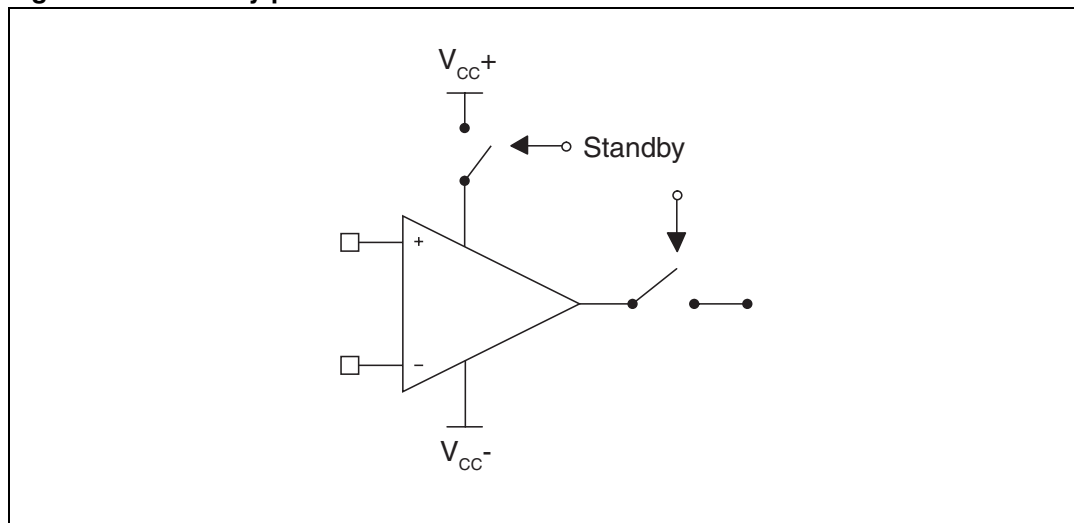
**Table 4. Standby mode:  $V_{CC+} = 5\text{ V}$ ,  $V_{CC-} = -5\text{ V}$ ,  $T_{amb} = 25\text{ °C}$  (unless otherwise specified)**

Symbol	Parameter	Min.	Typ.	Max.	Unit
$V_{SBY}$	Pin 8/9 threshold voltage for standby mode	$V_{CC+} - 2.2$	$V_{CC+} - 1.6$	$V_{CC+} - 1.0$	V
$I_{CC\ SBY}$	Total consumption:				mA
	Pin 8 (Standby 1) = 0, pin 9 (Standby 2) = 0		9.4		
	Pin 8 (Standby 1) = 0, pin 9 (Standby 2) = 1		9.4		
	Pin 8 (Standby 1) = 0, pin 9 (Standby 2) = 0		0.8		
$I_{sol}$	Input/output isolation ( $f = 1\text{ MHz}$ to $10\text{ MHz}$ )		70		dB
$t_{ON}$	Time from standby mode to active mode		200		ns
$t_{OFF}$	Time from active mode to standby mode		200		ns
$I_D$	Standby driving current		2		pA
$I_{OL}$	Output leakage current		20		pA
$I_{IL}$	Input leakage current		20		pA

**Table 5. Standby control pin status**

Logic input		Status	
Standby 1	Standby 2	Op amps 1 and 2	Op amps 2 and 3
0	0	Enable	Standby
0	1	Enable	Enable
1	0	Standby	Standby
1	1	Standby	Enable

Figure 2. Standby position

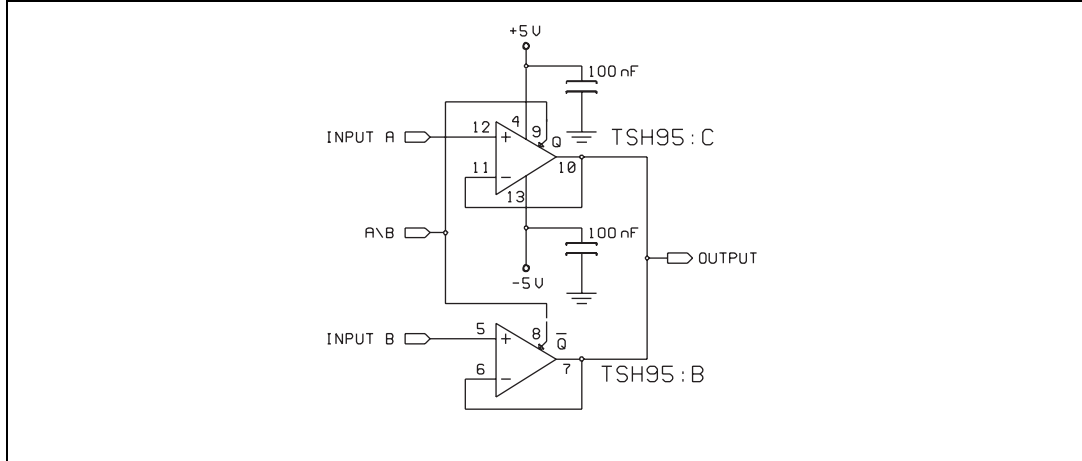


To put the device in standby, a logic level must be applied on the standby MOS input. Since ground is a virtual level for the device, the threshold voltage has been referred to  $V_{CC+}$  at  $V_{CC+} - 1.6\text{ V}$  typical.

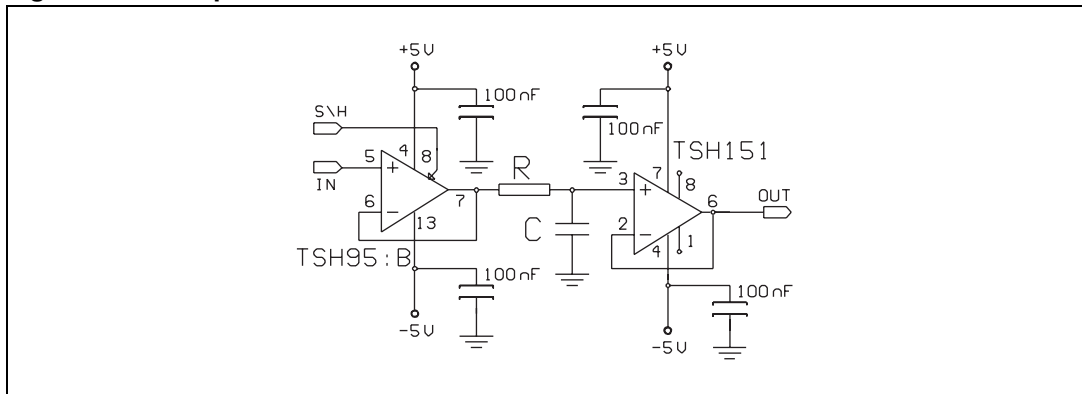
In standby mode, the output goes into high impedance in 200 ns. Note that all maximum ratings must still be followed in this mode. This mode leads to a swing limitation while using the device in a signal multiplexing configuration with followers; the differential input voltage must not exceed  $\pm 5\text{ V}$ , limiting the input swing to 2.5 Vpp.

## 4 Application information

**Figure 3. Signal multiplexing**



**Figure 4. Sample and hold**



### 4.1 Printed circuit layout recommendations

As with any high frequency device, a few rules must be observed when designing the PCB so as to maximize performance.

From the most to the least important points

- Each power supply lead must be bypassed to ground with a 10 nF ceramic capacitor and a 10  $\mu$ F capacitor placed very close to the device.
- To provide low inductance and low resistance common return, use a ground plane or common point return for power and signal.
- All leads must be wide and as short as possible, especially for the inputs, in order to decrease parasitic capacitance and inductance.
- Use small resistor values to decrease the time constant with parasitic capacitance.
- Choose the smallest possible component sizes (SMD).
- Decrease the capacitor load at the output to avoid degrading the circuit's stability and cause oscillation. You can also add a serial resistor to minimize its influence.

Figure 5. Large signal follower response

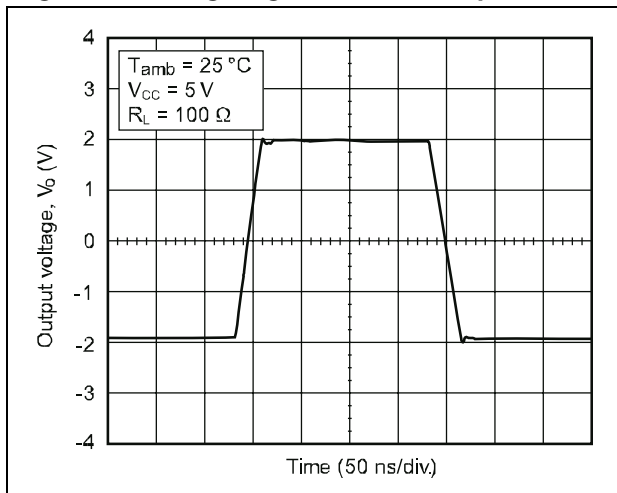


Figure 6. Static open loop voltage gain

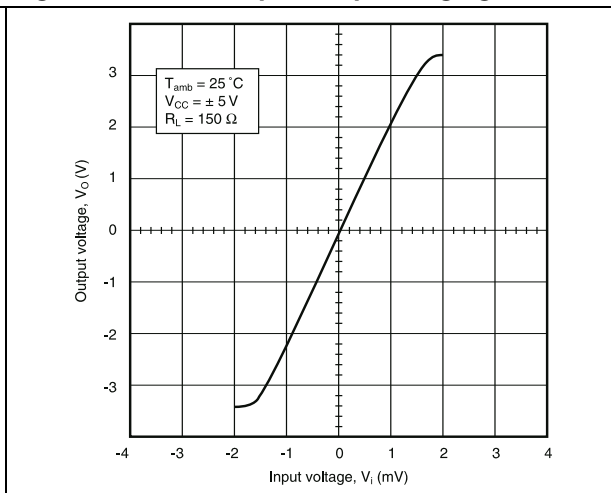


Figure 7. Input offset voltage drift vs. temperature

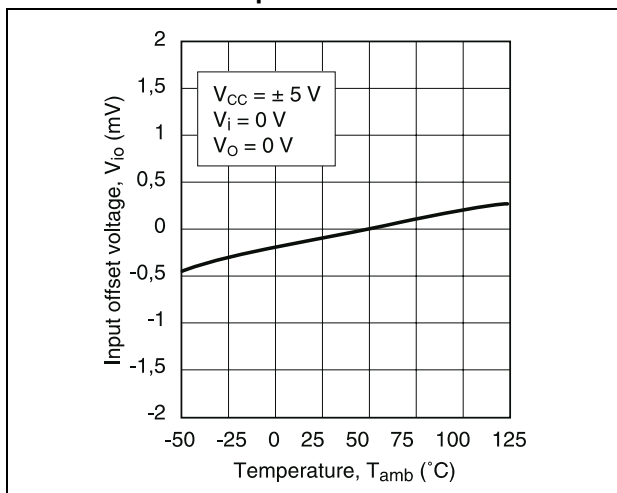


Figure 8. Small signal follower response

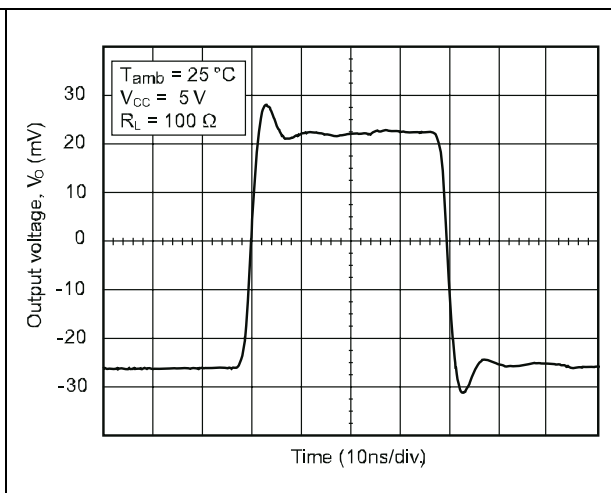


Figure 9. Closed loop frequency response and phase shift

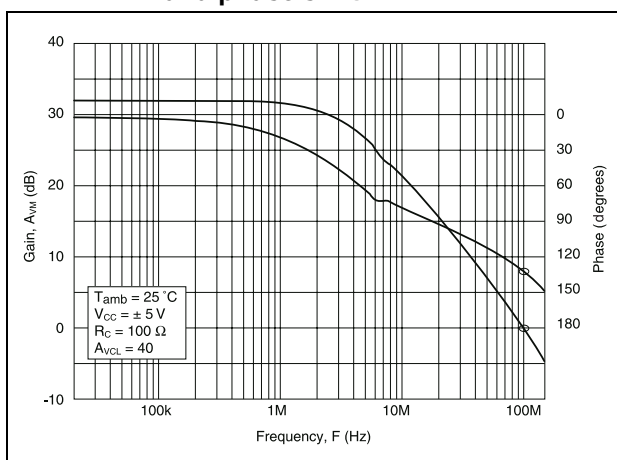
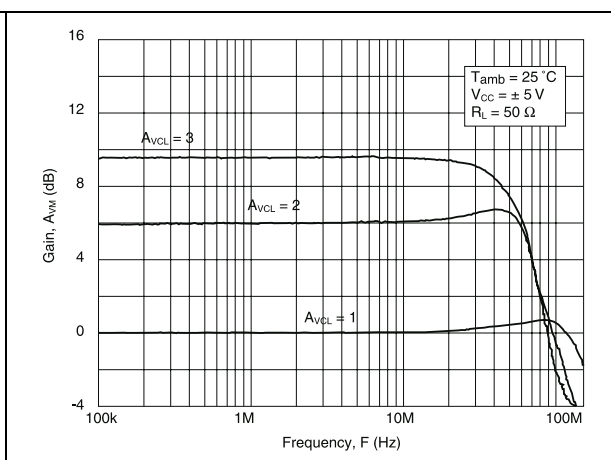
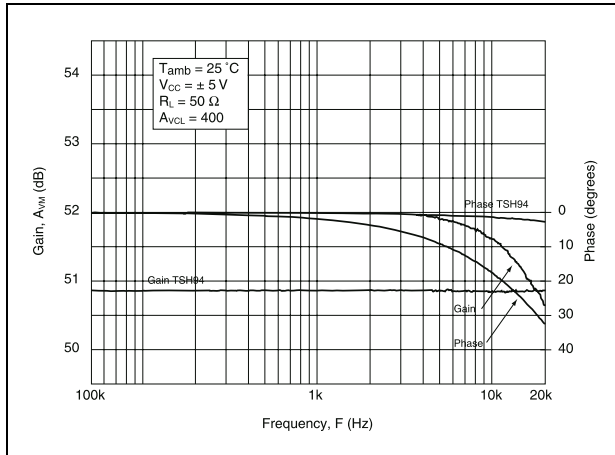


Figure 10. Closed loop frequency response

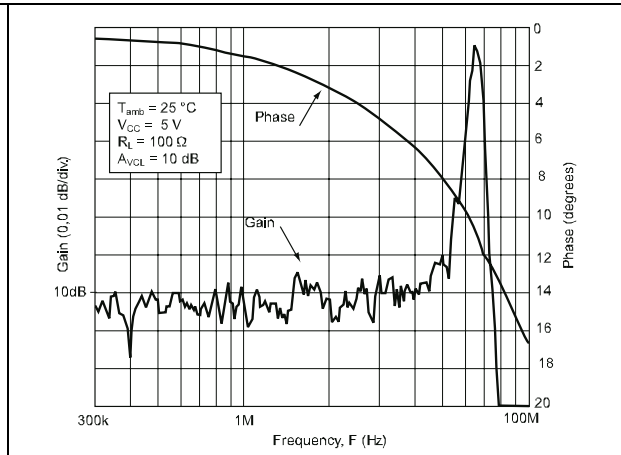




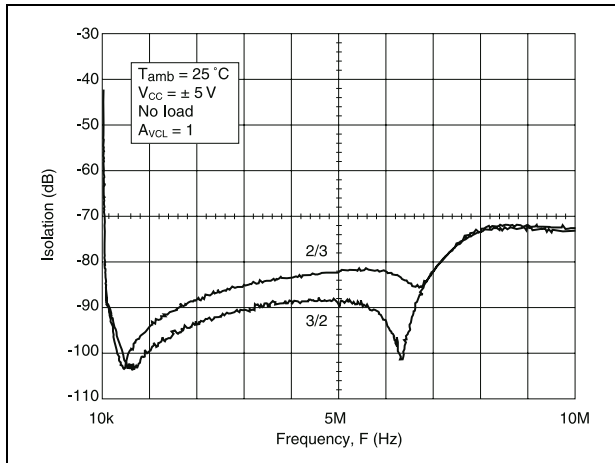
**Figure 11. Audio bandwidth frequency response and phase shift (TSH95 vs. standard 15 MHz audio op amp)**



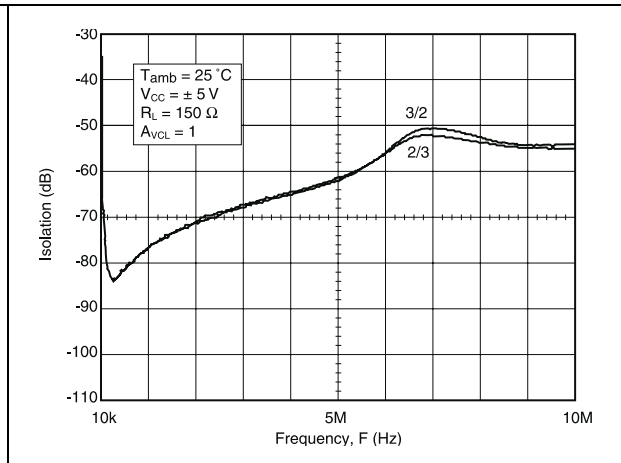
**Figure 12. Gain flatness and phase shift vs. frequency**



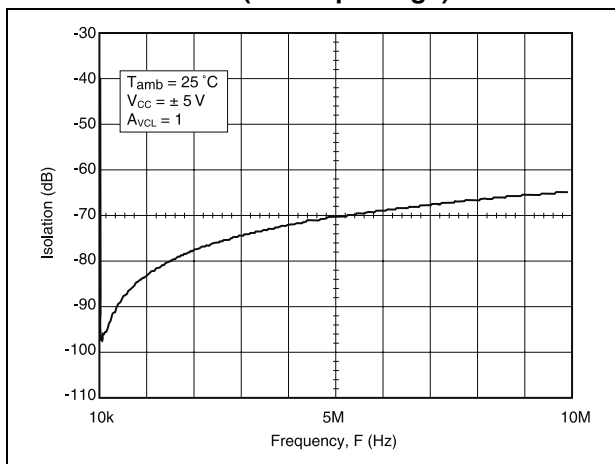
**Figure 13. Crosstalk isolation vs. frequency (SO-16 package) (no load)**



**Figure 14. Crosstalk isolation vs. frequency (SO-16 package) ( $R_L = 150\ \Omega$ )**



**Figure 15. Input/output isolation in standby mode (SO-16 package)**



**Figure 16. Standby switching**

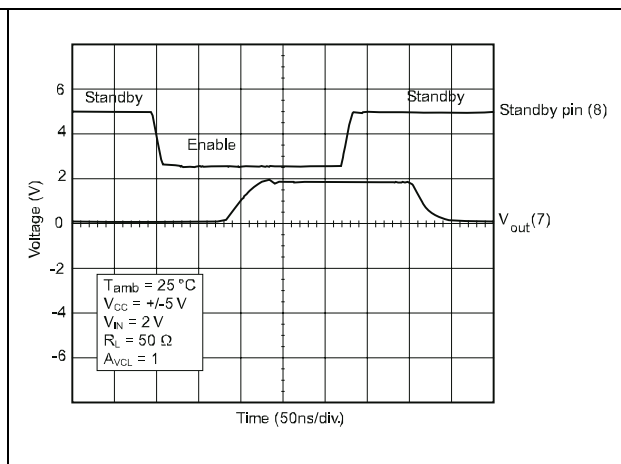


Figure 17. Signal multiplexing

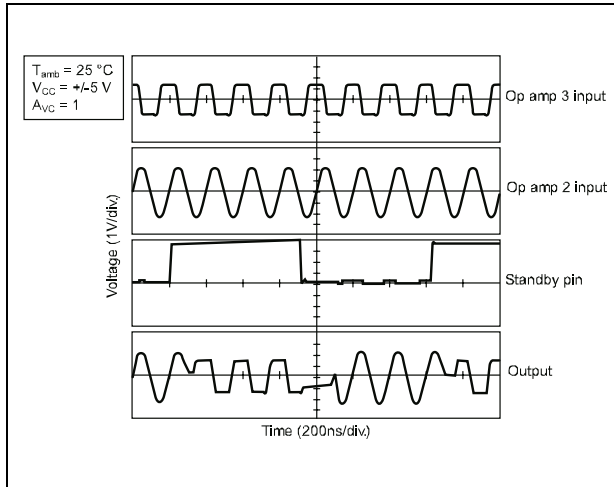


Figure 18. Differential input impedance vs. frequency

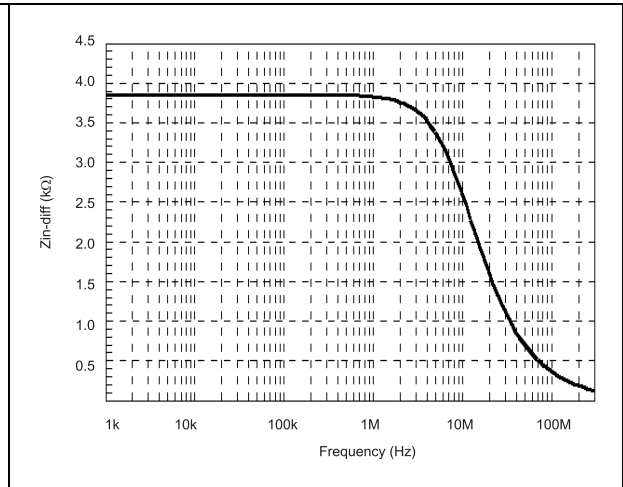
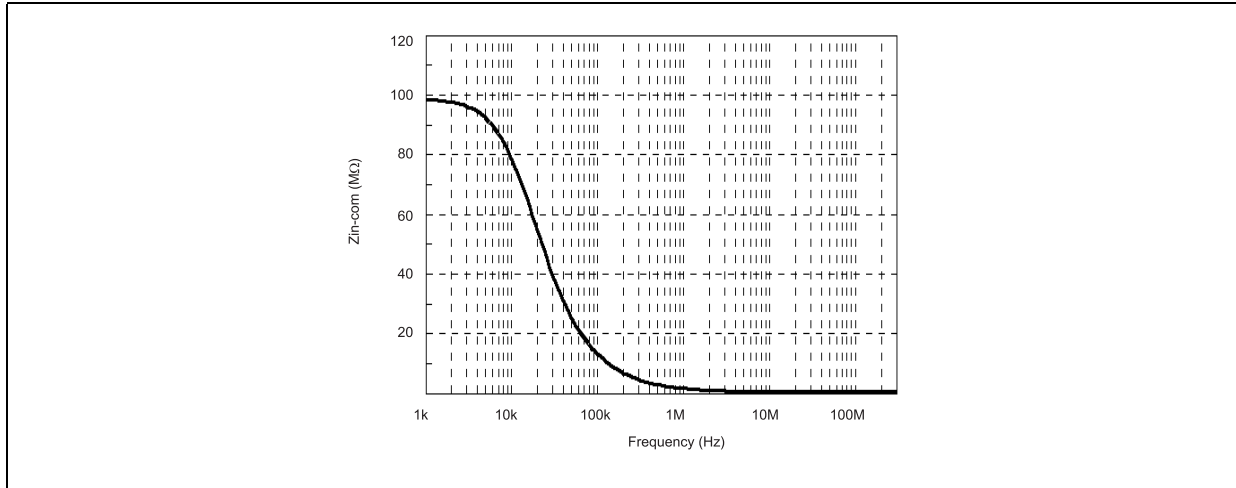


Figure 19. Common input impedance vs. frequency



## 5 Macromodel information

The information below applies to the TSH95I.

\*\* Standard Linear Ics Macromodels, 1996.

\*\* CONNECTIONS :

\* 1 INVERTING INPUT  
 \* 2 NON-INVERTING INPUT  
 \* 3 OUTPUT  
 \* 4 POSITIVE POWER SUPPLY  
 \* 5 NEGATIVE POWER SUPPLY  
 \* 6 STANDBY

.SUBCKT TSH95 1 3 2 4 5 6 (analog)

\*\*\*\*\*

\*\*\*\*\* switch \*\*\*\*\*

.SUBCKT SWITCH 20 10 IN OUT COM

.MODEL DIDEAL D N=0.1 IS=1E-08

DP IN 1 DIDEAL 400E-12

DN OUT 2 DIDEAL 400E-12

EP 1 OUT COM 10 2

EN 2 IN COM 10 2

RFUIT1 IN 1 1E+09

RFUIT2 OUT 2 1E+09

RCOM COM 0 1E+12

.ENDS SWITCH

\*\*\*\*\* inverter \*\*\*\*\*

.SUBCKT INV 20 10 IN OUT

.MODEL DIDEAL D N=0.1 IS=1E-08

RP1 20 15 1E+09

RN1 15 10 1E+09

RIN IN 10 1E+12

RIP IN 20 1E+12

DPINV OUT 20 DIDEAL 400E-12

DNINV 10 OUT DIDEAL 400E-12

GINV 0 OUT IN 15 -6.7E-7

CINV 0 OUT 210f

.ENDS INV

\*\*\*\*\* AOP \*\*\*\*\*

.MODEL MDTH D IS=1E-8 KF=1.809064E-15

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 2.600000E-01
RIN 15 16 2.600000E-01
RIS 11 15 3.645298E-01
DIP 11 12 MDTH 400E-12
DIN 15 14 MDTH 400E-12
VOFP 12 13 DC 0.000000E+00
VOFN 1314DC 0
FPOL 13 5 VSTB 1E+03
CPS 11 15 2.986990E-10
DINN 17 13 MDTH 400E-12
VIN 17 5 2.000000E+00
DINR 15 18 MDTH 400E-12
VIP 4 18 1.000000E+00
FCP 4 5 VOFP 3.500000E+00
FCN 5 4 VOFN 3.500000E+00
ISTB0 4 5 130UA
FIBP 2 5 VOFP 1.000000E-02
FIBN 5 1 VOFN 1.000000E-02
* AMPLIFYING STAGE
FIP 5 19 VOFP 2.530000E+02
FIN 5 19 VOFN 2.530000E+02
RG1 19 120 3.160721E+03
XCOM1 4 0 120 5 COM SWITCH
RG2 19 121 3.160721E+03
XCOM2 4 0 4 121 COM SWITCH
CC 19 5 2.000000E-09
DOPM 19 22 MDTH 400E-12
DONM 21 19 MDTH 400E-12
HOPM 22 28 VOUT 1.504000E+03
VIPM 28 4 5.000000E+01
HONM 21 27 VOUT 1.400000E+03
VINM 5 27 5.000000E+01
***** ZP *****
RZP1 5 80 1E+06
RZP2 4 80 1E+06
GZP 5 82 19 80 2.5E-05
RZP2H 83 4 10000
RZP1H 83 82 80000
RZP2B 84 5 10000
RZP1B 82 84 80000
LZPH 4 83 3.535E-02
LZPB 84 5 3.535E-02
*****
EOUT26 2382 51
VOUT 23 5 0
    
```

```

ROUT 26 103 35
COUT 103 5 30.000000E-12
XCOM 4 0 103 3 COM SWITCH
DOP 19 25 MDTH 400E-12
VOP 4 25 2.361965E+00
DON 24 19 MDTH 400E-12
VON 24 5 2.361965E+00
***** STAND BY *****
RMI1 4 111 1E+7
RMI2 0 111 2E+7
RONOFF 6 60 1K
CONOGG 60 0 10p
RSTBIN 60 0 1E+12
ESTBIN 106 0 6 0 1
ESTBREF 106 107 111 0 1
DSTB1 107 108 MDTH 400E-12
VSTB 108 109 0
ISTB 109 0 1U
RSTB 109 110 1
DSTB2 0 110 MDTH 400E-12
XINV 4 0 6 COM INV
.ENDS

```

**Table 6. Electrical characteristics with  $V_{CC} = \pm 5\text{ V}$ ,  $T_{amb} = 25\text{ }^{\circ}\text{C}$  (unless otherwise specified)**

Symbol	Conditions	Value	Unit
$V_{io}$		0	mV
$A_{vd}$	$R_L = 600\ \Omega$	3.2	V/mV
$I_{CC}$	No load/amplifier	5.2	mA
$V_{icm}$		-3 to 4	V
$V_{OH}$	$R_L = 600\ \Omega$	+3.6	V
$V_{OL}$	$R_L = 600\ \Omega$	-3.6	V
$I_{sink}$	$V_o = 0\text{ V}$	40	mA
$I_{source}$	$V_o = 0\text{ V}$	40	mA
GBP	$R_L = 600\ \Omega$ , $C_L = 15\text{ pF}$	147	MHz
SR	$R_L = 600\ \Omega$ , $C_L = 15\text{ pF}$	110	V/ $\mu\text{s}$
$\phi_m$	$R_L = 600\ \Omega$ , $C_L = 15\text{ pF}$	42	Degrees

## 6 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](http://www.st.com). ECOPACK is an ST trademark.

## 6.1 SO-16 package information

Figure 20. SO-16 package outline

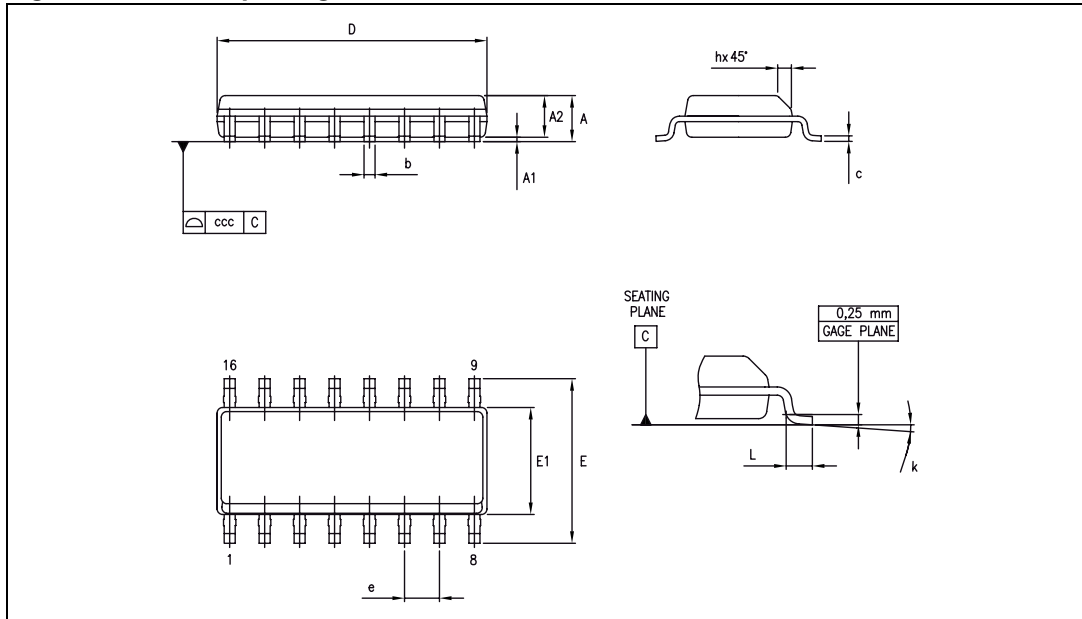


Table 7. SO-16 package mechanical data

Dimensions						
Symbol	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	0.31		0.51	0.012		0.020
c	0.17		0.25	0.007		0.010
D <sup>(1)</sup>	9.80	9.90	10.00	0.386	0.390	0.394
E	5.80	6.00	6.20	0.228	0.236	0.244
E1 <sup>(2)</sup>	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
k	0		8			
ccc			0.10			0.004

1. Does not include mold flash, protrusions or gate burrs. Mold flash, protrusions or gate burrs not to exceed 0.15 mm in total.
2. Does not include interlead flash or protrusions. Interlead flash or protrusions not to exceed 0.25 mm per side.

## 7 Ordering information

**Table 8. Order codes**

Part number	Temperature range	Package	Packing	Marking
TSH95ID	-40 °C to +125 °C	SO-16	Tube or tape and reel	TSH95I
TSH95IDT		SO-16		TSH95IY
TSH95IYDT <sup>(1)</sup>		(automotive grade)		

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



## 8 Revision history

**Table 9. Document revision history**

Date	Revision	Changes
01-Nov-2000	1	Initial release.
27-Aug-2009	2	Document format updated. Updated SO-16 package information in <a href="#">Chapter 6</a> . Added automotive grade order codes in <a href="#">Table 8</a> .
05-Nov-2012	3	Added conditions to title of <a href="#">Figure 13</a> and <a href="#">Figure 14</a> . Removed TSH95IYD order code, updated (qualified) status of TSH95IYDT order code in <a href="#">Table 8</a> . Minor corrections throughout document.

**Please Read Carefully:**

Information in this document is provided solely in connection with ST products. STMicroelectronics NV and its subsidiaries ("ST") reserve the right to make changes, corrections, modifications or improvements, to this document, and the products and services described herein at any time, without notice.

All ST products are sold pursuant to ST's terms and conditions of sale.

Purchasers are solely responsible for the choice, selection and use of the ST products and services described herein, and ST assumes no liability whatsoever relating to the choice, selection or use of the ST products and services described herein.

No license, express or implied, by estoppel or otherwise, to any intellectual property rights is granted under this document. If any part of this document refers to any third party products or services it shall not be deemed a license grant by ST for the use of such third party products or services, or any intellectual property contained therein or considered as a warranty covering the use in any manner whatsoever of such third party products or services or any intellectual property contained therein.

**UNLESS OTHERWISE SET FORTH IN ST'S TERMS AND CONDITIONS OF SALE ST DISCLAIMS ANY EXPRESS OR IMPLIED WARRANTY WITH RESPECT TO THE USE AND/OR SALE OF ST PRODUCTS INCLUDING WITHOUT LIMITATION IMPLIED WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE (AND THEIR EQUIVALENTS UNDER THE LAWS OF ANY JURISDICTION), OR INFRINGEMENT OF ANY PATENT, COPYRIGHT OR OTHER INTELLECTUAL PROPERTY RIGHT.**

**UNLESS EXPRESSLY APPROVED IN WRITING BY TWO AUTHORIZED ST REPRESENTATIVES, ST PRODUCTS ARE NOT RECOMMENDED, AUTHORIZED OR WARRANTED FOR USE IN MILITARY, AIR CRAFT, SPACE, LIFE SAVING, OR LIFE SUSTAINING APPLICATIONS, NOR IN PRODUCTS OR SYSTEMS WHERE FAILURE OR MALFUNCTION MAY RESULT IN PERSONAL INJURY, DEATH, OR SEVERE PROPERTY OR ENVIRONMENTAL DAMAGE. ST PRODUCTS WHICH ARE NOT SPECIFIED AS "AUTOMOTIVE GRADE" MAY ONLY BE USED IN AUTOMOTIVE APPLICATIONS AT USER'S OWN RISK.**

Resale of ST products with provisions different from the statements and/or technical features set forth in this document shall immediately void any warranty granted by ST for the ST product or service described herein and shall not create or extend in any manner whatsoever, any liability of ST.

ST and the ST logo are trademarks or registered trademarks of ST in various countries.

Information in this document supersedes and replaces all information previously supplied.

The ST logo is a registered trademark of STMicroelectronics. All other names are the property of their respective owners.

© 2012 STMicroelectronics - All rights reserved

STMicroelectronics group of companies

Australia - Belgium - Brazil - Canada - China - Czech Republic - Finland - France - Germany - Hong Kong - India - Israel - Italy - Japan - Malaysia - Malta - Morocco - Philippines - Singapore - Spain - Sweden - Switzerland - United Kingdom - United States of America

[www.st.com](http://www.st.com)