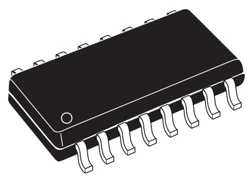
TSH94

High speed low power quad operational amplifier with standby position

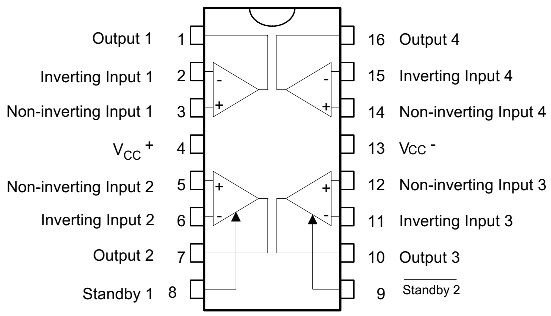
Features

- Two separate standby functions: low consumption and high impedance outputs
- Low supply current: 4.5mA
- High speed: 150MHz - 110V/µs
- Unity gain stability
- Low offset voltage: 3mV
- Low noise 4.2 nV/√Hz
- Low cost
- Specified for 600Ω and 150Ω loads
- High video performance:
  - Differential gain: 0.03%
  - Differential phase: 0.07°
  - Gain flatness: 6MHz, 0.1dB max @ 10dB gain
- High audio performance



D
SO-16
(Plastic micropackage)

Pin connections
(top view)



Description

The TSH94 is a quad low power high frequency op-amp, designed for high quality video signal processing. The device offers an excellent speed consumption ratio with 4.5mA per amplifier for 150MHz bandwidth.

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

The TSH94 offers 2 separate complementary STANDBY functions:

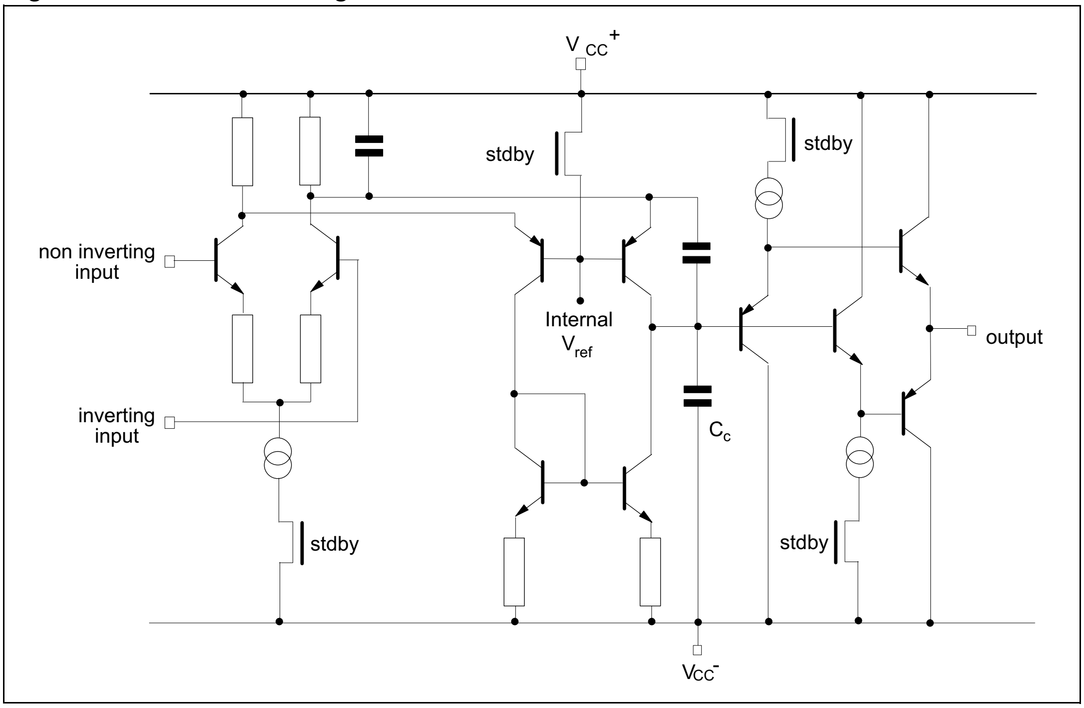
- STANDBY 1 acting on the n° 2 operator
- STANDBY 2 acting on the n° 3 operator

These functions reduce the consumption of the corresponding operator and put the output in a high impedance state.

www.st.com

1 Schematic diagram

Figure 1. Schematic diagram



2 Absolute maximum ratings and operating conditions

Table 1. Absolute maximum ratings (AMR)

Symbol	Parameter	Value	Unit
V_{CC}	Supply voltage (1)	14	V
V_{id}	Differential input voltage (2)	±5	V
V_i	Input voltage (3)	-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(4) HBM: human body model(5) MM: machine model(6)	1.5 2 200	kV kV V

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
3. The magnitude of input and output voltages must never exceed V_{CC}^+ +0.3V
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 100pF capacitor is charged to the specified voltage, then discharged through a 1.5kΩ 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 200pF capacitor is charged to the specified voltage, then discharged directly between two pins of the device with no external series resistor (internal resistor < 5Ω). 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_{icm}	Common mode input voltage range	V_{CC}^- +2 to V_{CC}^+ -1	V

3 Electrical characteristics

Table 3. V_{CC}^+ = 5V, V_{CC}^- = -5V, pin 8 connected to 0V, pin 9 connected to V_{CC}^+, T_{amb} = 25°C (unless otherwise specified)

Symbol	Parameter	Min.	Typ.	Max.	Unit
V_{io}	Input offset voltage V_{ic} = V_o = 0V $T_{min} \leq T_{amb} \leq T_{max}$			3 5	mV
I_{io}	Input offset current $T_{min} \leq T_{amb} \leq T_{max}$		1	2 5	µA
I_{ib}	Input bias current $T_{min} \leq T_{amb} \leq T_{max}$		5	15 20	µA
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} = -3V to +4V, V_o = 0V $T_{min} \leq T_{amb} \leq T_{max}$	80 70	100		dB
SVR	Supply voltage rejection ratio V_{CC} = ±5V to ±3V $T_{min} \leq T_{amb} \leq T_{max}$	60 50	75		dB
A_{vd}	Large signal voltage gain R_L = 10kΩ, Vo = ±2.5V $T_{min} \leq T_{amb} \leq T_{max}$	57 54	70		dB
V_{OH}	High level output voltage V_{id} = 1V R_L = 600Ω R_L = 150Ω $T_{min} \leq T_{amb} \leq T_{max}$. R_L = 150Ω	3 2.5 2.4	3.5 3		V
V_{OL}	Low level output voltage V_{id} = 11V R_L = 600Ω R_L = 150Ω $T_{min} \leq T_{amb} \leq T_{max}$. R_L = 150Ω		-3.5 -2.8	-3 -2.5 -2.4	V
I_o	Output short-circuit current V_{id} = ±1V 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 = 600Ω, C_L = 15pF, f = 7.5MHz	90	150		MHz
f_T	Transition frequency		90		MHz
SR	Slew rate V_{in} = -2 to +2V, A_{VCL} = +1, R_L = 600Ω, C_L = 15pF	70	110		V/µs
e_n	Equivalent input voltage noise R_s = 50Ω, f = 1kHz		4.2		nV/√Hz
φm	Phase margin A_{VM} = +1		35		Degrees
V_{O1}/V_{O2}	Channel separation f = 1MHz to 10MHz		65		dB
G_f	Gain flatness f = DC to 6MHz, A_{VCL} = 10dB			0.1	dB
THD	Total harmonic distortion f = 1kHz, V_o = ±2.5V, R_L = 600Ω		0.01		%

Table 3. V_{CC}^+ = 5V, V_{CC}^- = -5V, pin 8 connected to 0V, pin 9 connected to V_{CC}^+, T_{amb} = 25°C (unless otherwise specified) (continued)

Symbol	Parameter	Min.	Typ.	Max.	Unit
ΔG	Differential gain f = 3.58MHz, A_{VCL} = +2, R_L = 150Ω		0.03		%
Δφ	Differential phase f = 3.58MHz, A_{VCL} = +2, R_L = 150Ω		0.07		Degree

Standby mode

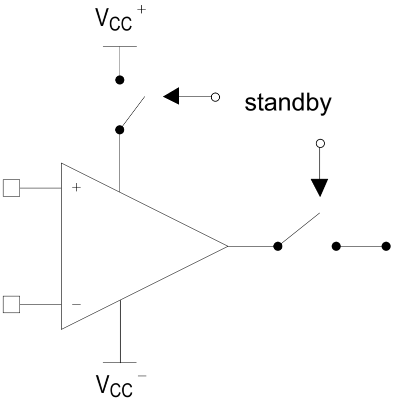
Table 4. V_{CC}^+ = 5V, V_{CC}^- = -5V, T_{amb} = 25°C (unless otherwise specified)

Symbol	Parameter	Min.	Typ.	Max.	Unit
V_{STBY}	Pin 8/9 threshold voltage for STANDBY mode	V_{CC}^+ -2.2	V_{CC}^+ -1.6	V_{CC}^+ -1.0	V
$I_{CC-STBY}$	Total consumption Standby 1 & 2 = 0 Standby 1 & 2 = 1 Standby 1 = 1, Standby 2 = 0		 13.7 13.7 9.4		mA
I_{sol}	Input/output isolation (f = 1MHz to 10MHz)		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-amp 2**	**Op-amp 3**	**Op-amps 1 & 4**
0	0	Enable	Standby	Enable
0	1	Enable	Enable	Enable
1	0	Standby	Standby	Enable
1	1	Standby	Enable	Enable

Figure 2. Standby position



To put the device in standby, just apply a logic level on the standby MOS input. Because ground is a virtual level for the device, the threshold voltage is to V_{CC}^+ (V_{CC}^+- 1.6V typ, see *Table 4*).

Figure 3. Closed loop frequency response

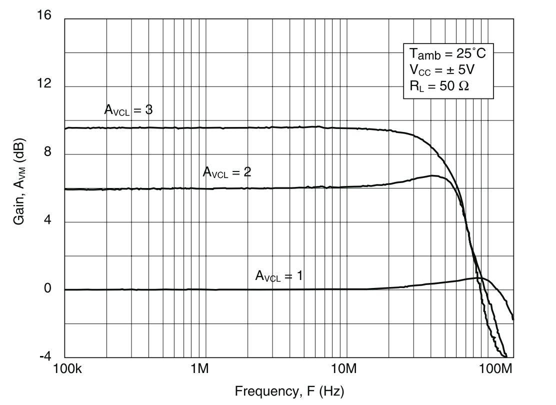


Figure 4. Gain flatness and phase shift versus frequency

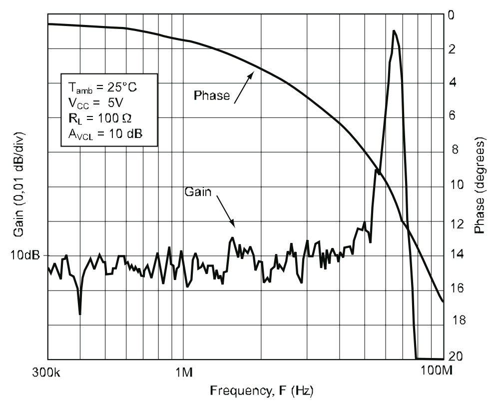


Figure 5. Open loop frequency response and phase shift

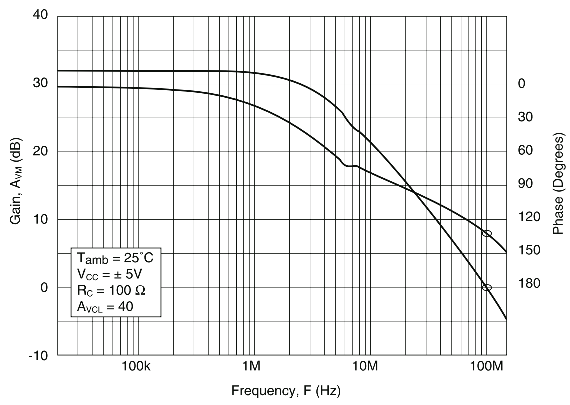


Figure 6. Static open loop voltage gain

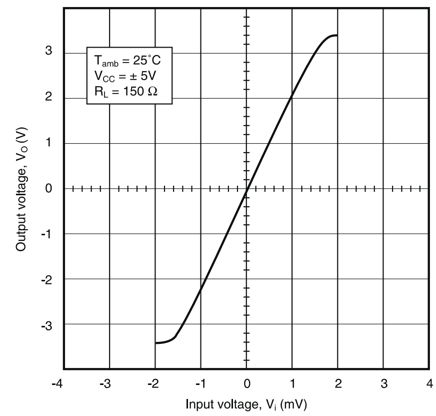


Figure 7. Audio bandwidth frequency response and phase shift (TSH94 vs standard 15MHz audio op-amp)

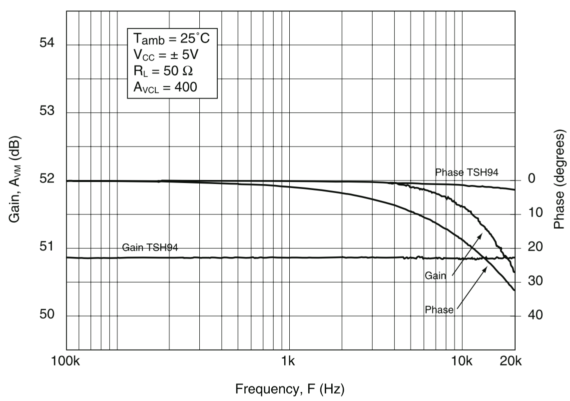


Figure 8. Large signal follower response

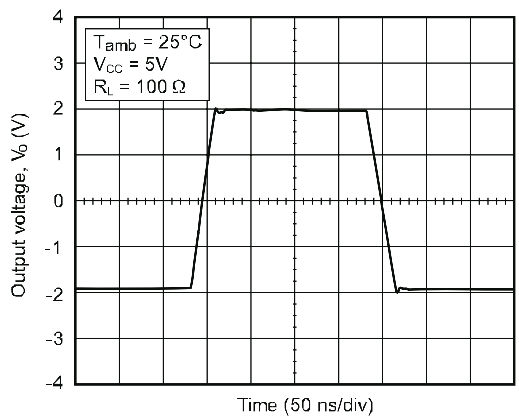


Figure 9. Small signal follower response

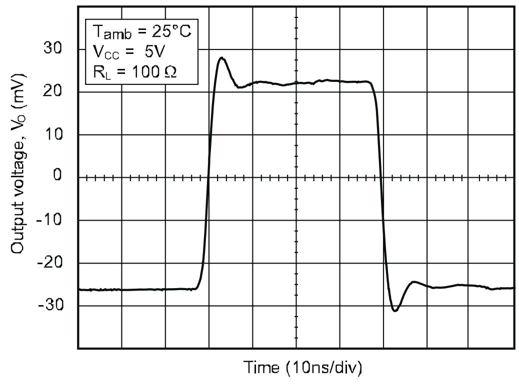


Figure 10. Crosstalk isolation versus frequency (SO-16 package)

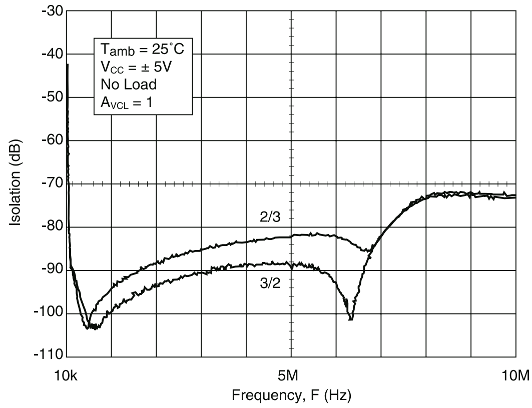


Figure 11. Crosstalk isolation versus frequency (SO-16 package)

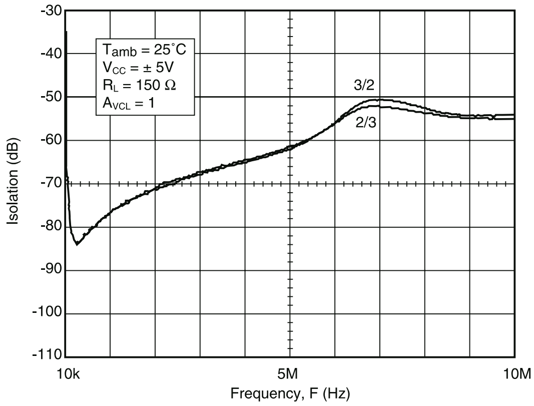


Figure 12. Input/output isolation in standby mode (SO-16 package)

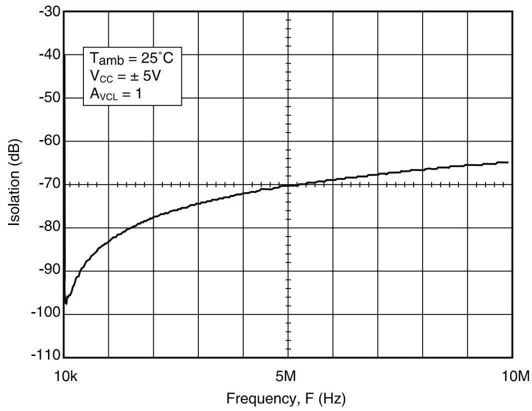


Figure 13. Standby switching

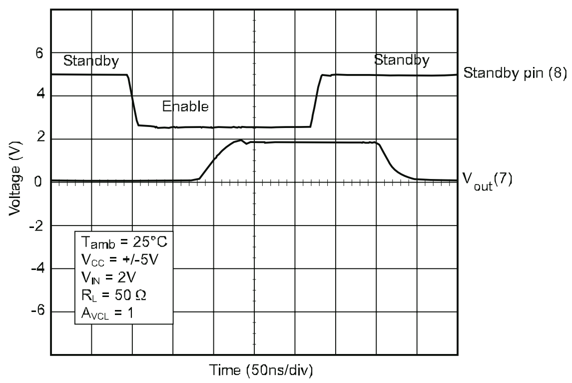


Figure 14. Signal multiplexing (see *Figure 18*)

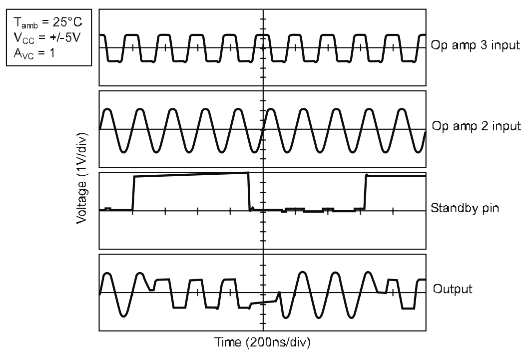


Figure 15. Common input impedance versus frequency

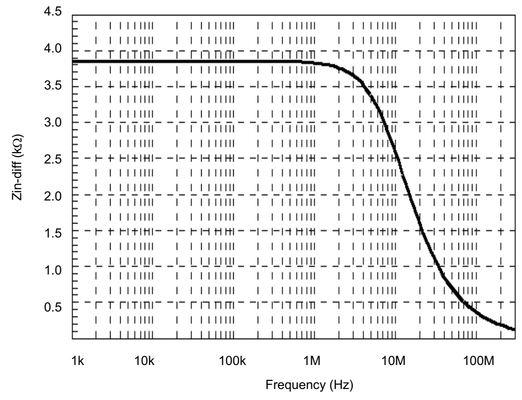


Figure 16. Differential input impedance versus frequency

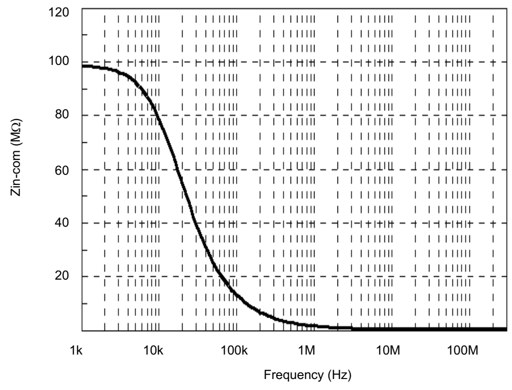
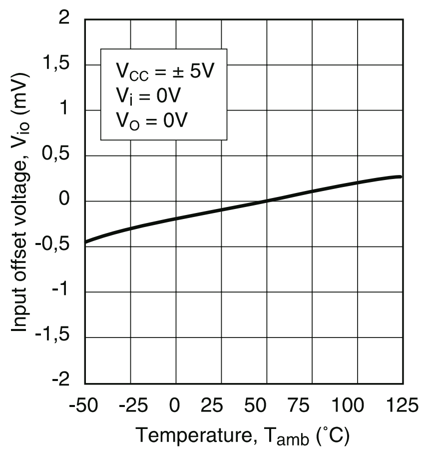


Figure 17. Input offset voltage drift versus temperature



4 Application information

Figure 18. Signal multiplexing

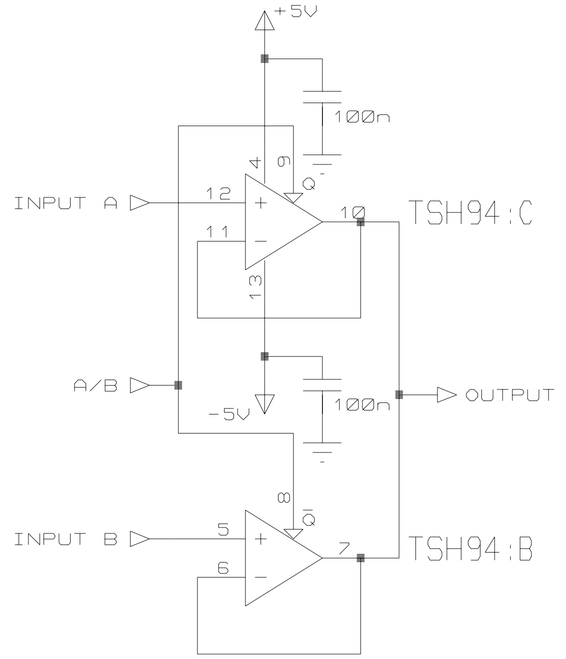


Figure 19. Sample and hold

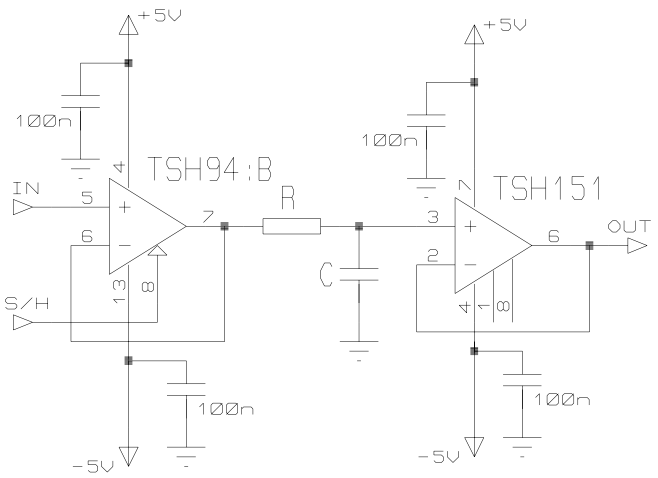
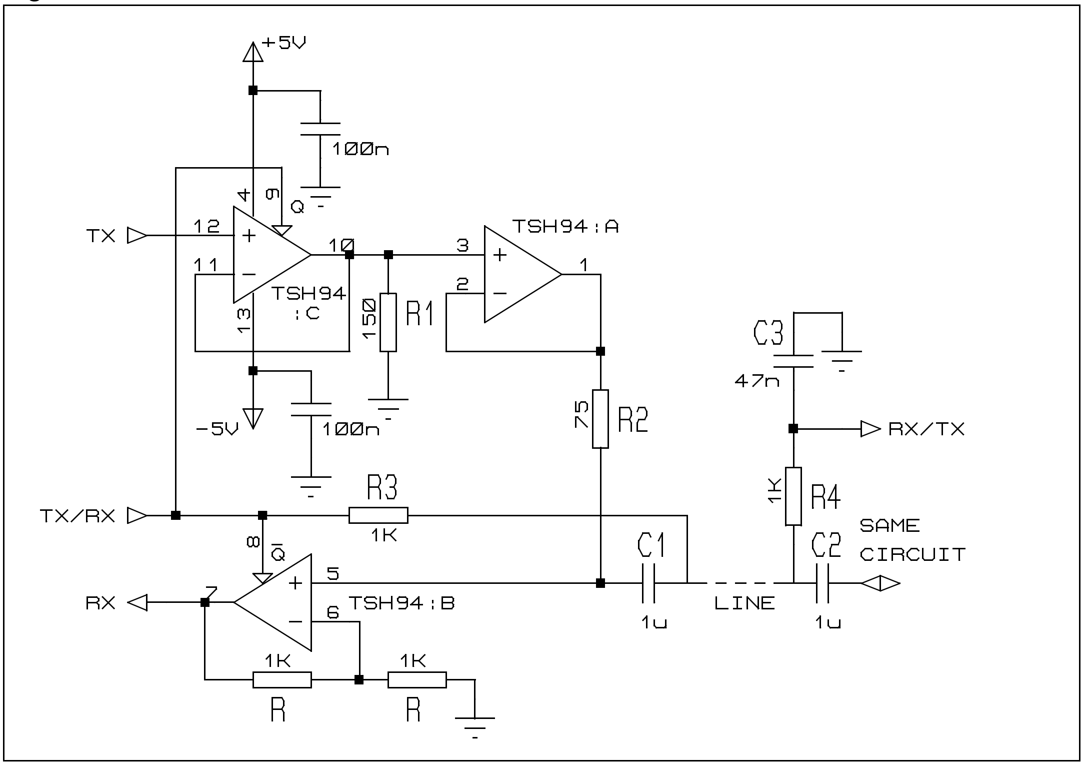


Figure 20. Video line transceiver with remote control



Printed circuit layout recommendations

As for any high frequency device, a few rules must be observed when designing the PCB to get the best performance from this high-speed op-amp.

Some recommendations are listed below, from the most important to the least important:

- By-pass each power supply lead to ground with a 10µF capacitor and a 10nF ceramic capacitor 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.
- Make sure all leads are wide and as short as possible, especially for op-amp inputs. This is to decrease parasitic capacitance and inductance.
- Use small resistor values to decrease the time constant with parasitic capacitance.
- Choose component sizes as small as possible (SMD).
- On the output, keep the capacitor load as low as possible to avoid oscillation which would degrade the circuit stability. You can also add a serial resistor in order to minimise the effect of the capacitor load.

5 Macromodel information

5.1 TSH94I without standby

The macromodel information provided in this section applies to TSH94I (model without standby).

```
** Standard Linear Ics Macromodels, 1996.
** CONNECTIONS :
* 1 INVERTING INPUT
* 2 NON-INVERTING INPUT
* 3 OUTPUT
* 4 POSITIVE POWER SUPPLY
* 5 NEGATIVE POWER SUPPLY
.SUBCKT TSH94 1 3 2 4 5 (analog)
*******************************************************
.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
IPOL 13 5 1.000000E-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
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 5 3.160721E+03
RG2 19 4 3.160721E+03
CC 19 5 2.00000E-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
*********************
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
EOUT 26 23 82 5 1
VOUT 23 5 0
ROUT 26 3 35
COUT 3 5 30.000000E-12
DOP 19 25 MDTH 400E-12
VOP 4 25 2.361965E+00
DON 24 19 MDTH 400E-12
VON 24 5 2.361965E+00
.ENDS
```

Table 6. Electrical characteristics with V_{CC} = ±5V, T_{amb} = 25°C (unless otherwise specified)

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

5.2 TSH94I with standby

The macromodel information provided in this section applies to TSH94I (model with standby).

```
* 1 INVERTING INPUT
* 2 NON-INVERTING INPUT
* 3 OUTPUT
* 4 POSITIVE POWER SUPPLY
* 5 NEGATIVE POWER SUPPLY
```

```
* 6 STANDBY
.SUBCKT TSH94 1 3 2 4 5 6 (analog)
*******************************************************
**************** switch ******************
.SUBCKT SWITCH20 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 2.00000E-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
**************************
EOUT 26 23 82 5 1
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
```

6 Package information

In order to meet environmental requirements, STMicroelectronics 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 STMicroelectronics trademark. ECOPACK specifications are available at: www.st.com.

Figure 21. SO-16 package mechanical drawing (16-pin plastic micropackage)

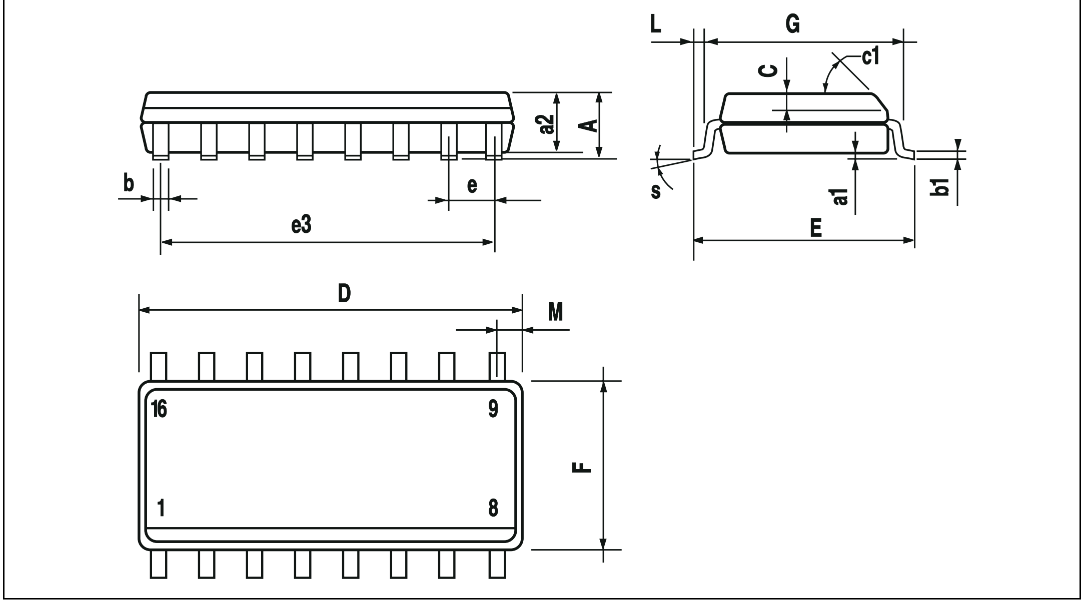


Table 7. SO-16 package mechanical data

Dim.	Millimeters			Inches		
	Min.	Typ.	Max.	Min.	Typ.	Max.
A			1.75			0.069
a1			0.25			0.01
a2	1.25			0.049		
b	0.31		0.51	0.012		0.02
b1	0.17		0.25	0.007		0.010
C		0.5			0.020	
c1	45° (typ.)					
D	9.8		10	0.386		0.394
E	5.8		6.2	0.228		0.244
e		1.27			0.050	
e3		8.89			0.350	
F	3.8		4.0	0.150		0.157
G	4.6		5.3	0.181		0.209
L	0.4		1.27	0.016		0.050
M			0.62			0.024
S	8° (max.)					

7 Ordering information

Table 8. Order codes

Part number	Temperature range	Package	Packing	Marking
TSH94ID TSH94IDT	-40°C to +125°C	SO-16	Tube or Tape & reel	TSH94I
TSH94IYD TSH94IYDT(1)		SO-16 (Automotive grade)	Tube or Tape & reel	TSH94Y

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.

8 Revision history

Table 9. Document revision history

Date	Revision	Changes
5-Oct-2000	1	Initial release.
6-Jun-2007	2	*Table 8: Order codes* updated and moved to *Section 7: Ordering information*. Automotive grade order codes added. Format update.
27-Nov-2007	3	Corrected unit in feature list on cover page from 110V/ms to 110V/µs. Added ESD parameters in *Table 1: Absolute maximum ratings (AMR)*. Updated footnote in *Table 8: Order codes*.