



**TS904**

## RAIL TO RAIL CMOS QUAD OPERATIONAL AMPLIFIER (WITH STANDBY POSITION)

- **RAIL TO RAIL** INPUT AND OUTPUT VOLTAGE RANGES
- 2 SEPARATE **STANDBY** : REDUCED **CONSUMPTION (0.5µA)** AND **HIGH IMPEDANCE OUTPUTS**
- SINGLE (OR DUAL) SUPPLY OPERATION FROM **2.7V TO 16V**
- EXTREMELY LOW INPUT BIAS CURRENT : **1pA TYP**
- LOW INPUT OFFSET VOLTAGE : 5mV max.
- SPECIFIED FOR **600Ω** AND **150Ω** LOADS
- LOW SUPPLY CURRENT : 200µA/Ampli
  
- **SPICE MACROMODEL** INCLUDED IN THIS SPECIFICATION

### DESCRIPTION

The TS904 is a RAIL TO RAIL quad CMOS operational amplifier designed to operate with a single or dual supply voltage.

The input voltage range  $V_{icm}$  includes the two supply rails  $V_{CC}^+$  and  $V_{CC}^-$ .

The output reaches :

- $V_{CC}^- + 50mV$   $V_{CC}^+ - 50mV$  with  $R_L = 10k\Omega$
- $V_{CC}^- + 350mV$   $V_{CC}^+ - 350mV$  with  $R_L = 600\Omega$

This product offers a broad supply voltage operating range from 2.7V to 16V and a supply current of only 200µA/amp. ( $V_{CC} = 3V$ )

Source and sink output current capability is typically 40mA (at  $V_{CC} = 3V$ ), fixed by an internal limitation circuit.

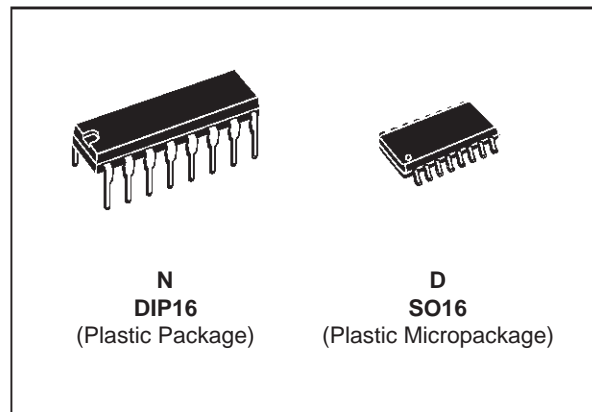
The TS904 offers two separate **STANDBY** pins

- STANDBY 1 acting on the n°2 and n°3 operators
- STANDBY 2 acting on the n°1 and n°4 operators

They reduce the consumption of the corresponding operators and put the outputs in a high impedance state.

These two STANDBY pins should never stay not connected.

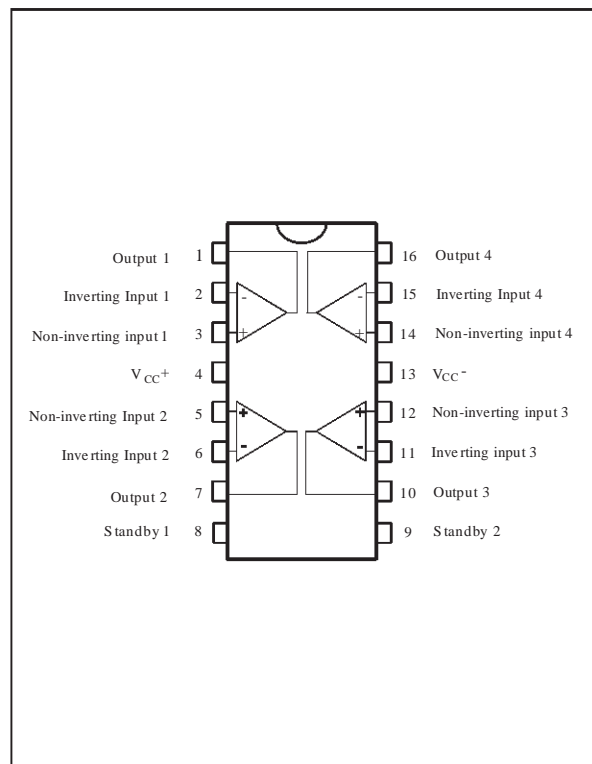
STMicroelectronics is offering a quad op-amp with the same features : TS902.



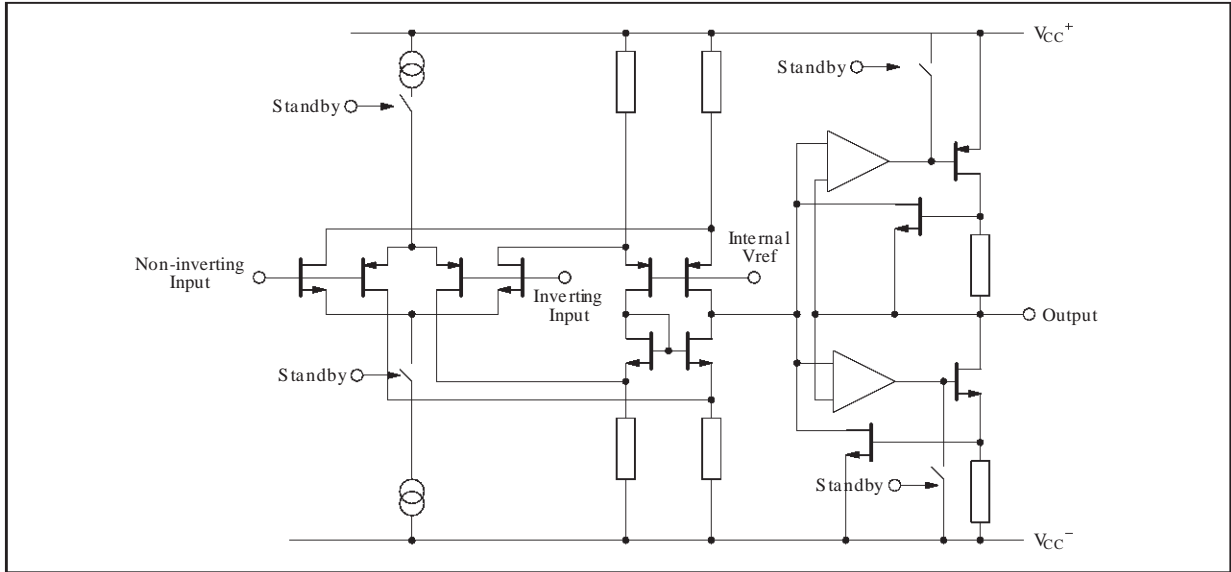
### ORDER CODES

Part Number	Temperature Range	Package	
		N	D
TS904I/AI	-40, +125°C	•	•

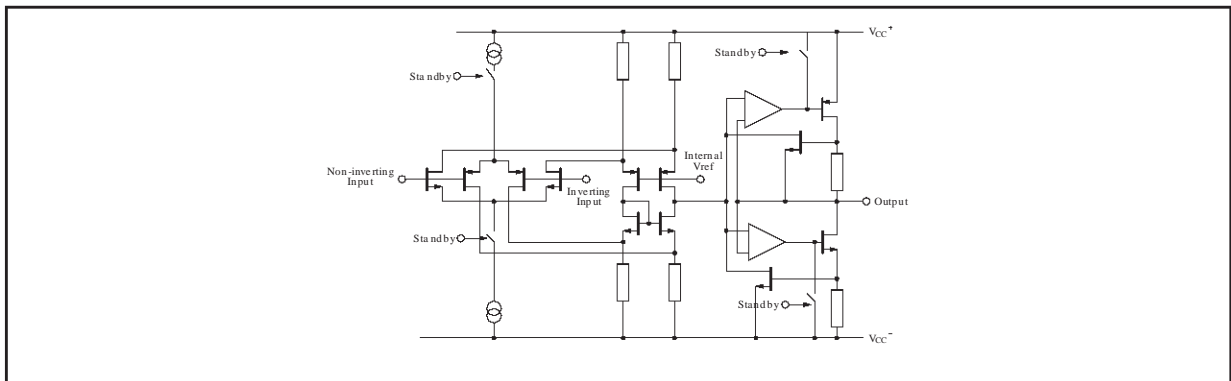
### PIN CONNECTIONS (top view)



**SCHEMATIC DIAGRAM (1/4 TS904)**



**STANDBY POSITION**



**ABSOLUTE MAXIMUM RATINGS**

Symbol	Parameter	Value	Unit
$V_{CC}$	Supply Voltage - (note 1)	18	V
$V_{id}$	Differential Input Voltage - (note 2)	$\pm 18$	V
$V_i$	Input Voltage - (note 3)	-0.3 to 18	V
$I_{in}$	Current on Inputs	$\pm 50$	mA
$I_o$	Current on Outputs	$\pm 130$	mA
$T_{oper}$	Operating Free Air Temperature Range	TS904I/AI -40 to +125	$^{\circ}C$
$T_{stg}$	Storage Temperature	-65 to +150	$^{\circ}C$

- Notes :**
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  $V_{CC}^{+} + 0.3V$ .

**OPERATING CONDITIONS**

Symbol	Parameter	Value	Unit
$V_{CC}$	Supply Voltage	2.7 to 16	V
$V_{icm}$	Common Mode Input Voltage Range	$V_{CC}^{-} - 0.2$ to $V_{CC}^{+} + 0.2$	V

**ELECTRICAL CHARACTERISTICS**

$V_{CC}^+ = 3V$ ,  $V_{CC}^- = 0V$ ,  $R_L, C_L$  connected to  $V_{CC}/2$ , pin 8 and pin 9 connected to  $V_{CC}^+$ ,  $T_{amb} = 25^\circ C$   
(unless otherwise specified)

Symbol	Parameter	Min.	Typ.	Max.	Unit
$V_{io}$	Input Offset Voltage ( $V_{ic} = V_o = V_{CC}/2$ ) $T_{min.} \leq T_{amb} \leq T_{max.}$			10 5 12 7	mV
$DV_{io}$	Input Offset Voltage Drift		5		$\mu V/^\circ C$
$I_{io}$	Input Offset Current - (note 1) $T_{min.} \leq T_{amb} \leq T_{max.}$		1	100 200	pA
$I_{ib}$	Input Bias Current - (note 1) $T_{min.} \leq T_{amb} \leq T_{max.}$		1	150 300	pA
$I_{CC}$	Supply Current (per amplifier, $A_{VCL} = 1$ , no load) $T_{min.} \leq T_{amb} \leq T_{max.}$		200	300 400	$\mu A$
CMR	Common Mode Rejection Ratio $V_{ic} = 0$ to $3V$ , $V_o = 1.5V$	40	70		dB
SVR	Supply Voltage Rejection Ratio ( $V_{CC}^+ = 2.7$ to $3.3V$ , $V_o = V_{CC}/2$ )	40	70		dB
$A_{vd}$	Large Signal Voltage Gain ( $R_L = 10k\Omega$ , $V_o = 1.2V$ to $1.8V$ ) $T_{min.} \leq T_{amb} \leq T_{max.}$	3 2	10		V/mV
$V_{OH}$	High Level Output Voltage ( $V_{id} = 1V$ ) $T_{min.} \leq T_{amb} \leq T_{max.}$	$R_L = 10k\Omega$ 2.9 $R_L = 600\Omega$ 2.3 $R_L = 100\Omega$	2.96 2.6 2		V
$V_{OL}$	Low Level Output Voltage ( $V_{id} = -1V$ ) $T_{min.} \leq T_{amb} \leq T_{max.}$	$R_L = 10k\Omega$ $R_L = 600\Omega$ $R_L = 100\Omega$		50 300 900  150 600	mV
$I_o$	Output Short Circuit Current ( $V_{id} = \pm 1V$ ) Source ( $V_o = V_{CC}^-$ ) Sink ( $V_o = V_{CC}^+$ )		40 40		mA
GBP	Gain Bandwidth Product ( $A_{VCL} = 100$ , $R_L = 10k\Omega$ , $C_L = 100pF$ , $f = 100kHz$ )		0.8		MHz
$SR^+$	Positive Slew Rate ( $A_{VCL} = 1$ , $R_L = 10k\Omega$ , $C_L = 100pF$ , $V_i = 1.3V$ to $1.7V$ )		0.5		V/ $\mu s$
$SR^-$	Negative Slew Rate ( $A_{VCL} = 1$ , $R_L = 10k\Omega$ , $C_L = 100pF$ , $V_i = 1.3V$ to $1.7V$ )		0.4		V/ $\mu s$
$\phi_m$	Phase Margin		30		Degrees
$e_n$	Equivalent Input Noise Voltage ( $R_s = 100\Omega$ , $f = 1kHz$ )		30		$\frac{nV}{\sqrt{Hz}}$
$V_{O1}/V_{O2}$	Channel Separation ( $f = 1kHz$ )		120		dB

**Note 1** : Maximum values including unavoidable inaccuracies of the industrial test.

**ELECTRICAL CHARACTERISTICS**

$V_{CC}^+ = 5V$ ,  $V_{CC}^- = 0V$ ,  $R_L, C_L$  connected to  $V_{CC}/2$ , pin 8 and pin 9 connected to  $V_{CC}^+$ ,  $T_{amb} = 25^\circ C$   
(unless otherwise specified)

Symbol	Parameter	Min.	Typ.	Max.	Unit
$V_{io}$	Input Offset Voltage ( $V_{ic} = V_o = V_{CC}/2$ ) $T_{min.} \leq T_{amb} \leq T_{max.}$			10 5 12 7	mV
$DV_{io}$	Input Offset Voltage Drift		5		$\mu V/^\circ C$
$I_{io}$	Input Offset Current - (note 1) $T_{min.} \leq T_{amb} \leq T_{max.}$		1	100 200	pA
$I_{ib}$	Input Bias Current - (note 1) $T_{min.} \leq T_{amb} \leq T_{max.}$		1	150 300	pA
$I_{CC}$	Supply Current (per amplifier, $A_{VCL} = 1$ , no load) $T_{min.} \leq T_{amb} \leq T_{max.}$		230	350 450	$\mu A$
CMR	Common Mode Rejection Ratio $V_{ic} = 1.5$ to $3.5V$ , $V_o = 2.5V$	50	75		dB
SVR	Supply Voltage Rejection Ratio ( $V_{CC}^+ = 3$ to $5V$ , $V_o = V_{CC}/2$ )	50	80		dB
$A_{vd}$	Large Signal Voltage Gain ( $R_L = 10k\Omega$ , $V_o = 1.5V$ to $3.5V$ ) $T_{min.} \leq T_{amb} \leq T_{max.}$	10 7	30		V/mV
$V_{OH}$	High Level Output Voltage ( $V_{id} = 1V$ ) $T_{min.} \leq T_{amb} \leq T_{max.}$	$R_L = 10k\Omega$ 4.9 $R_L = 600\Omega$ 4.25 $R_L = 100\Omega$	4.95 4.65 3.7		V
$V_{OL}$	Low Level Output Voltage ( $V_{id} = -1V$ ) $T_{min.} \leq T_{amb} \leq T_{max.}$	$R_L = 10k\Omega$ $R_L = 600\Omega$ $R_L = 100\Omega$	50 350 1400	100 500	mV
$I_o$	Output Short Circuit Current ( $V_{id} = \pm 1V$ )	Source ( $V_o = V_{CC}^-$ ) 45 Sink ( $V_o = V_{CC}^+$ ) 45	60 60		mA
GBP	Gain Bandwidth Product ( $A_{VCL} = 100$ , $R_L = 10k\Omega$ , $C_L = 100pF$ , $f = 100kHz$ )		0.9		MHz
$SR^+$	Positive Slew Rate ( $A_{VCL} = 1$ , $R_L = 10k\Omega$ , $C_L = 100pF$ , $V_i = 1V$ to $4V$ )		0.8		V/ $\mu s$
$SR^-$	Negative Slew Rate ( $A_{VCL} = 1$ , $R_L = 10k\Omega$ , $C_L = 100pF$ , $V_i = 1V$ to $4V$ )		0.5		V/ $\mu s$
$\phi_m$	Phase Margin		30		Degrees

**Note 1** : Maximum values including unavoidable inaccuracies of the industrial test.

**ELECTRICAL CHARACTERISTICS**

$V_{CC}^+ = 10V$ ,  $V_{CC}^- = 0V$ ,  $R_L, C_L$  connected to  $V_{CC}/2$ , pin 8 and 9 connected to  $V_{CC}^+$ ,  $T_{amb} = 25^\circ C$   
(unless otherwise specified)

Symbol	Parameter	Min.	Typ.	Max.	Unit
$V_{io}$	Input Offset Voltage ( $V_{ic} = V_o = V_{CC}/2$ ) $T_{min.} \leq T_{amb} \leq T_{max.}$			10 5 12 7	mV
$DV_{io}$	Input Offset Voltage Drift		5		$\mu V/^\circ C$
$I_{io}$	Input Offset Current - (note 1) $T_{min.} \leq T_{amb} \leq T_{max.}$		1	100 200	pA
$I_{ib}$	Input Bias Current - (note 1) $T_{min.} \leq T_{amb} \leq T_{max.}$		1	150 300	pA
$I_{CC}$	Supply Current (per amplifier, $A_{VCL} = 1$ , no load) $T_{min.} \leq T_{amb} \leq T_{max.}$		400	600 700	$\mu A$
CMR	Common Mode Rejection Ratio $V_{ic} = 3$ to $7V$ , $V_o = 5V$ $V_{ic} = 0$ to $10V$ , $V_o = 5V$	50	75 70		dB
SVR	Supply Voltage Rejection Ratio ( $V_{CC}^+ = 5$ to $10V$ , $V_o = V_{CC}/2$ )	50	80		dB
$A_{vd}$	Large Signal Voltage Gain ( $R_L = 10k\Omega$ , $V_o = 2.5V$ to $7.5V$ ) $T_{min.} \leq T_{amb} \leq T_{max.}$	20 15	60		V/mV
$V_{OH}$	High Level Output Voltage ( $V_{id} = 1V$ ) $T_{min.} \leq T_{amb} \leq T_{max.}$	$R_L = 10k\Omega$ 9.85 $R_L = 600\Omega$ 9.2 $R_L = 100\Omega$ 9.8 $R_L = 10k\Omega$ 9 $R_L = 600\Omega$	9.95 9.35 7.8		V
$V_{OL}$	Low Level Output Voltage ( $V_{id} = -1V$ ) $T_{min.} \leq T_{amb} \leq T_{max.}$	$R_L = 10k\Omega$ $R_L = 600\Omega$ $R_L = 100\Omega$ $R_L = 10k\Omega$ $R_L = 600\Omega$	50 650 2300	150 800 150 900	mV
$I_o$	Output Short Circuit Current ( $V_{id} = \pm 1V$ ) Source ( $V_o = V_{CC}^-$ ) Sink ( $V_o = V_{CC}^+$ )	45 45	60 60		mA
GBP	Gain Bandwidth Product ( $A_{VCL} = 100$ , $R_L = 10k\Omega$ , $C_L = 100pF$ , $f = 100kHz$ )		1.3		MHz
$SR^+$	Positive Slew Rate ( $A_{VCL} = 1$ , $R_L = 10k\Omega$ , $C_L = 100pF$ , $V_i = 2.5V$ to $7.5V$ )		1.3		V/ $\mu s$
$SR^-$	Negative Slew Rate ( $A_{VCL} = 1$ , $R_L = 10k\Omega$ , $C_L = 100pF$ , $V_i = 2.5V$ to $7.5V$ )		0.8		V/ $\mu s$
$\phi_m$	Phase Margin		40		Degrees
$e_n$	Equivalent Input Noise Voltage ( $R_s = 100\Omega$ , $f = 1kHz$ )		30		$\frac{nV}{\sqrt{Hz}}$
THD	Total Harmonic Distortion ( $A_{VCL} = 1$ , $R_L = 10k\Omega$ , $C_L = 100pF$ , $V_o = 4.75V$ to $5.25V$ , $f = 1kHz$ )		0.024		%
$C_{in}$	Input Capacitance		1.5		pF
$V_{O1}/V_{O2}$	Channel Separation ( $f = 1kHz$ )		120		dB

**Note 1** : Maximum values including unavoidable inaccuracies of the industrial test.

**STANDBY MODE**

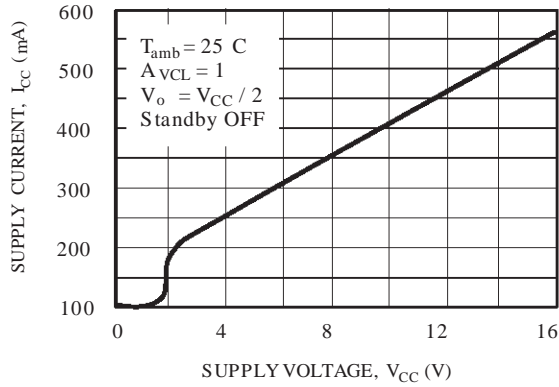
$V_{CC}^+ = 10V$ ,  $V_{CC}^- = 0V$ ,  $T_{amb} = 25^\circ C$  (unless otherwise specified)

Symbol	Parameter	TS904/AI			Unit
		Min.	Typ.	Max.	
$V_{in SBY/ON}$	Pin 8/9 Threshold Voltage for STANDBY ON		8.2		V
$V_{in SBY/OFF}$	Pin 8/9 Threshold Voltage for STANDBY OFF		8.5		V
$I_{CC SBY}$	Total Consumption Standby 1 ON - Standby 2 OFF Standby 1 OFF - Standby 2 ON Standby 1 and 2 ON		800 800 2		$\mu A$

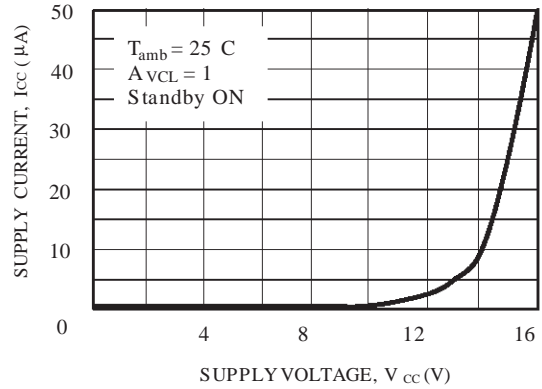
**TYPICAL CHARACTERISTICS**

(standby OFF = standby 1 and 2 OFF)  
 (standby ON = standby 1 and 2 ON)

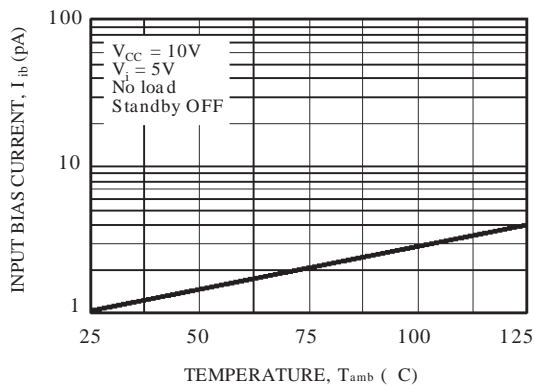
**Figure 1a :** Supply Current (each amplifier) versus Supply Voltage



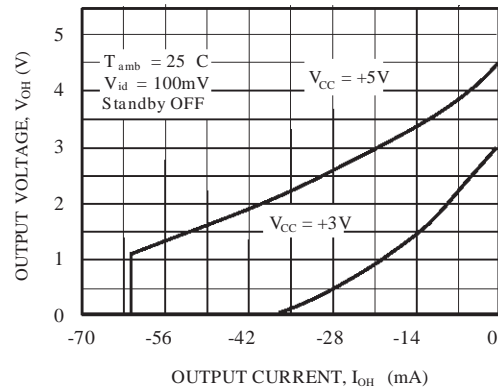
**Figure 1b :** Supply Current (each amplifier) versus Supply Voltage (in STANDBY mode)



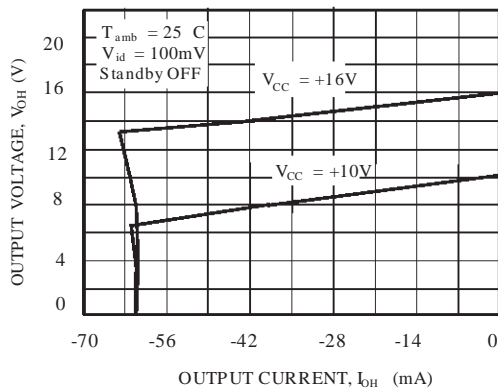
**Figure 2 :** Input Bias Current versus Temperature



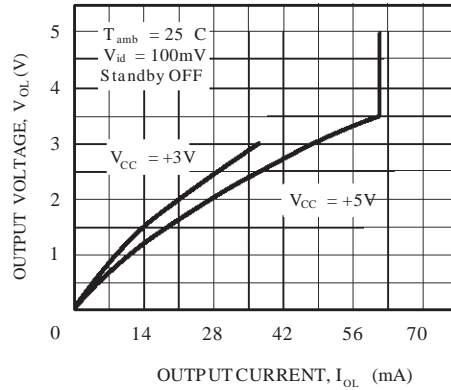
**Figure 3a :** High Level Output Voltage versus High Level Output Current



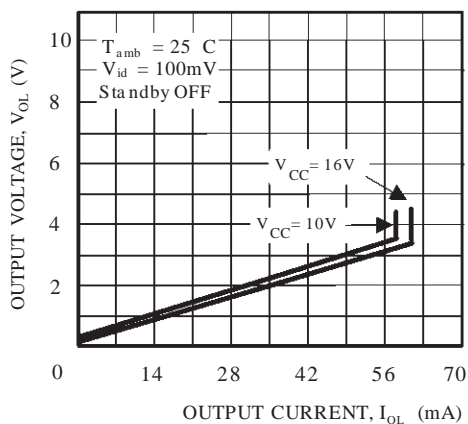
**Figure 3b :** High Level Output Voltage versus High Level Output Current



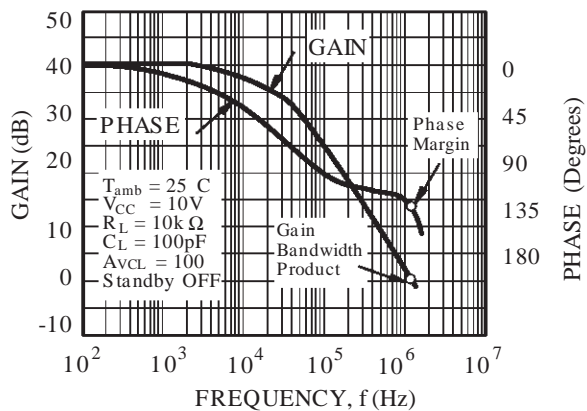
**Figure 4a :** Low Level Output Voltage versus Low Level Output Current



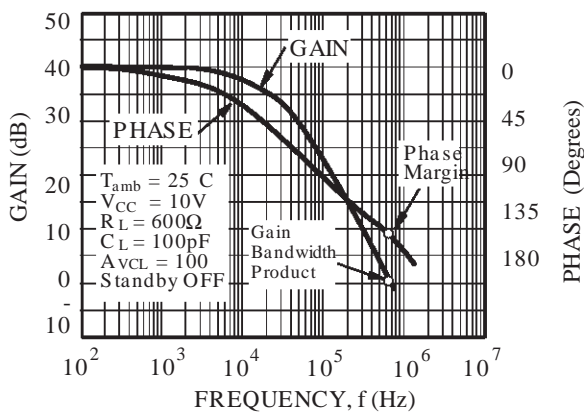
**Figure 4b :** Low Level Output Voltage versus Low Level Output Current



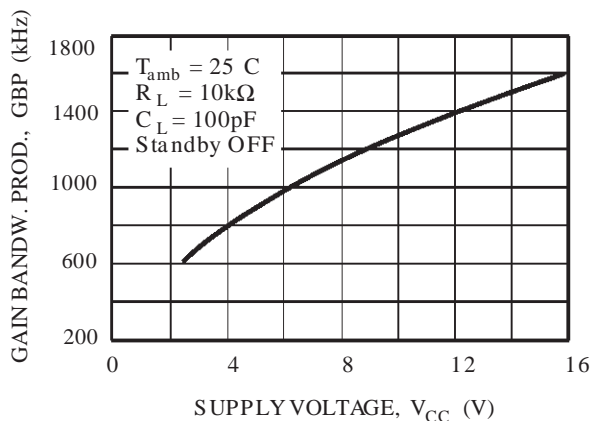
**Figure 5a :** Gain and Phase vs Frequency



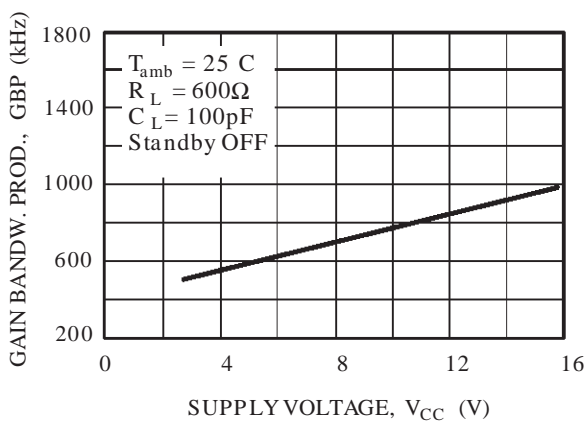
**Figure 5b :** Gain and Phase vs Frequency



**Figure 6a :** Gain Bandwidth Product versus Supply Voltage



**Figure 6b :** Gain bandwidth Product versus Supply Voltage



**Figure 7a :** Phase Margin versus Supply Voltage

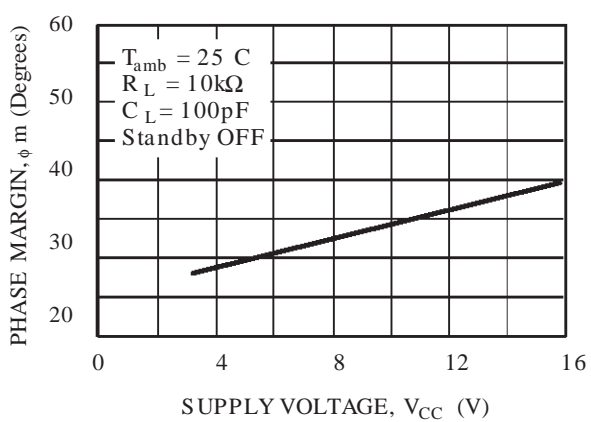


Figure 7b : Phase Margin versus Supply Voltage

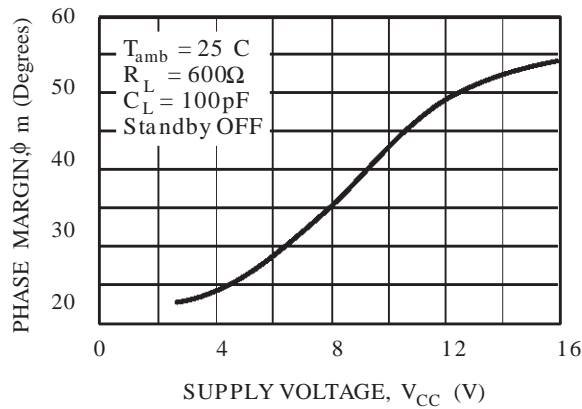
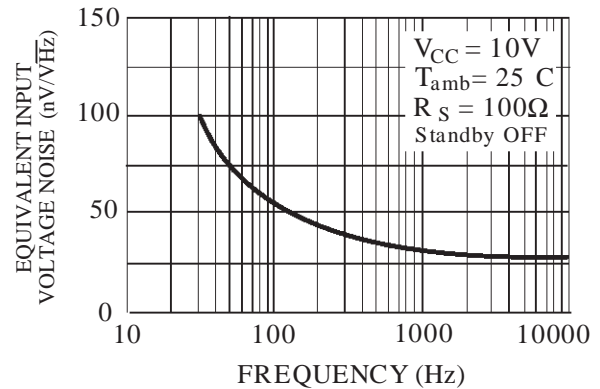


Figure 8 : Input Voltage Noise versus Frequency



**STANDBY APPLICATION**

The TS904 offers two separate STANDBY pins :

- **STANDBY 1** (pin 8) acting on the n°2 and n°3 operators.
- **STANDBY 2** (pin 9) acting on the n°1 and n°4 operators.

When one of these standby is activated (STANDBY ON) :

- The supply current of the corresponding operators is considerably reduced. The total consumption of the circuit is then divided by 2 (one STANDBY ON) or decreased down to 0.5μA ( $V_{CC} = 3V$ , two STANDBY ON) (ref. figure 1b).
- All the outputs of the corresponding operators are in high impedance state. No output current can then be sourced or sinked.

The standby pins 8 and 9 should never stay unconnected.

- The **”standby OFF”** state, is reached when the pins 8 or 9 voltage is **higher than  $V_{in\ SBY/OFF}$** .
- The **”standby ON”** state, is assured by the pins 8 or 9 voltage **lower than  $V_{in\ SBY/OFF}$** . (see electrical characteristics)



## MACROMODEL

- **RAIL TO RAIL** INPUT AND OUTPUT VOLTAGE RANGES
- 2 SEPARATE **STANDBY** : REDUCED **CONSUMPTION (2 $\mu$ A)** AND **HIGH IMPEDANCE OUTPUTS**
- SINGLE (OR DUAL) SUPPLY OPERATION FROM **2.7V TO 16V** ( $\pm 1.35V$  to  $\pm 8V$ )
- **EXTREMELY LOW INPUT BIAS CURRENT** : **1pA TYP**
- **LOW INPUT OFFSET VOLTAGE** : **5mV max.**
- **SPECIFIED FOR 600 $\Omega$  AND 150 $\Omega$  LOADS**
- **LOW SUPPLY CURRENT** : 400 $\mu$ A/Ampli ( $V_{CC} = 10V$ )

\*\* Standard Linear Ics Macromodels, 1993.

\*\* CONNECTIONS :

\* 1 INVERTING INPUT

\* 2 NON-INVERTING INPUT

\* 3 OUTPUT

\* 4 POSITIVE POWER SUPPLY

\* 5 NEGATIVE POWER SUPPLY

\* 6 STANDBY

.SUBCKT TS904 1 3 2 4 5 6 (analog)

\*\*\*\*\*

.MODEL MDTH D IS=1E-8 KF=6.563355E-14 CJO=10F

\* INPUT STAGE

CIP 2 5 1.500000E-12

CIN 1 5 1.500000E-12

EIP 10 0 2 0 1

EIN 16 0 1 0 1

RIP 10 11 6.500000E+00

RIN 15 16 6.500000E+00

RIS 11 15 7.655100E+00

DIP 11 12 MDTH 400E-12

DIN 15 14 MDTH 400E-12

VOFP 12 13 DC 0.000000E+00

VOFN 13 14 DC 0

FPOL 13 0 VSTB 1

CPS 11 15 3.82E-08

DINN 17 13 MDTH 400E-12

VIN 17 5 -0.5000000E+00

DINR 15 18 MDTH 400E-12

VIP 4 18 -0.5000000E+00

FCP 4 5 VOFP 8.6E+00

FCN 5 4 VOFN 8.6E+00

ISTB0 5 4 900NA

\* AMPLIFYING STAGE

FIP 0 19 VOFP 5.500000E+02

FIN 0 19 VOFN 5.500000E+02

RG1 19 120 5.087344E+05

GCOM1 120 5 POLY(1) 110 109 LEVEL=1 6.25E+11

RG2 121 19 5.087344E+05

GCOM2 121 4 POLY(1) 110 109 LEVEL=1 6.25E+11

CC 19 29 2.200000E-08

HZTP 30 29 VOFP 12.33E+02

HZTN 5 30 VOFN 12.33E+02

DOPM 19 22 MDTH 400E-12

DONM 21 19 MDTH 400E-12

HOPM 22 28 VOUT 3135

VIPM 28 4 150

HONM 21 27 VOUT 3135

VINM 5 27 150

EOUT 26 23 19 5 1

VOUT 23 5 0

ROUT 26 103 65

COUT 103 5 1.000000E-12

GCOM 103 3 POLY(1) 110 109 LEVEL=1 6.25E+11

\* OUTPUT SWING

DOP 19 68 MDTH 400E-12

VOP 4 25 1.924

HSCP 68 25 VSCP1 1E8

DON 69 19 MDTH 400E-12

VON 24 5 2.4419107

HSCN 24 69 VSCN1 1.5E8

VSCTHP 60 61 0.1375

DSCP1 61 63 MDTH 400E-12

VSCP1 63 64 0

ISCP 64 0 1.000000E-8

DSCP2 0 64 MDTH 400E-12

DSCN2 0 74 MDTH 400E-12

ISCN 74 0 1.000000E-8

VSCN1 73 74 0

DSCN1 71 73 MDTH 400E-12

VSCTHN 71 70 -0.75

ESCP 60 0 2 1 500

ESCN 70 0 2 1 -2000

\* STANDBY

RMI1 4 111 1E+12

RMI2 5 111 1E+12

RSTBIN 6 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 40U

RSTB 109 110 1

DSTB2 0 110 MDTH 400E-12

.ENDS

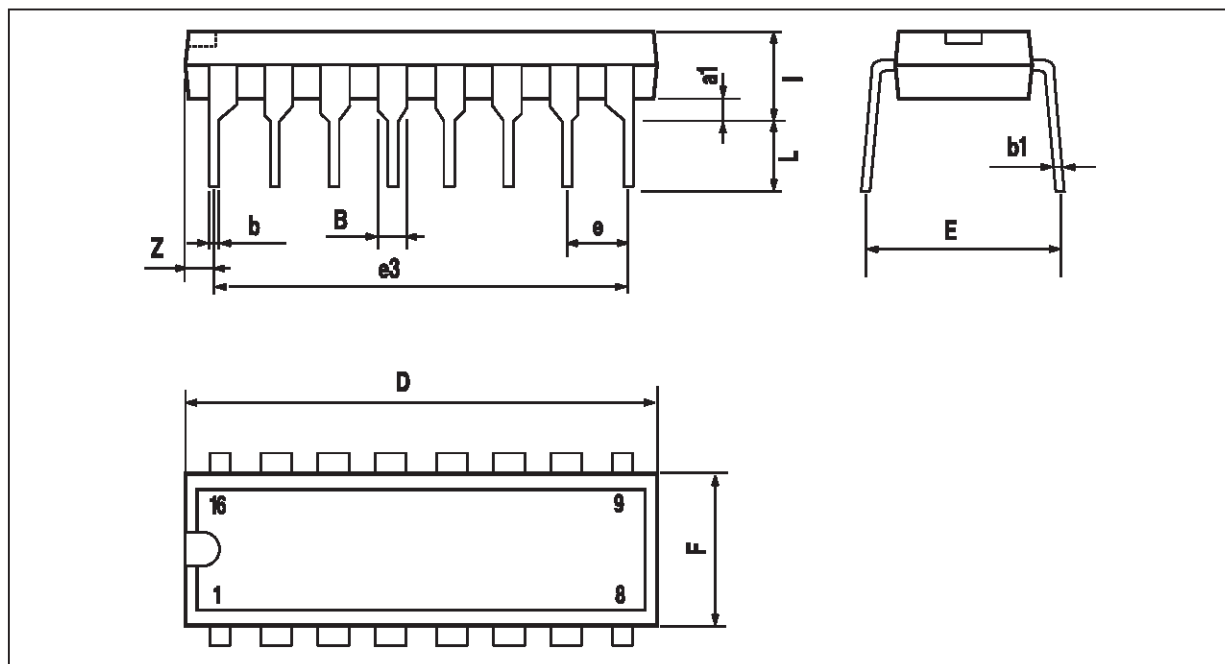
**ELECTRICAL CHARACTERISTICS**

$V_{CC}^+ = 10V$ ,  $V_{CC}^- = 0V$ ,  $R_L, C_L$  connected to  $V_{CC}/2$ , standby off,  $T_{amb} = 25^\circ C$   
(unless otherwise specified)

Symbol	Conditions	Value	Unit
$V_{io}$		0	mV
$A_{vd}$	$R_L = 10k\Omega$	40	V/mV
$I_{CC}$	No load, per operator	400	$\mu A$
$V_{icm}$		-0.2 to 10.2	V
$V_{OH}$	$R_L = 10k\Omega$	9.95	V
$V_{OL}$	$R_L = 10k\Omega$	50	mV
$I_{sink}$	$V_O = 10V$	60	mA
$I_{source}$	$V_O = 0V$	60	mA
GBP	$R_L = 10k\Omega, C_L = 100pF$	1.3	MHz
SR	$R_L = 10k\Omega, C_L = 100pF$	1.3	V/ $\mu s$
$\varnothing m$	$R_L = 10k\Omega, C_L = 100pF$	40	Degrees
$I_{CC\ STBY}$	$V_{STBY} = 0V$	800	nA

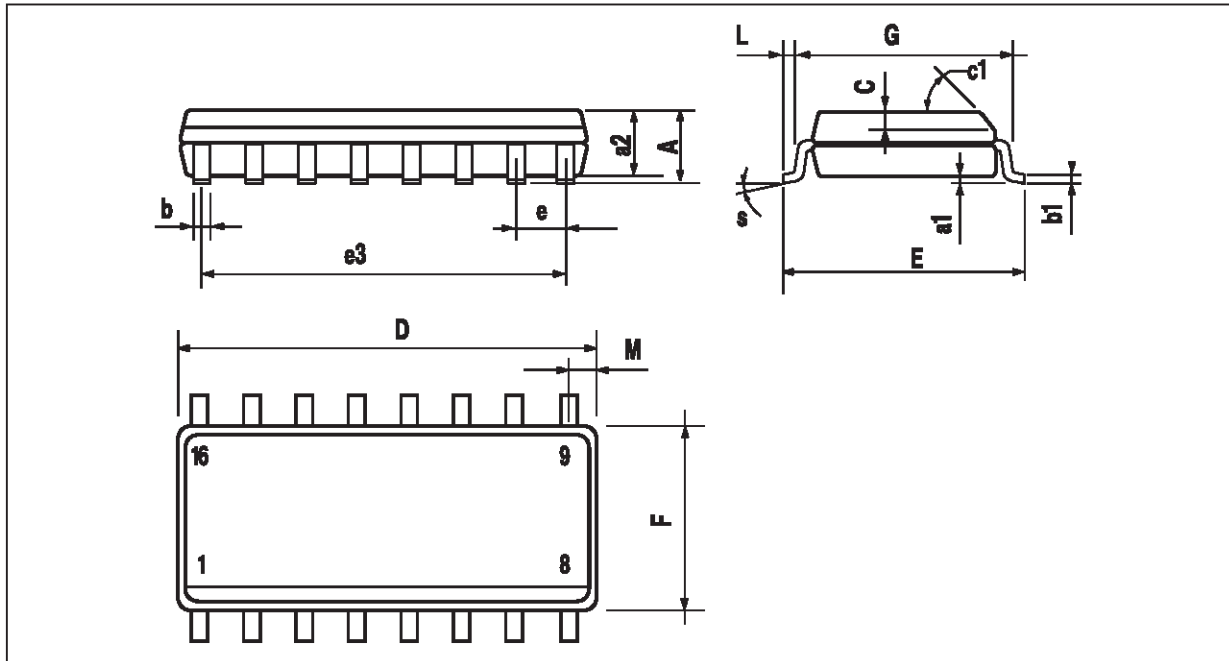
**PACKAGE MECHANICAL DATA**

16 PINS - PLASTIC DIP



Dimensions	Millimeters			Inches		
	Min.	Typ.	Max.	Min.	Typ.	Max.
a1	0.51			0.020		
B	0.77		1.65	0.030		0.065
b		0.5			0.020	
b1		0.25			0.010	
D			20			0.787
E		8.5			0.335	
e		2.54			0.100	
e3		17.78			0.700	
F			7.1			0.280
i			5.1			0.201
L		3.3			0.130	
Z			1.27			0.050

**PACKAGE MECHANICAL DATA**  
 16 PINS - PLASTIC MICROPACKAGE (SO)



Dimensions	Millimeters			Inches		
	Min.	Typ.	Max.	Min.	Typ.	Max.
A			1.75			0.069
a1	0.1		0.2	0.004		0.008
a2			1.6			0.063
b	0.35		0.46	0.014		0.018
b1	0.19		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	0.5		1.27	0.020		0.050
M			0.62			0.024
S	8° (max.)					

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