



TS904

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

- **RAIL TO RAIL** INPUT AND OUTPUT VOLTAGE RANGES
- 2 SEPARATE **STANDBY** : REDUCED CONSUMPTION ($0.5\mu\text{A}$) 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 **600 Ω** AND **150 Ω** LOADS
- LOW SUPPLY CURRENT : 200 μA /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 :

- $V_{\text{CC}}^- + 50\text{mV}$ $V_{\text{CC}}^+ - 50\text{mV}$ with $R_L = 10\text{k}\Omega$
- $V_{\text{CC}}^- + 350\text{mV}$ $V_{\text{CC}}^+ - 350\text{mV}$ 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 200 μA /amp. ($V_{\text{CC}} = 3\text{V}$)

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

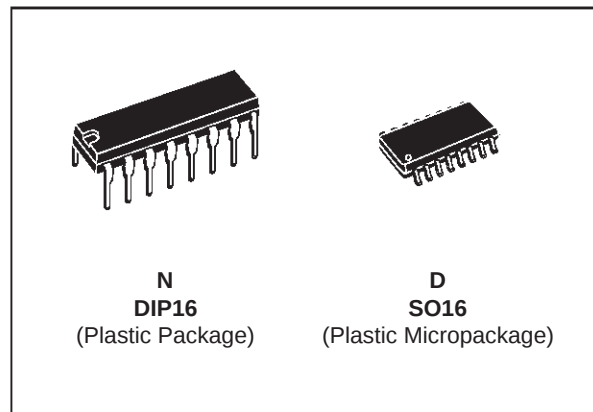
The TS904 offers two separate **STANDBY** pins

- 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.

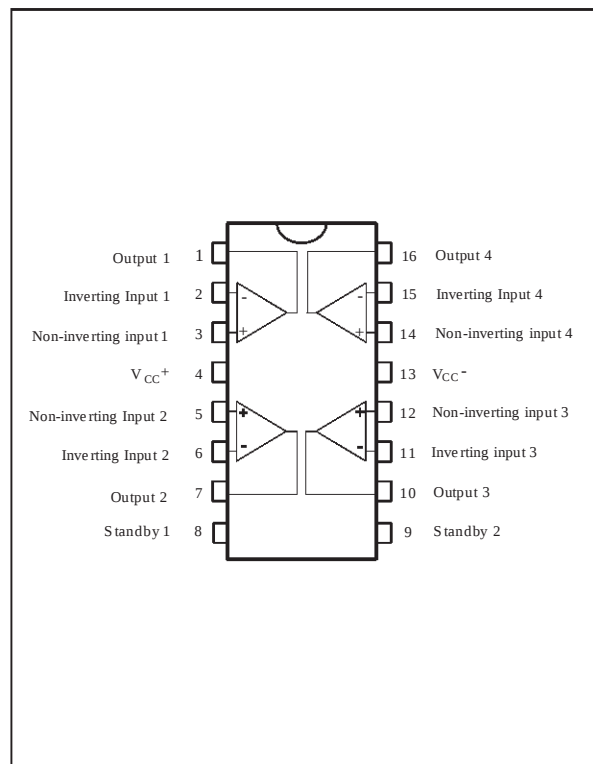
STMicroelectronics is offering a quad op-amp with the same features : TS902.



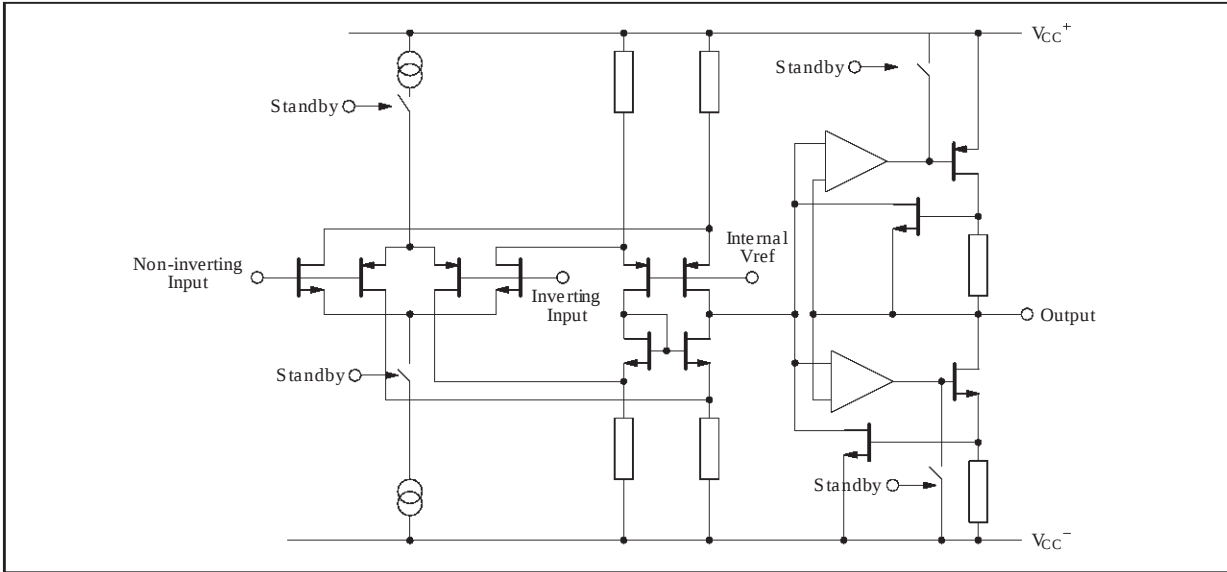
ORDER CODES

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

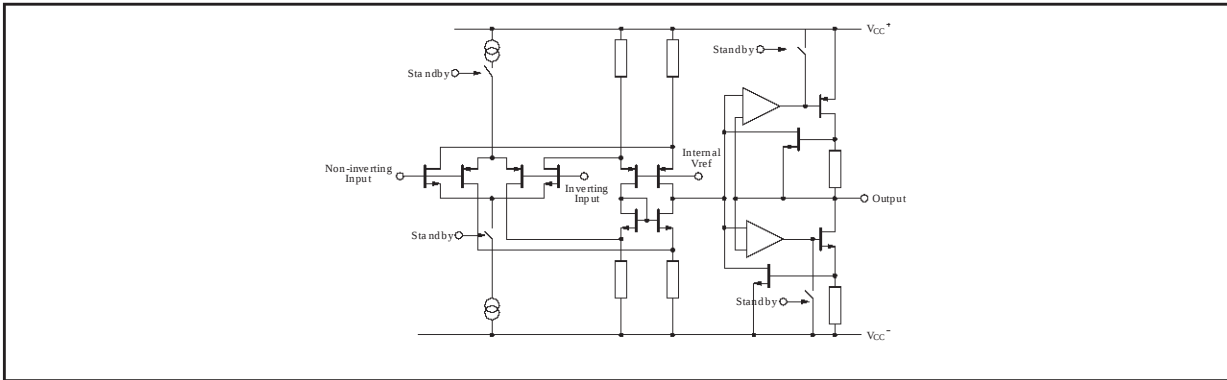
PIN CONNECTIONS (top view)



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)	± 18	V
V_i	Input Voltage - (note 3)	-0.3 to 18	V
I_{in}	Current on Inputs	± 50	mA
I_o	Current on Outputs	± 130	mA
T_{oper}	Operating Free Air Temperature Range	-40 to +125	$^{\circ}\text{C}$
T_{stg}	Storage Temperature	-65 to +150	$^{\circ}\text{C}$

- 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 $V_{CC}^{+} + 0.3\text{V}$.

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	μA
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	100 400 150 600	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/ μs
SR^-	Negative Slew Rate ($A_{VCL} = 1$, $R_L = 10k\Omega$, $C_L = 100pF$, $V_i = 1.3V$ to $1.7V$)		0.4		V/ μs
ϕ_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	μA
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 ($V_o = V_{CC}^-$) Sink ($V_o = V_{CC}^+$)	45 45	60 60		mA
GBP	Gain Bandwidth Product ($A_{VCL} = 100$, $R_L = 10k\Omega$, $C_L = 100pF$, $f = 100kHz$)		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/ μs
SR^-	Negative Slew Rate ($A_{VCL} = 1$, $R_L = 10k\Omega$, $C_L = 100pF$, $V_i = 1V$ to $4V$)		0.5		V/ μs
ϕ_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	μA
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 150 900	150 800	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/ μs
SR^-	Negative Slew Rate ($A_{VCL} = 1$, $R_L = 10k\Omega$, $C_L = 100pF$, $V_i = 2.5V$ to $7.5V$)		0.8		V/ μs
ϕ_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	TS904II/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		μA

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

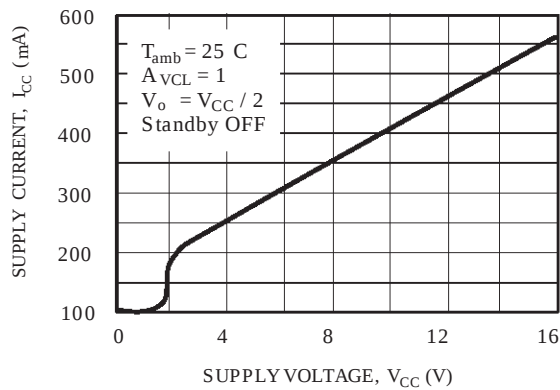


Figure 1b : Supply Current (each amplifier)
versus Supply Voltage (in STANDBY mode)

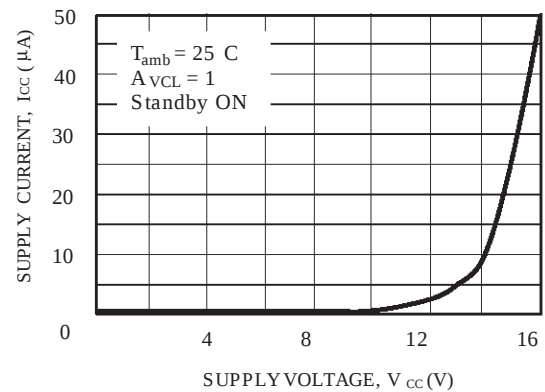


Figure 2 : Input Bias Current versus Temperature

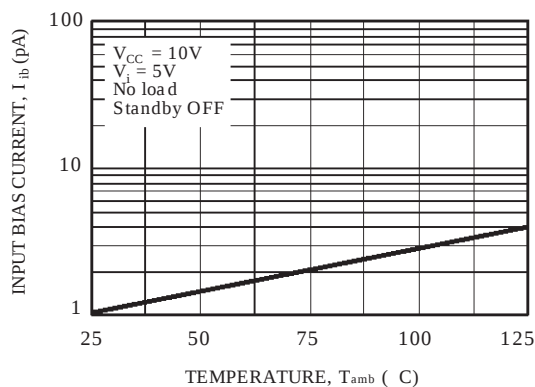


Figure 3a : High Level Output Voltage versus
High Level Output Current

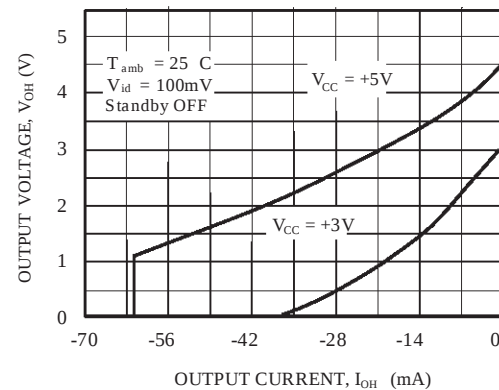


Figure 3b : High Level Output Voltage versus
High Level Output Current

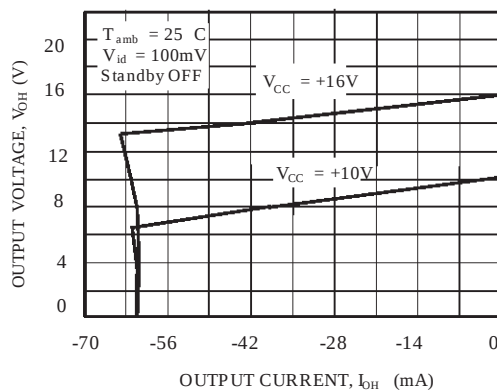


Figure 4a : Low Level Output Voltage versus
Low Level Output Current

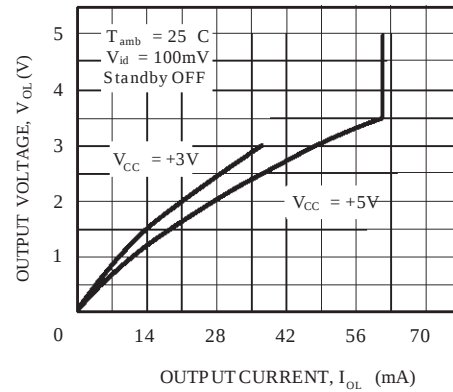


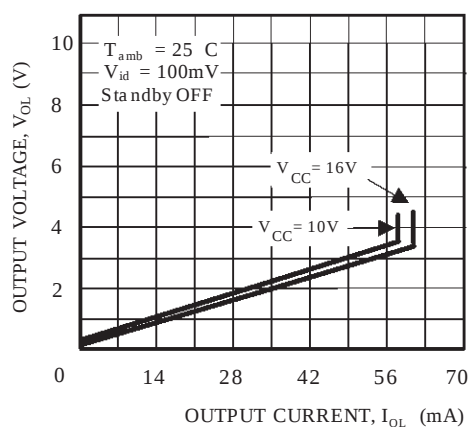
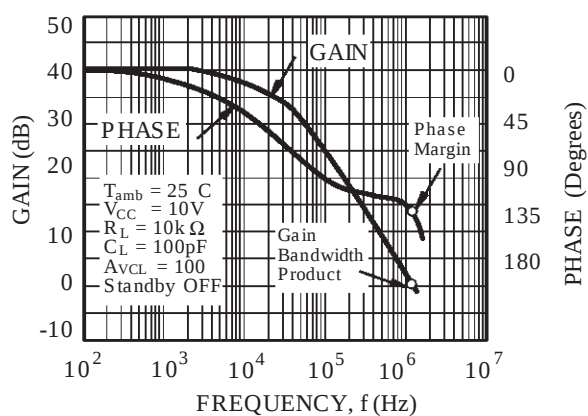
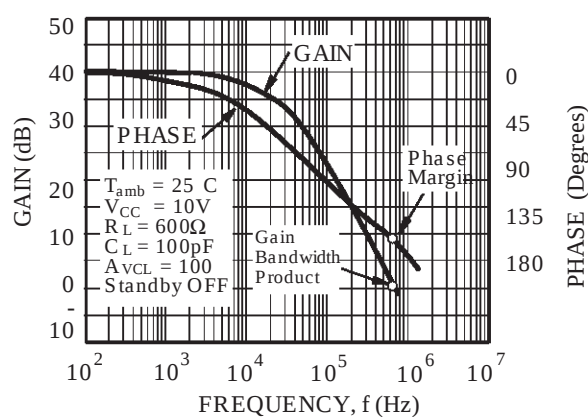
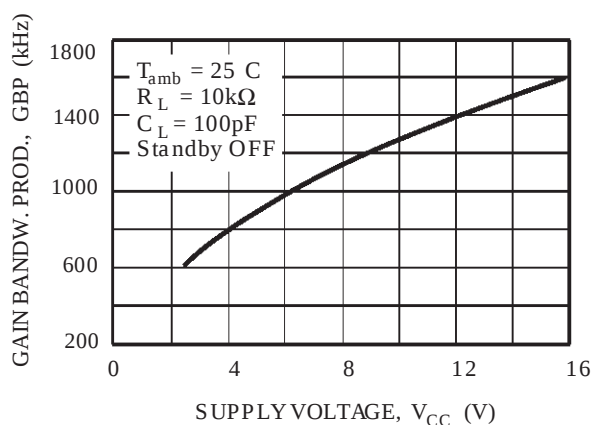
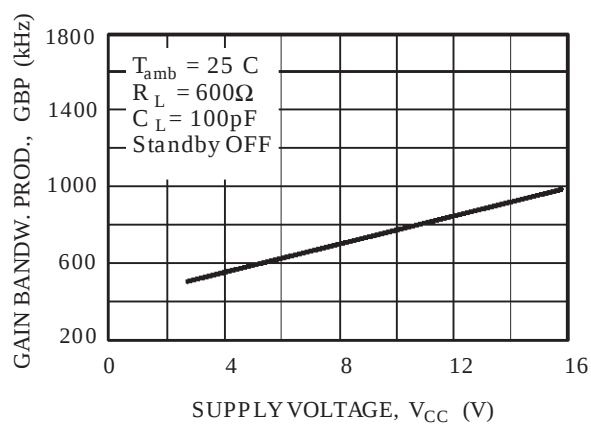
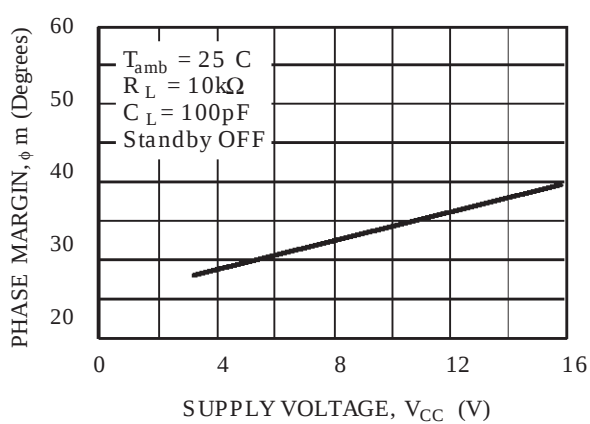
Figure 4b : Low Level Output Voltage versus Low Level Output Current**Figure 5a : Gain and Phase vs Frequency****Figure 5b : Gain and Phase vs Frequency****Figure 6a : Gain Bandwidth Product versus Supply Voltage****Figure 6b : Gain bandwidth Product versus Supply Voltage****Figure 7a : Phase Margin versus Supply Voltage**

Figure 7b : Phase Margin versus Supply Voltage

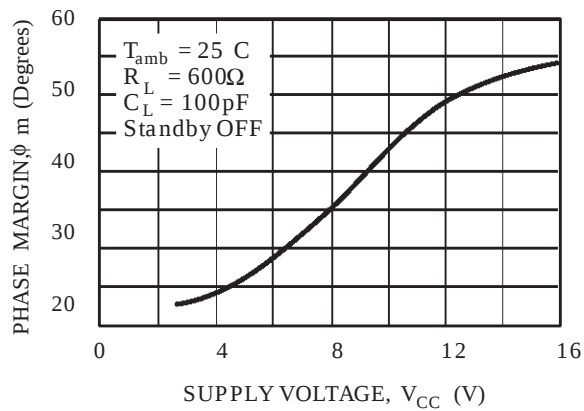
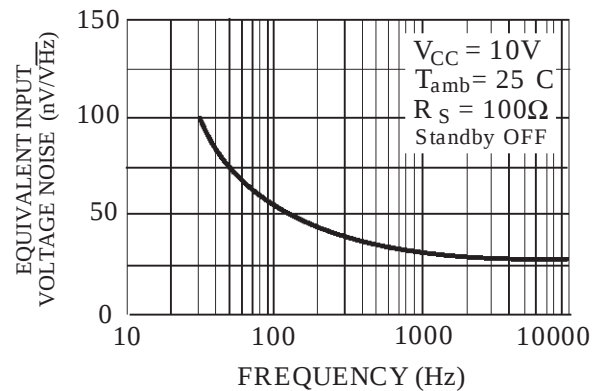


Figure 8 : Input Voltage Noise versus Frequency



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 $0.5\mu A$ ($V_{CC} = 3V$, 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 μ 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 Ω** AND **150 Ω** LOADS
- LOW SUPPLY CURRENT : 400 μ 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

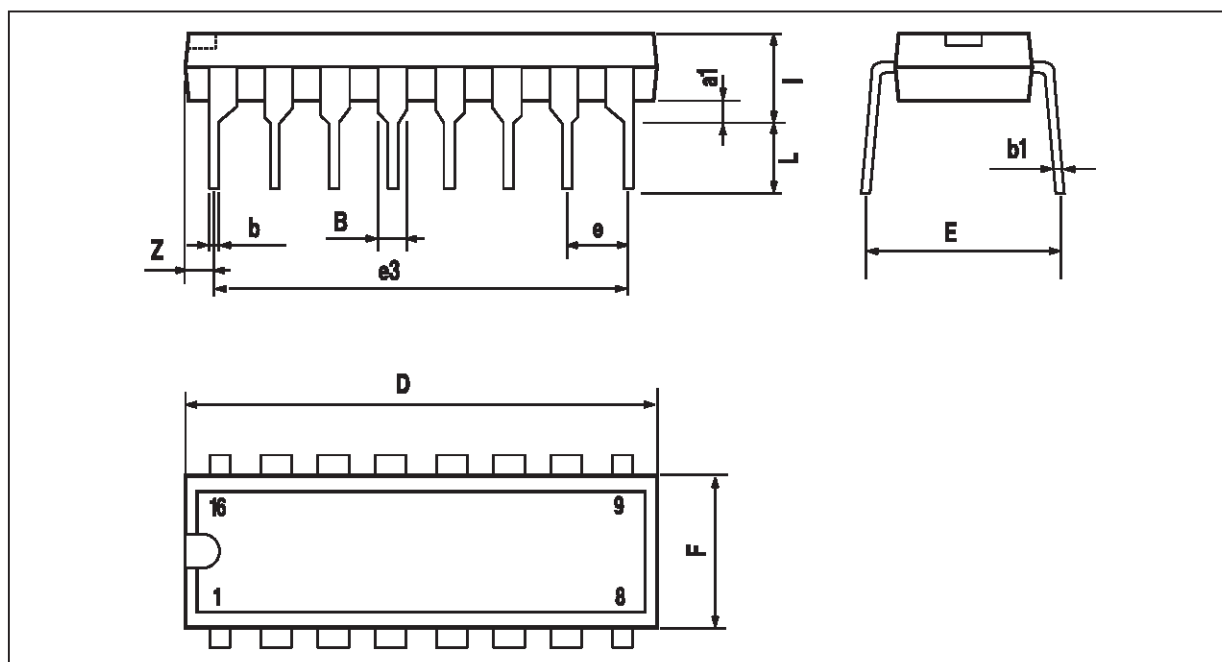
ELECTRICAL CHARACTERISTICS

$V_{CC}^+ = 10V$, $V_{CC}^- = 0V$, 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	μA
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/ μs
$\varnothing m$	$R_L = 10k\Omega$, $C_L = 100pF$	40	Degrees
$I_{CC\ STBY}$	$V_{STBY} = 0V$	800	nA

PACKAGE MECHANICAL DATA

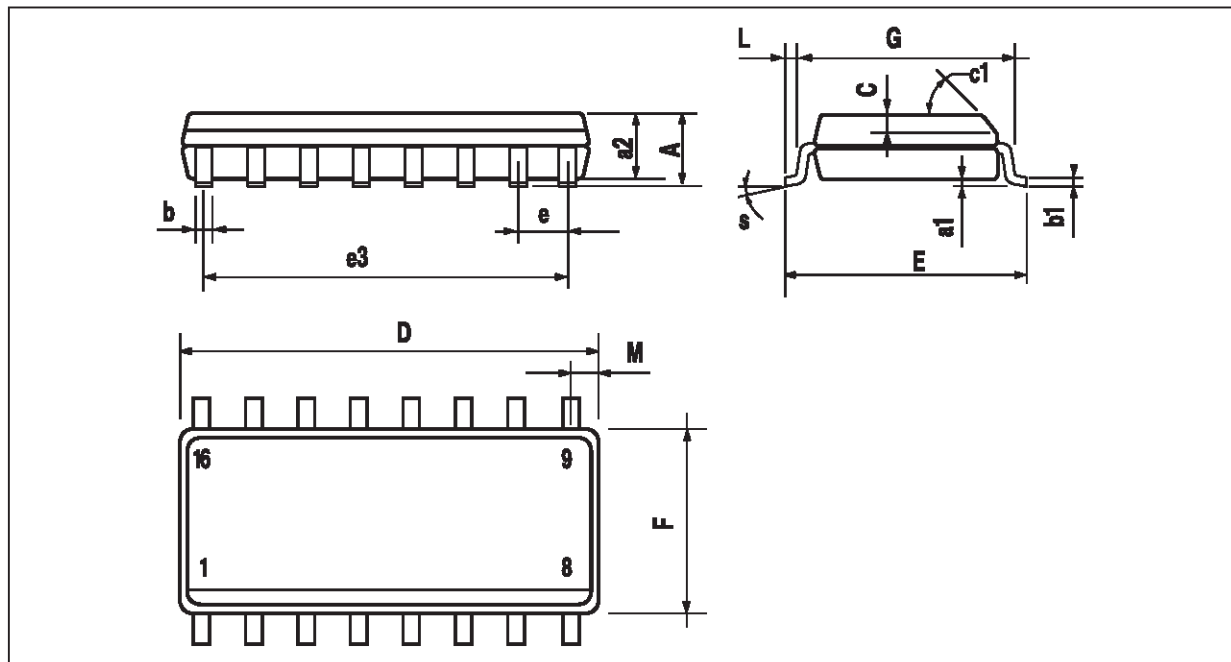
16 PINS - PLASTIC DIP



Dimensions	Millimeters			Inches		
	Min.	Typ.	Max.	Min.	Typ.	Max.
a_1	0.51			0.020		
B	0.77		1.65	0.030		0.065
b		0.5			0.020	
b_1		0.25			0.010	
D			20			0.787
E		8.5			0.335	
e		2.54			0.100	
e_3		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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