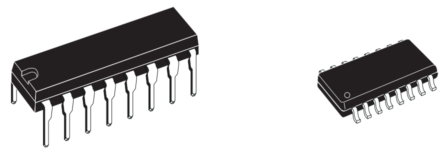
TS904

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



N
DIP16
(Plastic Package)

D
SO16
(Plastic Micropackage)

ORDER CODES

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

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 :

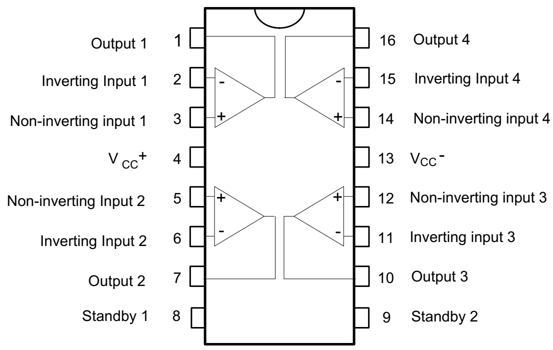
- V_{CC}^- +50mV V_{CC}^+ -50mV with R_L = 10kΩ
- V_{CC}^- +350mV V_{CC}^+ -350mV with R_L = 600Ω

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

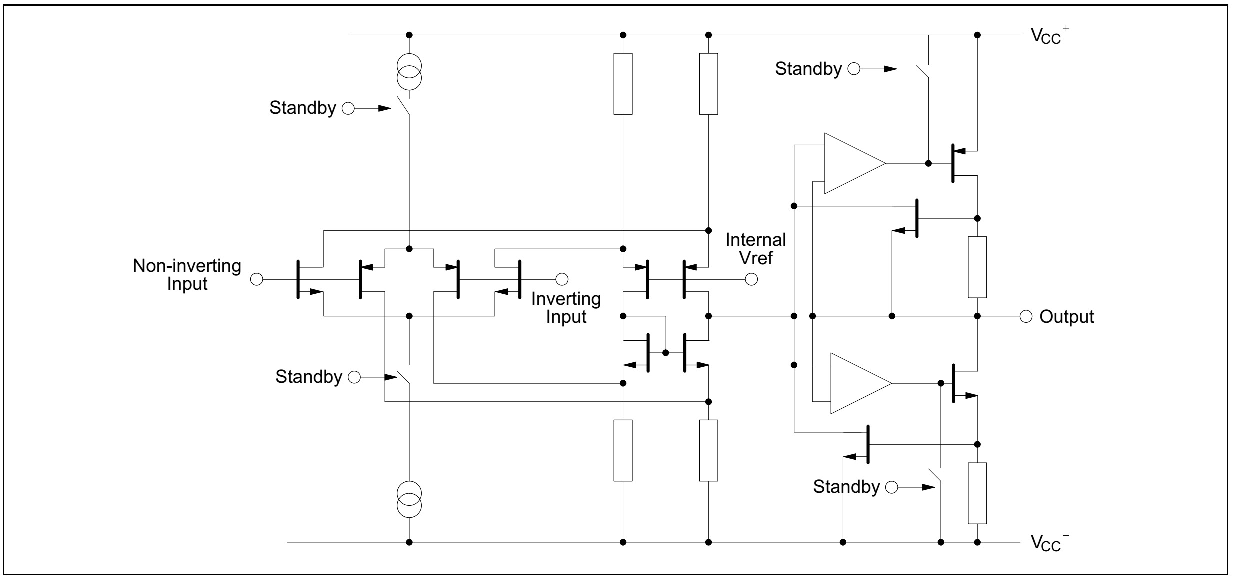
- STANDBY 1 acting on the n°2 and n°3 operators
- STANDBY 2 acting on the n°1 and n°4 operators

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.

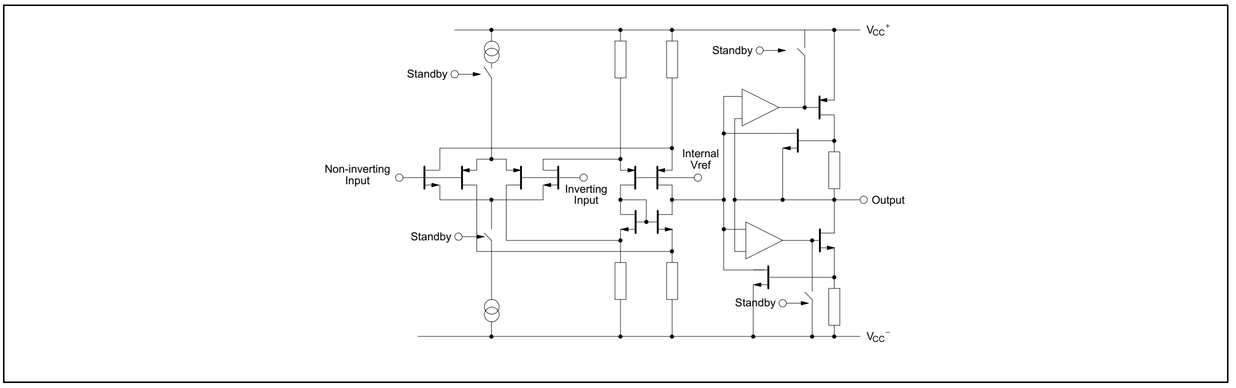
PIN CONNECTIONS (top view)



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 TS904I/AI	-40 to +125	°C
T_{stg}	Storage Temperature	-65 to +150	°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}^+, $T_{amb} = 25^oC$ (unless otherwise specified)

Symbol	Parameter	Min.	Typ.	Max.	Unit
V_{io}	Input Offset Voltage ($V_{ic} = V_o = V_{CC}/2$) TS904 TS904A $T_{min.} \leq T_{amb} \leq T_{max.}$ TS904 TS904A			10 5 12 7	mV
DV_{io}	Input Offset Voltage Drift		5		$\mu V/^oC$
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 ($V_{id} = 1V$) $R_L = 10k\Omega$ $R_L = 600\Omega$ $R_L = 100\Omega$ $T_{min.} \leq T_{amb} \leq T_{max.}$ $R_L = 10k\Omega$ $R_L = 600\Omega$	2.9 2.3 2.8 2.1	2.96 2.6 2		V
V_{OL}	Low Level Output Voltage ($V_{id} = -1V$) $R_L = 10k\Omega$ $R_L = 600\Omega$ $R_L = 100\Omega$ $T_{min.} \leq T_{amb} \leq T_{max.}$ $R_L = 10k\Omega$ $R_L = 600\Omega$		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
∅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°C (unless otherwise specified)

Symbol	Parameter		Min.	Typ.	Max.	Unit
V_{io}	Input Offset Voltage (V_{ic} = V_o = V_{CC}/2) $T_{min.} \le T_{amb} \le T_{max.}$	TS904 TS904A TS904 TS904A			10 5 12 7	mV
DV_{io}	Input Offset Voltage Drift			5		μV/°C
I_{io}	Input Offset Current - (note 1) $T_{min.} \le T_{amb} \le T_{max.}$			1	100 200	pA
I_{ib}	Input Bias Current - (note 1) $T_{min.} \le T_{amb} \le T_{max.}$			1	150 300	pA
I_{CC}	Supply Current (per amplifier, A_{VCL} = 1, no load) $T_{min.} \le T_{amb} \le T_{max.}$			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 = 10kΩ, V_O = 1.5V to 3.5V) $T_{min.} \le T_{amb} \le T_{max.}$		10 7	30		V/mV
V_{OH}	High Level Output Voltage (V_{id} = 1V) $T_{min.} \le T_{amb} \le T_{max.}$	R_L = 10kΩ R_L = 600Ω R_L = 100Ω R_L = 10kΩ R_L = 600Ω	4.9 4.25 4.8 4.1	4.95 4.65 3.7		V
V_{OL}	Low Level Output Voltage (V_{id} = -1V $T_{min.} \le T_{amb} \le T_{max.}$	R_L = 10kΩ R_L = 600Ω R_L = 100Ω R_L = 10kΩ R_L = 600Ω		50 350 1400	100 500 150 750	mV
I_o	Output Short Circuit Current (V_{id} = ±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 = 10kΩ, C_L = 100pF, f = 100kHz)			0.9		MHz
SR^{+}	Positive Slew Rate (A_{VCL} = 1, R_L = 10kΩ, C_L = 100pF, V_i =1V to 4V)			0.8		V/μs
SR^{-}	Negative Slew Rate (A_{VCL} = 1, R_L = 10kΩ, C_L = 100pF, V_i =1V to 4V)			0.5		V/μs
∅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°C (unless otherwise specified)

Symbol	Parameter	Min.	Typ.	Max.	Unit
V_{io}	Input Offset Voltage (V_{ic} = V_o = V_{CC}/2) TS904 TS904A $T_{min.} \leq T_{amb} \leq T_{max.}$ TS904 TS904A			10 5 12 7	mV
DV_{io}	Input Offset Voltage Drift		5		μV/°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 = 10kΩ, 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) R_L = 10kΩ R_L = 600Ω R_L = 100Ω $T_{min.} \leq T_{amb} \leq T_{max.}$ R_L = 10kΩ R_L = 600Ω	9.85 9.2 9.8 9	9.95 9.35 7.8		V
V_{OL}	Low Level Output Voltage (V_{id} = -1V) R_L = 10kΩ R_L = 600Ω R_L = 100Ω $T_{min.} \leq T_{amb} \leq T_{max.}$ R_L = 10kΩ R_L = 600Ω		50 650 2300	150 800 150 900	mV
I_o	Output Short Circuit Current (V_{id} = ±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 = 10kΩ, C_L = 100pF, f = 100kHz)		1.3		MHz
SR^{+}	Positive Slew Rate (A_{VCL} = 1, R_L = 10kΩ, C_L = 100pF, V_i = 2.5V to 7.5V)		1.3		V/μs
SR^{-}	Negative Slew Rate (A_{VCL} = 1, R_L = 10kΩ, C_L = 100pF, V_i = 2.5V to 7.5V)		0.8		V/μs
∅m	Phase Margin		40		Degrees
e_n	Equivalent Input Noise Voltage (R_s = 100Ω, f = 1kHz)		30		$\frac{nV}{\sqrt{Hz}}$
THD	Total Harmonic Distortion (A_{VCL} = 1, R_L = 10kΩ, 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°C (unless otherwise specified)

Symbol	Parameter	TS904I/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

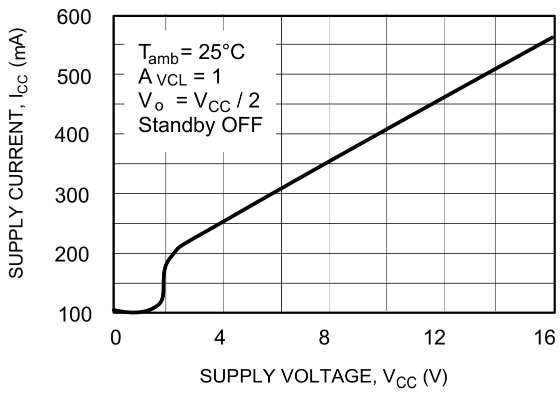


Figure 1b : Supply Current (each amplifier) versus Supply Voltage (in STANDBY mode)

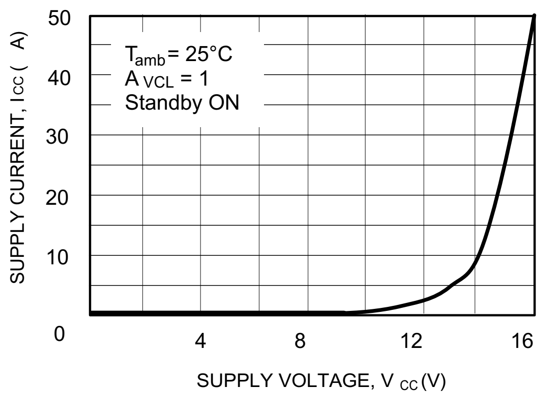


Figure 2 : Input Bias Current versus Temperature

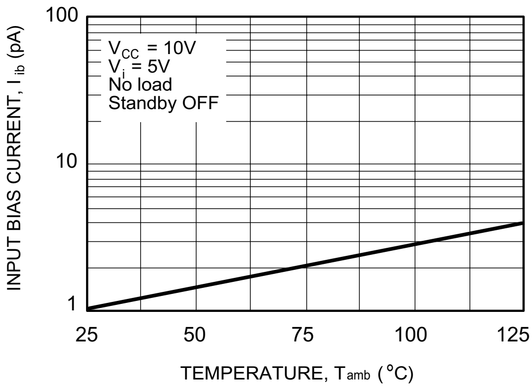


Figure 3a : High Level Output Voltage versus High Level Output Current

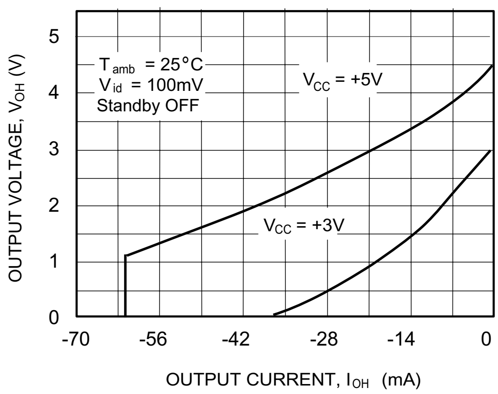


Figure 3b : High Level Output Voltage versus High Level Output Current

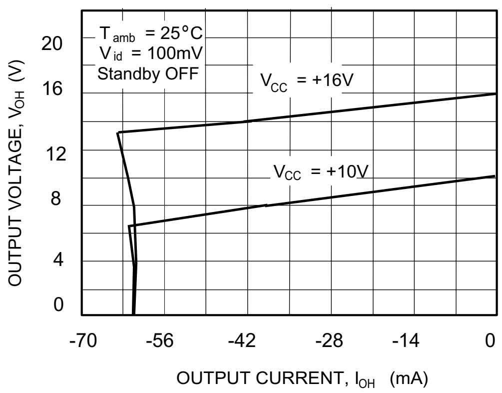


Figure 4a : Low Level Output Voltage versus Low Level Output Current

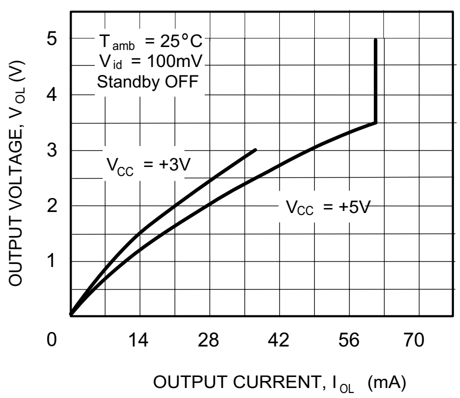


Figure 4b : Low Level Output Voltage versus Low Level Output Current

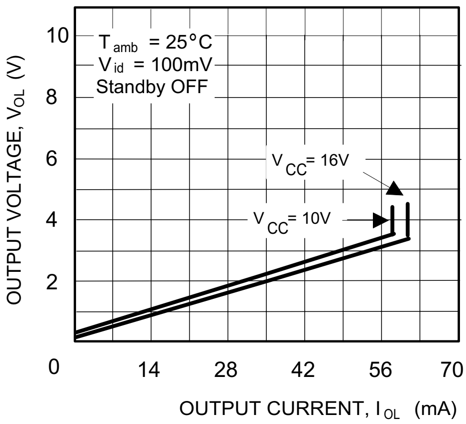


Figure 5a : Gain and Phase vs Frequency

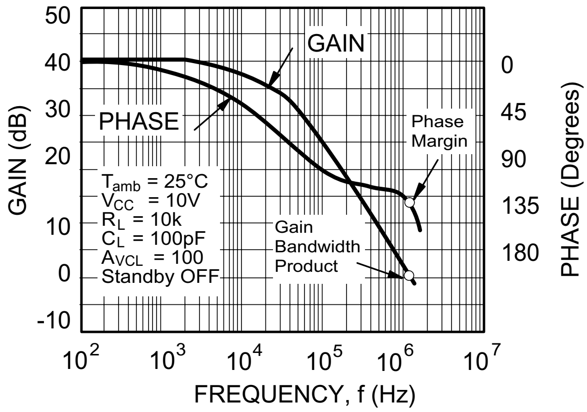


Figure 5b : Gain and Phase vs Frequency

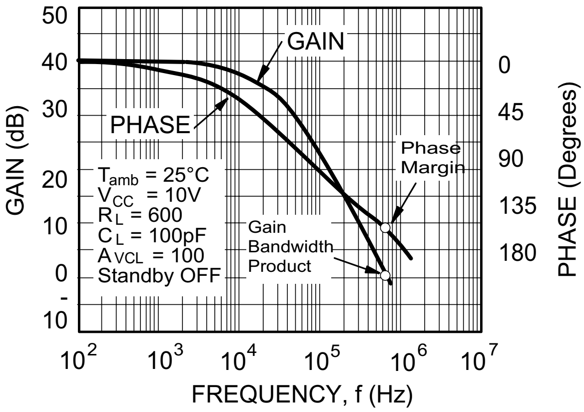


Figure 6a : Gain Bandwidth Product versus Supply Voltage

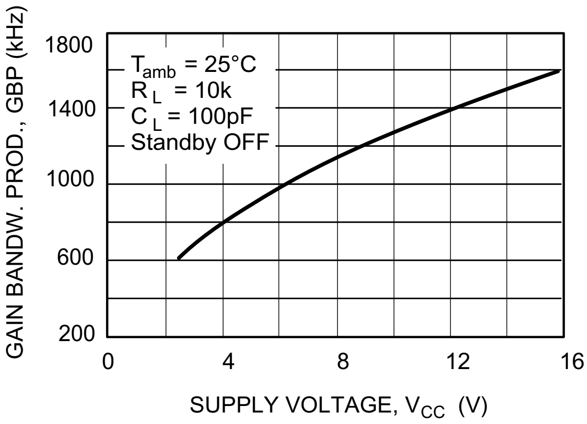


Figure 6b : Gain bandwidth Product versus Supply Voltage

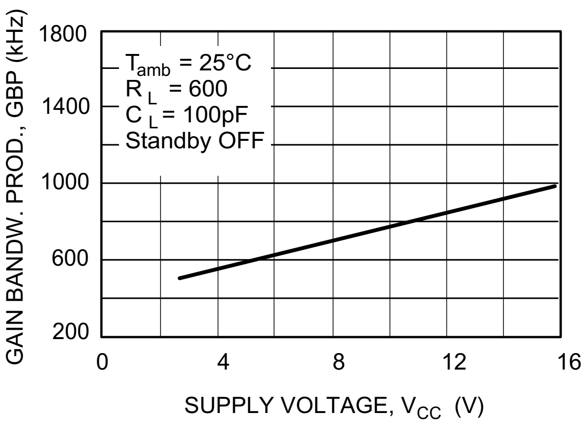


Figure 7a : Phase Margin versus Supply Voltage

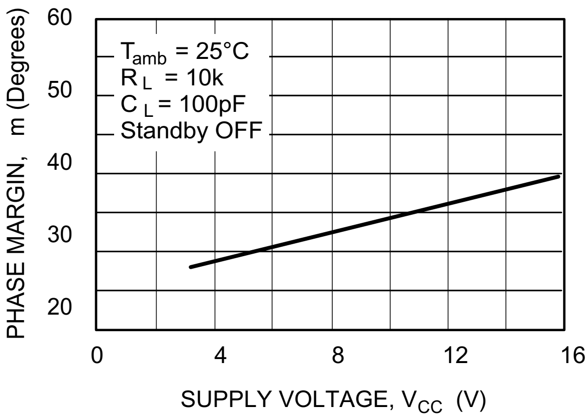


Figure 7b : Phase Margin versus Supply Voltage

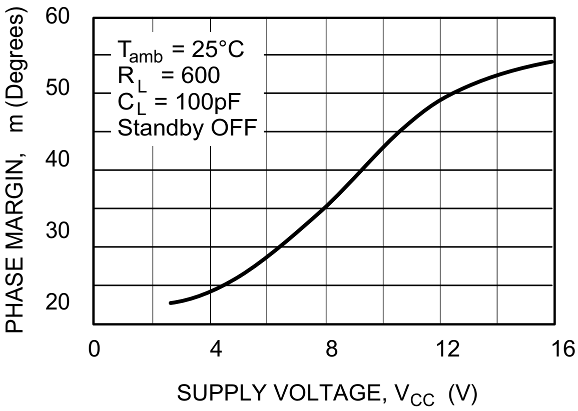
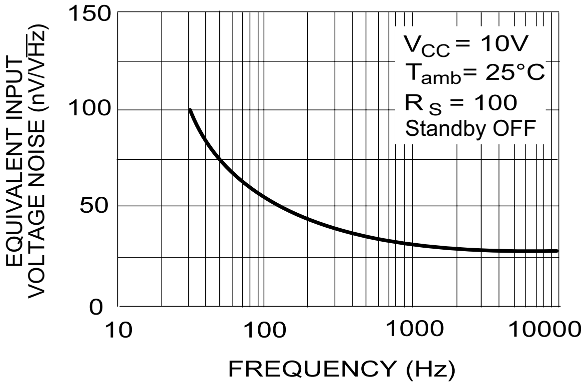


Figure 8 : Input Voltage Noise versus Frequency



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 0.5µA (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 (2µA)** AND **HIGH IMPEDANCE OUTPUTS**
- SINGLE (OR DUAL) SUPPLY OPERATION FROM **2.7V TO 16V** (±1.35V to ±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 : 400µA/Ampli (V_{CC} = 10V)

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** 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
* STAND BY
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
```

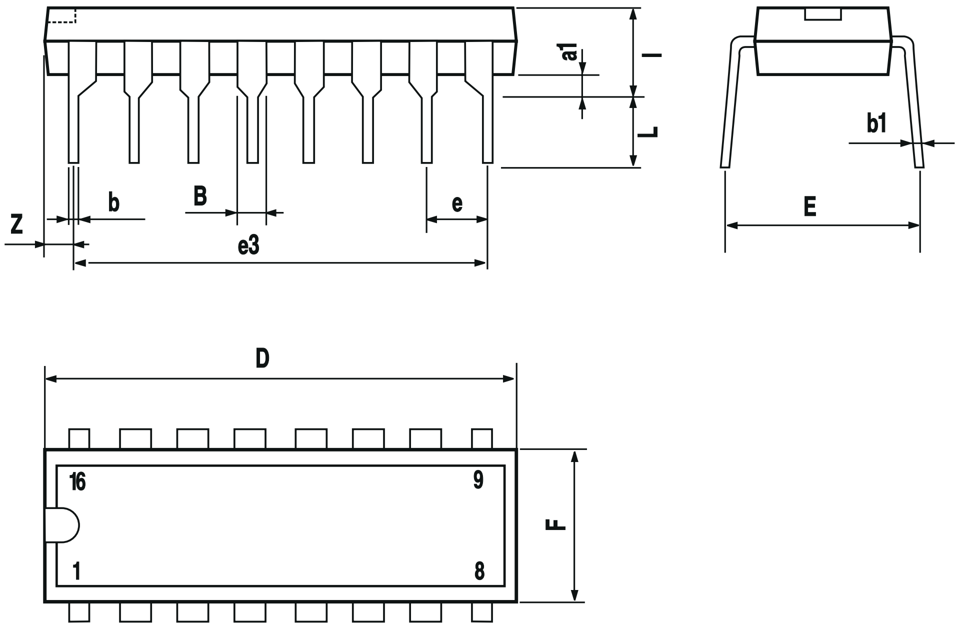
ELECTRICAL CHARACTERISTICS

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

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

PACKAGE MECHANICAL DATA

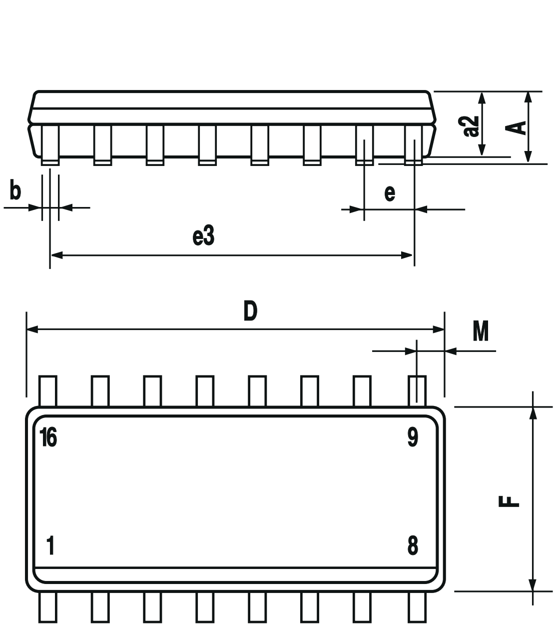
16 PINS - PLASTIC DIP



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^o (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^o (max.)					