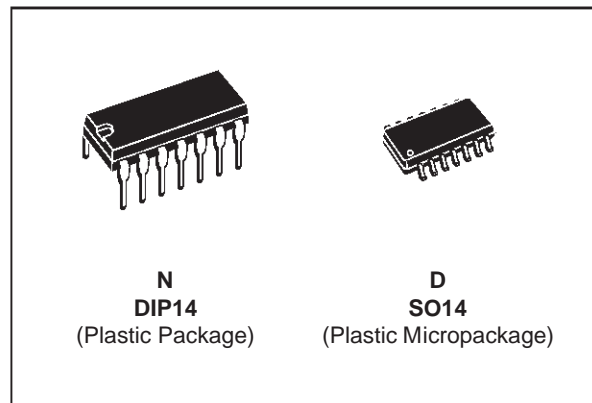




# TS902

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

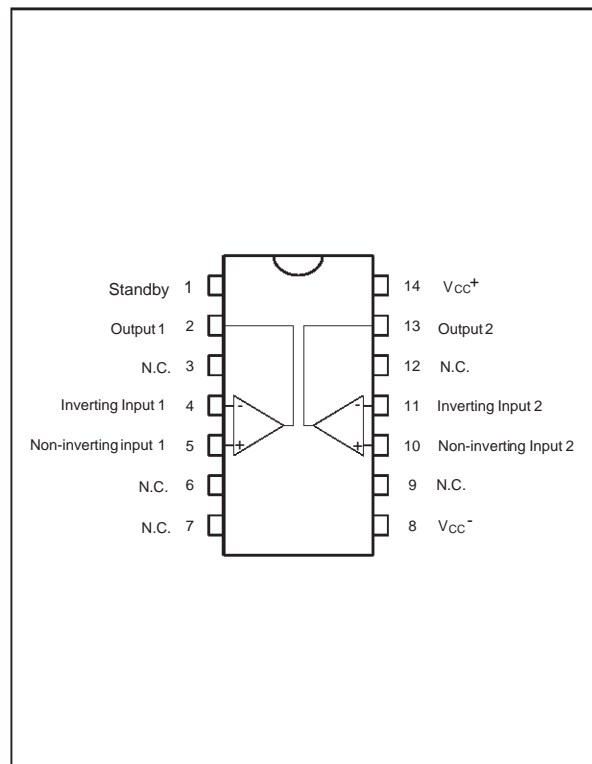
- RAIL TO RAIL INPUT AND OUTPUT VOLTAGE RANGES
- **STANDBY POSITION** : REDUCED CONSUMPTION (0.5 $\mu$ A) AND HIGH IMPEDANCE OUTPUTS
- SINGLE (OR DUAL) SUPPLY OPERATION FROM **2.7V TO 16V**
- EXTREMELY LOW INPUT BIAS CURRENT : **1pA TYP**
- SPECIFIED FOR **600 $\Omega$**  AND **100 $\Omega$**  LOADS
- LOW SUPPLY CURRENT : 200 $\mu$ A/Ampli
  
- **SPICE MACROMODEL** INCLUDED IN THIS SPECIFICATION



### ORDER CODES

Part Number	Temperature Range	Package	
		N	D
TS902I/AI	-40, +125 $^{\circ}$ C	•	•

### PIN CONNECTIONS (top view)



### DESCRIPTION

The TS902 is a RAIL TO RAIL dual CMOS operational amplifier designed to operate with single or dual supply voltage.

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

The output reaches ( $V_{CC} = 5V$ ) :

- $V_{CC}^- +50mV$   $V_{CC}^+ -50mV$  with  $R_L = 10k\Omega$
- $V_{CC}^- +350mV$   $V_{CC}^+ -400mV$  with  $R_L = 600\Omega$

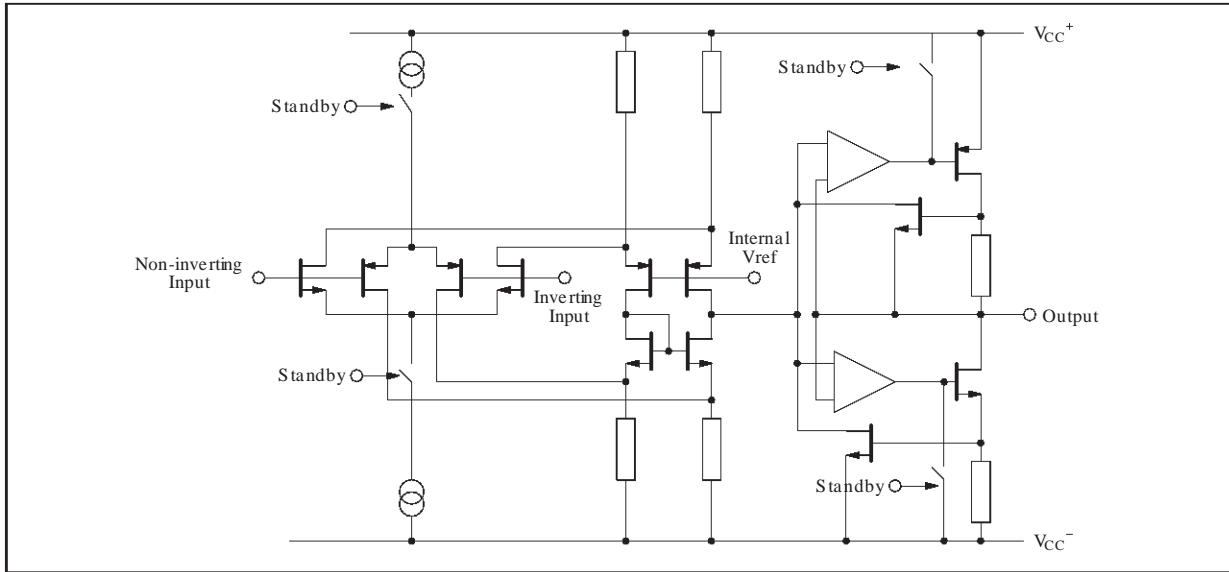
This product offers a broad supply voltage operating range from 2.7V to 16V and a supply current of only 200 $\mu$ A/amp. ( $V_{CC} = 3V$ ).

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

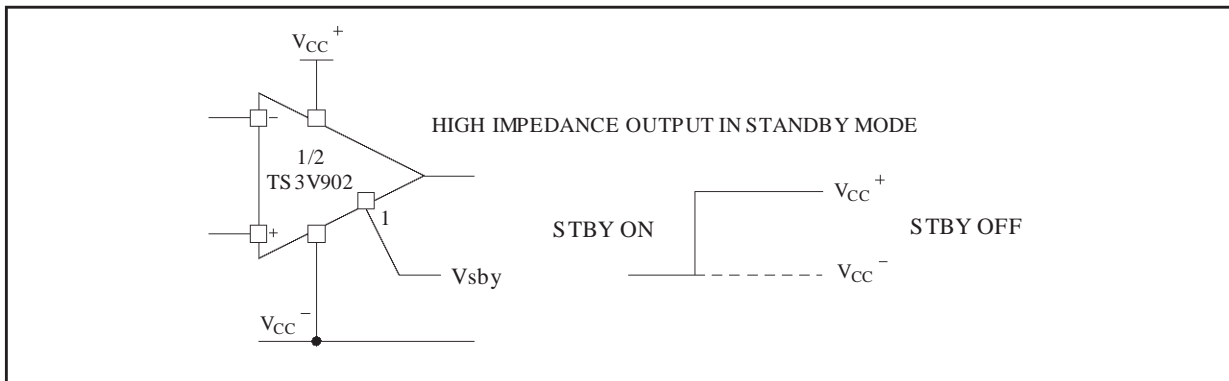
The TS902 can be put on STANDBY position (only 0.5 $\mu$ A and high impedance outputs).

STMicroelectronics is offering a quad op-amp with the same features : TS904.

**SCHEMATIC DIAGRAM (1/2 TS902)**



**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	-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  $V_{CC}/2$ , Standby OFF,  $T_{amb} = 25^\circ C$   
(unless otherwise specified)

Symbol	Parameter	TS902/AI			Unit
		Min.	Typ.	Max.	
$V_{io}$	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 $3V, V_o = 1.5V$		60		dB
SVR	Supply Voltage Rejection Ratio ( $V_{CC}^+ = 2.7$ to $3.3V, V_o = V_{CC}/2$ )		80		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 ( $V_{id} = 1V$ ) $T_{min.} \leq T_{amb} \leq T_{max.}$	$R_L = 10k\Omega$ $R_L = 600\Omega$ $R_L = 100\Omega$ $R_L = 10k\Omega$ $R_L = 600\Omega$	2.9 2.2 2.8 2.1	2.97 2.7 2	V
$V_{OL}$	Low Level Output Voltage ( $V_{id} = -1V$ ) $T_{min.} \leq T_{amb} \leq T_{max.}$	$R_L = 10k\Omega$ $R_L = 600\Omega$ $R_L = 100\Omega$ $R_L = 10k\Omega$ $R_L = 600\Omega$		30 250 900 150 900	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 ( $A_{VCL} = 100, R_L = 10k\Omega, C_L = 100pF, f = 100kHz$ )		0.7		MHz
SR	Slew Rate ( $A_{VCL} = 1, R_L = 10k\Omega, C_L = 100pF, V_i = 1.3V$ to $1.7V$ )		0.5		V/ $\mu s$
$\phi_m$	Phase Margin		30		Degrees
$e_n$	Equivalent Input Noise Voltage ( $R_s = 100\Omega, f = 1kHz$ )		30		$\frac{nV}{\sqrt{Hz}}$

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

**STANDBY MODE**

$V_{CC}^+ = 3V, V_{CC}^- = 0V, T_{amb} = 25^\circ C$  (unless otherwise specified)

Symbol	Parameter	TS902/AI			Unit
		Min.	Typ.	Max.	
$V_{inSBY/ON}$	Pin 1 Threshold Voltage for STANDBY ON		1.2		V
$V_{inSBY/OFF}$	Pin 1 Threshold Voltage for STANDBY OFF		1.2		V
$I_{CC SBY}$	Total Consumption in Standby Position (STANDBY ON)		0.5		$\mu A$

**ELECTRICAL CHARACTERISTICS**

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

Symbol	Parameter	TS902/AI			Unit
		Min.	Typ.	Max.	
$V_{io}$	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 $3.5V, V_o = 2.5V$		85		dB
SVR	Supply Voltage Rejection Ratio ( $V_{CC}^+ = 2.7$ to $3.3V, V_o = V_{CC}/2$ )		80		dB
$A_{vd}$	Large Signal Voltage Gain ( $R_L = 10k\Omega, V_o = 1.5V$ to $3.5V$ ) $T_{min.} \leq T_{amb} \leq T_{max.}$	7 5	30		V/mV
$V_{OH}$	High Level Output Voltage ( $V_{id} = 1V$ ) $T_{min.} \leq T_{amb} \leq T_{max.}$	$R_L = 10k\Omega$ $R_L = 600\Omega$ $R_L = 100\Omega$ $R_L = 10k\Omega$ $R_L = 600\Omega$	4.85 4.2 4.8 4.1	4.95 4.6 3.7	V
$V_{OL}$	Low Level Output Voltage ( $V_{id} = -1V$ ) $T_{min.} \leq T_{amb} \leq T_{max.}$	$R_L = 10k\Omega$ $R_L = 600\Omega$ $R_L = 100\Omega$ $R_L = 10k\Omega$ $R_L = 600\Omega$		50 350 1400 150 900	mV
$I_o$	Output Short Circuit Current ( $V_{id} = \pm 1V$ )	Source ( $V_o = V_{CC}^-$ ) Sink ( $V_o = V_{CC}^+$ )		60 60	mA
GBP	Gain Bandwidth Product ( $A_{VCL} = 100, R_L = 10k\Omega, C_L = 100pF, f = 100kHz$ )		0.8		MHz
SR	Slew Rate ( $A_{VCL} = 1, R_L = 10k\Omega, C_L = 100pF, V_i = 1V$ to $4V$ )		0.8		V/ $\mu s$
$\phi_m$	Phase Margin		30		Degrees

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

**STANDBY MODE**

$V_{CC}^+ = 5V, V_{CC}^- = 0V, T_{amb} = 25^\circ C$  (unless otherwise specified)

Symbol	Parameter	TS902/AI			Unit
		Min.	Typ.	Max.	
$V_{inSBY/ON}$	Pin 1 Threshold Voltage for STANDBY ON		5.2		V
$V_{inSBY/OFF}$	Pin 1 Threshold Voltage for STANDBY OFF		5.2		V
$I_{CC SBY}$	Total Consumption in Standby Position (STANDBY ON)		0.5		$\mu A$

**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	Parameter	TS902/AI			Unit
		Min.	Typ.	Max.	
$V_{io}$	Input Offset Voltage ( $V_{ic} = V_o = V_{CC}/2$ ) $T_{min.} \leq T_{amb} \leq T_{max.}$	TS902 TS902A		10 5	mV
		TS902 TS902A		12 7	
$DV_{io}$	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 $10V$ , $V_o = 5V$		90 70		dB
SVR	Supply Voltage Rejection Ratio ( $V_{CC}^+ = 5$ to $10V$ , $V_o = V_{CC}/2$ )		80		dB
$A_{vd}$	Large Signal Voltage Gain ( $R_L = 10k\Omega$ , $V_o = 2.5V$ to $7.5V$ ) $T_{min.} \leq T_{amb} \leq T_{max.}$		15 10	40	V/mV
$V_{OH}$	High Level Output Voltage ( $V_{id} = 1V$ ) $T_{min.} \leq T_{amb} \leq T_{max.}$	$R_L = 10k\Omega$ $R_L = 600\Omega$ $R_L = 100\Omega$ $R_L = 10k\Omega$ $R_L = 600\Omega$	9.85 9.2 9.8	9.95 9.35 7.8 9	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	mV
$I_o$	Output Short Circuit Current ( $V_{id} = \pm 1V$ )	Source ( $V_o = V_{CC}^-$ ) Sink ( $V_o = V_{CC}^+$ )		60 60	mA
GBP	Gain Bandwidth Product ( $A_{VCL} = 100$ , $R_L = 10k\Omega$ , $C_L = 100pF$ , $f = 100kHz$ )			1.3	MHz
SR	Slew Rate ( $A_{VCL} = 1$ , $R_L = 10k\Omega$ , $C_L = 100pF$ , $V_i = 2.5V$ to $7.5V$ )			1.3	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

**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	TS902/AI			Unit
		Min.	Typ.	Max.	
$V_{inSBY/ON}$	Pin 1 Threshold Voltage for STANDBY ON		8.2		V
$V_{inSBY/OFF}$	Pin 1 Threshold Voltage for STANDBY OFF		8.5		V
$I_{CC SBY}$	Total Consumption in Standby Position (STANDBY ON)		1		$\mu A$

TYPICAL CHARACTERISTICS

Figure 1a : Supply Current (each amplifier) vs Supply Voltage

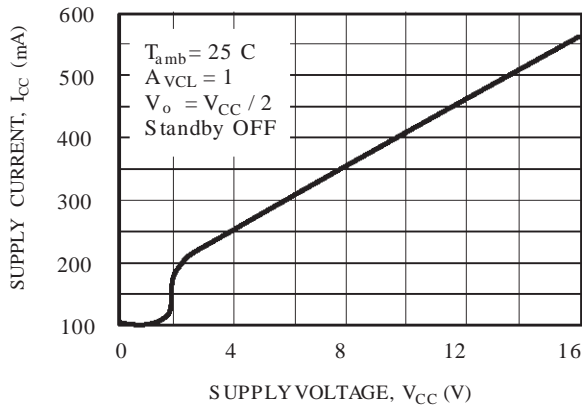


Figure 1b : Supply Current (each amplifier) vs Supply Voltage (in STANDBY mode)

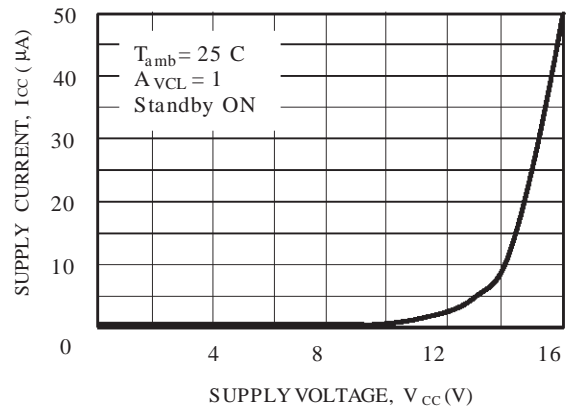


Figure 2 : Input Bias Current vs Temperature

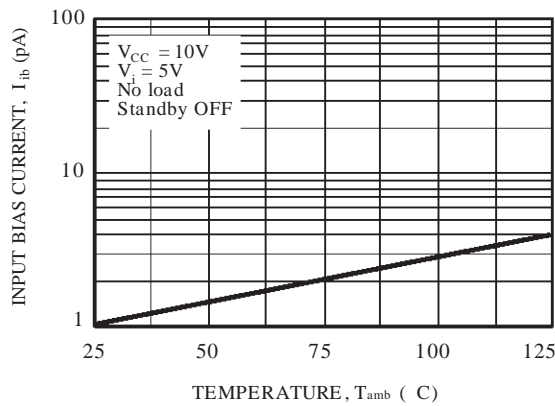


Figure 3a : High Level Output Voltage vs High Level Output Current

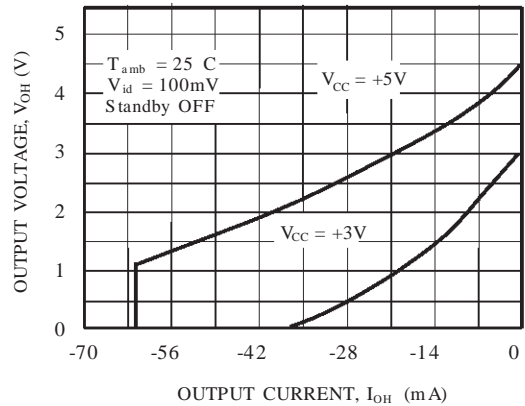


Figure 3b : High Level Output Voltage vs High Level Output Current

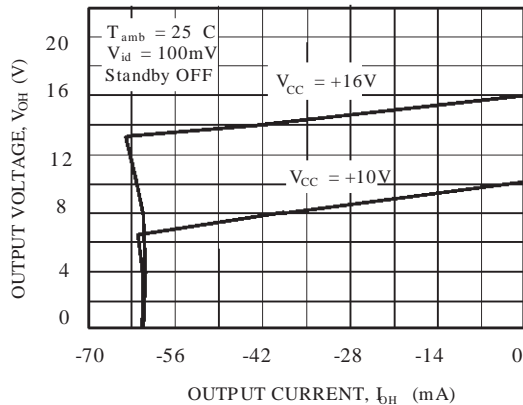
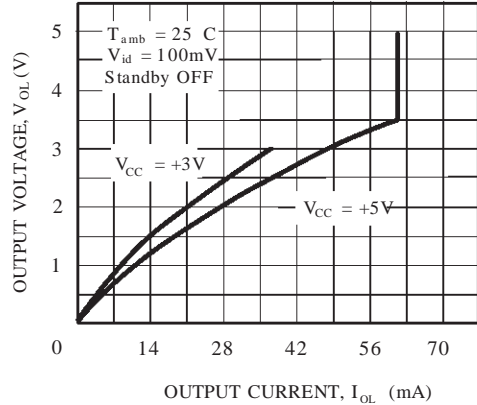
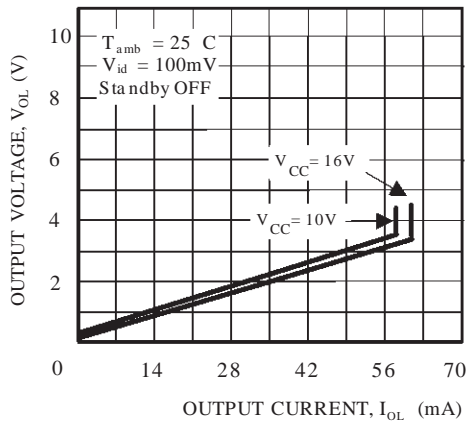


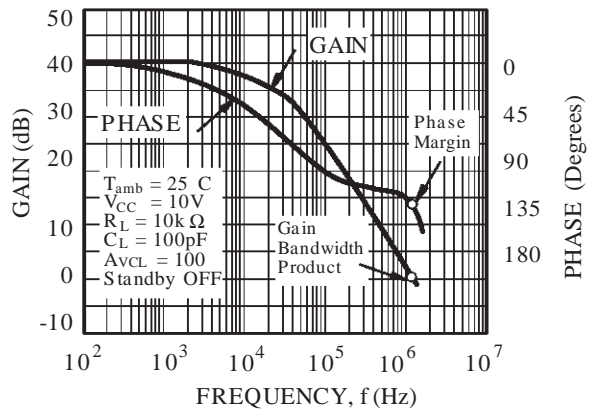
Figure 4a : Low Level Output Voltage vs Low Level Output Current



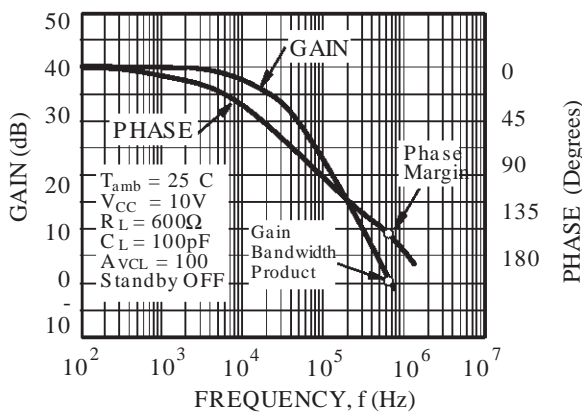
**Figure 4b** : Low Level Output Voltage vs Low Level Output Current



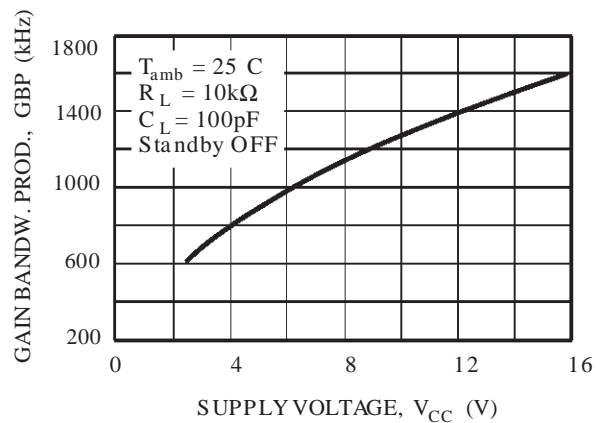
**Figure 5a** : Gain and Phase vs Frequency



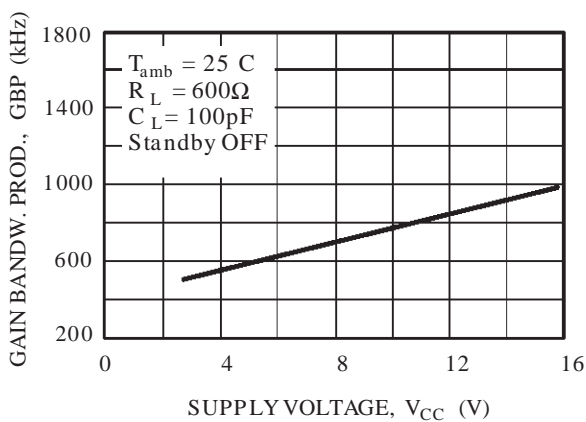
**Figure 5b** : Gain and Phase vs Frequency



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



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



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

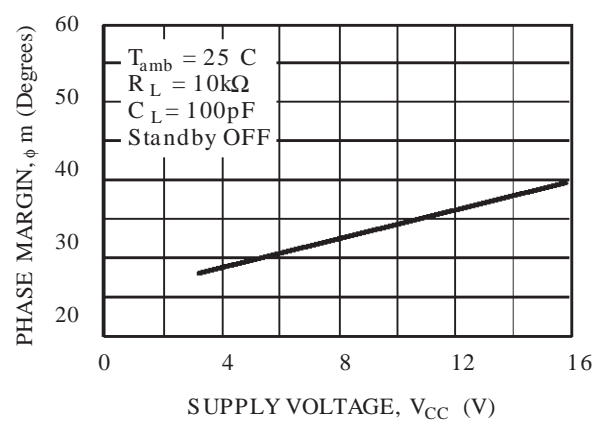


Figure 7b : Phase Margin vs Supply Voltage

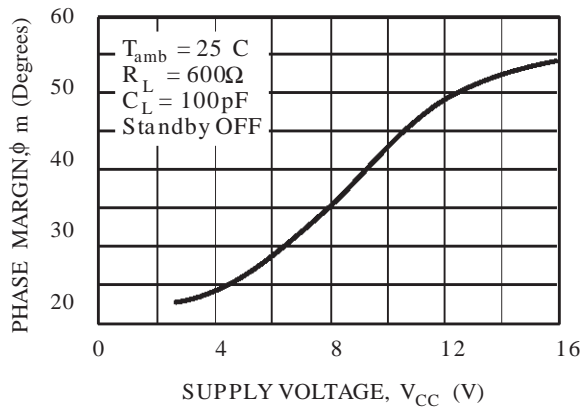
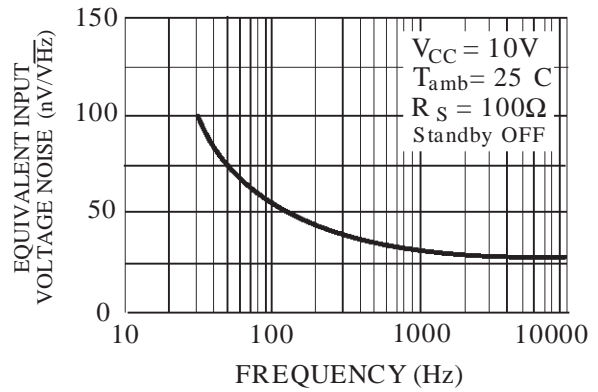


Figure 8 : Input Voltage Noise vs Frequency



**STANDBY APPLICATION**

The two operators of the TS902 are **both** put on **STANDBY**.

In this configuration (standby ON) :

- The **total consumption** of the circuit is considerably **reduced** down to **0.5μA** ( $V_{CC} = 3V$ ). This standby consumption vs  $V_{CC}$  curve is given figure 1b.
- The **both outputs** are in **high impedance** state. No output current can then be sourced or sinked by the device.

The standby pin 1 should never stay unconnected.

- The **”standby OFF”** state, is reached when the pin 1 voltage is **higher than  $V_{in\ SBY/OFF}$** .
- The **”standby ON”** state is assured by a pin 1 voltage **lower than  $V_{in\ SBY/ON}$** . (see electrical characteristics)



## MACROMODEL

- **RAIL TO RAIL** INPUT AND OUTPUT VOLTAGE RANGES
- **STANDBY POSITION** : REDUCED **CONSUMPTION (0.5 $\mu$ 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 **100 $\Omega$**  LOADS
- **LOW SUPPLY CURRENT** : 200 $\mu$ A/Ampli
- **SPEED** : 0.7MHz - 0.5V/ $\mu$ s

### Applies to : TS902I,AI

\*\* 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 TS902 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

COU1 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

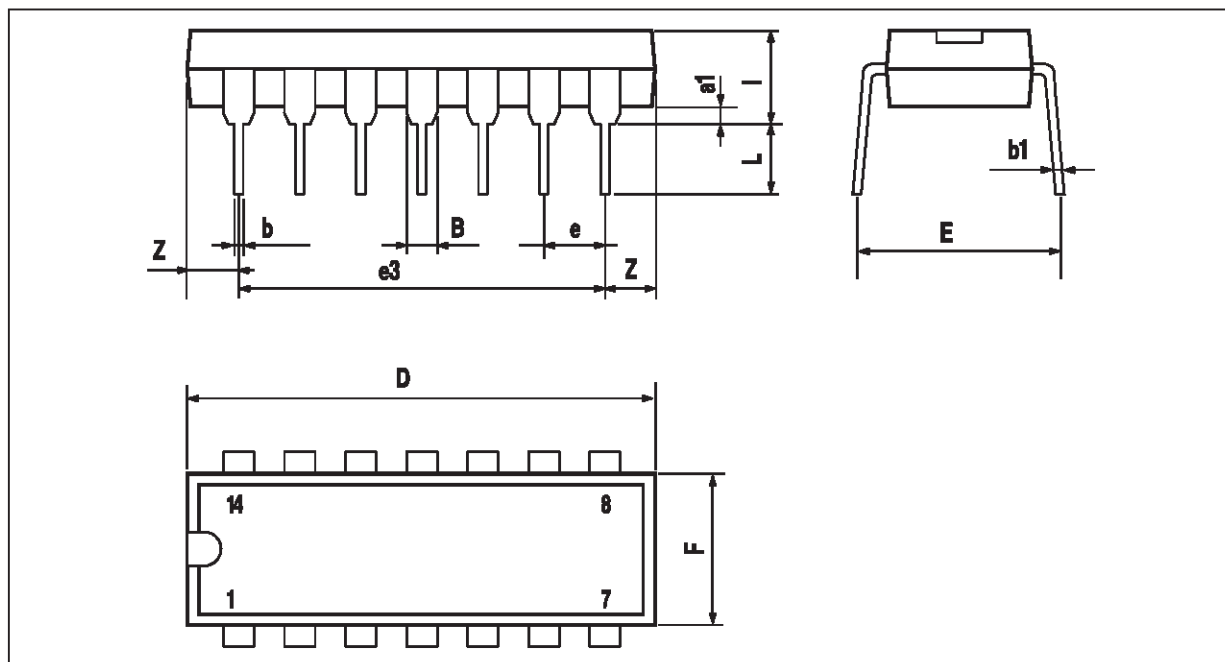
**ELECTRICAL CHARACTERISTICS**

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

Symbol	Conditions	Value	Unit
$V_{io}$		0	mV
$A_{vd}$	$R_L = 10k\Omega$	30	V/mV
$I_{CC}$	No load, per operator	230	$\mu A$
$V_{icm}$		-0.2 to 5.2	V
$V_{OH}$	$R_L = 10k\Omega$	4.95	V
$V_{OL}$	$R_L = 10k\Omega$	50	mV
$I_{sink}$	$V_O = 10V$	60	mA
$I_{source}$	$V_O = 0V$	60	mA
GBP	$R_L = 10k\Omega, C_L = 100pF$	0.8	MHz
SR	$R_L = 10k\Omega, C_L = 100pF$	0.8	V/ $\mu s$
$\varnothing m$	$R_L = 10k\Omega, C_L = 100pF$	30	Degrees
$I_{CC STBY}$	$V_{STBY} = 0V$	500	nA

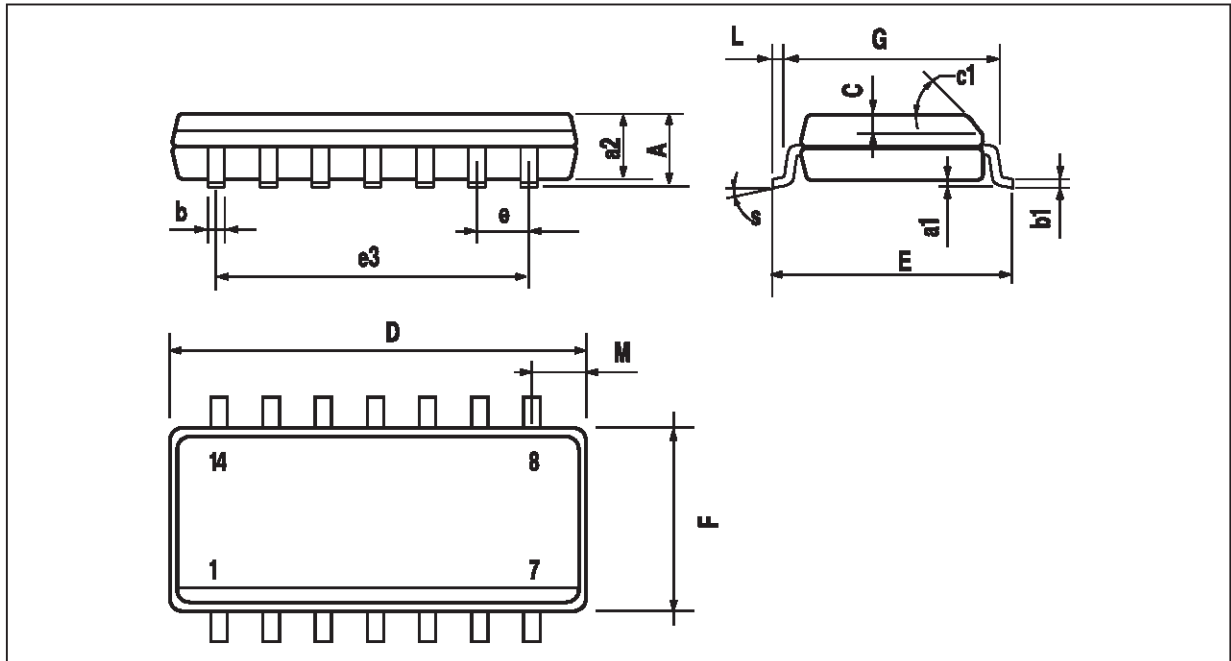
**PACKAGE MECHANICAL DATA**

14 PINS - PLASTIC DIP



Dimensions	Millimeters			Inches		
	Min.	Typ.	Max.	Min.	Typ.	Max.
a1	0.51			0.020		
B	1.39		1.65	0.055		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		15.24			0.600	
F			7.1			0.280
i			5.1			0.201
L		3.3			0.130	
Z	1.27		2.54	0.050		0.100

**PACKAGE MECHANICAL DATA**  
 14 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	8.55		8.75	0.336		0.334
E	5.8		6.2	0.228		0.244
e		1.27			0.050	
e3		7.62			0.300	
F	3.8		4.0	0.150		0.157
G	4.6		5.3	0.181		0.208
L	0.5		1.27	0.020		0.050
M			0.68			0.027
S	8° (max.)					

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