

RAIL TO RAIL CMOS DUAL OPERATIONAL AMPLIFIER

- RAIL TO RAIL INPUT AND OUTPUT VOLTAGE RANGES
- SINGLE (OR DUAL) SUPPLY OPERATION FROM **2.7V TO 16V**
- EXTREMELY LOW INPUT BIAS CURRENT : **1pA** typ
- LOW INPUT OFFSET VOLTAGE : **2mV max.**
- SPECIFIED FOR **600Ω** AND **100Ω** LOADS
- LOW SUPPLY CURRENT : 200μA/Ampli ($V_{CC} = 3V$)
- LATCH-UP IMMUNITY
- ESD TOLERANCE : 3KV
- **SPICE MACROMODEL** INCLUDED IN THIS-SPECIFICATION

DESCRIPTION

The TS912 is a RAIL TO RAIL CMOS dual 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}^- .

At 3V, the output reaches :

- $V_{CC}^- + 30mV$ $V_{CC}^+ - 40mV$ with $R_L = 10k\Omega$
- $V_{CC}^- + 300mV$ $V_{CC}^+ - 400mV$ with $R_L = 600\Omega$

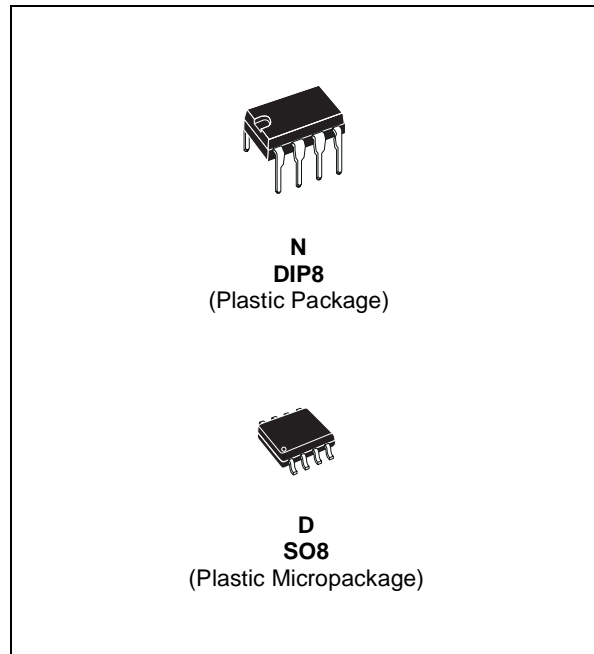
This product offers a broad supply voltage operating range from 2.7V to 16V and a supply current of only 200μA/amp @ $V_{CC} = 3V$.

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

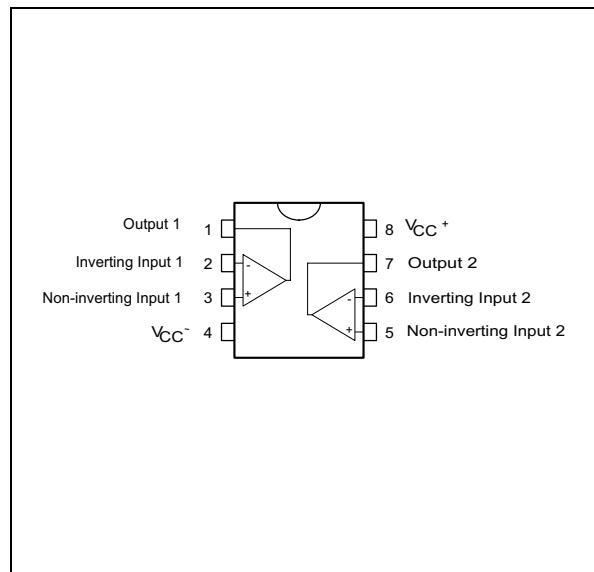
ORDER CODE

Part Number	Temperature Range	Package	
		N	D
TS912I/AI/BI	-40, +125°C	•	•

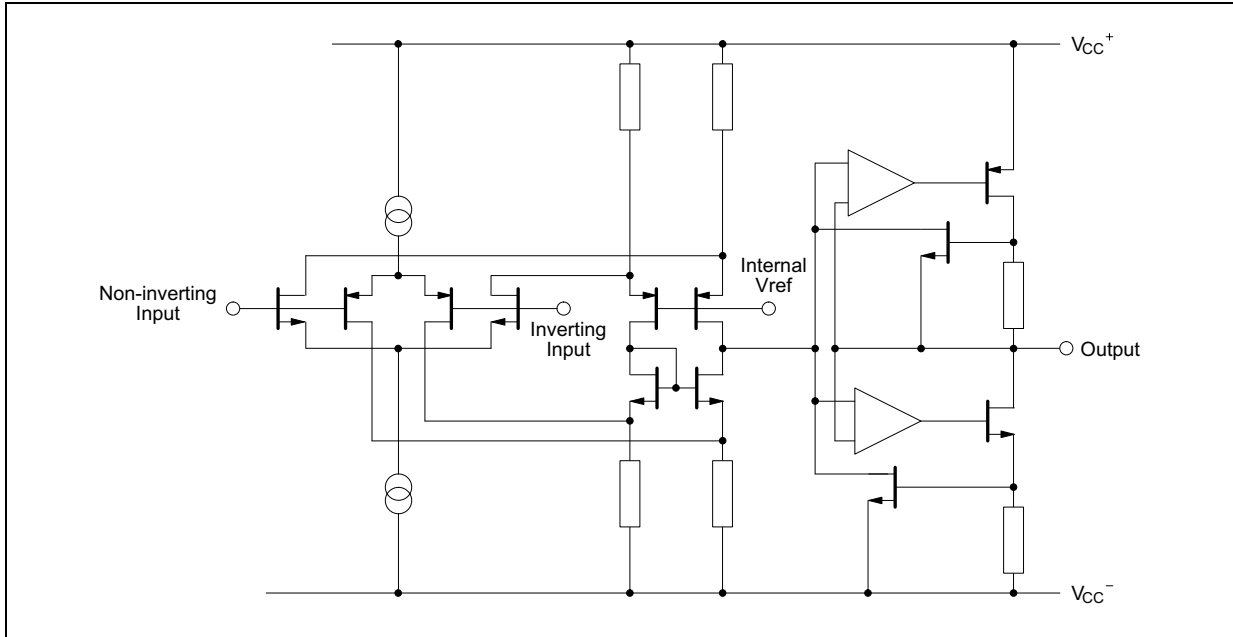
N = Dual in Line Package (DIP)
D = Small Outline Package (SO) - also available in Tape & Reel (DT)



PIN CONNECTIONS (top view)



SCHEMATIC DIAGRAM (1/2 TS912)



ABSOLUTE MAXIMUM RATINGS

Symbol	Parameter	Value	Unit
V_{CC}	Supply voltage ¹⁾	18	V
V_{id}	Differential Input Voltage ²⁾	± 18	V
V_i	Input Voltage 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 TS912/AI/BI	-40 to + 125	$^{\circ}C$
T_{stg}	Storage Temperature	-65 to +150	$^{\circ}C$

1. All voltages values, except differential voltage are with respect to network ground terminal.
2. Differential voltages are 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 $V_{CC/2}$, $T_{amb} = 25^\circ C$ (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 2 12 7 3	mV
ΔV_{io}	Input Offset Voltage Drift		5		$\mu V/^\circ C$
I_{io}	Input Offset Current ¹⁾ $T_{min.} \leq T_{amb} \leq T_{max.}$		1	100 200	pA
I_{ib}	Input Bias Current 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 $3V$, $V_o = 1.5V$		70		dB
SVR	Supply Voltage Rejection Ratio ($V_{CC^+} = 2.7$ to $3.3V$, $V_o = V_{CC/2}$)	50	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 ($V_{id} = 1V$) $T_{min.} \leq T_{amb} \leq T_{max.}$	$R_L = 100k\Omega$ 2.95 $R_L = 10k\Omega$ 2.9 $R_L = 600\Omega$ 2.3 $R_L = 100\Omega$	2.96 2.6 2		V
V_{OL}	Low Level Output Voltage ($V_{id} = -1V$) $T_{min.} \leq T_{amb} \leq T_{max.}$	$R_L = 100k\Omega$ $R_L = 10k\Omega$ $R_L = 600\Omega$ $R_L = 100\Omega$	30 300 900	50 70 400 100 600	mV
I_o	Output Short Circuit Current ($V_{id} = \pm 1V$) Source ($V_o = V_{CC^-}$) Sink ($V_o = V_{CC^+}$)	20 20	40 40		mA
GBP	Gain Bandwidth Product ($A_{VCL} = 100$, $R_L = 10k\Omega$, $C_L = 100pF$, $f = 100kHz$)		0.8		MHz
SR ⁺	Slew Rate ($A_{VCL} = 1$, $R_L = 10k\Omega$, $C_L = 100pF$, $V_i = 1.3V$ to $1.7V$)		0.4		V/ μs
SR ⁻	Slew Rate ($A_{VCL} = 1$, $R_L = 10k\Omega$, $C_L = 100pF$, $V_i = 1.3V$ to $1.7V$)		0.3		V/ μs
ϕ_m	Phase Margin		30		Degrees
en	Equivalent Input Noise Voltage ($R_s = 100\Omega$, $f = 1kHz$)		30		nV/ \sqrt{Hz}

1. Maximum values including unavoidable inaccuracies of the industrial test

ELECTRICAL CHARACTERISTICS

$V_{CC^+} = 5V$, $V_{CC^-} = 0V$, R_L , C_L connected to $V_{CC/2}$, $T_{amb} = 25^\circ C$ (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 2 12 7 3	mV
ΔV_{io}	Input Offset Voltage Drift		5		$\mu V/^\circ C$
I_{io}	Input Offset Current ¹⁾ $T_{min.} \leq T_{amb} \leq T_{max.}$		1	100 200	pA
I_{ib}	Input Bias Current 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 $3.5V$, $V_o = 2.5V$	60	85		dB
SVR	Supply Voltage Rejection Ratio ($V_{CC^+} = 3$ to $5V$, $V_o = V_{CC/2}$)	55	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	40		V/mV
V_{OH}	High Level Output Voltage ($V_{id} = 1V$) $T_{min.} \leq T_{amb} \leq T_{max.}$	$R_L = 100k\Omega$ 4.95 $R_L = 10k\Omega$ 4.9 $R_L = 600\Omega$ 4.25 $R_L = 100\Omega$	4.95 4.95 4.55 3.7		V
V_{OL}	Low Level Output Voltage ($V_{id} = -1V$) $T_{min.} \leq T_{amb} \leq T_{max.}$	$R_L = 100k\Omega$ $R_L = 10k\Omega$ $R_L = 600\Omega$ $R_L = 100\Omega$	40 350 1400	50 100 500 150 750	mV
I_o	Output Short Circuit Current ($V_{id} = \pm 1V$) Source ($V_o = V_{CC^-}$) Sink ($V_o = V_{CC^+}$)	45 45	65 65		mA
GBP	Gain Bandwidth Product ($A_{VCL} = 100$, $R_L = 10k\Omega$, $C_L = 100pF$, $f = 100kHz$)		1		MHz
SR ⁺	Slew Rate ($A_{VCL} = 1$, $R_L = 10k\Omega$, $C_L = 100pF$, $V_i = 1V$ to $4V$)		0.8		
SR ⁻	Slew Rate ($A_{VCL} = 1$, $R_L = 10k\Omega$, $C_L = 100pF$, $V_i = 1V$ to $4V$)		0.6		V/ μs
en	Equivalent Input Noise Voltage ($R_s = 100\Omega$, $f = 1kHz$)		30		nV/ \sqrt{Hz}
V_{O1}/V_{O2}	Channel Separation ($f = 1kHz$)		120		dB
ϕ_m	Phase Margin		30		Degrees

1. Maximum values including unavoidable inaccuracies of the industrial test

ELECTRICAL CHARACTERISTICS

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

Symbol	Parameter	Min.	Typ.	Max.	Unit
V_{io}	Input Offset Voltage ($V_{ic} = V_o = V_{CC/2}$)			10	mV
	$T_{min.} \leq T_{amb} \leq T_{max.}$			5	
				2	
				12	
				7	
				3	
ΔV_{io}	Input Offset Voltage Drift		5		$\mu V/^\circ C$
I_{io}	Input Offset Current ¹⁾		1	100	pA
	$T_{min.} \leq T_{amb} \leq T_{max.}$			200	
I_{ib}	Input Bias Current ¹⁾		1	150	pA
	$T_{min.} \leq T_{amb} \leq T_{max.}$			300	
I_{CC}	Supply Current (per amplifier, $A_{VCL} = 1$, no load)		400	600	μA
	$T_{min.} \leq T_{amb} \leq T_{max.}$			700	
CMR	Common Mode Rejection Ratio				dB
	$V_{ic} = 3$ to $7V$, $V_o = 5V$	60	90		
	$V_{ic} = 0$ to $10V$, $V_o = 5V$	50	75		
SVR	Supply Voltage Rejection Ratio ($V_{CC^+} = 5$ to $10V$, $V_o = V_{CC/2}$)	60	90		dB
A_{vd}	Large Signal Voltage Gain ($R_L = 10k\Omega$, $V_o = 2.5V$ to $7.5V$)	15	50		V/mV
	$T_{min.} \leq T_{amb} \leq T_{max.}$	10			
V_{OH}	High Level Output Voltage ($V_{id} = 1V$)	$R_L = 100k\Omega$	9.95		V
		$R_L = 10k\Omega$	9.85	9.95	
	$R_L = 600\Omega$	9	9.35		
	$R_L = 100\Omega$		7.8		
	$T_{min.} \leq T_{amb} \leq T_{max.}$	$R_L = 10k\Omega$	9.8		
		$R_L = 600\Omega$	8.8		
V_{OL}	Low Level Output Voltage ($V_{id} = -1V$)	$R_L = 100k\Omega$		50	mV
		$R_L = 10k\Omega$		150	
	$R_L = 600\Omega$		800		
	$R_L = 100\Omega$				
	$T_{min.} \leq T_{amb} \leq T_{max.}$	$R_L = 10k\Omega$		150	
		$R_L = 600\Omega$		900	
I_o	Output Short Circuit Current ($V_{id} = \pm 1V$)				mA
	Source ($V_o = V_{CC^-}$)	45	65		
	Sink ($V_o = V_{CC^+}$)	50	75		
GBP	Gain Bandwidth Product ($A_{VCL} = 100$, $R_L = 10k\Omega$, $C_L = 100pF$, $f = 100kHz$)		1.4		MHz
SR ⁺	Slew Rate ($A_{VCL} = 1$, $R_L = 10k\Omega$, $C_L = 100pF$, $V_i = 2.5V$ to $7.5V$)		1.3		V/ μs
SR ⁻	Slew Rate ($A_{VCL} = 1$, $R_L = 10k\Omega$, $C_L = 100pF$, $V_i = 2.5V$ to $7.5V$)		0.8		
ϕ_m	Phase Margin		40		Degrees
en	Equivalent Input Noise Voltage ($R_s = 100\Omega$, $f = 1kHz$)		30		nV/ \sqrt{Hz}
THD	Total Harmonic Distortion ($A_{VCL} = 1$, $R_L = 10k\Omega$, $C_L = 100pF$, $V_o = 4.75V$ to $5.25V$, $f = 1kHz$)		0.02		%
C_{in}	Input Capacitance		1.5		pF

1. Maximum values including unavoidable inaccuracies of the industrial test



TYPICAL CHARACTERISTICS

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

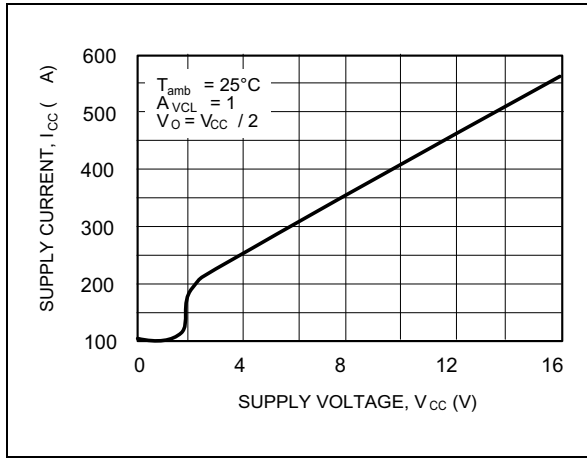


Figure 2 : Input Bias Current vs Temperature

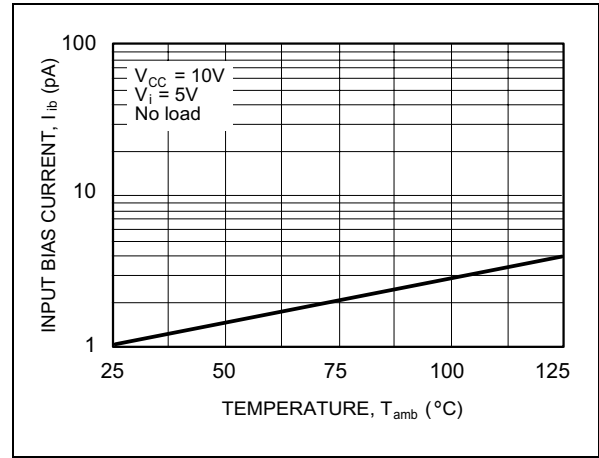


Figure 3a : High Level Output Voltage vs High Level Output Current

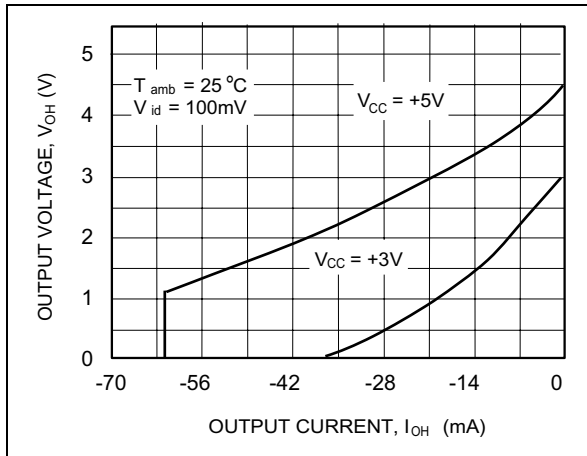


Figure 3b : High Level Output Voltage vs High Level Output Current

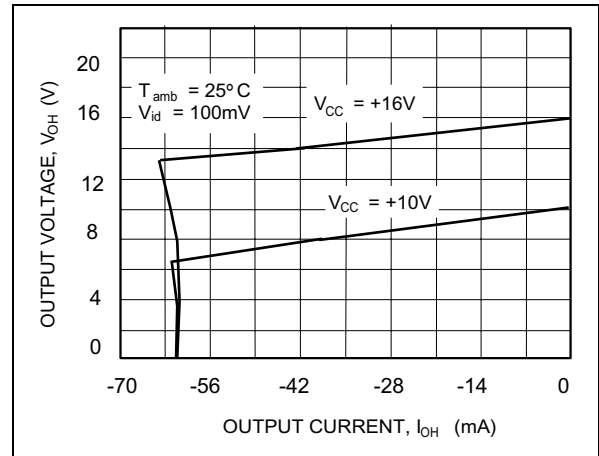


Figure 4a : Low Level Output Voltage vs Low Level Output Current

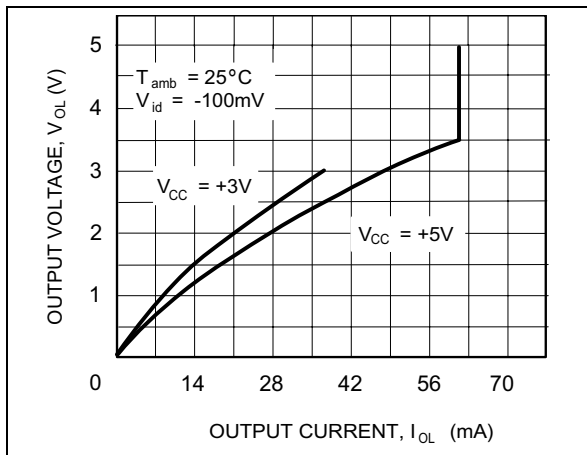


Figure 4b : Low Level Output Voltage vs Low Level Output Current

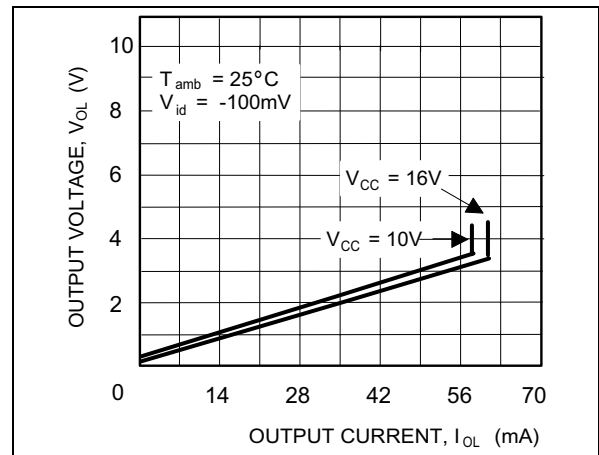


Figure 5a : Gain and Phase vs Frequency

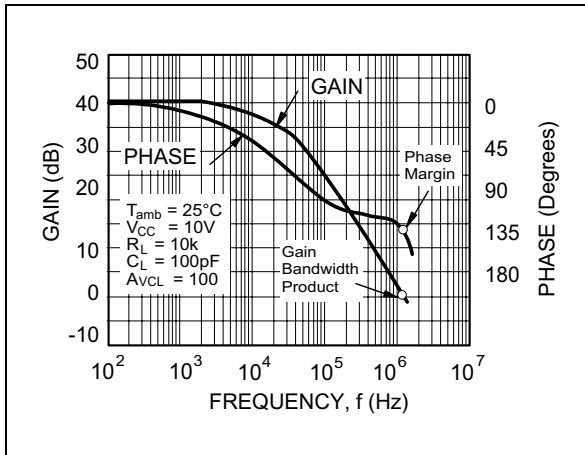


Figure 5b : Gain and Phase vs Frequency

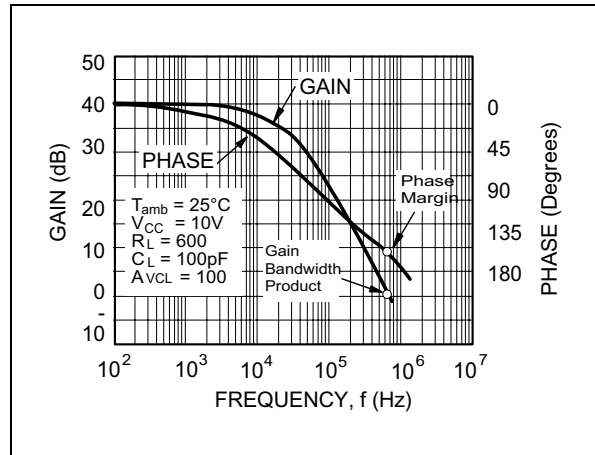


Figure 6a : Gain Bandwidth Product vs Supply Voltage

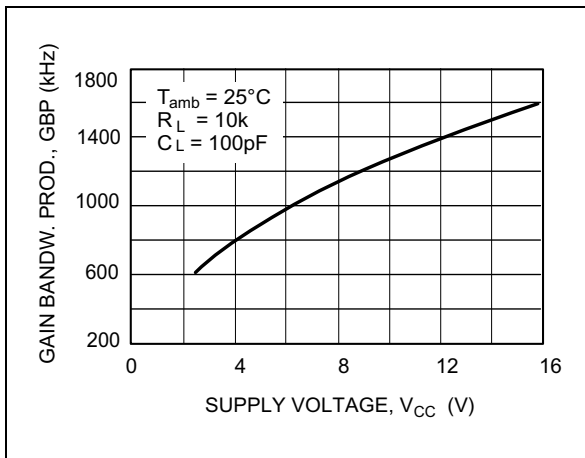


Figure 6b : Gain Bandwidth Product vs Supply Voltage

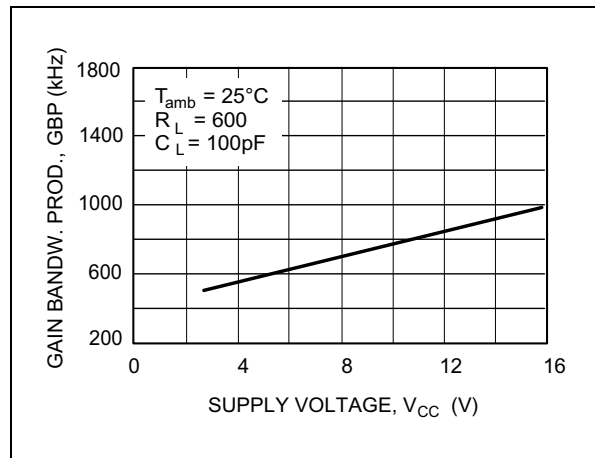


Figure 7a : Phase Margin vs Supply Voltage

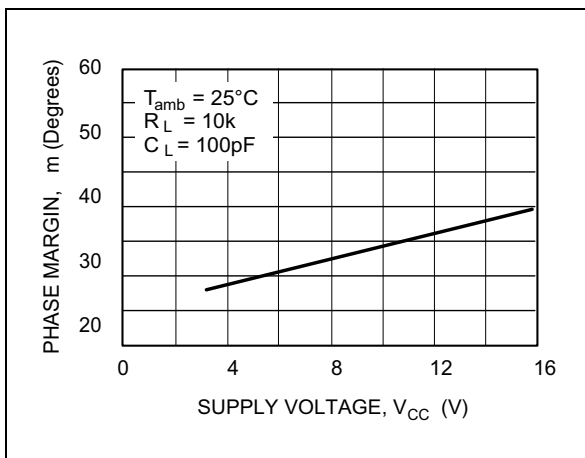


Figure 7b : Phase Margin vs Supply Voltage

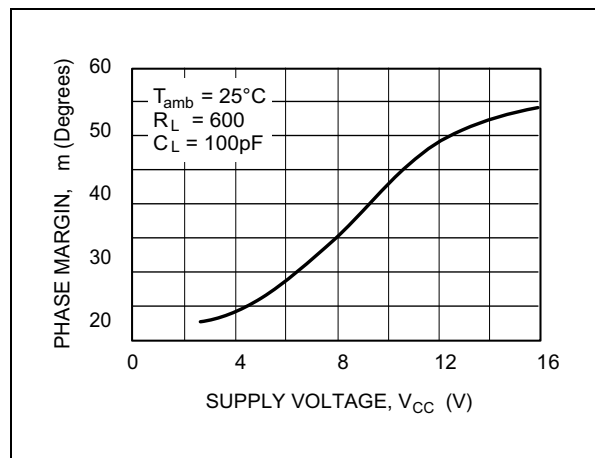
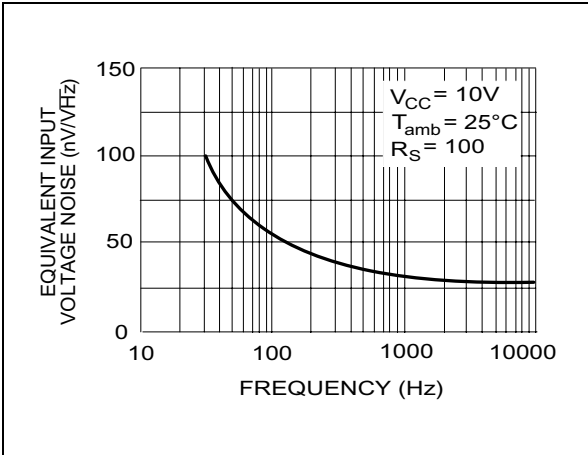


Figure 8 : Input Voltage Noise vs Frequency



MACROMODEL

Applies to : TS912 (V_{CC} = 3V)

** Standard Linear Ics Macromodels, 1993.

** CONNECTIONS :

* 1 INVERTING INPUT

* 2 NON-INVERTING INPUT

* 3 OUTPUT

* 4 POSITIVE POWER SUPPLY

* 5 NEGATIVE POWER SUPPLY

.SUBCKT TS912_3 1 3 2 4 5 (analog)

.MODEL MDTH D IS=1E-8 KF=6.564344E-14 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 6.500000E+00

RIN 15 16 6.500000E+00

RIS 11 15 1.271505E+01

DIP 11 12 MDTH 400E-12

DIN 15 14 MDTH 400E-12

VOFP 12 13 DC 0.000000E+00

VOFN 13 14 DC 0

IPOL 13 5 4.000000E-05

CPS 11 15 2.125860E-08

DINN 17 13 MDTH 400E-12

VIN 17 5 0.000000E+00

DINR 15 18 MDTH 400E-12

VIP 4 18 0.000000E+00

FCP 4 5 VOFP 5.000000E+00

FCN 5 4 VOFN 5.000000E+00

* AMPLIFYING STAGE

FIP 5 19 VOFP 2.750000E+02

FIN 5 19 VOFN 2.750000E+02

RG1 19 5 1.916825E+05

RG2 19 4 1.916825E+05

CC 19 29 2.200000E-08

HZTP 30 29 VOFP 1.3E+03

HZTN 5 30 VOFN 1.3E+03

DOPM 19 22 MDTH 400E-12

DONM 21 19 MDTH 400E-12

HOPM 22 28 VOUT 3800

VIPM 28 4 150

HONM 21 27 VOUT 3800

VINM 5 27 150

EOUT 26 23 19 5 1

VOUT 23 5 0

ROUT 26 3 75

COUT 3 5 1.000000E-12

DOP 19 68 MDTH 400E-12

VOP 4 25 1.724

HSCP 68 25 VSCP1 0.8E8

DON 69 19 MDTH 400E-12

VON 24 5 1.7419107

HSCN 24 69 VSCN1 0.8E+08

VSCTHP 60 61 0.0875

** VSCTHP = le seuil au dessus de vio * 500

** c.a.d 275U-000U dus a l'offset

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 -0.55

** VSCTHN = le seuil au dessous de vio * 2000

** c.a.d -375U-000U dus a l'offset

ESCP 60 0 2 1 500

ESCN 70 0 2 1 -2000

.ENDS

ELECTRICAL CHARACTERISTICS

V_{CC}⁺ = 3V, V_{CC}⁻ = 0V, R_L, C_L connected to V_{CC}⁺, T_{amb} = 25°C (unless otherwise specified)

Symbol	Conditions	Value	Unit
V _{io}		0	mV
A _{vd}	R _L = 10kΩ	10	V/mV
I _{CC}	No load, per operator	200	μA
V _{icm}		-0.2 to 3.2	V
V _{OH}	R _L = 10kΩ	2.96	V
V _{OL}	R _L = 10kΩ	30	mV
I _{sink}	V _O = 3V	40	mA
I _{source}	V _O = 0V	40	mA
GBP	R _L = 10kΩ, C _L = 100pF	0.8	MHz
SR	R _L = 10kΩ, C _L = 100pF	0.3	V/μs



MACROMODEL

Applies to : TS912 (V_{CC} = 5V)

** 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 TS912_5 1 3 2 4 5 (analog)

.MODEL MDTH D IS=1E-8 KF=6.564344E-14 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 6.500000E+00

RIN 15 16 6.500000E+00

RIS 11 15 7.322092E+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

IPOL 13 5 4.000000E-05

CPS 11 15 2.498970E-08

DINN 17 13 MDTH 400E-12

VIN 17 5 0.000000E+00

DINR 15 18 MDTH 400E-12

VIP 4 18 0.000000E+00

FCP 4 5 VOFP 5.750000E+00

FCN 5 4 VOFN 5.750000E+00

ISTB0 5 4 500N

* AMPLIFYING STAGE

FIP 5 19 VOFP 4.400000E+02

FIN 5 19 VOFN 4.400000E+02

RG1 19 5 4.904961E+05

RG2 19 4 4.904961E+05

CC 19 29 2.200000E-08

HZTP 30 29 VOFP 1.8E+03

HZTN 5 30 VOFN 1.8E+03

DOPM 19 22 MDTH 400E-12

DONM 21 19 MDTH 400E-12

HOPM 22 28 VOUT 3800

VIPM 28 4 230

HONM 21 27 VOUT 3800

VINM 5 27 230

EOUT 26 23 19 5 1

VOUT 23 5 0

ROUT 26 3 82

COUT 3 5 1.000000E-12

DOP 19 68 MDTH 400E-12

VOP 4 25 1.724

HSCP 68 25 VSCP1 0.8E+08

DON 69 19 MDTH 400E-12

VON 24 5 1.7419107

HSCN 24 69 VSCN1 0.8E+08

VSCTHP 60 61 0.0875

** VSCTHP = le seuil au dessus de vio * 500

** c.a.d 275U-000U dus a l'offset

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 -0.55

** VSCTHN = le seuil au dessous de vio * 2000

** c.a.d -375U-000U dus a l'offset

ESCP 60 0 2 1 500

ESCN 70 0 2 1 -2000

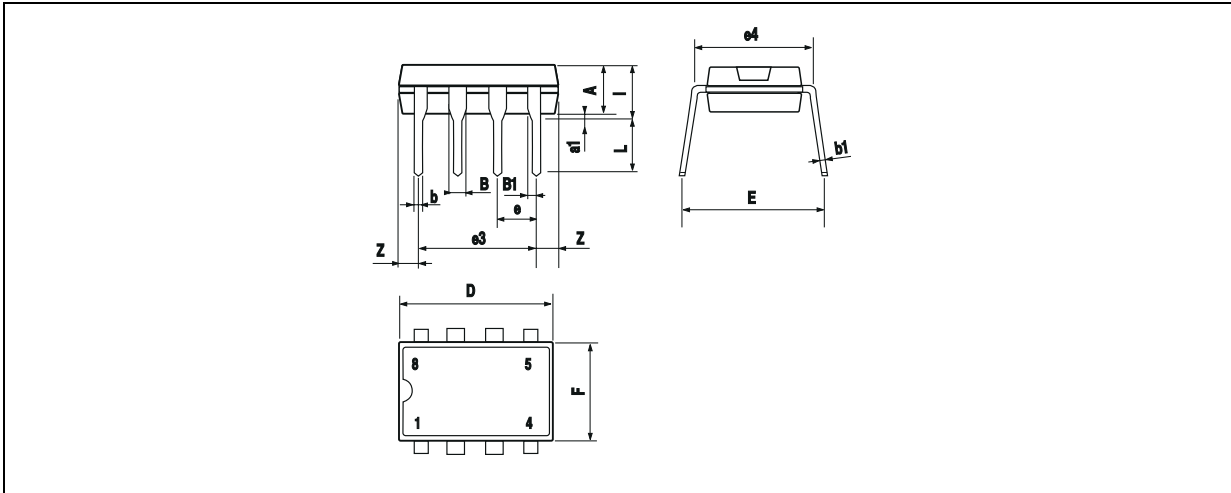
.ENDS

ELECTRICAL CHARACTERISTICS

V_{CC+} = 5V, V_{CC-} = 0V, R_L, C_L connected to V_{CC}/2, T_{amb} = 25°C (unless otherwise specified)

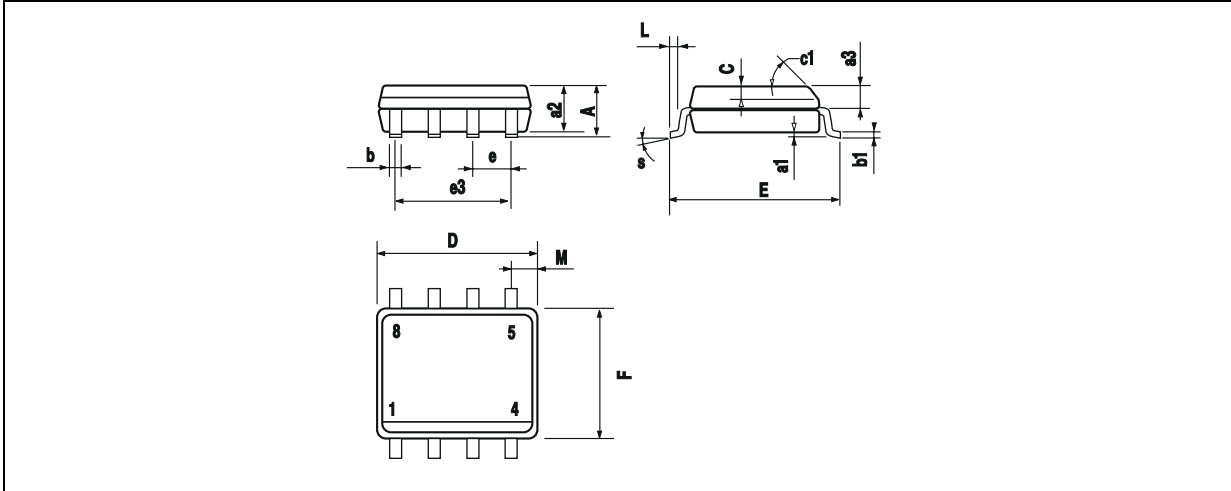
Symbol	Conditions	Value	Unit
V _{io}		0	mV
A _{vd}	R _L = 10kΩ	50	V/mV
I _{CC}	No load, per operator	230	μA
V _{icm}		-0.2 to 5.2	V
V _{OH}	R _L = 10kΩ	4.95	V
V _{OL}	R _L = 10kΩ	40	mV
I _{sink}	V _O = 5V	65	mA
I _{source}	V _O = 0V	65	mA
GBP	R _L = 10kΩ, C _L = 100pF	1	MHz
SR	R _L = 10kΩ, C _L = 100pF	0.8	V/μs

PACKAGE MECHANICAL DATA
8 PINS - PLASTIC DIP



Dim.	Millimeters			Inches		
	Min.	Typ.	Max.	Min.	Typ.	Max.
A		3.32			0.131	
a1	0.51			0.020		
B	1.15		1.65	0.045		0.065
b	0.356		0.55	0.014		0.022
b1	0.204		0.304	0.008		0.012
D			10.92			0.430
E	7.95		9.75	0.313		0.384
e		2.54			0.100	
e3		7.62			0.300	
e4		7.62			0.300	
F			6.6			0.260
i			5.08			0.200
L	3.18		3.81	0.125		0.150
Z			1.52			0.060

PACKAGE MECHANICAL DATA
8 PINS - PLASTIC MICROPACKAGE (SO)



Dim.	Millimeters			Inches		
	Min.	Typ.	Max.	Min.	Typ.	Max.
A			1.75			0.069
a1	0.1		0.25	0.004		0.010
a2			1.65			0.065
a3	0.65		0.85	0.026		0.033
b	0.35		0.48	0.014		0.019
b1	0.19		0.25	0.007		0.010
C	0.25		0.5	0.010		0.020
c1	45° (typ.)					
D	4.8		5.0	0.189		0.197
E	5.8		6.2	0.228		0.244
e		1.27			0.050	
e3		3.81			0.150	
F	3.8		4.0	0.150		0.157
L	0.4		1.27	0.016		0.050
M			0.6			0.024
S	8° (max.)					

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