



TS914

# RAIL TO RAIL CMOS QUAD 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
  
- SPICE MACROMODEL INCLUDED IN THIS-SPECIFICATION

### DESCRIPTION

The TS914 is a RAIL TO RAIL CMOS quad 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  $R_L = 600\Omega$

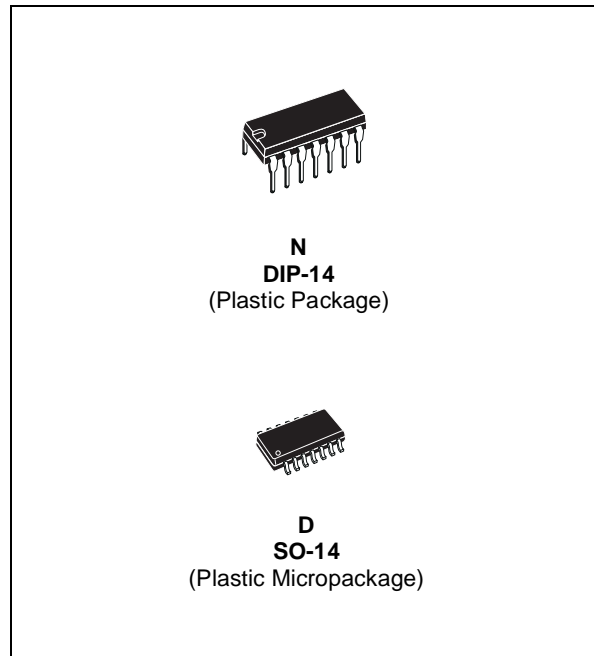
This product offers a broad supply voltage operating range from 2.7V to 16V and a supply current of only 200μA/amp. ( $V_{CC} = 3V$ ).

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

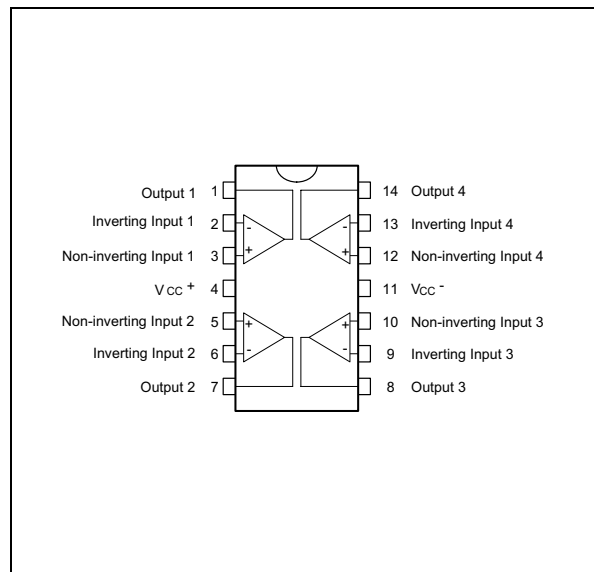
### ORDER CODE

Part Number	Temperature Range	Package	
		N	D
TS914I/AI	-40, +125°C	•	•

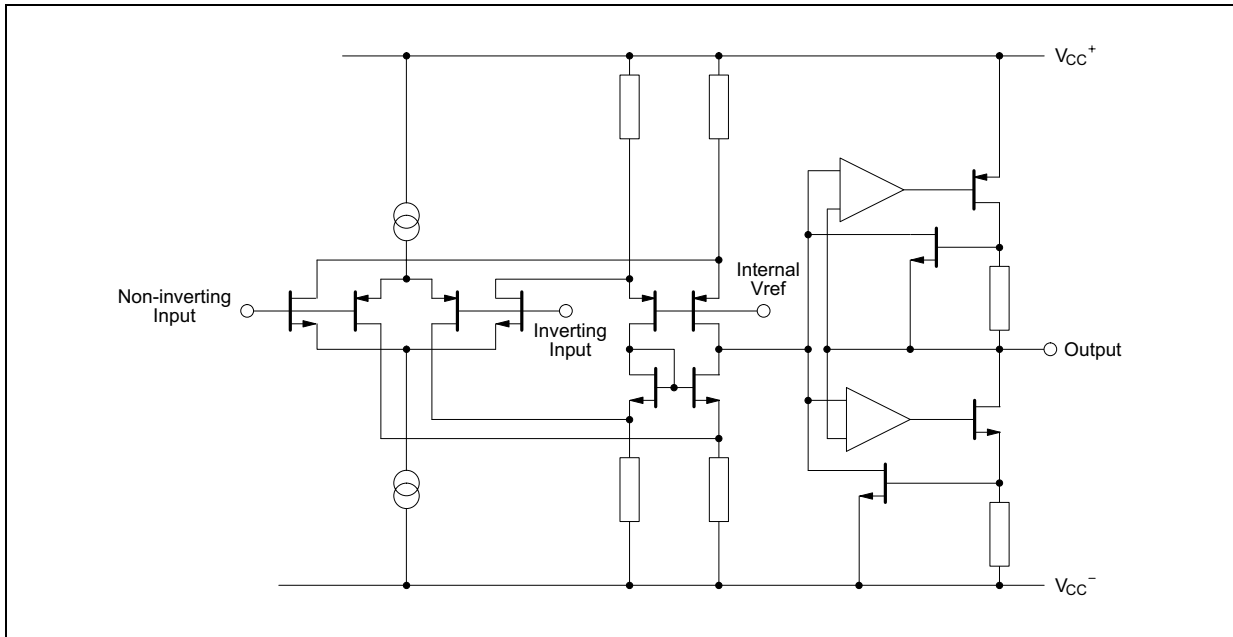
N = Dual in Line Package (DIP)  
D = Small Outline Package (SO) - also available in Tape & Reel (DT)



### PIN CONNECTIONS (top view)



**SCHEMATIC DIAGRAM (1/2 TS914)**



**ABSOLUTE MAXIMUM RATINGS**

Symbol	Parameter	Value	Unit
$V_{CC}$	Supply voltage <sup>1)</sup>	18	V
$V_{id}$	Differential Input Voltage <sup>2)</sup>	$\pm 18$	V
$V_i$	Input Voltage <sup>3)</sup>	-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 TS914/AI	-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 12 7	mV
$\Delta V_{io}$	Input Offset Voltage Drift		5		$\mu V/^\circ C$
$I_{io}$	Input Offset Current <sup>1)</sup> $T_{min.} \leq T_{amb} \leq T_{max.}$		1	100 200	pA
$I_{ib}$	Input Bias Current <sup>1)</sup> $T_{min.} \leq T_{amb} \leq T_{max.}$		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 $3V$ , $V_o = 1.5V$		70		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 ( $V_{id} = 1V$ ) $T_{min.} \leq T_{amb} \leq T_{max.}$	$R_L = 10k\Omega$ 2.9 $R_L = 600\Omega$ 2.2 $R_L = 100\Omega$ 2.8 $R_L = 10k\Omega$ 2.1 $R_L = 600\Omega$	2.97 2.7 2		V
$V_{OL}$	Low Level Output Voltage ( $V_{id} = -1V$ ) $T_{min.} \leq T_{amb} \leq T_{max.}$	$R_L = 10k\Omega$ $R_L = 600\Omega$ $R_L = 100\Omega$ $R_L = 10k\Omega$ $R_L = 600\Omega$	50 300 900	100 600 150 900	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 ( $A_{VCL} = 100$ , $R_L = 10k\Omega$ , $C_L = 100pF$ , $f = 100kHz$ )		0.8		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
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

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 12 7	mV
$\Delta V_{io}$	Input Offset Voltage Drift		5		$\mu V/^\circ C$
$I_{io}$	Input Offset Current <sup>1)</sup> $T_{min.} \leq T_{amb} \leq T_{max.}$		1	100 200	pA
$I_{ib}$	Input Bias Current <sup>1)</sup> $T_{min.} \leq T_{amb} \leq T_{max.}$		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 ( $V_{CC^+} = 3$ to $5V$ , $V_o = V_{CC/2}$ )		80		dB
$A_{vd}$	Large Signal Voltage Gain ( $R_L = 10k\Omega$ , $V_o = 1.5V$ to $3.5V$ ) $T_{min.} \leq T_{amb} \leq T_{max.}$	10 7	40		V/mV
$V_{OH}$	High Level Output Voltage ( $V_{id} = 1V$ ) $T_{min.} \leq T_{amb} \leq T_{max.}$	$R_L = 10k\Omega$ 4.85 $R_L = 600\Omega$ 4.20 $R_L = 100\Omega$ 4.8 $R_L = 10k\Omega$ 4.1 $R_L = 600\Omega$	4.95 4.65 3.7		V
$V_{OL}$	Low Level Output Voltage ( $V_{id} = -1V$ ) $T_{min.} \leq T_{amb} \leq T_{max.}$	$R_L = 10k\Omega$ $R_L = 600\Omega$ $R_L = 100\Omega$ $R_L = 10k\Omega$ $R_L = 600\Omega$	50 350 1400	100 680 150 900	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		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
$e_n$	Equivalent Input Noise Voltage ( $R_s = 100\Omega$ , $f = 1kHz$ )		30		nV/ $\sqrt{Hz}$
$V_{O1}/V_{O2}$	Channel Separation ( $f = 1kHz$ )		120		dB

1. Maximum values including unavoidable inaccuracies of the industrial test

**ELECTRICAL CHARACTERISTICS**

$V_{CC^+} = 10V$ ,  $V_{DD} = 0V$ ,  $R_L$ ,  $C_L$  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		
				12		
				7		
$\Delta V_{io}$	Input Offset Voltage Drift		5		$\mu V/^\circ C$	
$I_{io}$	Input Offset Current <sup>1)</sup>		1	100	pA	
	$T_{min.} \leq T_{amb} \leq T_{max.}$			200		
$I_{ib}$	Input Bias Current <sup>1)</sup>		1	150	pA	
	$T_{min.} \leq T_{amb} \leq T_{max.}$			300		
$V_{icm}$	Common Mode Input Voltage Range	$V_{DD} - 0.2$ to $V_{CC^+} + 0.2$			V	
CMR	Common Mode Rejection Ratio		90		dB	
	$V_{ic} = 3$ to $7V$ , $V_o = 5V$		75			
	$V_{ic} = 0$ to $10V$ , $V_o = 5V$					
SVR	Supply Voltage Rejection Ratio ( $V_{CC^+} = 5$ to $10V$ , $V_o = V_{CC/2}$ )		90		dB	
$A_{vd}$	Large Signal Voltage Gain ( $R_L = 10k\Omega$ , $V_o = 2.5V$ to $7.5V$ )	15	60		V/mV	
	$T_{min.} \leq T_{amb} \leq T_{max.}$	10				
$V_{OH}$	High Level Output Voltage ( $V_{id} = 1V$ )	$R_L = 10k\Omega$	9.85	9.95	V	
		$R_L = 600\Omega$	9	9.35		
		$R_L = 100\Omega$		7.8		
		$R_L = 10k\Omega$	9.8			
	$T_{min.} \leq T_{amb} \leq T_{max.}$		9			
$V_{OL}$	Low Level Output Voltage ( $V_{id} = -1V$ )	$R_L = 10k\Omega$		50	180	mV
		$R_L = 600\Omega$		650	800	
		$R_L = 100\Omega$		2300		
		$R_L = 10k\Omega$			150	
	$T_{min.} \leq T_{amb} \leq T_{max.}$				900	
$I_o$	Output Short Circuit Current ( $V_{id} = \pm 1V$ )		60		mA	
$I_{CC}$	Supply Current (per amplifier, $A_{VCL} = 1$ , no load)		400	600	$\mu A$	
	$T_{min.} \leq T_{amb} \leq T_{max.}$			700		
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		V/ $\mu s$	
$\phi_m$	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	
$R_{in}$	Input Resistance		>10		Tera $\Omega$	
$V_{O1}/V_{O2}$	Channel Separation ( $f = 1kHz$ )		120		dB	

1. Maximum values including unavoidable inaccuracies of the industrial test

TYPICAL CHARACTERISTICS

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

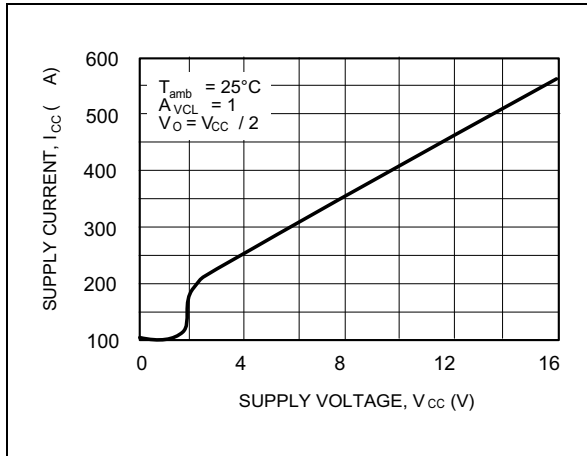


Figure 2 : Input Bias Current vs Temperature

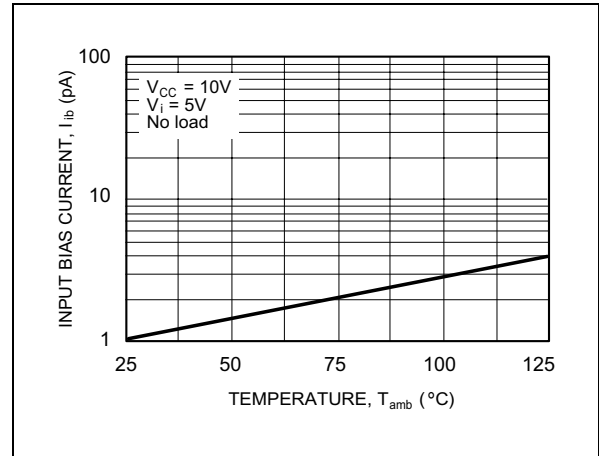


Figure 3a : High Level Output Voltage vs High Level Output Current

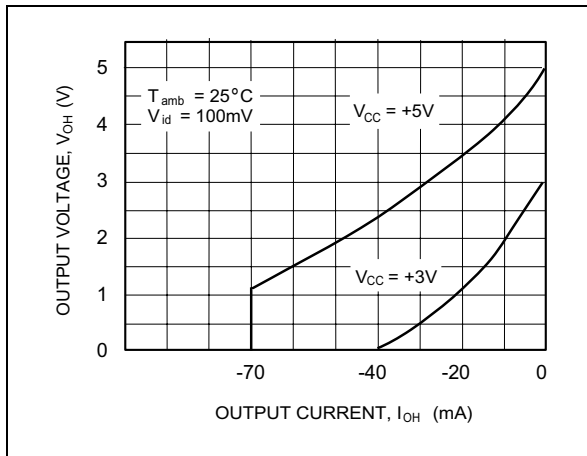


Figure 3b : High Level Output Voltage vs High Level Output Current

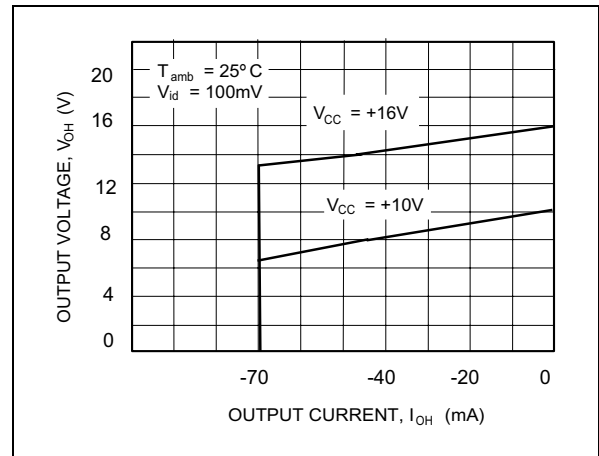


Figure 4a : Low Level Output Voltage vs Low Level Output Current

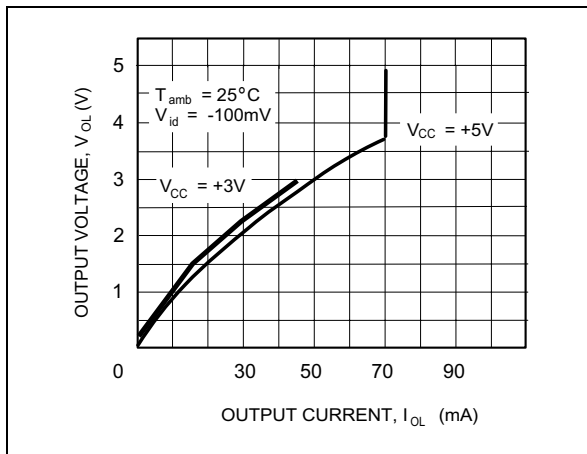


Figure 4b : Low Level Output Voltage vs Low Level Output Current

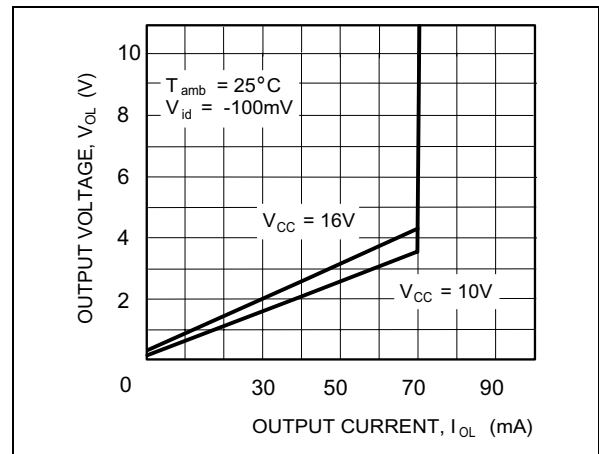


Figure 5a : Gain and Phase vs Frequency

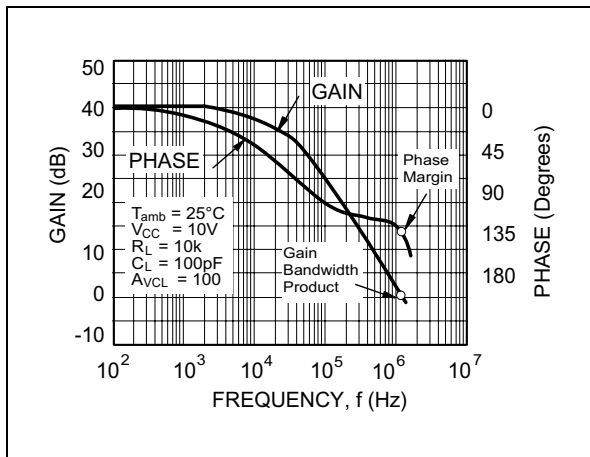


Figure 5b : Gain and Phase vs Frequency

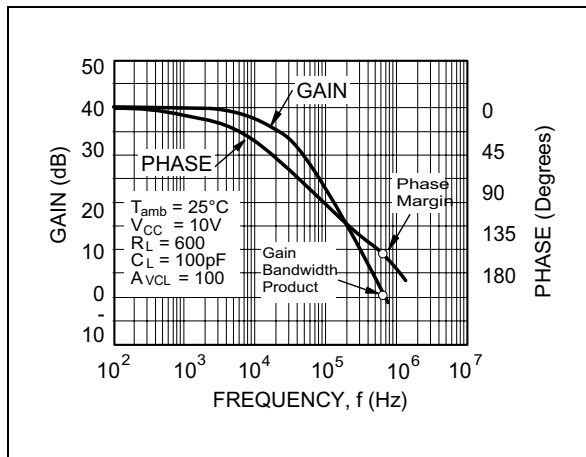


Figure 6a : Gain Bandwidth Product vs Supply Voltage

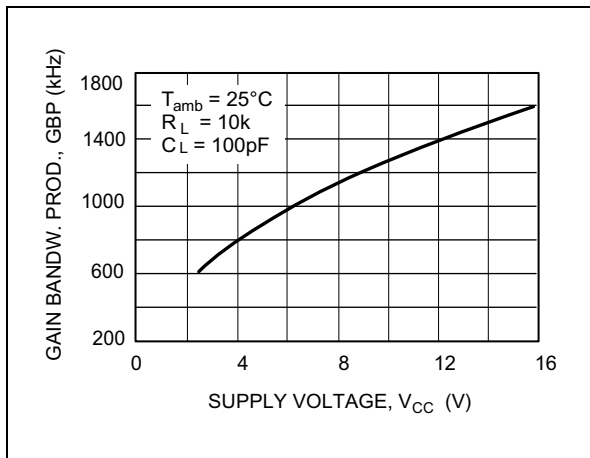


Figure 6b : Gain Bandwidth Product vs Supply Voltage

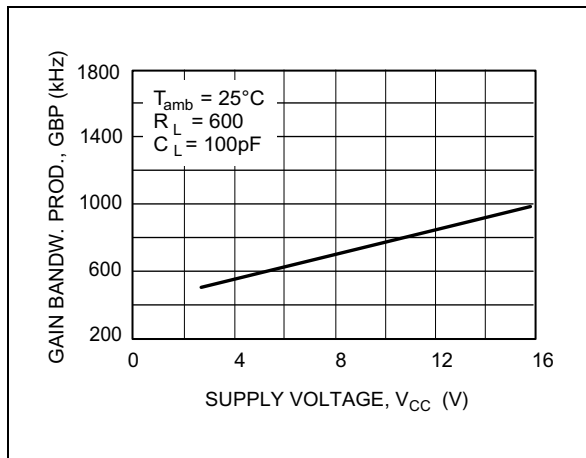


Figure 7a : Phase Margin vs Supply Voltage

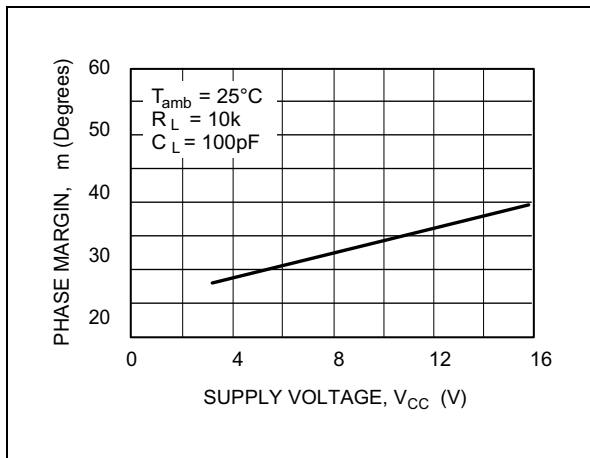


Figure 7b : Phase Margin vs Supply Voltage

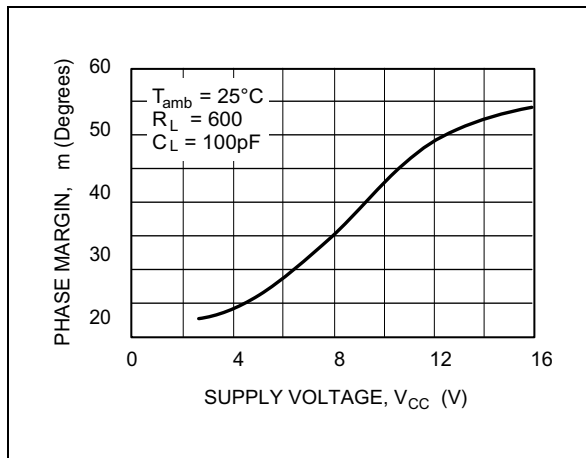
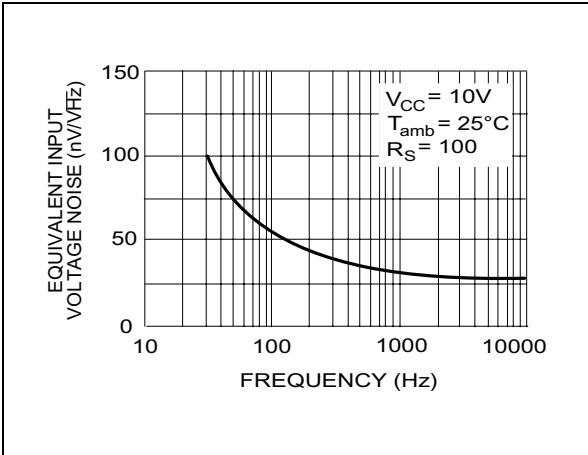


Figure 8 : Input Voltage Noise vs Frequency





**MACROMODEL**

**Applies to : TS914i,AI,BI (V<sub>CC</sub> = 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 TS914\_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

COU 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<sub>CC</sub><sup>+</sup> = 3V, V<sub>CC</sub><sup>-</sup> = 0V, R<sub>L</sub>, C<sub>L</sub> connected to V<sub>CC/2</sub>, T<sub>amb</sub> = 25°C (unless otherwise specified)

Symbol	Conditions	Value	Unit
V <sub>io</sub>		0	mV
A <sub>vd</sub>	R <sub>L</sub> = 10kΩ	10	V/mV
I <sub>CC</sub>	No load, per operator	100	μA
V <sub>Icm</sub>		-0.2 to 3.2	V
V <sub>OH</sub>	R <sub>L</sub> = 600Ω	2.96	V
V <sub>OL</sub>	R <sub>L</sub> = 60Ω	300	mV
I <sub>sink</sub>	V <sub>O</sub> = 3V	40	mA
I <sub>source</sub>	V <sub>O</sub> = 0V	40	mA
GBP	R <sub>L</sub> = 10kΩ, C <sub>L</sub> = 100pF	0.8	MHz
SR	R <sub>L</sub> = 10kΩ, C <sub>L</sub> = 100pF	0.3	V/μs
φ <sub>m</sub>	Phase Margin	30	Degrees



**MACROMODEL**

**Applies to : TS914I,AI,BI (V<sub>CC</sub> = 5V)**

\*\* Standard Linear lcs Macromodels, 1993.

\*\* CONNECTIONS :

\* 1 INVERTING INPUT

\* 2 NON-INVERTING INPUT

\* 3 OUTPUT

\* 4 POSITIVE POWER SUPPLY

\* 5 NEGATIVE POWER SUPPLY

\* 6 STANDBY

.SUBCKT TS914\_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

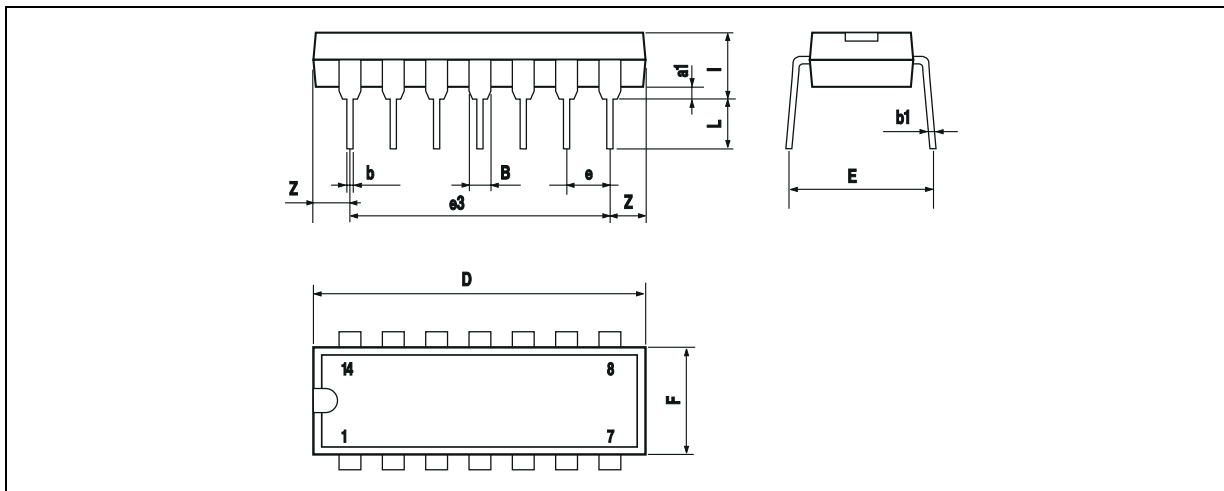
\*\* c.a.d -375U-000U dus a l'offset

ESCP 60 0 2 1 500

ESCN 70 0 2 1 -2000

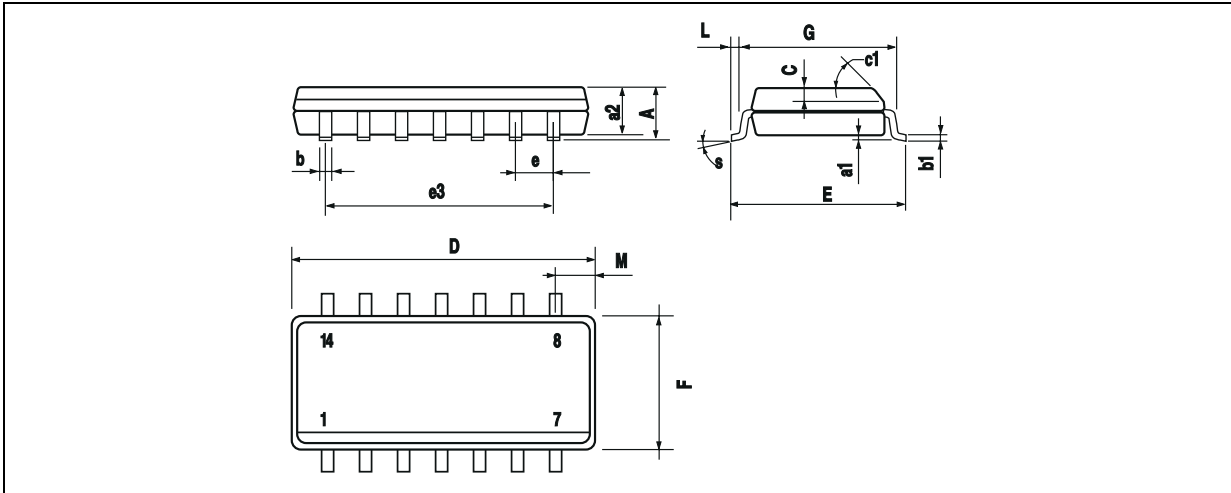
.ENDS

**PACKAGE MECHANICAL DATA**  
14 PINS - PLASTIC DIP



Dim.	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)



Dim.	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 (1)	8.55		8.75	0.336		0.344
E	5.8		6.2	0.228		0.244
e		1.27			0.050	
e3		7.62			0.300	
F (1)	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.)					

Note : (1) D and F do not include mold flash or protrusions - Mold flash or protrusions shall not exceed 0.15mm (.066 inc) ONLY FOR DATA BOOK.

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