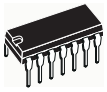
TS914

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: 5mv max.
- Specified for 600Ω and 100Ω loads
- Low supply current: 200µA/ampli (V_{CC} = 3V)
- Latch-up immunity
- Spice macromodel included in this specification



N
DIP-14
(Plastic Package)

D
SO-14
(Plastic Micropackage)

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}^-.

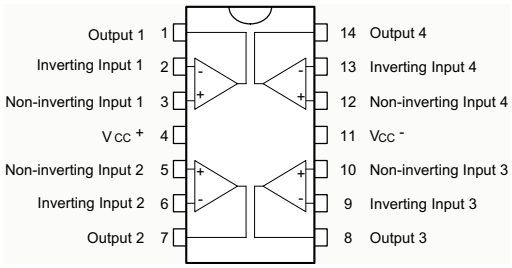
The output reaches:

- V_{CC}^- +50mV, V_{CC}^+ -50mV, with R_L = 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.

Pin Connections (top view)



Order Code

Part Number	Temperature Range	Package	Packaging
TS914IN	-40, +125°C	DIP14	Tube
TS914ID/IDT		SO-4	Tube or Tape & Reel
TS914AIN		DIP14	Tube
TS914AID/AIDT		SO-4	Tube or Tape & Reel
TS914IYD/IYDT/ AIYD/AIYDT		SO14 (automotive grade level)	Tube or Tape & Reel

1 Absolute Maximum Ratings

Table 1. Key parameters and their absolute maximum ratings

Symbol	Parameter	Value	Unit
V_{CC}	Supply voltage (1)	18	V
Vid	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 TS914I/AI	-40 to + 125	°C
T_{stg}	Storage Temperature	-65 to +150	°C

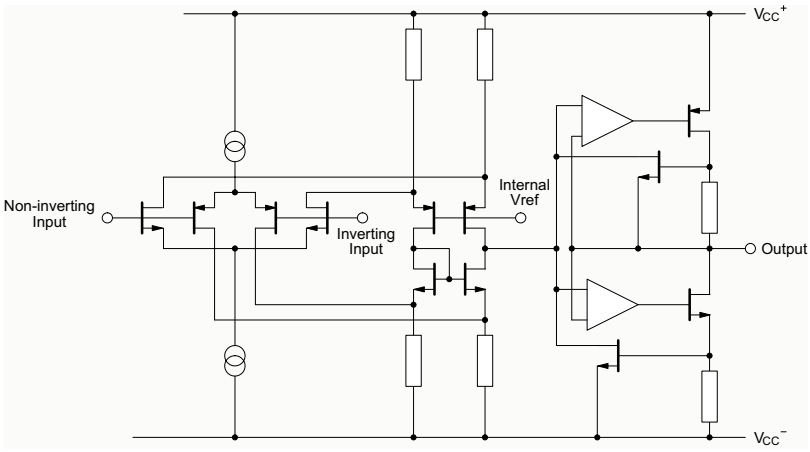
1. All voltages values, except differential voltage are with respect to network ground terminal.
2. Differential voltagesare non-inverting input terminal with respect to the inverting input terminal.
3. The magnitude of input and output voltages must never exceed V_{CC}^+ +0.3V.

Table 2. 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

2 Typical Application Information

Figure 1. Typical application information



3 Electrical Characteristics

Table 3. $V_{CC}^+ = 3V$, $V_{cc}^- = 0V$, R_L, C_L connected to $V_{CC/2}$, $T_{amb} = 25°C$ (unless otherwise specified)

Symbol	Parameter	Min.	Typ.	Max.	Unit
V_{io}	Input Offset Voltage ($V_{ic} = V_o = V_{CC/2}$) TS914 TS914A $T_{min.} \le T_{amb} \le T_{max.}$TS914 TS914A			 10 5 12 7	mV
ΔV_{io}	Input Offset Voltage Drift		5		µV/°C
I_{io}	Input Offset Current (1) $T_{min.} \le T_{amb} \le T_{max.}$		1	100 200	pA
I_{ib}	Input Bias Current 1) $T_{min.} \le T_{amb} \le T_{max.}$		1	150 300	pA
I_{CC}	Supply Current (per amplifier, $A_{VCL} = 1$, no load) $T_{min.} \le T_{amb} \le T_{max.}$		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 = $V_{CC/2}$)		80		dB
A_{vd}	Large Signal Voltage Gain (R_L = 10kΩ, V_o = 1.2V to 1.8V) $T_{min.} \le T_{amb} \le T_{max.}$	3 2	10		V/mV
V_{OH}	High Level Output Voltage (V_{id} = 1V)R_L = 10kΩ R_L = 600Ω R_L = 100Ω $T_{min.} \le T_{amb} \le T_{max.}R_L$ = 10kΩ R_L = 600Ω	2.9 2.2 2.8 2.1	2.97 2.7 2		V
V_{OL}	Low Level Output Voltage (V_{id} = -1V)R_L = 10kΩ R_L = 600Ω R_L = 100Ω $T_{min.} \le T_{amb} \le T_{max.}R_L$ = 10kΩ R_L = 600Ω		50 300 900	100 600 150 900	mV
I_o	Output Short Circuit Current (V_{id} = ±1V) Source ($V_o = V_{CC}$) Sink ($V_o = V_{CC}^+$)		 40 40		mA
GBP	Gain Bandwith Product (A_{VCL} = 100, R_L = 10kΩ, C_L = 100pF, f = 100kHz)		0.8		MHz
SR	Slew Rate (A_{VCL} = 1, R_L = 10kΩ, C_L = 100pF, V_i = 1.3V to 1.7V)		0.5		V/µs
ϕm	Phase Margin		30		Degrees
en	Equivalent Input Noise Voltage (R_s = 100Ω, f = 1kHz)		30		nV/√Hz
V_{O1}/ V_{O2}	Channel Separation (f = 1kHz)		120		dB

1. Maximum values including unavoidable inaccuracies of the industrial test

Table 4. $V_{CC}^+ = 5V$, $V_{cc}^- = 0V$, R_L, C_L connected to $V_{CC/2}$, $T_{amb} = 25°C$ (unless otherwise specified)

Symbol	Parameter	Min.	Typ.	Max.	Unit
V_{io}	Input Offset Voltage ($V_{ic} = V_o = V_{CC/2}$) TS914 TS914A $T_{min.} \le T_{amb} \le T_{max.}$TS914 TS914A			 10 5 12 7	mV
ΔV_{io}	Input Offset Voltage Drift		5		µV/°C
I_{io}	Input Offset Current (1) $T_{min.} \le T_{amb} \le T_{max.}$		1	100 200	pA
I_{ib}	Input Bias Current 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 $3.5V$, $V_o = 2.5V$		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 $3.5V$) $T_{min.} \le T_{amb} \le T_{max.}$	10 7	40		V/mV
V_{OH}	High Level Output Voltage ($V_{id} = 1V$)$R_L = 10k\Omega$ $R_L = 600\Omega$ $R_L = 100\Omega$ $T_{min.} \le T_{amb} \le T_{max.}R_L = 10k\Omega$ $R_L = 600\Omega$	 4.85 4.20 4.8 4.1	 4.95 4.65 3.7		V
V_{OL}	Low Level Output Voltage ($V_{id} = -1V$)$R_L = 10k\Omega$ $R_L = 600\Omega$ $R_L = 100\Omega$ $T_{min.} \le T_{amb} \le T_{max.}R_L = 10k\Omega$ $R_L = 600\Omega$		 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 Bandwith 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/µs
ϕm	Phase Margin		30		Degrees
en	Equivalent Input Noise Voltage ($R_s = 100\Omega$, f = 1kHz)		30		nV/√Hz
V_{O1}/V_{O2}	Channel Separation (f = 1kHz)		120		dB

1. Maximum values including unavoidable inaccuracies of the industrial test

Table 5. $V_{CC}^+ = 10V$, $V_{DD} = 0V$, R_L, C_L connected to $V_{CC/2}$, $T_{amb} = 25°C$ (unless otherwise specified)

Symbol	Parameter	Min.	Typ.	Max.	Unit
V_{io}	Input Offset Voltage ($V_{ic} = V_o = V_{CC/2}$) TS914 TS914A $T_{min.} \le T_{amb} \le T_{max.}$TS914 TS914A			 10 5 12 7	mV
ΔV_{io}	Input Offset Voltage Drift		5		µV/°C
I_{io}	Input Offset Current (1) $T_{min.} \le T_{amb} \le T_{max.}$		1	100 200	pA
I_{ib}	Input Bias Current 1) $T_{min.} \le T_{amb} \le T_{max.}$		1	150 300	pA
V_{icm}	Common Mode Input Voltage Range	V_{DD} - 0.2 to V_{CC}^+ 0.2			V
CMR	Common Mode Rejection Ratio V_{ic} = 3 to 7V, V_o = 5V V_{ic} = 0 to 10V, V_o = 5V		 90 75		dB
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 = 10kΩ, V_o = 2.5V to 7.5V) $T_{min.} \le T_{amb} \le T_{max.}$	15 10	60		V/mV
V_{OH}	High Level Output Voltage (V_{id} = 1V)R_L = 10kΩ R_L = 600Ω R_L = 100Ω $T_{min.} \le T_{amb} \le T_{max.}R_L$ = 10kΩ R_L = 600Ω	9.85 9 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 $T_{min.} \le T_{amb} \le T_{max.}R_L$ = 10kΩ R_L = 600Ω		50 650 2300	180 800 150 900	mV
I_o	Output Short Circuit Current (V_{id} = ±1V)		60		mA
I_{CC}	Supply Current (per amplifier, A_{VCL} = 1, no load) $T_{min.} \le T_{amb} \le T_{max.}$		400	600 700	µA
GBP	Gain Bandwith Product (A_{VCL} = 100, R_L = 10kΩ, C_L = 100pF, f = 100kHz)		1.4		MHz
SR	Slew Rate (A_{VCL} = 1, R_L = 10kΩ, C_L = 100pF, V_i = 2.5V to 7.5V)		1		V/µs
ϕm	Phase Margin		40		Degrees
en	Equivalent Input Noise Voltage (R_s = 100Ω, f = 1kHz)		30		nV/√Hz
THD	Total Harmonic Distortion (A_{VCL} = 1, R_L = 10kΩ, 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 Ω
V_{O1}/V_{O2}	Channel Separation (f = 1kHz)		120		dB

1. Maximum values including unavoidable inaccuracies of the industrial test

Table 6. $V_{CC}^+ = 3V$, $V_{CC}^- = 0V$, 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}	$R_L = 10k\Omega$	10	V/mV
I_{CC}	No load, per operator	100	µA
V_{icm}		-0.2 to 3.2	V
V_{OH}	$R_L = 600\Omega$	2.96	V
V_{OL}	$R_L = 60\Omega$	300	mV
I_{sink}	$V_O = 3V$	40	mA
I_{source}	$V_O = 0V$	40	mA
GBP	$R_L = 10k\Omega$, $C_L = 100pF$	0.8	MHz
SR	$R_L = 10k\Omega$, $C_L = 100pF$	0.3	V/µs
ϕm	Phase Margin	30	Degrees

Figure 2. Supply current (each amplifier) vs supply voltage

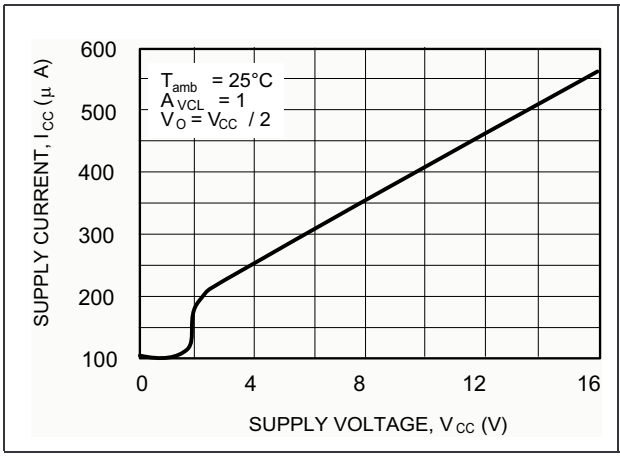


Figure 3. High level output voltage vs high level output current

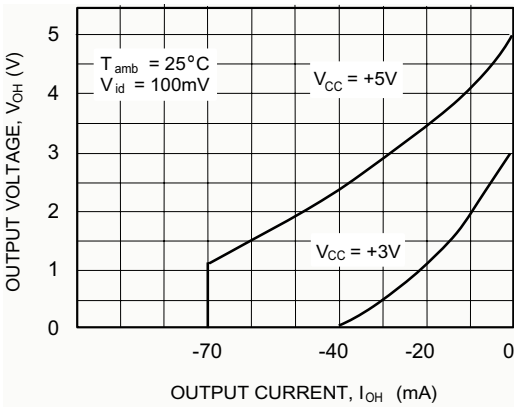


Figure 4. Low level output voltage vs low level output current

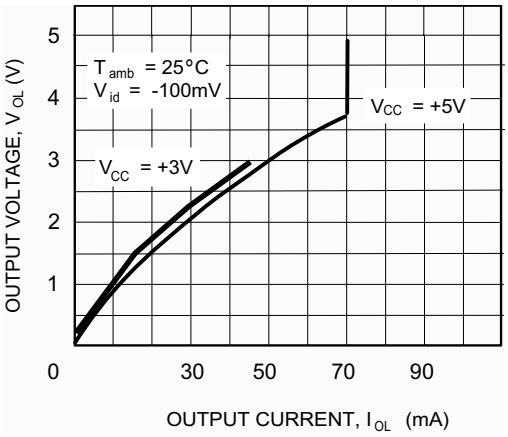


Figure 5. Input bias current vs temperature

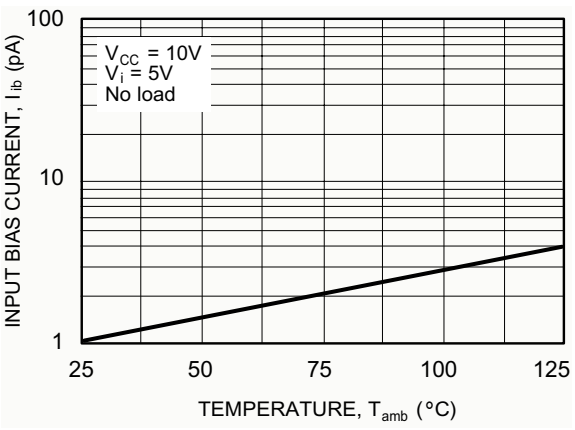


Figure 6. High level output voltage vs high level output current

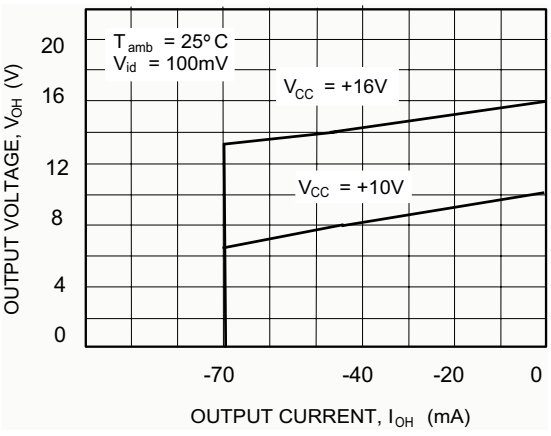


Figure 7. Low level output voltage vs low level output current

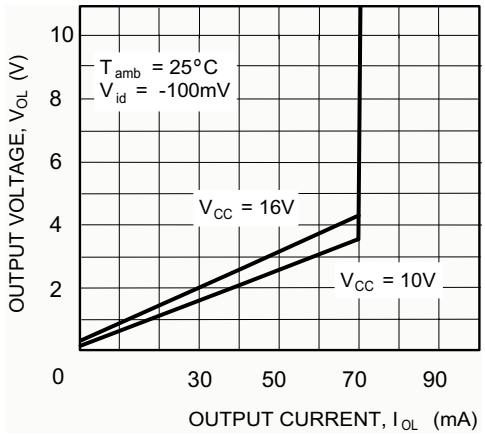


Figure 8. Gain and phase vs frequency

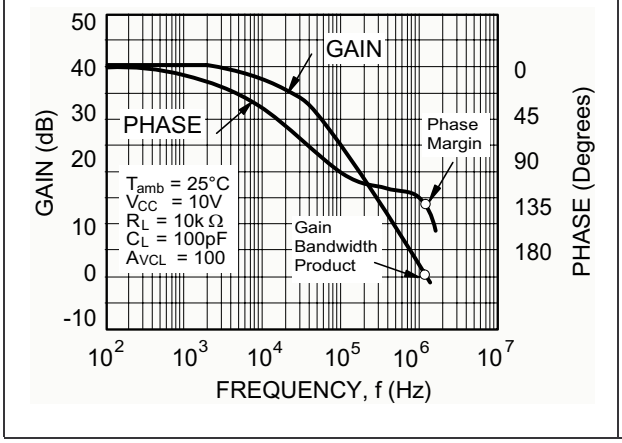


Figure 9. Gain bandwidth product vs supply voltage

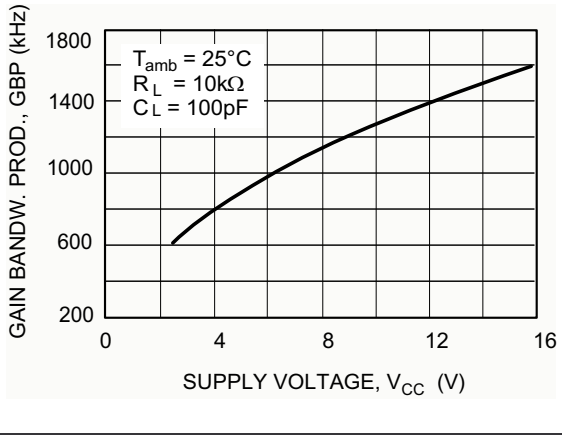


Figure 10. Phase margin vs supply voltage

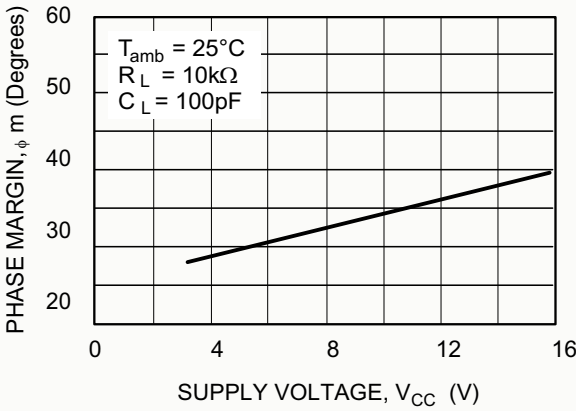


Figure 11. Gain and phase vs frequency

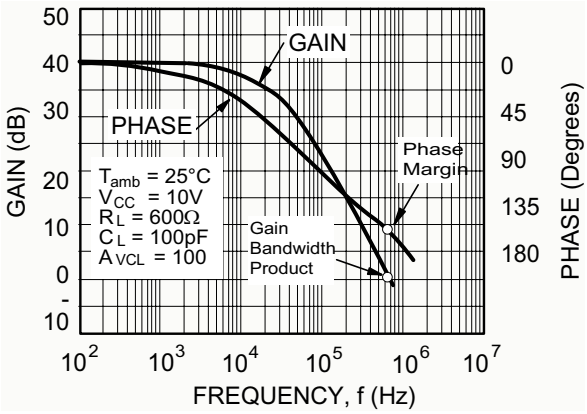


Figure 12. Gain bandwidth product vs supply voltage

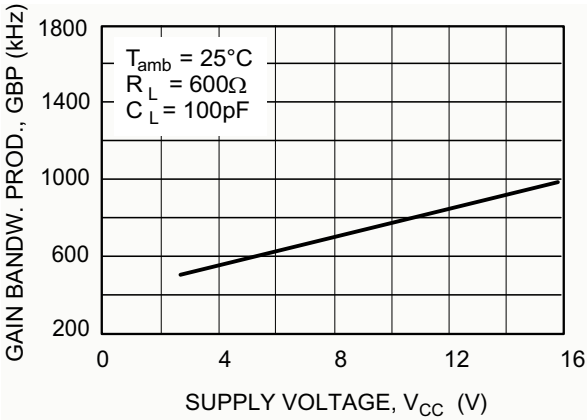


Figure 13. Phase margin vs supply voltage

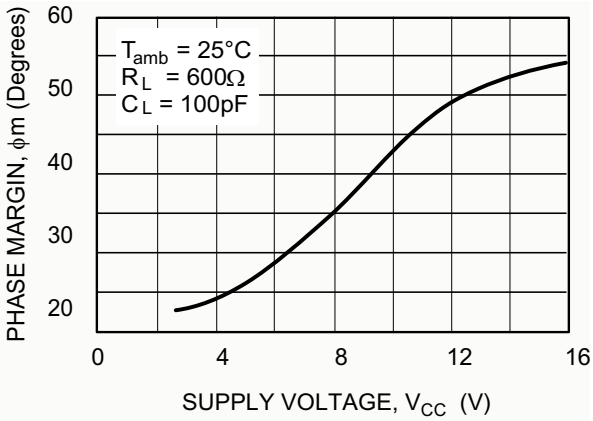
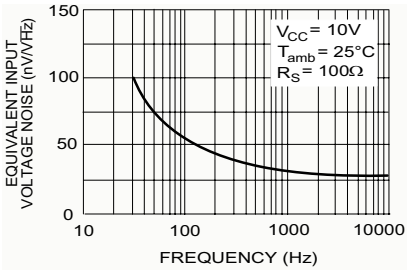


Figure 14. Input voltage noise vs frequency



4 Macromodels

Note: Please consider following remarks before using this macromodel:
All models are a trade-off between accuracy and complexity (i.e. simulation time).
Macromodels are not a substitute to breadboarding; rather, they confirm the validity of a design approach and help to select surrounding component values.
A macromodel emulates the NOMINAL performance of a TYPICAL device within SPECIFIED OPERATING CONDITIONS (i.e. temperature, supply voltage, etc.). Thus the macromodel is often not as exhaustive as the datasheet, its goal is to illustrate the main parameters of the product.
Data issued from macromodels used outside of its specified conditions (Vcc, Temperature, etc) or even worse: outside of the device operating conditions (Vcc, Vicm, etc) are not reliable in any way.

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Applies to : TS914I,AI,BI (Vcc = 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
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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
```

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Macromodels
Applies to : TS914I,AI,BI (Vcc = 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 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
```

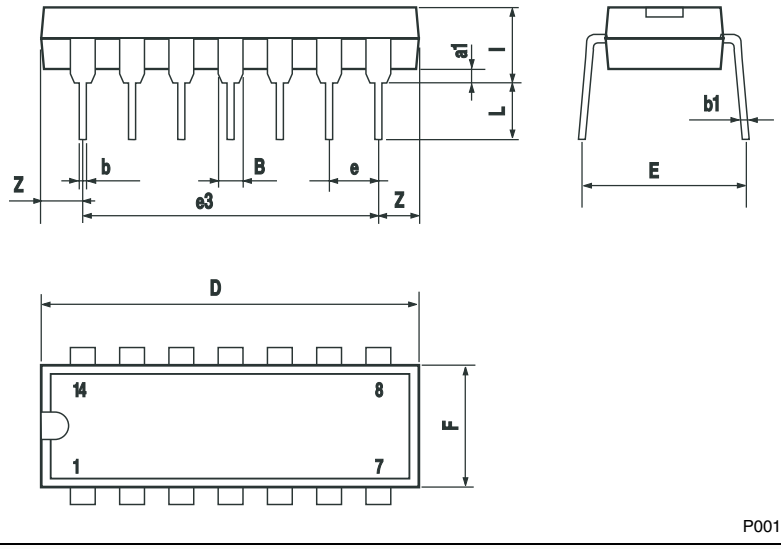
5 Package Mechanical Data

In order to meet environmental requirements, ST offers these devices in ECOPACK® packages. These packages have a Lead-free second level interconnect. The category of second level interconnect is marked on the package and on the inner box label, in compliance with JEDEC Standard JESD97. The maximum ratings related to soldering conditions are also marked on the inner box label. ECOPACK is an ST trademark. ECOPACK specifications are available at: www.st.com.

5.1 DIP-14 Package

Plastic DIP-14 MECHANICAL DATA

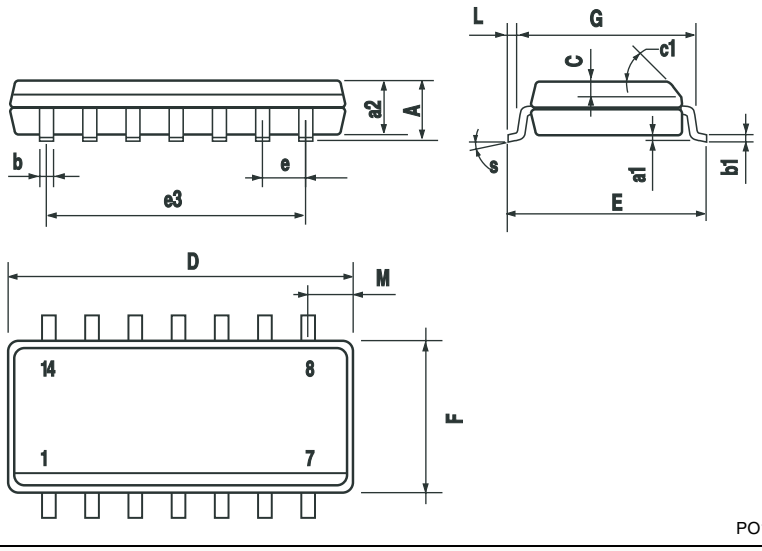
DIM.	mm.			inch		
	MIN.	TYP	MAX.	MIN.	TYP.	MAX.
a1	0.51			0.020		
B	1.39		1.65	0.055		0.065
b		0.5			0.020	
b1		0.25			0.010	
D			20			0.787
E		8.5			0.335	
e		2.54			0.100	
e3		15.24			0.600	
F			7.1			0.280
I			5.1			0.201
L		3.3			0.130	
Z	1.27		2.54	0.050		0.100



5.2 SO-14 Package

SO-14 MECHANICAL DATA

DIM.	mm.			inch		
	MIN.	TYP	MAX.	MIN.	TYP.	MAX.
A			1.75			0.068
a1	0.1		0.2	0.003		0.007
a2			1.65			0.064
b	0.35		0.46	0.013		0.018
b1	0.19		0.25	0.007		0.010
C		0.5			0.019	
c1	45° (typ.)					
D	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	3.8		4.0	0.149		0.157
G	4.6		5.3	0.181		0.208
L	0.5		1.27	0.019		0.050
M			0.68			0.026
S	8° (max.)					



6 Revision History

Date	Revision	Changes
Dec 2001	1	First Release
Nov 2004	2	Vio max on 1st page from 2mV to 5mV
June 2005	2	PIPAP references inserted in the datasheet see table order code p1