



# PRECISION LOW NOISE QUAD OPERATIONAL AMPLIFIER

- LOW INPUT OFFSET VOLTAGE **950µV max.**
- LOW VOLTAGE NOISE : **4.5nV/√Hz**
- HIGH GAIN BANDWIDTH PRODUCT :  
**15MHz**
- HIGH SLEW RATE : **7V/µs**
- LOW DISTORTION : 0.002%
- ESD INTERNAL PROTECTION 2kV
- MACROMODEL INCLUDED IN THIS SPECIFICATION

### DESCRIPTION

The TS524 is a monolithic quad operational amplifier particularly well-suited for audio applications. The TS524 offers a very low input offset voltage as well as low voltage noise (**4.5nV/√Hz**) and high dynamic performances (15MHz gain bandwidth product, 7V/µs slew rate).

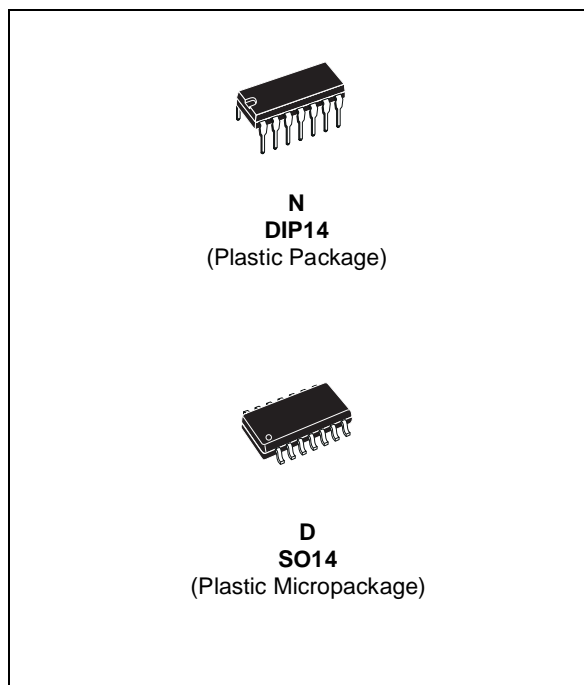
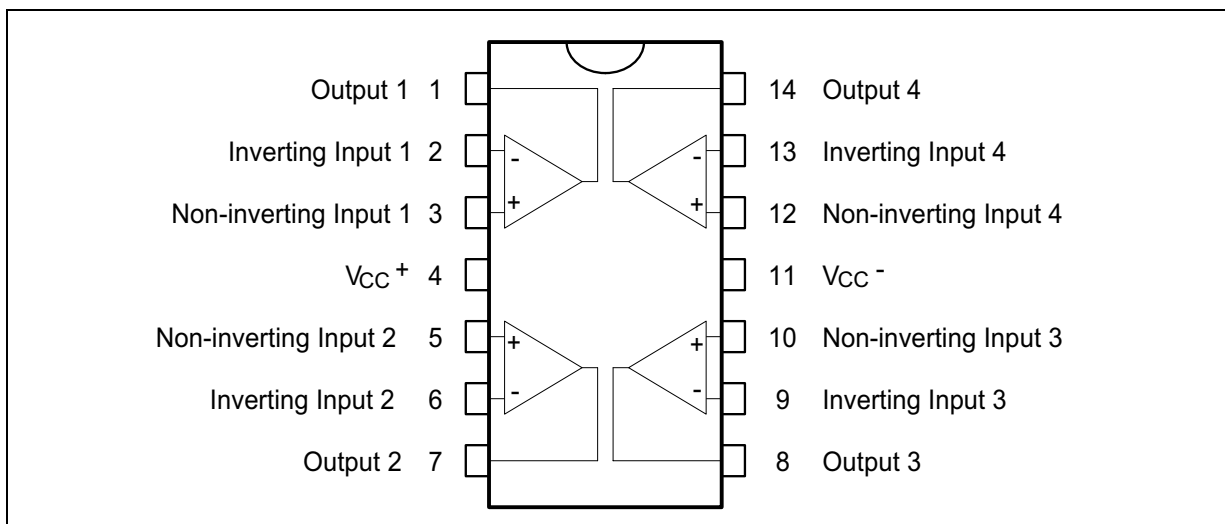
The output stage allows a large output voltage swing and symmetrical source and sink currents.

### ORDER CODE

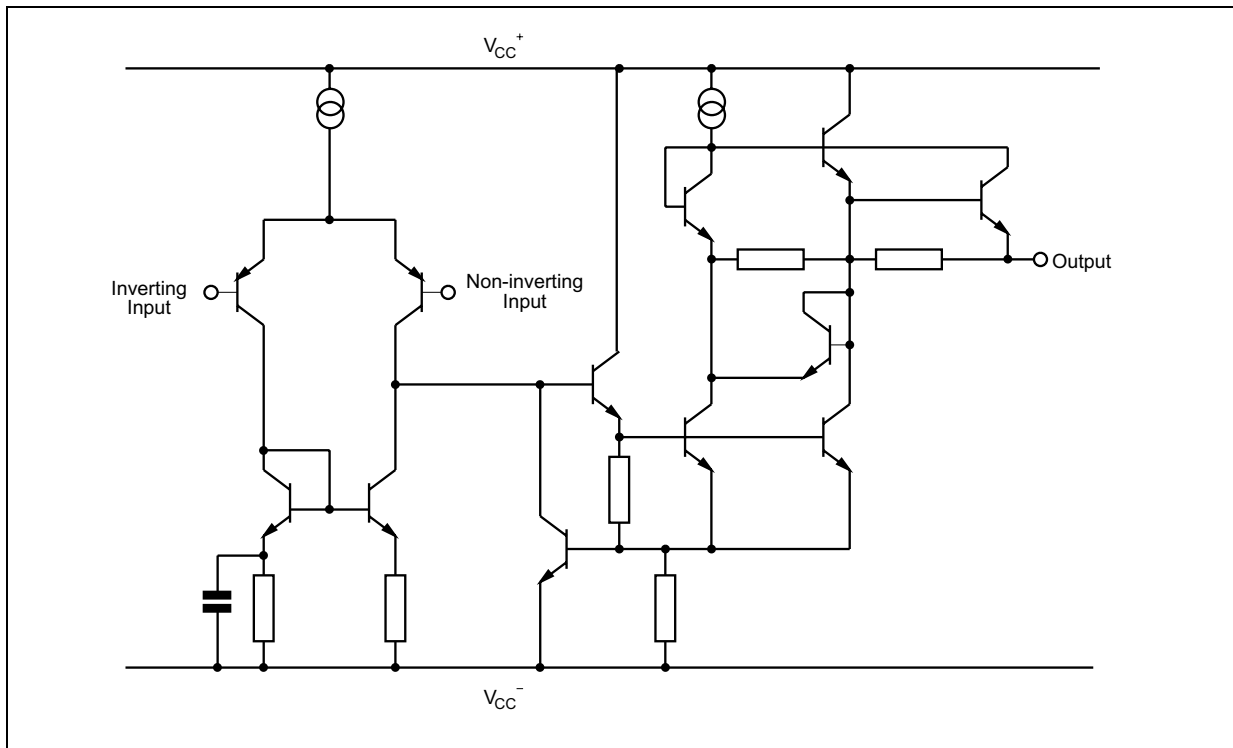
Part Number	Temperature Range	Package	
		N	D
TS524I	-40°C, +125°C	•	•

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

### PIN CONNECTIONS (top view)



**SCHEMATIC DIAGRAM (1/4 TS524)**



**ABSOLUTE MAXIMUM RATINGS**

Symbol	Parameter	Value	Unit
$V_{CC}$	Supply Voltage	$\pm 18$ to 36	V
$V_{id}$	Differential Input Voltage <sup>1)</sup>	$\pm 30$	V
$V_i$	Input Voltage (see note 1)	$\pm 15$	V
	Output Short-circuit Duration <sup>2)</sup>	Infinite	
$T_{oper}$	Operating Free-Air Temperature Range	-40 to +105	°C
$T_j$	Maximum Junction Temperature	+ 150	°C
$T_{stg}$	Storage Temperature Range	-65 to +150	°C
$P_{tot}$	Maximum Power Dissipation (see note 2)	500	mW

1. Either or both input voltages must not exceed the magnitude of  $V_{CC}^+$  or  $V_{CC}^-$
2. Power dissipation must be considered to ensure maximum junction temperature ( $T_j$ ) is not exceeded

**OPERATING CONDITIONS**

Symbol	Parameter	Value	Unit
$V_{CC}$	Supply Voltage	$\pm 2.5$ to $\pm 15$	V

**ELECTRICAL CHARACTERISTICS**
 $V_{CC}^+ = 15V$ ,  $V_{CC}^- = -15V$ ,  $T_{amb} = 25^\circ C$  (unless otherwise specified)

Symbol	Parameter	Min.	Typ.	Max.	Unit
$V_{io}$	Input Offset Voltage ( $V_o = 0V$ , $V_{ic} = 0V$ ) $T_{min} \leq T_{amb} \leq T_{max}$			0.95 1.8	mV
$\Delta V_{io}$	Input Offset Voltage Drift $V_{ic} = 0V$ , $V_o = 0V$ , $T_{min} \leq T_{amb} \leq T_{max}$		2		$\mu V/^\circ C$
$I_{io}$	Input Offset Current ( $V_{ic} = 0V$ , $V_o = 0V$ ) $T_{amb} = +25^\circ C$ $T_{min} \leq T_{amb} \leq T_{max}$		10	150 175	nA
$I_{ib}$	Input Bias Current ( $V_{ic} = 0V$ , $V_o = 0V$ ) $T_{amb} = +25^\circ C$ $T_{min} \leq T_{amb} \leq T_{max}$		250	750 800	nA
$V_{icm}$	Common Mode Input Voltage Range ( $\Delta V_{io} = 5mV$ , $V_o = 0V$ )	$\pm 13$	$\pm 14$		V
$A_{vd}$	Large Signal Voltage Gain ( $R_L = 2k\Omega$ , $V_o = \pm 10V$ ) $T_{amb} = +25^\circ C$ $T_{min} \leq T_{amb} \leq T_{max}$	90 85	100		dB
$\pm V_{opp}$	Output Voltage Swing ( $V_{id} = \pm 1V$ ) $R_L = 600\Omega$ $R_L = 600\Omega$ $R_L = 2.0k\Omega$ $R_L = 2.0k\Omega$ $R_L = 10k\Omega$ $R_L = 10k\Omega$	13.2 13.5	12.2 -12.7 14 -14.2 14.3 -14.6	-13.2 -14	V
CMR	Common Mode Rejection Ratio ( $V_{ic} = \pm 13V$ )	80	100		dB
SVR	Supply Voltage Rejection Ratio $V_{CC}^+/V_{CC}^- = +15V/-15V$ to $+5V/-5V$	80	105		dB
$I_o$	Output Short Circuit Current ( $V_{id} = \pm 1V$ , Output to ground) Source Sink	15 20	29 37		mA
$I_{CC}$	Supply Current ( $V_o = 0V$ , All amplifiers) $T_{amb} = +25^\circ C$ $T_{min} \leq T_{amb} \leq T_{max}$		8	10 12	mA
SR	Slew Rate ( $V_i = -10V$ to $+10V$ , $R_L = 2k\Omega$ , $C_L = 100pF$ , $A_V = +1$ )	5	7		$V/\mu s$
GBP	Gain Bandwidth Product ( $f = 100kHz$ , $R_L = 2k\Omega$ , $C_L = 100pF$ )	10	15		MHz
B	Unity Gain Bandwidth (Open loop)		9		MHz
$A_m$	Gain Margin ( $R_L = 2k\Omega$ ) $C_L = 0pF$ $C_L = 100pF$		-11 -6		dB
$\phi_m$	Phase Margin $C_L = 0pF$ $C_L = 100pF$		55 30		Degrees
$e_n$	Equivalent Input Noise Voltage ( $R_s = 100\Omega$ , $f = 1kHz$ )		4.5		$\frac{nV}{\sqrt{Hz}}$
$i_n$	Equivalent Input Noise current ( $f = 1kHz$ )		0.5		$\frac{pA}{\sqrt{Hz}}$
THD	Total Harmonic Distortion $R_L = 2k\Omega$ , $f = 20Hz$ to $20kHz$ , $V_o = 3V_{rms}$ , $A_V = +1$		0.002		%
$V_{o1}/V_{o2}$	Channel Separation ( $f = 20Hz$ to $20kHz$ )		120		dB
FPB	Full Power Bandwidth ( $V_o = 27V_{pp}$ , $R_L = 2k\Omega$ , $THD \leq 1\%$ )		120		kHz
$Z_o$	Output Impedance ( $V_o = 0V$ , $f = 9MHz$ )		37		$\Omega$
$R_i$	Input Resistance ( $V_{ic} = 0V$ )		175		$k\Omega$
$C_i$	Input Capacitance ( $V_{ic} = 0V$ )		12		pF

**MACROMODEL**

\*\* Standard Linear Ics Macromodels, 1993.

\*\* CONNECTIONS :

- \* 1 INVERTING INPUT
  - \* 2 NON-INVERTING INPUT
  - \* 3 OUTPUT
  - \* 4 POSITIVE POWER SUPPLY
  - \* 5 NEGATIVE POWER SUPPLY
- .SUBCKT TS524 1 3 2 4 5 (analog)

```
*****
.MODEL MDTH D IS=1E-8 KF=2.286238E-16
CJO=10F
* INPUT STAGE
CIP 2 5 1.200000E-11
CIN 1 5 1.200000E-11
EIP 10 5 2 5 1
EIN 16 5 1 5 1
RIP 10 11 2.363636E+00
RIN 15 16 2.363636E+00
RIS 11 15 1.224040E+01
DIP 11 12 MDTH 400E-12
DIN 15 14 MDTH 400E-12
VOFP 12 13 DC 0
VOFN 13 14 DC 0
IPOL 13 5 1.100000E-04
CPS 11 15 2.35E-09
DINN 17 13 MDTH 400E-12
VIN 17 5 1.000000E+00
DINR 15 18 MDTH 400E-12
VIP 4 18 1.000000E+00
FCP 4 5 VOFP 1.718182E+01
FCN 5 4 VOFN 1.718182E+01
FIBP 2 5 VOFN 4.545455E-03
FIBN 5 1 VOFP 4.545455E-03
* AMPLIFYING STAGE
FIP 5 19 VOFP 9.545455E+02
FIN 5 19 VOFN 9.545455E+02
CC 19 29 1.500000E-08
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HZTP 30 29 VOFP 1.523529E+02
HZTN 5 30 VOFN 1.523529E+02
DOPM 51 22 MDTH 400E-12
DONM 21 52 MDTH 400E-12
HOPM 22 28 VOUT 5.172414E+03
VIPM 28 4 1.500000E+02
HONM 21 27 VOUT 4.054054E+03
VINM 5 27 1.500000E+02
DBIDON1 19 53 MDTH 400E-12
V1 51 53 0.68
DBIDON2 54 19 MDTH 400E-12
V2 54 52 0.68
RG11 51 5 3.04E+05
RG12 51 4 3.04E+05
RG21 52 5 0.6072E+05
RG22 52 4 0.6072E+05
E1 50 40 51 0 1 E2 40 39 52 0 1
EDEC1 38 39 4 0 0.5
EDEC2 0 38 5 0 0.5
DOP 51 25 MDTH 400E-12
VOP 4 25 1.474575E+00
DON 24 52 MDTH 400E-12
VON 24 5 1.474575E+00
RAJUS 50 5 1E12
GCOMP 5 4 4 5 8.1566068E-04
RPM1 5 80 1E+06
RPM2 4 80 1E+06
GAVPH 5 82 50 80 3.26E-03
RAVPHGH 82 4 613
RAVPHGB 82 5 613
RAVPHDH 82 83 1000
RAVPHDB 82 84 1000
CAVPHH 4 83 0.159E-09
CAVPHB 5 84 0.159E-09
EOUT 26 23 82 5 1
VOUT 23 5 0
ROUT 26 3 4.780354E+01
COUT 3 5 1.000000E-12
.ENDS
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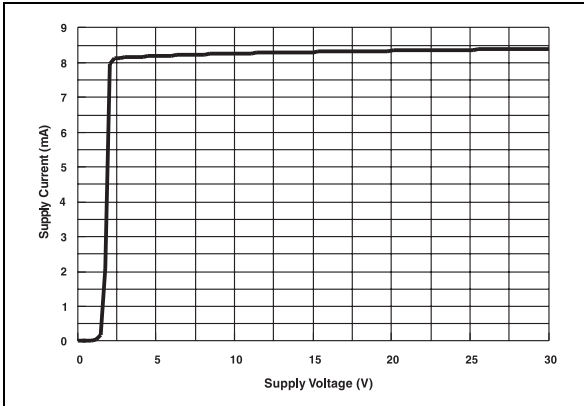
**ELECTRICAL CHARACTERISTICS**

V<sub>CC</sub> = ±15V, T<sub>amb</sub> = 25°C (unless otherwise specified)

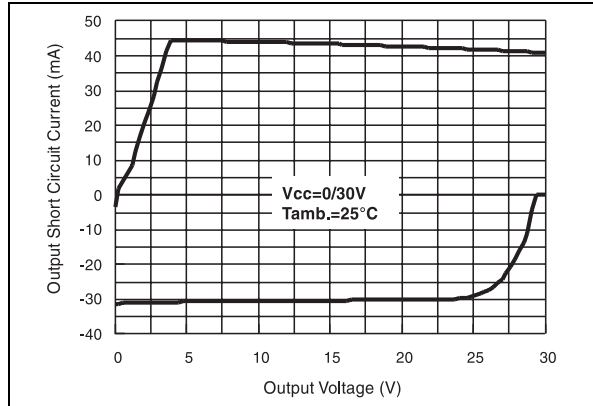
Symbol	Conditions	Value	Unit
V <sub>io</sub>		0	mV
A <sub>vd</sub>	R <sub>L</sub> = 2kΩ, V <sub>o</sub> = ±10V	100	dB
I <sub>cc</sub>	No load, per operator	2	mA
V <sub>icm</sub>	ΔV <sub>io</sub> = 5mV, V <sub>o</sub> = 0V	28	V
V <sub>opp</sub>	R <sub>L</sub> = 2kΩ	28.2	V
I <sub>sink</sub>	V <sub>o</sub> = 0V	37	mA
I <sub>source</sub>	V <sub>o</sub> = 0V	29	mA
GBP	R <sub>L</sub> = 2kΩ, C <sub>L</sub> = 100pF	15	MHz
SR	R <sub>L</sub> = 2kΩ, C <sub>L</sub> = 100pF, A <sub>v</sub> = +1	7	V/μs
∅m	R <sub>L</sub> = 2kΩ, C <sub>L</sub> = 0pF	55	Degrees



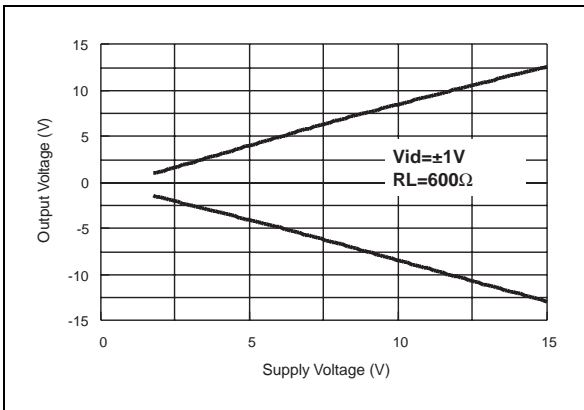
**TOTAL SUPPLY CURRENT vs SUPPLY VOLTAGE**



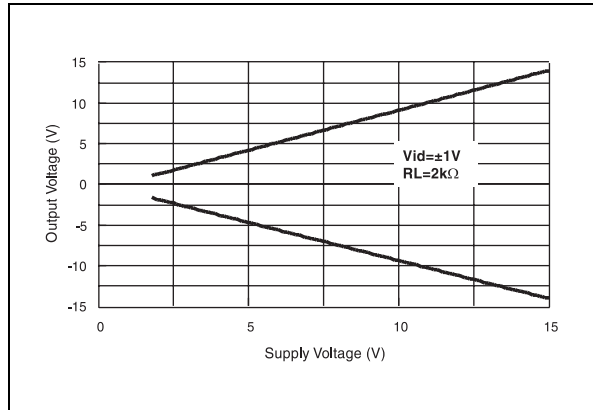
**OUTPUT SHORT CIRCUIT CURRENT vs OUTPUT VOLTAGE**



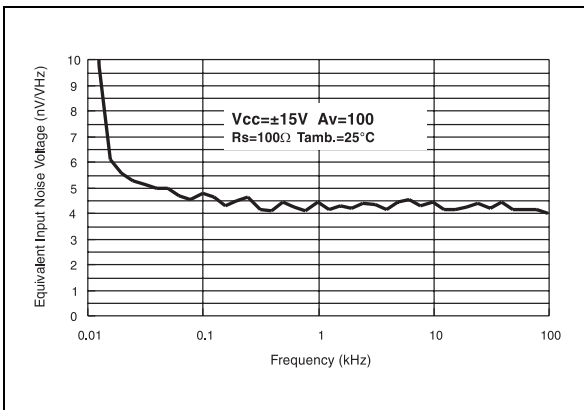
**OUTPUT VOLTAGE vs SUPPLY VOLTAGE**



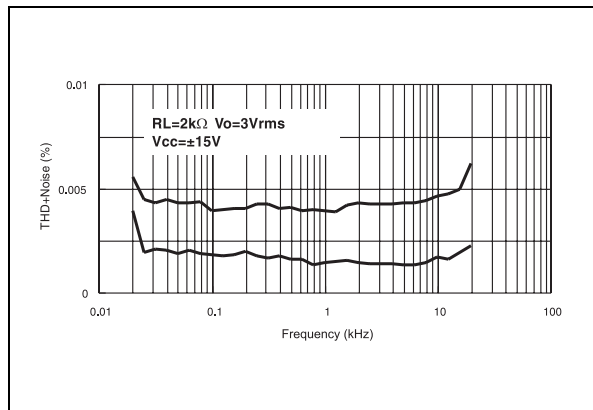
**OUTPUT VOLTAGE vs SUPPLY VOLTAGE**



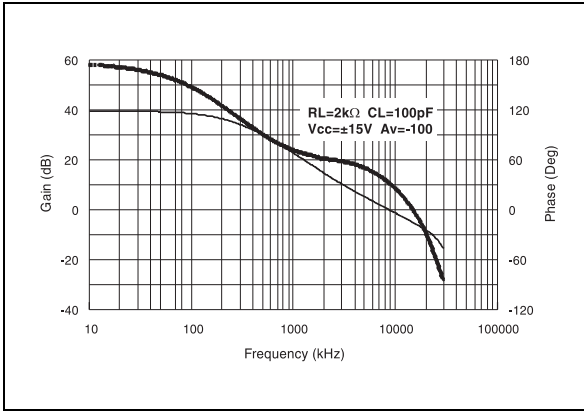
**EQUIVALENT INPUT NOISE VOLTAGE vs FREQUENCY**



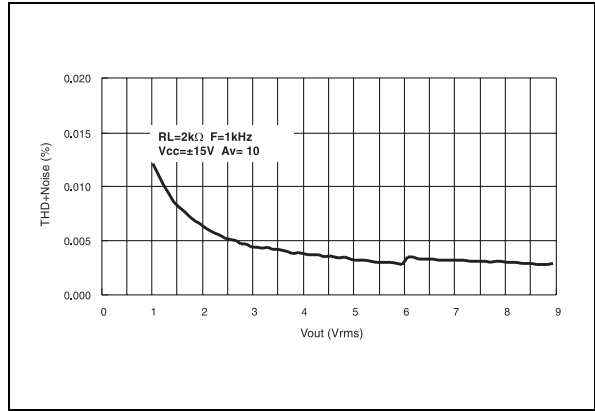
**THD + NOISE vs FREQUENCY**



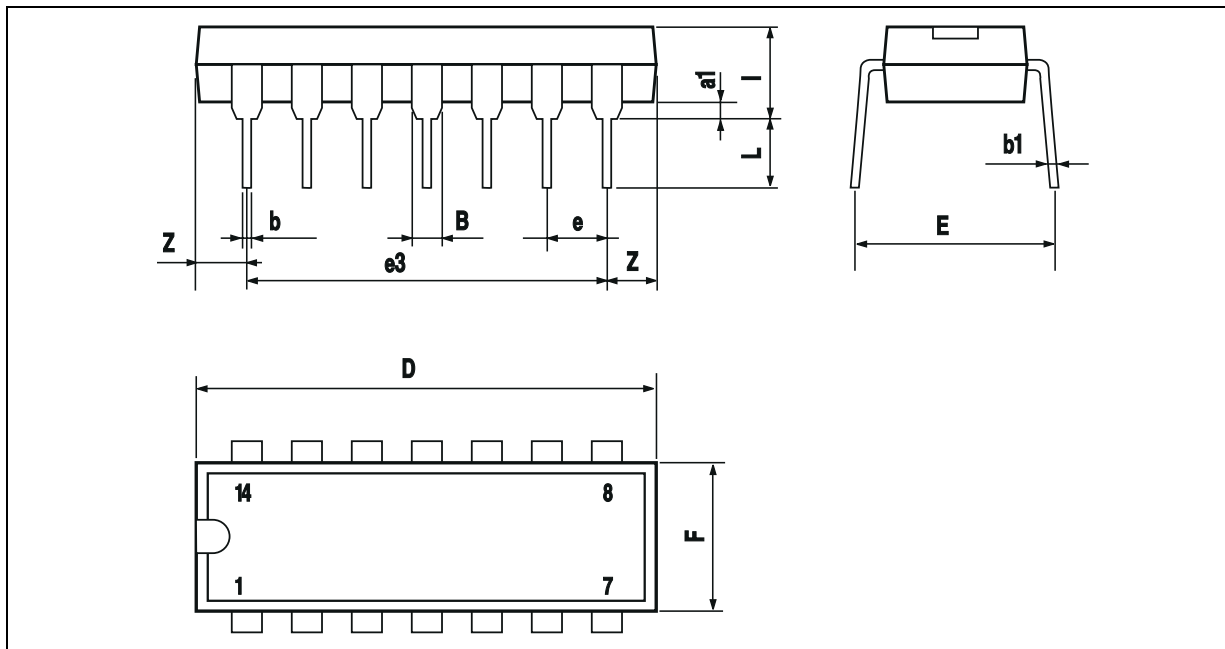
VOLTAGE GAIN AND PHASE vs FREQUENCY



THD + NOISE vs  $V_{out}$

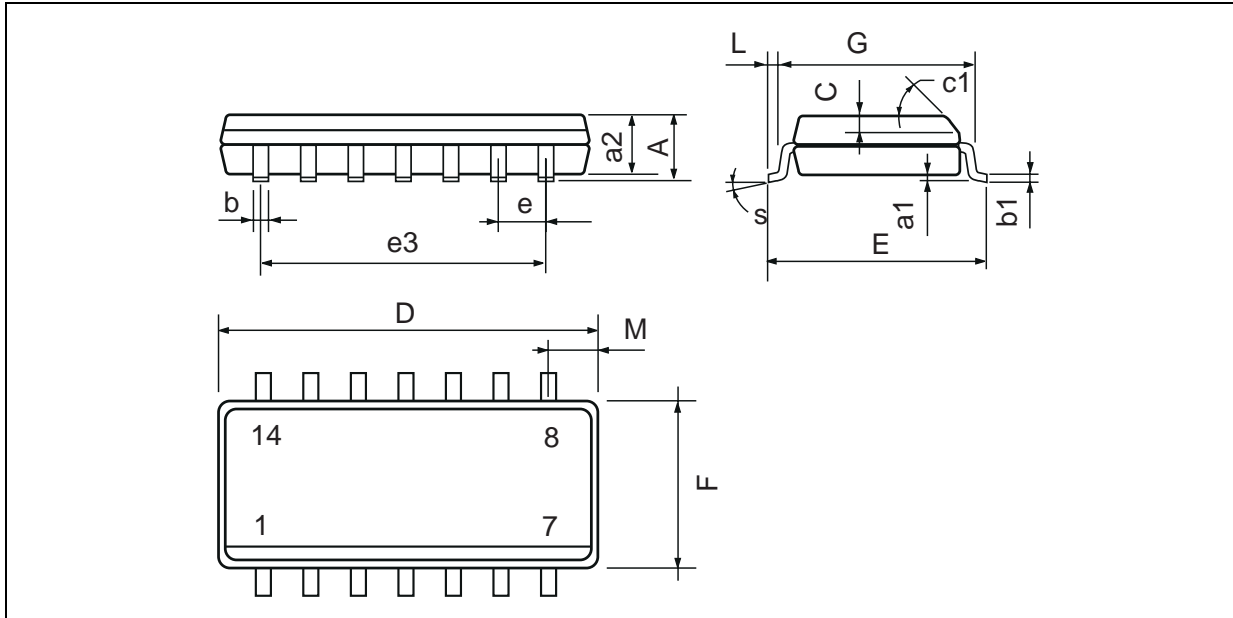


**PACKAGE MECHANICAL DATA**  
14 PINS - PLASTIC DIP



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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