

## Output Rail-to-Rail Micropower Operational Amplifiers

- Rail-to-rail output voltage swing
- Micropower consumption (1.2μA)
- Single supply operation (2.5V to 10V)
- CMOS inputs
- Ultra low input bias current (1pA)
- ESD protection (2kV)
- Latch-up immunity (class A)
- Available in SOT23-5 micropackage

### Description

The TS94x (single, dual & quad) series are operational amplifiers characterized for 2.5V to 10V operation over -40°C to +85°C temperature range.

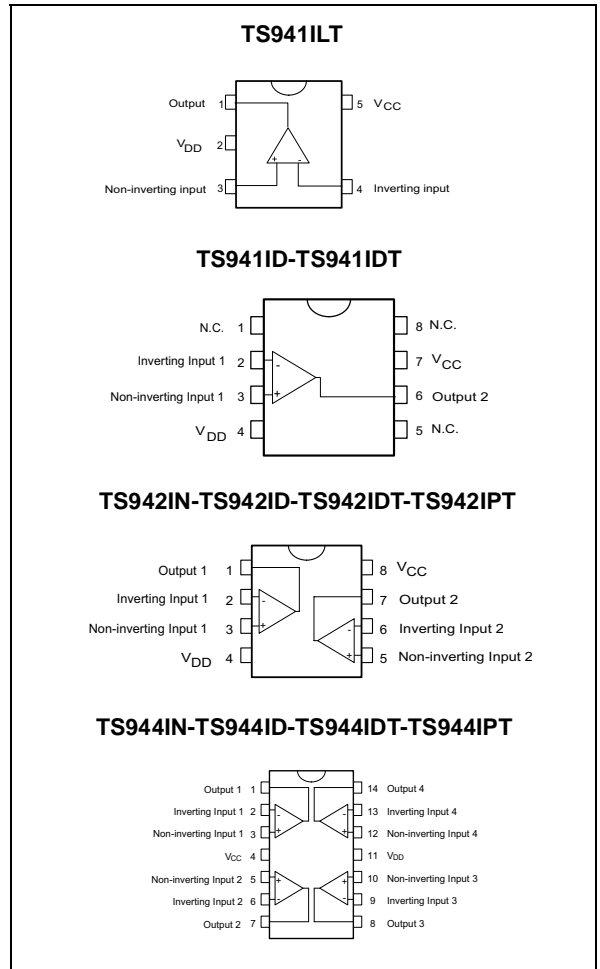
They exhibit excellent consumption - 1.2μA, while featuring 10kHz gain bandwidth product, 1.5mA output capability and output rail-to-rail operation - 2.85V typ @ 3V with RL=10kΩ.

The TS94x op-amps are ideal for battery-powered systems, where very low supply current and output rail-to-rail are required. Their very low - 1pA typ input bias current and constant supply current over supply voltage enhance TS94x's performance near the end of the life battery charge.

### Applications

- Battery-powered systems (alarm)
- Portable communication systems (paggers)
- Smoke/gas/fire detectors
- Instrumentation & sensing
- PH meter

### Pin Connections (top view)



**Order Codes**

Part Number	Temperature Range	Package	Packaging	Marking
TS941ID/IDT/AID/AIDT/BID/BIDT	-40°C, +85°C	SO	Tube or Tape & Reel	
TS941ILT/AILT/BILT		SOT23-5L	Tape & Reel	K201 K202 K203
TS942IN/AIN/BIN		DIP	Tube	
TS942ID/IDT/AID/AIDT/BID/BIDT		SO	Tube or Tape & Reel	
TS942IPT/AIPT/BIPT		TSSOP (Thin Shrink Outline Package)	Tape & Reel	
TS944IN/AIN/BIN		DIP	Tube	
TS944ID/IDT/AID/AIDT/BIDT/BIDT		SO	Tube or Tape & Reel	
TS944IPT/AIPT/BIPT		TSSOP (Thin Shrink Outline Package)	Tape & Reel	

## 1 Absolute Maximum Ratings

**Table 1: Key parameters and their absolute maximum ratings**

Symbol	Parameter	Value	Unit
VCC	Supply voltage <sup>1</sup>	12	V
V <sub>id</sub>	Differential Input Voltage <sup>2</sup>	±12	V
V <sub>in</sub>	Input Voltage Range <sup>3</sup>	V <sub>DD</sub> -0.3 to V <sub>CC</sub> +0.3	V
T <sub>std</sub>	Storage Temperature Range	-65 to +150	°C
T <sub>j</sub>	Maximum Junction Temperature	150	°C
R <sub>thja</sub>	Thermal Resistance Junction to Ambient <sup>4</sup>	250	°C/W
	SOT23-5	85	
	DIP8	66	
	DIP14	125	
	SO8	103	
	SO14	120	
	TSSOP8 TSSOP14	100	
ESD	HBM: Human Body Model <sup>5</sup>	2	kV
	MM: Machine Model <sup>6</sup> (TS941, TS942)	200	V
	CDM: Charged Device Model TS941	1.5	kV
	TS942	1	kV
	Latch-up Immunity	200	mA
	Lead Temperature (soldering, 10sec)	250	°C

1) All voltages values, except differential voltage are with respect to network 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<sub>CC</sub> +0.3V.

4) Short-circuits can cause excessive heating and destructive dissipation.

5) Human body model, 100pF discharged through a 1.5kΩ resistor into pin of device.

6) Machine model ESD, a 200pF cap is charged to the specified voltage, then discharged directly into the IC with no external series resistor (internal resistor < 5Ω), into pin to pin of device.

**Table 2: Operating Conditions**

Symbol	Parameter	Value	Unit
VCC	Supply Voltage	2.5 to 10	V
V <sub>icm</sub>	Common Mode Input Voltage Range	V <sub>DD</sub> -0.2 to V <sub>CC</sub> -1.3	V
T <sub>oper</sub>	Operating Free Air Temperature Range	-40 to + 85	°C

## 2 Electrical Characteristics

**Table 3:  $V_{CC} = +2.5V$ ,  $V_{DD} = 0V$ ,  $R_L$  connected to  $V_{CC/2}$ ,  $T_{amb} = 25^\circ C$  (unless otherwise specified)**

Symbol	Parameter	Min.	Typ.	Max.	Unit
$V_{io}$	Input Offset Voltage TS941/2/4 TS941/2/4A TS941/2/4B			10 5 2	mV
$\Delta V_{io}$	Input Offset Voltage Drift		7		$\mu V/^\circ C$
$I_{io}$	Input Offset Current <sup>1)</sup>		1	100	pA
$I_{ib}$	Input Bias Current <sup>1)</sup>		1	150	pA
CMR	Common Mode Rejection Ratio	60	85		dB
SVR	Supply Voltage Rejection Ratio	50	78		dB
$A_{vd}$	Large Signal Voltage Gain $V_O = 2V_{pp}$ $R_L = 1M\Omega$		100		dB
$V_{OH}$	High Level Output Voltage $V_{ID} = 100mV$ $R_L = 1M\Omega$ $R_L = 10k\Omega$	2.45 2.3	2.49 2.4		V
$V_{OL}$	Low Level Output Voltage $V_{ID} = -100mV$ $R_L = 1M\Omega$ $R_L = 10k\Omega$		1 100	5 200	mV
$I_o$	Output Source Current $V_{ID} = 100mV$ , $V_O = V_{DD}$ Output Sink Current $V_{ID} = -100mV$ , $V_O = V_{CC}$	350 280	650 500		$\mu A$
$I_{CC}$	Supply Current (per amplifier) $A_{VCL} = 1$ , no load		1.2	1.8	$\mu A$
GBP	Gain Bandwidth Product $R_L = 1M\Omega$ , $C_L = 50pF$		10		kHz
SR	Slew Rate $R_L = 1M\Omega$ , $C_L = 50pF$	3	4.5		V/ms
$\phi_m$	Phase Margin $C_L = 50pF$		65		Degrees

1) Maximum values including unavoidable inaccuracies of the industrial test.

Table 4:  $V_{CC} = +3V$ ,  $V_{DD} = 0V$ ,  $R_L$  connected to  $V_{CC/2}$ ,  $T_{amb} = 25^\circ C$  (unless otherwise specified) <sup>2)</sup>

Symbol	Parameter	Min.	Typ.	Max.	Unit
$V_{io}$	Input Offset Voltage TS941/2/4 TS941/2/4A TS941/2/4B			10 5 2	mV
$\Delta V_{io}$	Input Offset Voltage Drift		7		$\mu V/^\circ C$
$I_{io}$	Input Offset Current <sup>1)</sup>		1	100	pA
$I_{ib}$	Input Bias Current <sup>1)</sup>		1	150	pA
CMR	Common Mode Rejection Ratio	60	85		dB
SVR	Supply Voltage Rejection Ratio	50	85		dB
$A_{vd}$	Large Signal Voltage Gain $V_O = 2V_{pp} R_L = 1M\Omega$		100		dB
$V_{OH}$	High Level Output Voltage $V_{ID} = 100mV$ $R_L = 1M\Omega$ $R_L = 10k\Omega$	2.9 2.8	2.99 2.85		V
$V_{OL}$	Low Level Output Voltage $V_{ID} = -100mV$ $R_L = 1M\Omega$ $R_L = 10k\Omega$		1 100	5 200	mV
$I_o$	Output Source Current $V_{ID} = 100mV, V_O = V_{DD}$	680	1500		$\mu A$
	Output Sink Current $V_{ID} = -100mV, V_O = V_{CC}$	650	1300		
$I_{CC}$	Supply Current (per amplifier) $A_{VCL} = 1, \text{ no load}$		1.2	1.8	$\mu A$
GBP	Gain Bandwidth Product $R_L = 1M\Omega, C_L = 50pF$		10		kHz
SR	Slew Rate $R_L = 1M\Omega, C_L = 50pF$	3	4.5		V/ms
$\phi_m$	Phase Margin $C_L = 50pF$		65		Degrees

1) Maximum values including unavoidable inaccuracies of the industrial test.

2) All electrical values are guaranteed with correlation measurements at 2.5V and 5V

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

Symbol	Parameter	Min.	Typ.	Max.	Unit
$V_{io}$	Input Offset Voltage TS941/2/4 TS941/2/4A TS941/2/4B			10 5 2	mV
$\Delta V_{io}$	Input Offset Voltage Drift		7		$\mu V/^\circ C$
$I_{io}$	Input Offset Current <sup>1</sup>		1	100	pA
$I_{ib}$	Input Bias Current <sup>1</sup>		1	150	pA
CMR	Common Mode Rejection Ratio	60	85		dB
SVR	Supply Voltage Rejection Ratio	50	85		dB
$A_{vd}$	Large Signal Voltage Gain $V_O = 2V_{pp}$ $R_L = 1M\Omega$		100		dB
$V_{OH}$	High Level Output Voltage $V_{ID} = 100mV$ $R_L = 1M\Omega$ $R_L = 10k\Omega$	4.9 4.8	4.99 4.85		V
$V_{OL}$	Low Level Output Voltage $V_{ID} = -100mV$ $R_L = 1M\Omega$ $R_L = 10k\Omega$		1 100	5 150	mV
$I_o$	Output Source Current $V_{ID} = 100mV$ , $V_O = V_{DD}$	3	4.5		mA
	Output Sink Current $V_{ID} = -100mV$ , $V_O = V_{CC}$	3.7	5		
$I_{CC}$	Supply Current (per amplifier) $A_{VCL} = 1$ , no load		1.2	1.85	$\mu A$
GBP	Gain Bandwidth Product $R_L = 1M\Omega$ , $C_L = 50pF$		10		kHz
SR	Slew Rate $R_L = 1M\Omega$ , $C_L = 50pF$	3	4.5		V/ms
$\phi_m$	Phase Margin $C_L = 50pF$		65		Degrees

1) Maximum values including unavoidable inaccuracies of the industrial test.

Figure 1:

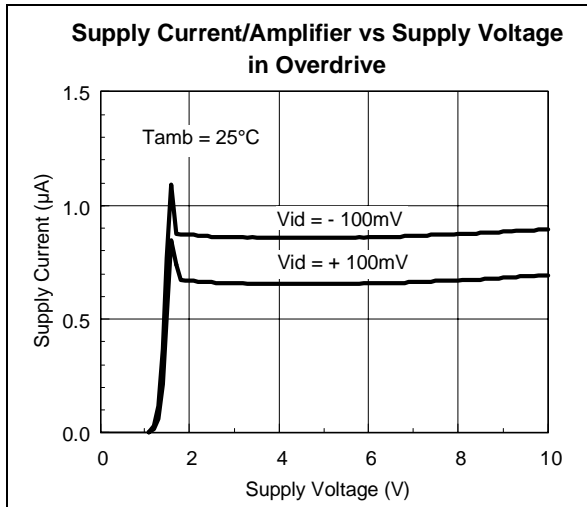


Figure 3:

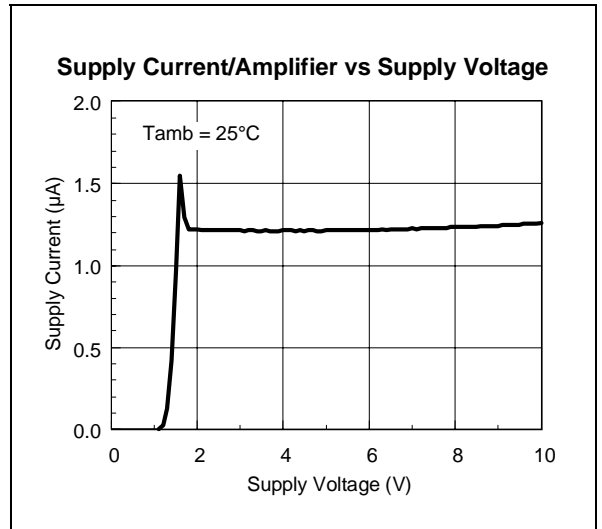


Figure 2:

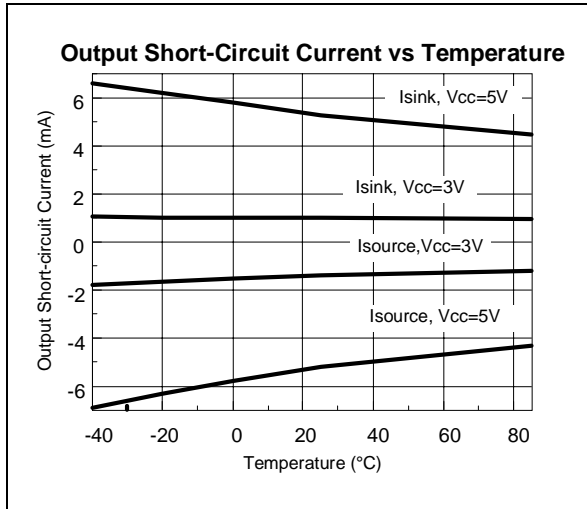


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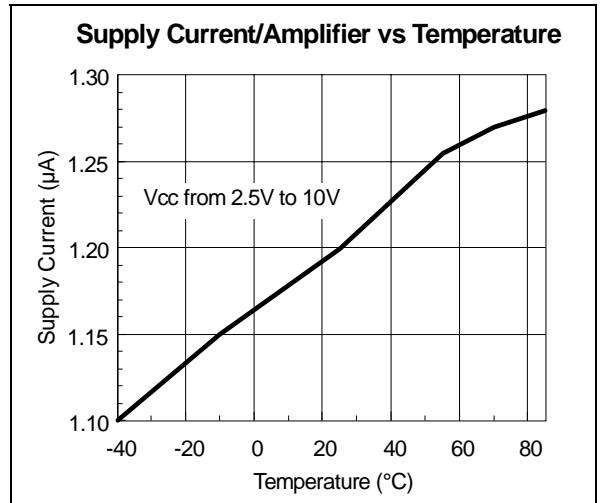


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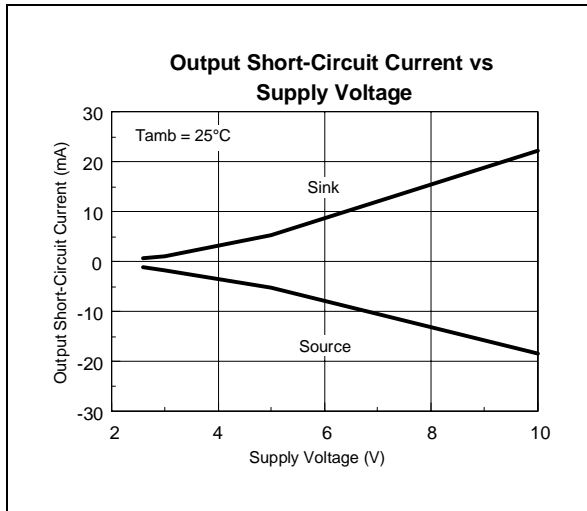


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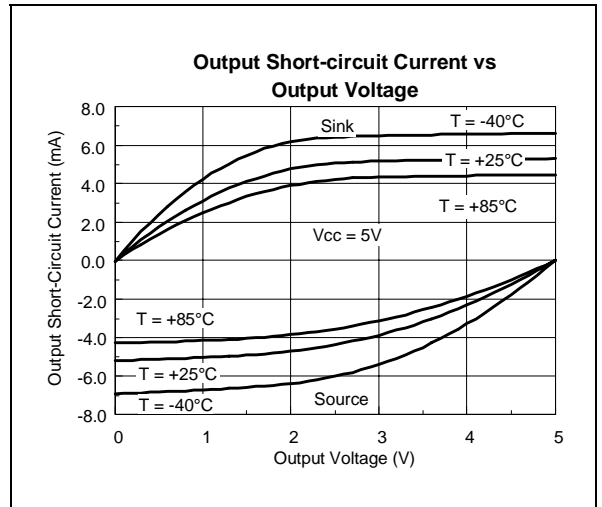


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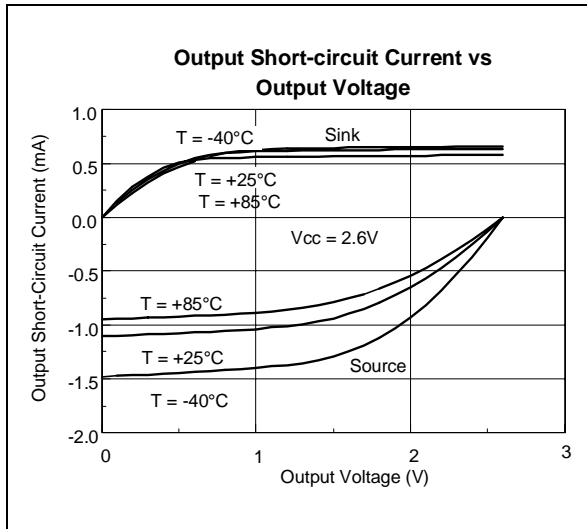


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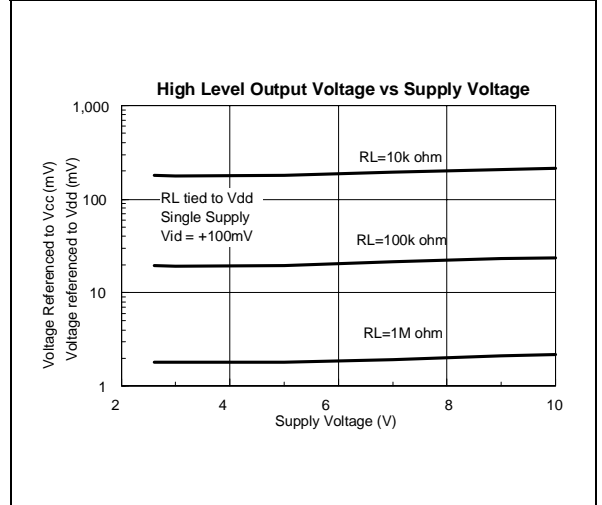




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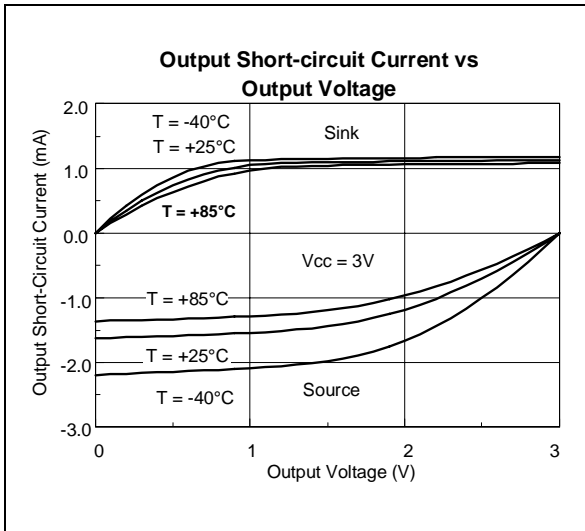


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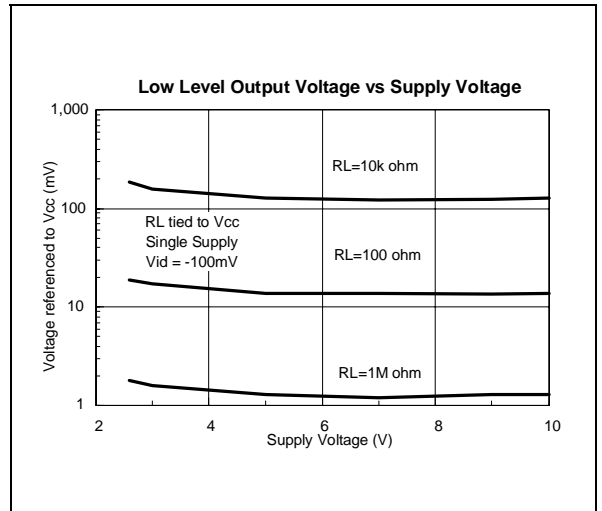


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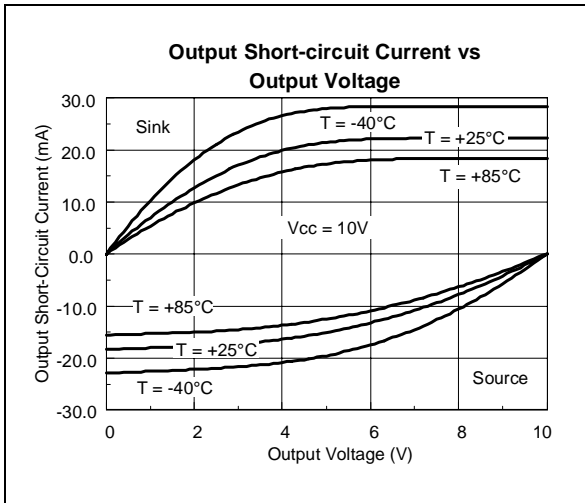


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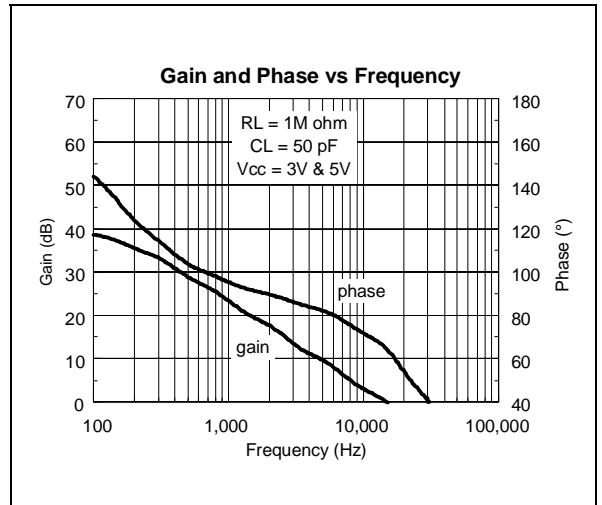


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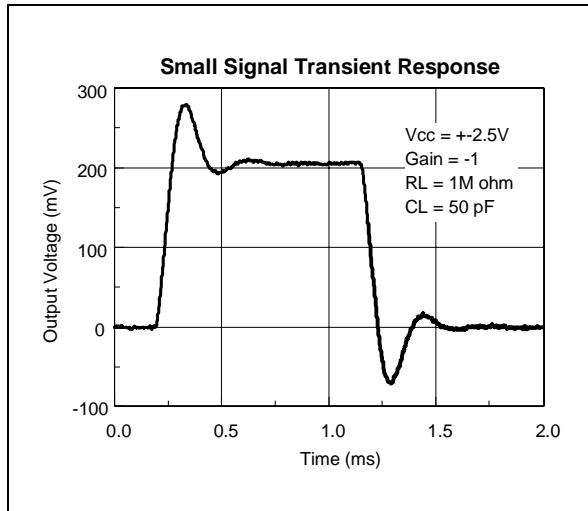


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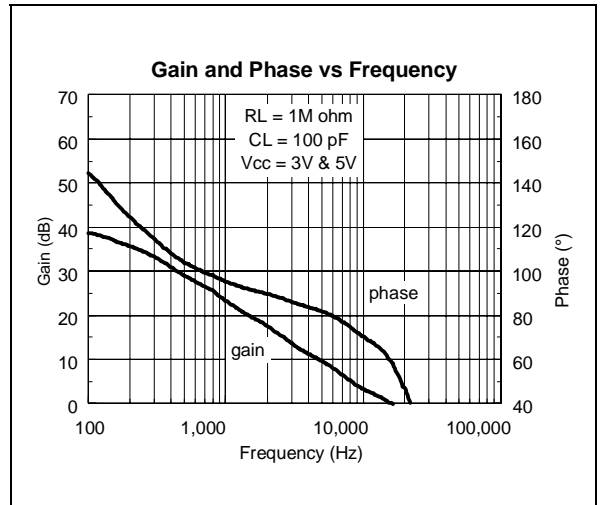


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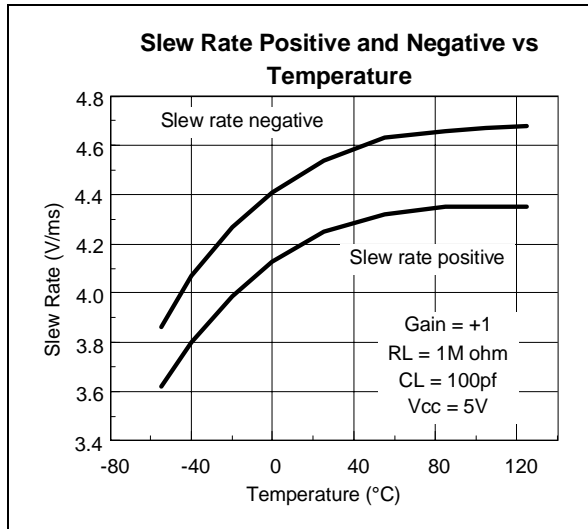
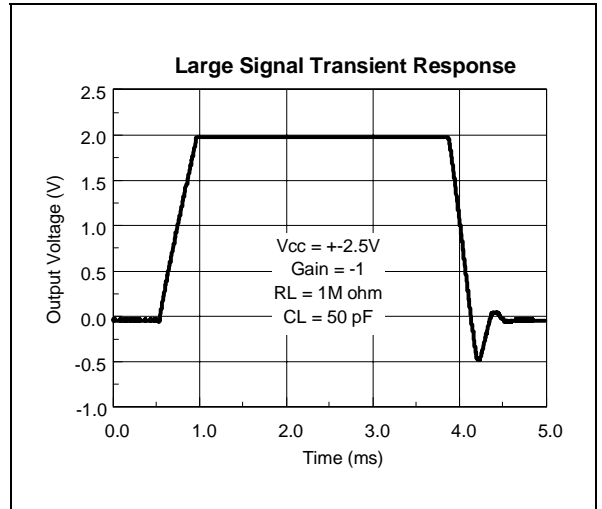


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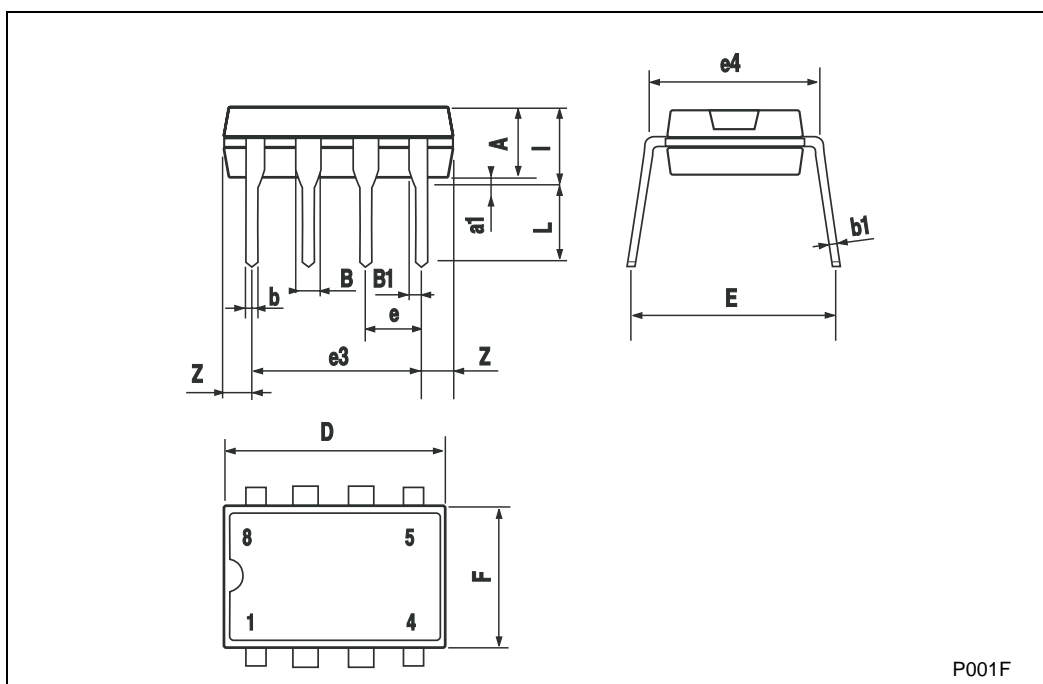


### 3 Package Mechanical Data

#### 3.1 DIP8 package

**Plastic DIP-8 MECHANICAL DATA**

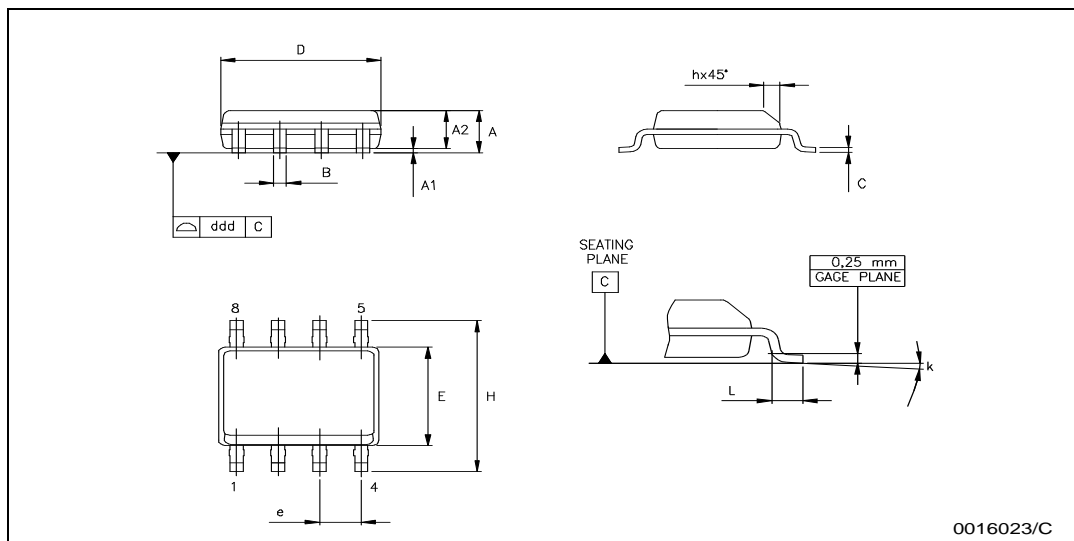
DIM.	mm.			inch		
	MIN.	TYP	MAX.	MIN.	TYP.	MAX.
A		3.3			0.130	
a1	0.7			0.028		
B	1.39		1.65	0.055		0.065
B1	0.91		1.04	0.036		0.041
b		0.5			0.020	
b1	0.38		0.5	0.015		0.020
D			9.8			0.386
E		8.8			0.346	
e		2.54			0.100	
e3		7.62			0.300	
e4		7.62			0.300	
F			7.1			0.280
I			4.8			0.189
L		3.3			0.130	
Z	0.44		1.6	0.017		0.063



3.2 SO8 package

**SO-8 MECHANICAL DATA**

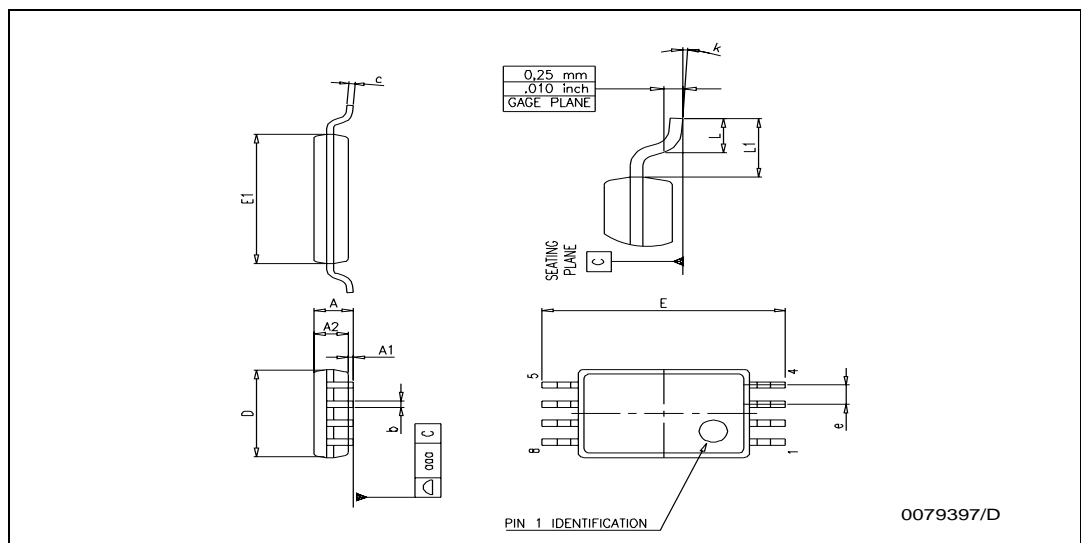
DIM.	mm.			inch		
	MIN.	TYP.	MAX.	MIN.	TYP.	MAX.
A	1.35		1.75	0.053		0.069
A1	0.10		0.25	0.04		0.010
A2	1.10		1.65	0.043		0.065
B	0.33		0.51	0.013		0.020
C	0.19		0.25	0.007		0.010
D	4.80		5.00	0.189		0.197
E	3.80		4.00	0.150		0.157
e		1.27			0.050	
H	5.80		6.20	0.228		0.244
h	0.25		0.50	0.010		0.020
L	0.40		1.27	0.016		0.050
k	8° (max.)					
ddd			0.1			0.04



3.3 TSSOP8 package

**TSSOP8 MECHANICAL DATA**

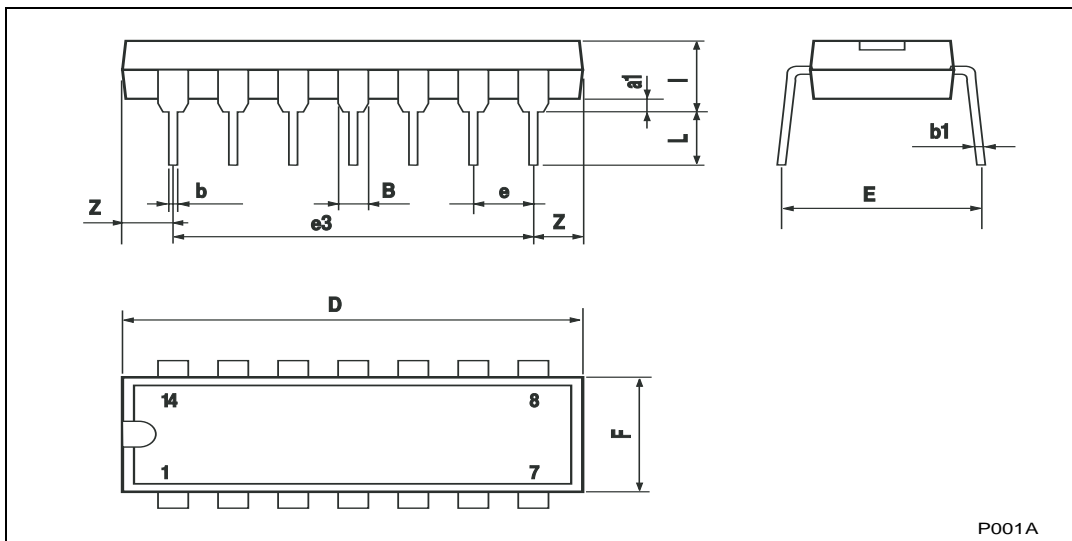
DIM.	mm.			inch		
	MIN.	TYP	MAX.	MIN.	TYP.	MAX.
A			1.2			0.047
A1	0.05		0.15	0.002		0.006
A2	0.80	1.00	1.05	0.031	0.039	0.041
b	0.19		0.30	0.007		0.012
c	0.09		0.20	0.004		0.008
D	2.90	3.00	3.10	0.114	0.118	0.122
E	6.20	6.40	6.60	0.244	0.252	0.260
E1	4.30	4.40	4.50	0.169	0.173	0.177
e		0.65			0.0256	
K	0°		8°	0°		8°
L	0.45	0.60	0.75	0.018	0.024	0.030
L1		1			0.039	



3.4 DIP14 package

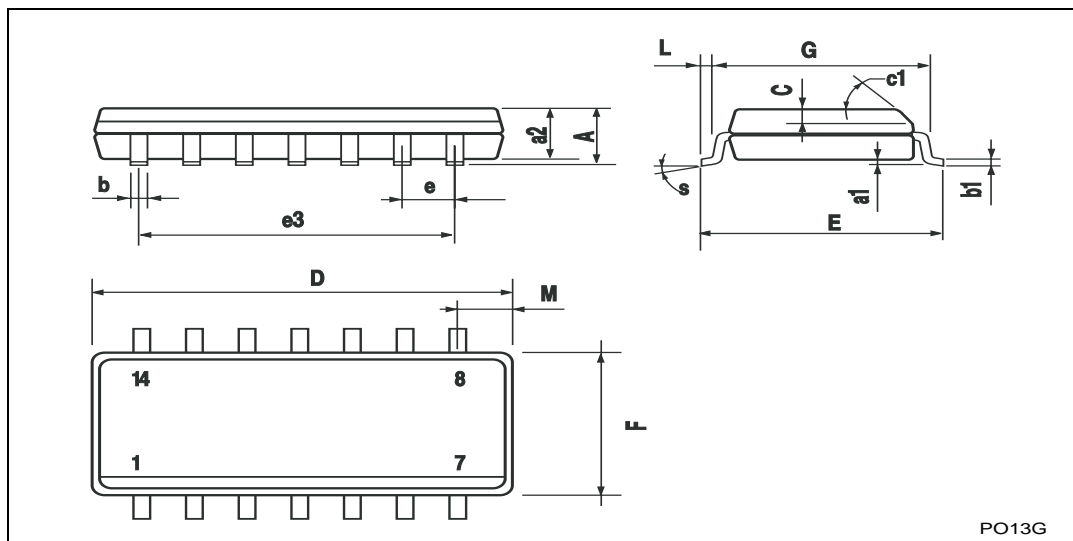
**Plastic DIP-14 MECHANICAL DATA**

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



3.5 SO14 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.)					

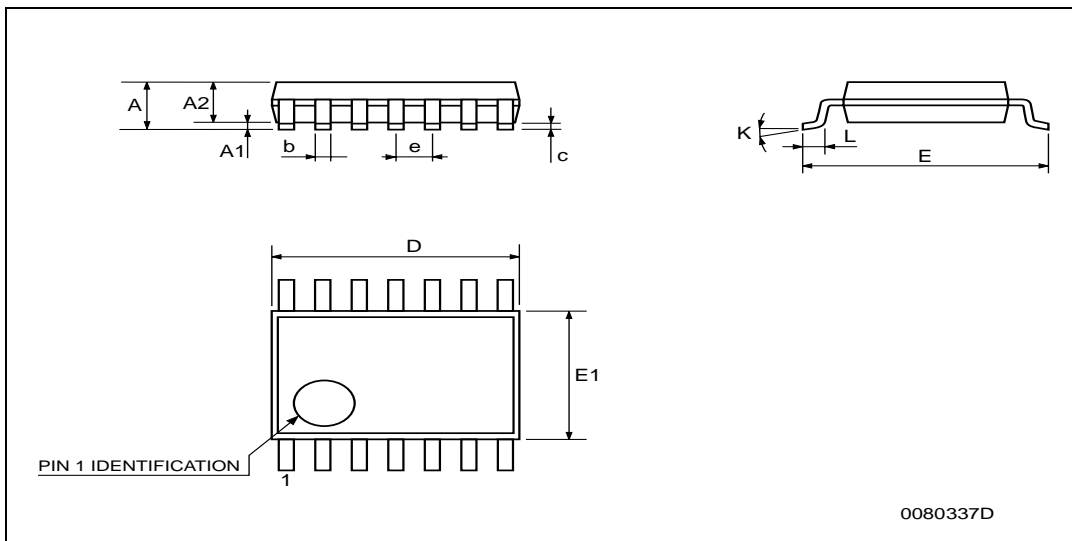


PO13G

3.6 TSSOP14 package

**TSSOP14 MECHANICAL DATA**

DIM.	mm.			inch		
	MIN.	TYP	MAX.	MIN.	TYP.	MAX.
A			1.2			0.047
A1	0.05		0.15	0.002	0.004	0.006
A2	0.8	1	1.05	0.031	0.039	0.041
b	0.19		0.30	0.007		0.012
c	0.09		0.20	0.004		0.0089
D	4.9	5	5.1	0.193	0.197	0.201
E	6.2	6.4	6.6	0.244	0.252	0.260
E1	4.3	4.4	4.48	0.169	0.173	0.176
e		0.65 BSC			0.0256 BSC	
K	0°		8°	0°		8°
L	0.45	0.60	0.75	0.018	0.024	0.030

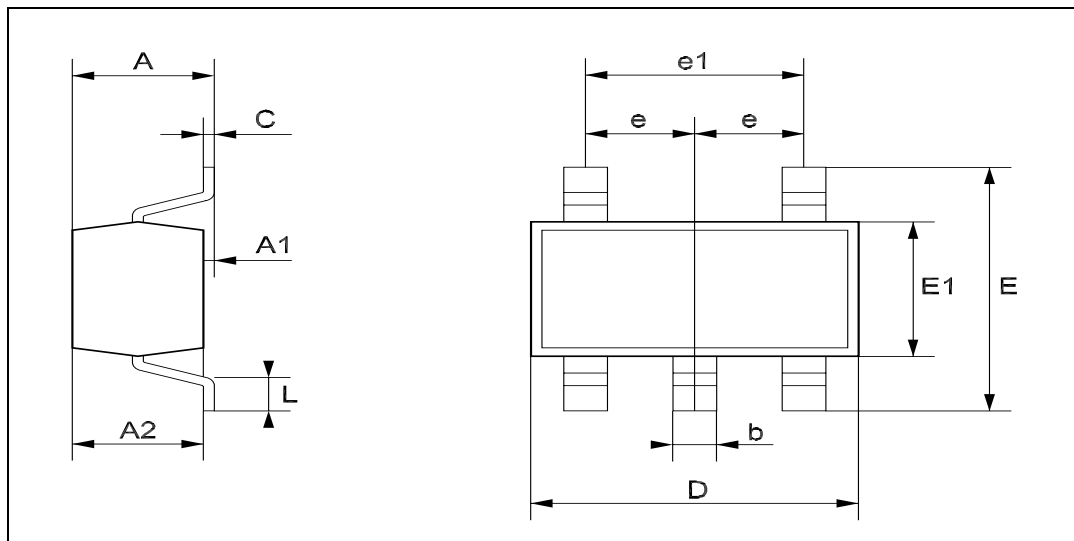




3.7 SOT23-5 package

**SOT23-5L MECHANICAL DATA**

DIM.	mm.			mils		
	MIN.	TYP	MAX.	MIN.	TYP.	MAX.
A	0.90		1.45	35.4		57.1
A1	0.00		0.15	0.0		5.9
A2	0.90		1.30	35.4		51.2
b	0.35		0.50	13.7		19.7
C	0.09		0.20	3.5		7.8
D	2.80		3.00	110.2		118.1
E	2.60		3.00	102.3		118.1
E1	1.50		1.75	59.0		68.8
e		0.95			37.4	
e1		1.9			74.8	
L	0.35		0.55	13.7		21.6



## 4 Summary of Changes OU

Date	Revision	Description of Changes
01 Dec 2001	1	First Release
01 Dec 2004	2	Modifications on AMR table page 2 (explanation of Vid and Vi limits)

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