

Output Rail-to-Rail Micropower Operational Amplifiers

- Rail-to-rail output voltage swing
- Micropower consumption (1.2 μ A)
- 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.

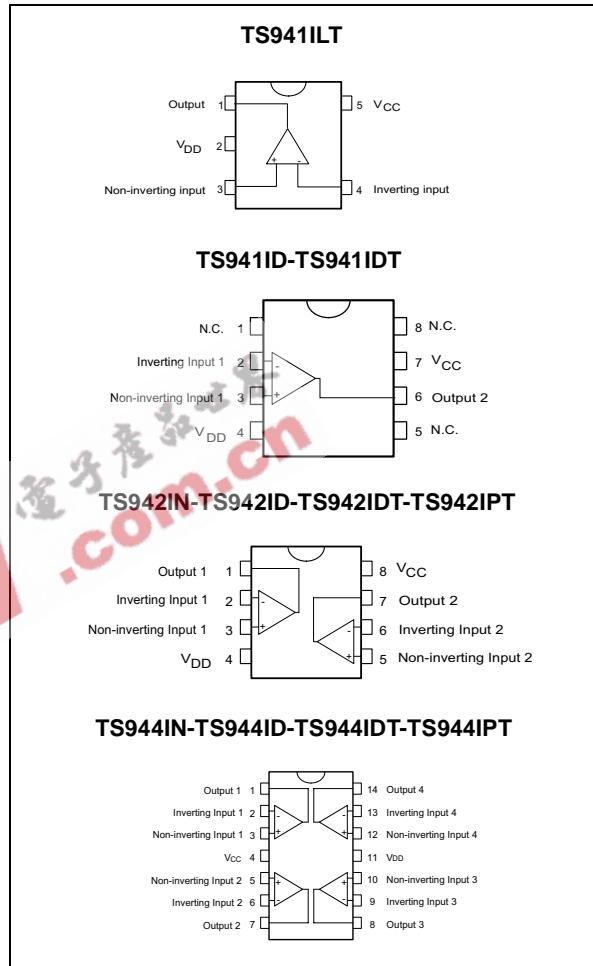
They exhibit excellent consumption - 1.2 μ A, while featuring 10kHz gain bandwidth product, 1.5mA output capability and output rail-to-rail operation - 2.85V typ @ 3V with $R_L=10\text{k}\Omega$.

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 (pagers)
- Smoke/gas/fire detectors
- Instrumentation & sensing
- PH meter

Pin Connections (top view)



TS941-TS942-TS944

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	

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1 Absolute Maximum Ratings

Table 1: Key parameters and their absolute maximum ratings

Symbol	Parameter	Value	Unit
VCC	Supply voltage ¹	12	V
Vid	Differential Input Voltage ²	±12	V
V _{in}	Input Voltage Range ³	Vdd-0.3 to Vcc+0.3	V
T _{std}	Storage Temperature Range	-65 to +150	°C
T _j	Maximum Junction Temperature	150	°C
R _{thja}	Thermal Resistance Junction to Ambient ⁴ SOT23-5 DIP8 DIP14 SO8 SO14 TSSOP8 TSSOP14	250 85 66 125 103 120 100	°C/W
ESD	HBM: Human Body Model ⁵	2	kV
	MM: Machine Model ⁶ (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_{CC} +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
Vicm	Common Mode Input Voltage Range	V _{DD} -0.2 to V _{CC} -1.3	V
T _{oper}	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
ΔV_{io}	Input Offset Voltage Drift		7		$\mu V/^\circ C$
I_{io}	Input Offset Current ¹⁾		1	100	pA
I_{ib}	Input Bias Current ¹⁾		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		μA
I_{cc}	Supply Current (per amplifier) $A_{VCL} = 1$, no load		1.2	1.8	μA
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
ϕ_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)²⁾

Symbol	Parameter	Min.	Typ.	Max.	Unit
V_{io}	Input Offset Voltage TS941/2/4 TS941/2/4A TS941/2/4B			10 5 2	mV
ΔV_{io}	Input Offset Voltage Drift		7		$\mu V/^\circ C$
I_{io}	Input Offset Current ¹⁾		1	100	pA
I_{ib}	Input Bias Current ¹⁾		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 $V_{ID} = 100mV, V_O = V_{DD}$ Output Sink Current $V_{ID} = -100mV, V_O = V_{CC}$	680 650	1500 1300		μA
I_{cc}	Supply Current (per amplifier) $A_{VCL} = 1$, no load		1.2	1.8	μA
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
ϕ_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
ΔV_{io}	Input Offset Voltage Drift		7		$\mu V/^\circ C$
I_{io}	Input Offset Current ¹⁾		1	100	pA
I_{ib}	Input Bias Current ¹⁾		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 $V_{ID} = 100mV$, $V_O = V_{DD}$ Output Sink Current $V_{ID} = -100mV$, $V_O = V_{CC}$	3	4.5 5		mA
I_{CC}	Supply Current (per amplifier) $A_{VCL} = 1$, no load		1.2	1.85	μA
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
ϕ_m	Phase Margin $C_L = 50pF$		65		Degrees

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

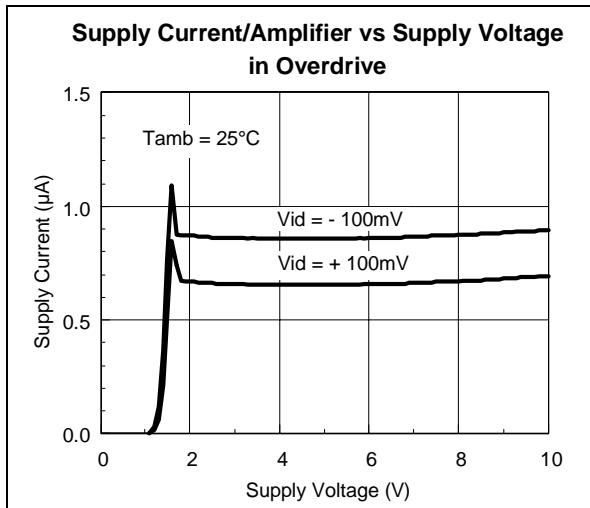
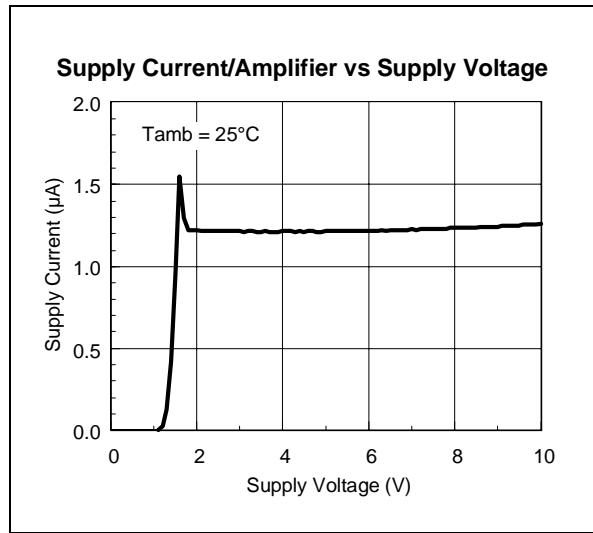
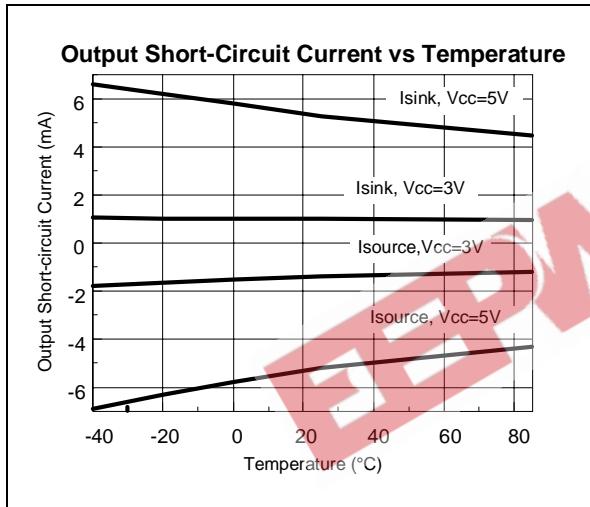
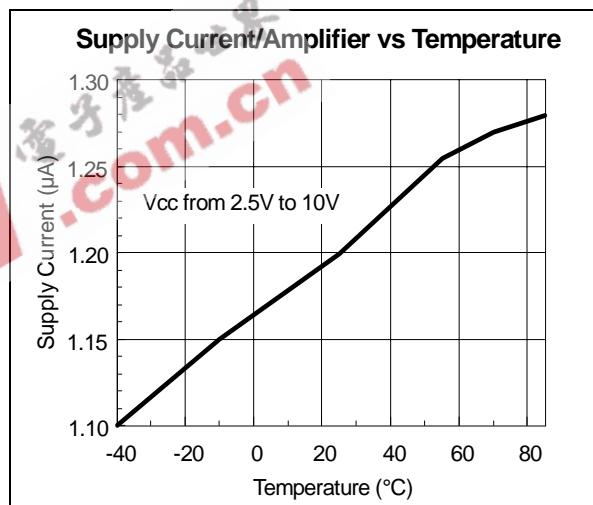
Figure 1:**Figure 3:****Figure 2:****Figure 4:**

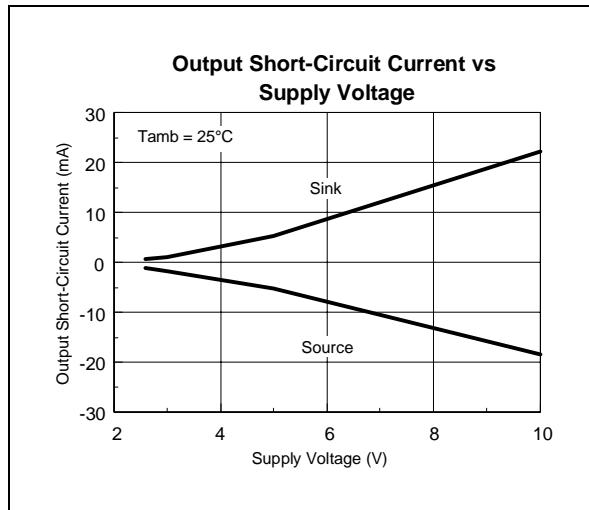
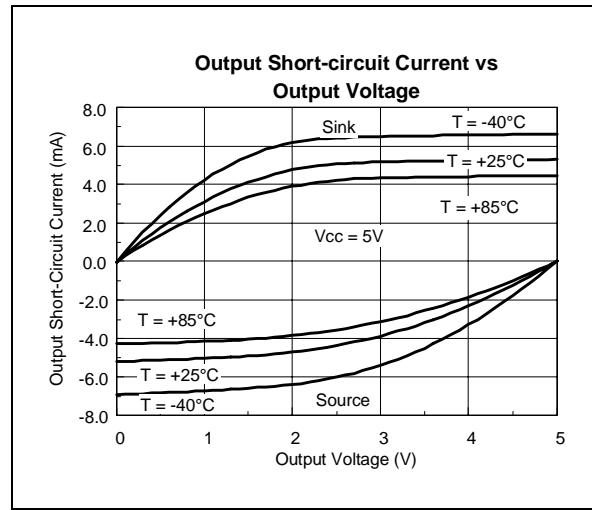
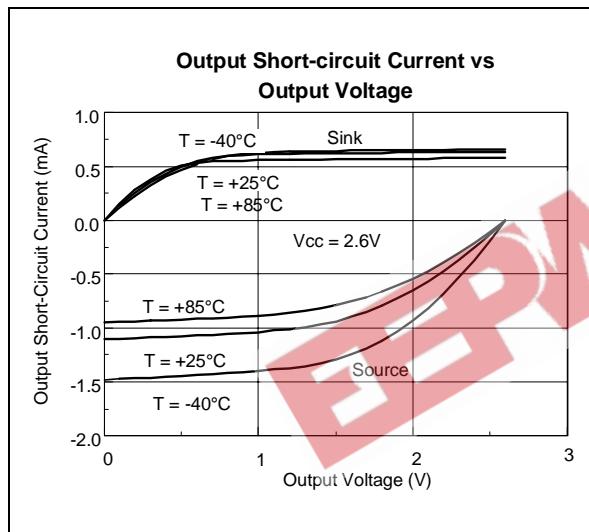
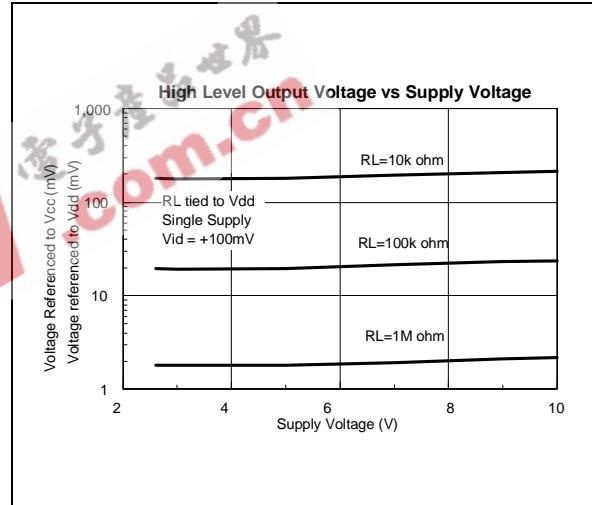
Figure 5:**Figure 7:****Figure 6:****Figure 8:**

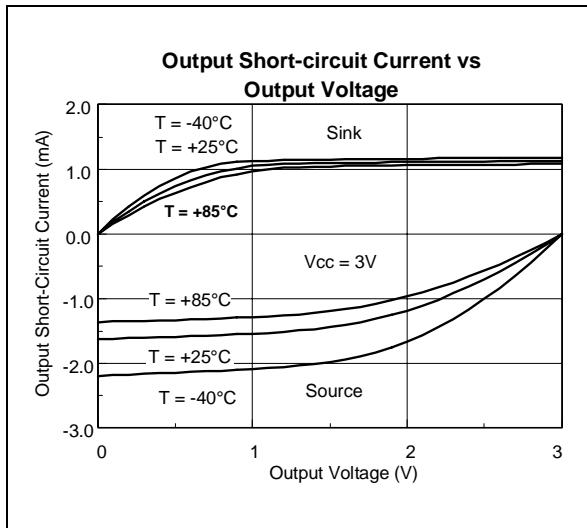
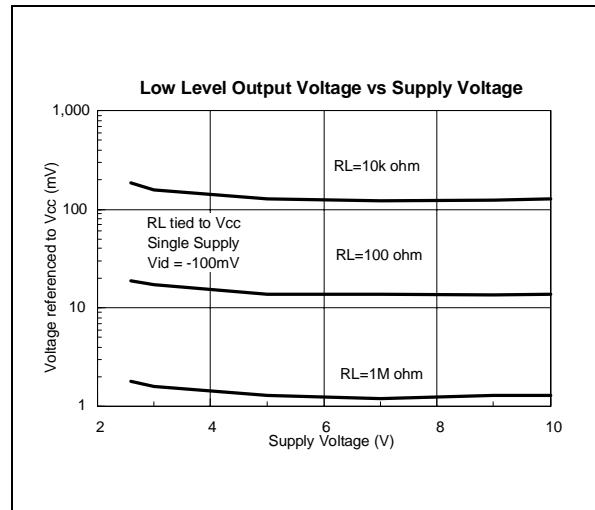
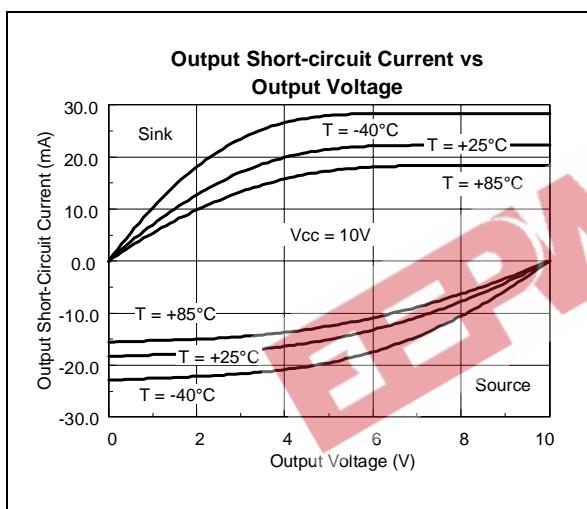
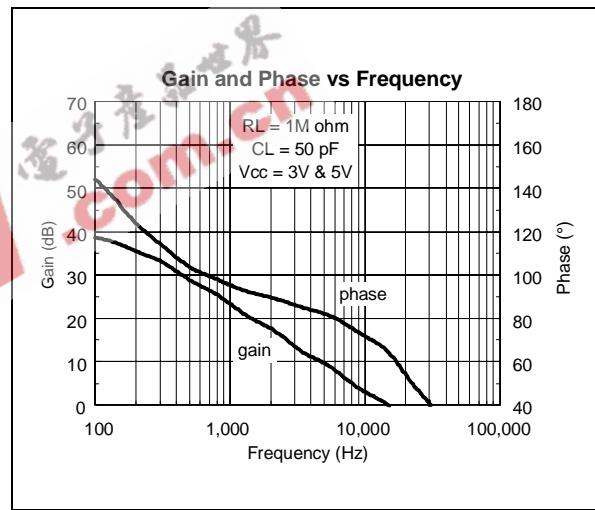
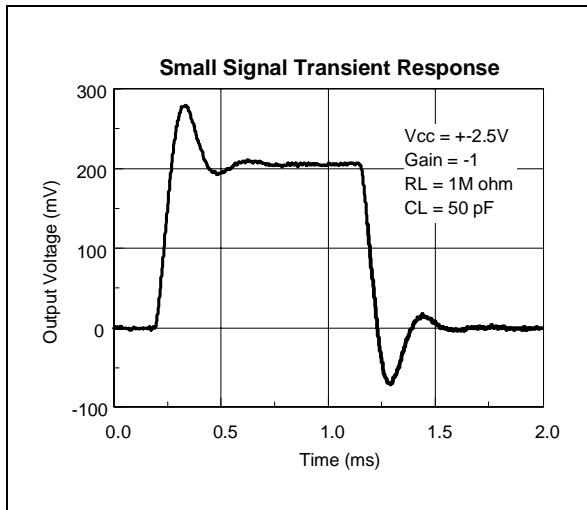
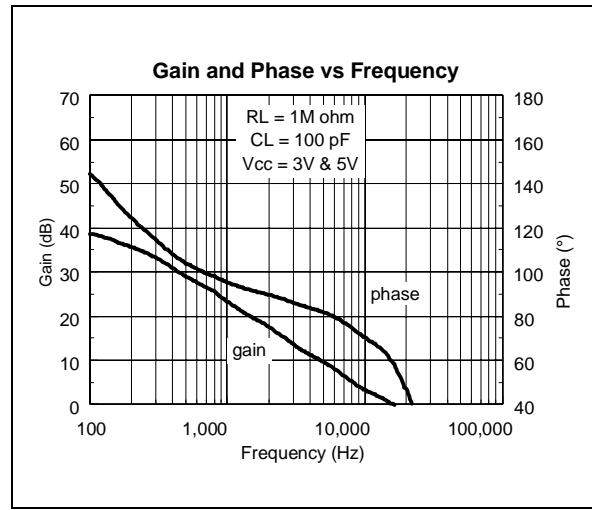
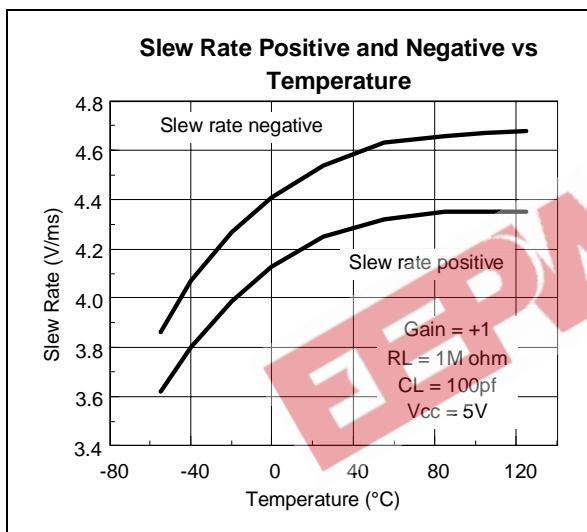
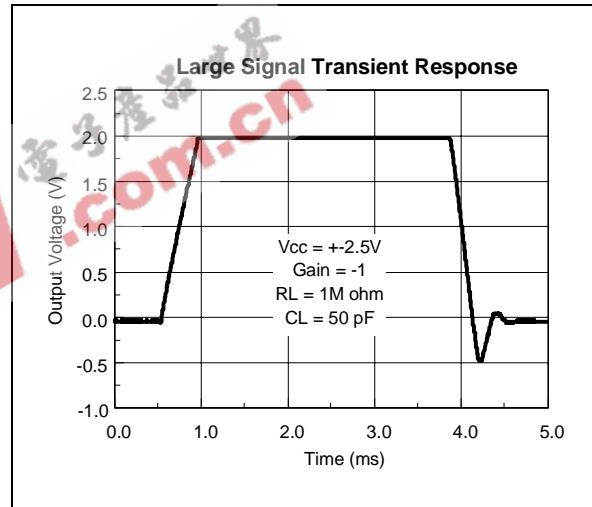
Figure 9:**Figure 11:****Figure 10:****Figure 12:**

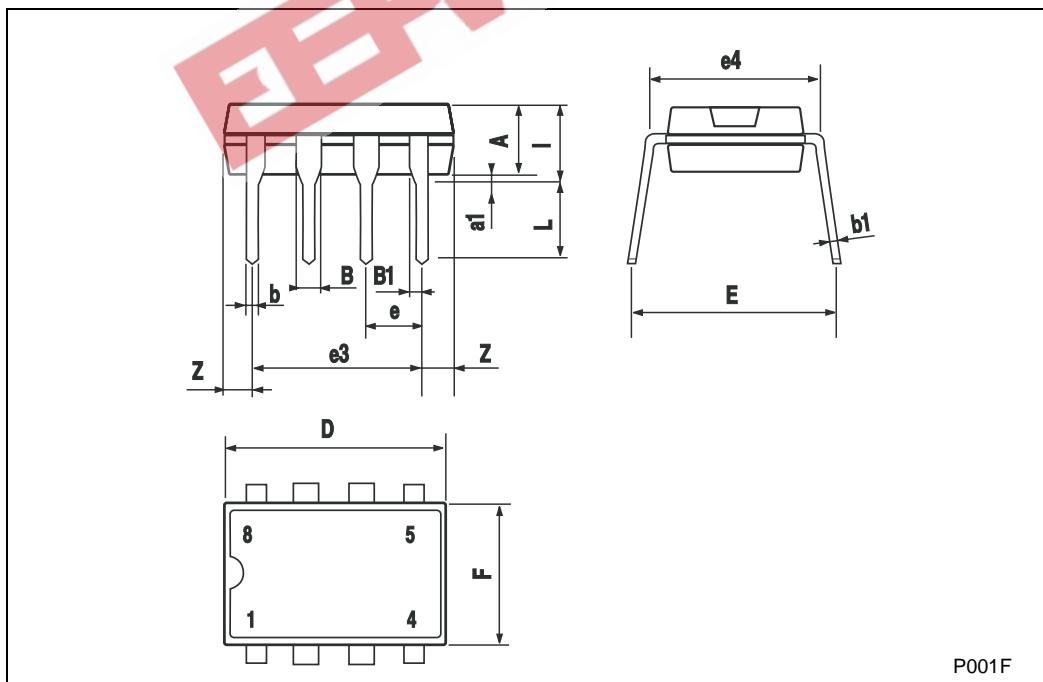
Figure 13:**Figure 15:****Figure 14:****Figure 16:**

3 Package Mechanical Data

3.1 DIP8 package

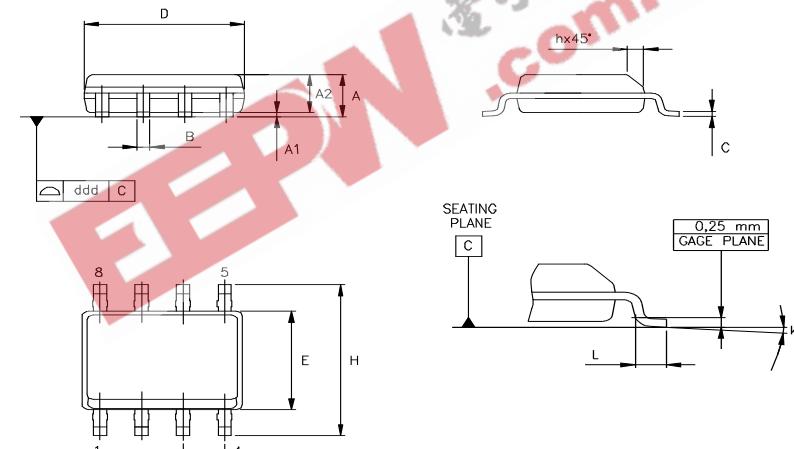
Plastic DIP-8 MECHANICAL DATA

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



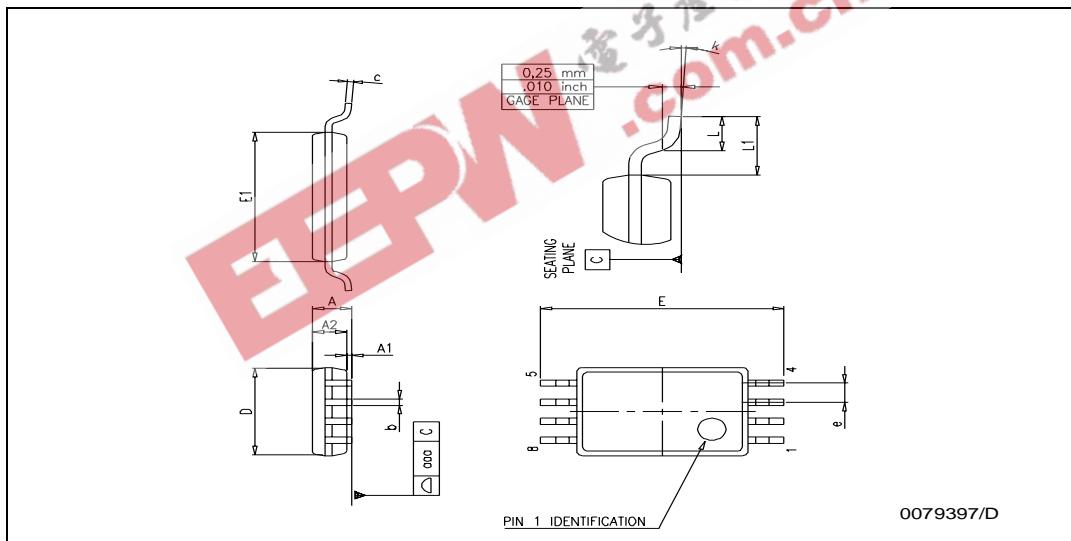
The technical drawing illustrates the physical dimensions of the SO-8 package. It includes a top view showing leads numbered 1 through 8, a side view showing height H and lead thickness h, and a cross-sectional view showing lead pitch e, lead height A, lead thickness A1, lead width A2, and lead angle k. A note specifies a seating plane at 0.25 mm above the gage plane.

0016023/C

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	

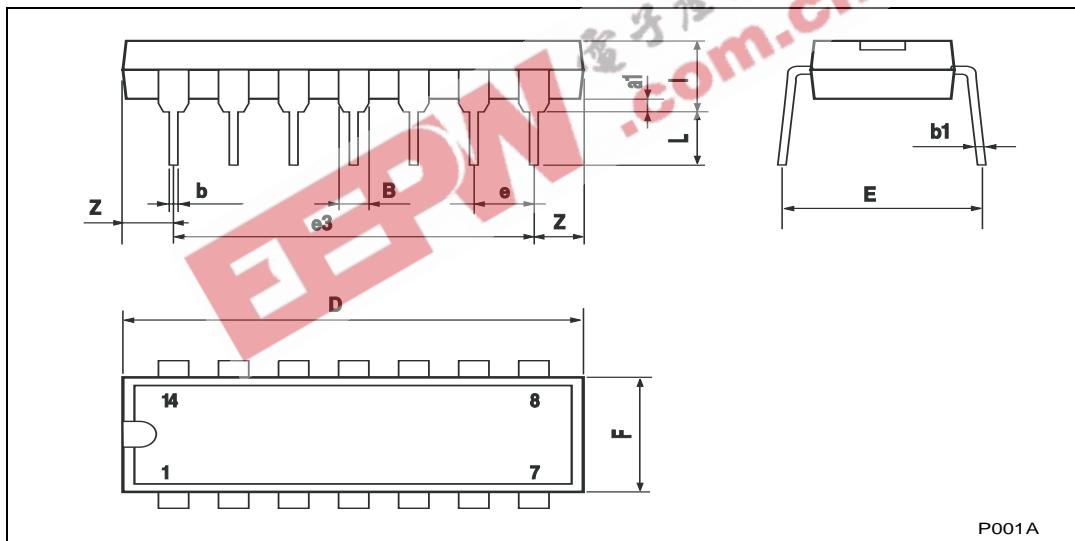


0079397/D

3.4 DIP14 package

Plastic DIP-14 MECHANICAL DATA

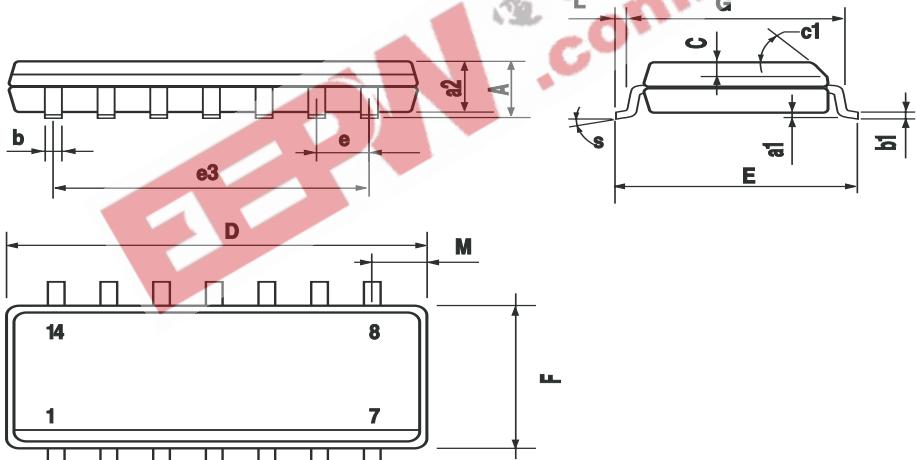
DIM.	mm.			inch		
	MIN.	TYP.	MAX.	MIN.	TYP.	MAX.
a1	0.51			0.020		
B	1.39		1.65	0.055		0.065
b		0.5			0.020	
b1		0.25			0.010	
D			20			0.787
E		8.5			0.335	
e		2.54			0.100	
e3		15.24			0.600	
F			7.1			0.280
I			5.1			0.201
L		3.3			0.130	
Z	1.27		2.54	0.050		0.100



P001A

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.)				



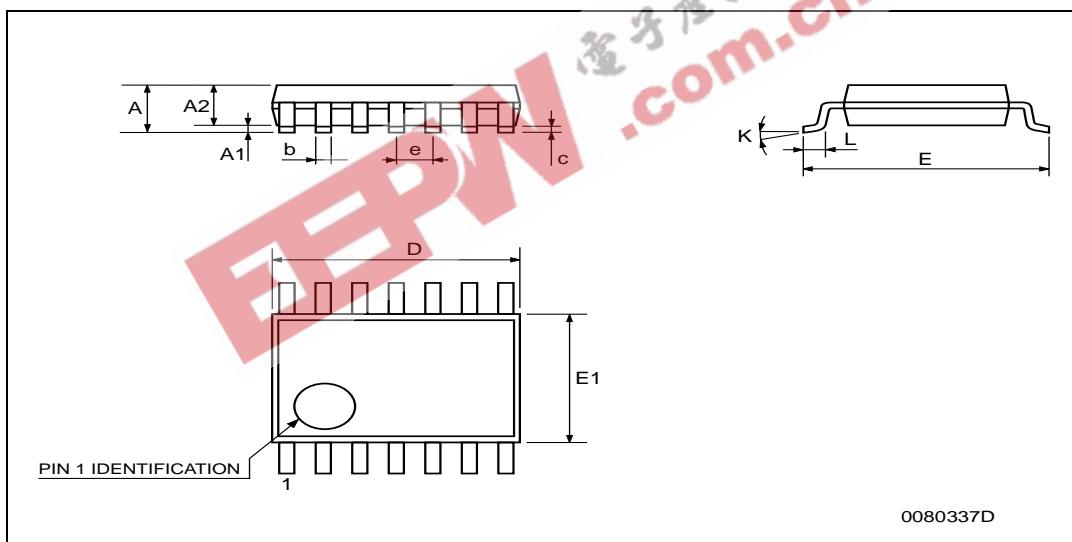
The technical drawing illustrates the physical dimensions of an SO-14 package. The top view shows the package outline with pins numbered 1 through 14. The cross-sectional view provides a detailed look at the lead profile, defining terms like A (lead thickness), a1 (lead pitch), a2 (lead height), b (width), b1 (inner lead width), c (lead gap), c1 (lead angle), D (lead length), E (body length), G (body width), L (lead height), M (lead thickness), and S (lead slope). The drawing also indicates the lead spacing (e) and the overall body width (e3).

PO13G

3.6 TSSOP14 package

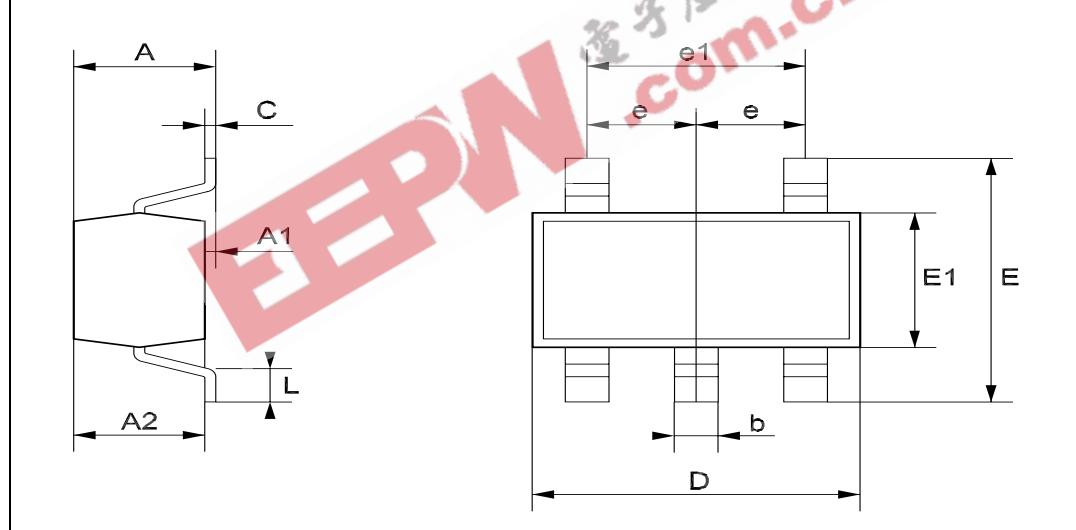
TSSOP14 MECHANICAL DATA

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



The diagram illustrates the physical dimensions of the SOT23-5 package. It shows a side view of the package with dimensions A, C, A1, A2, L, and e. The top view shows the lead pitch b, the total width D, the total height E, the height of the body E1, and the lead thickness e1. The lead thickness e is also indicated. A large red watermark 'EEBN.com.cn' is diagonally across the drawing.

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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