



TS941-TS942-TS944

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.

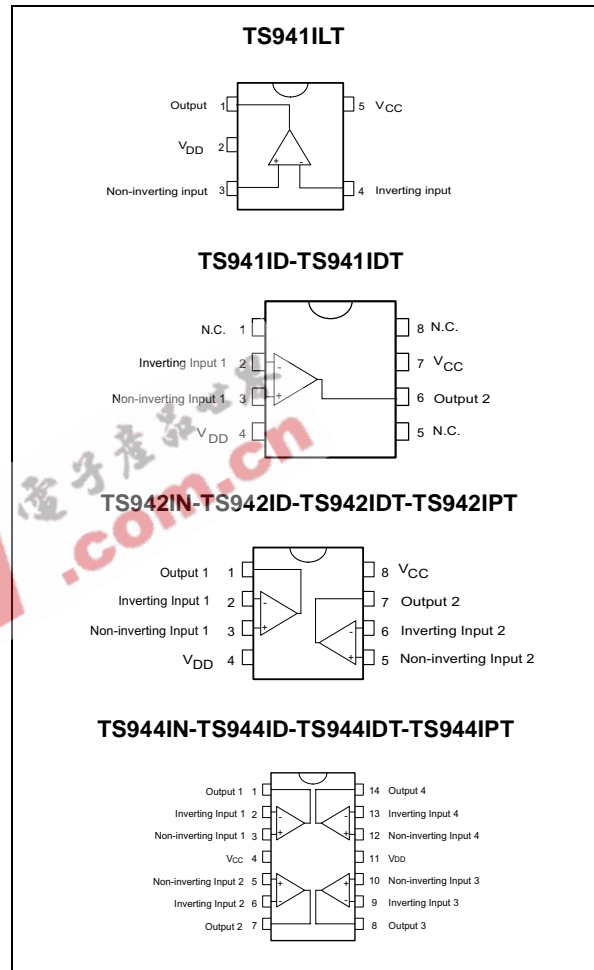
They exhibit excellent consumption - 1.2 μ A, while featuring 10kHz gain bandwidth product, 1.5mA output capability and output rail-to-rail operation - 2.85V typ @ 3V with $R_L=10k\Omega$.

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 | V _{dd} -0.3 to V _{cc} +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 | 250 | °C/W |
| | SOT23-5 | 85 | |
| | DIP8 | 66 | |
| | DIP14 | 125 | |
| | SO8 | 103 | |
| | SO14 | 120 | |
| | TSSOP8 TSSOP14 | 100 | |
| 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 |
| V _{icm} | 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 $V_{ID} = 100mV, V_O = V_{DD}$ | 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 | 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:

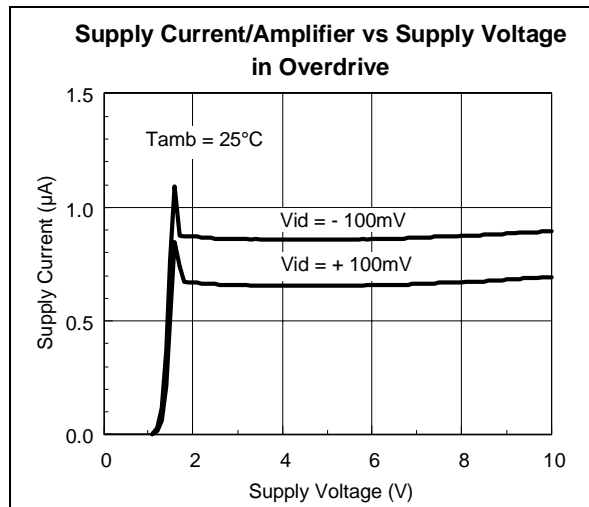


Figure 3:

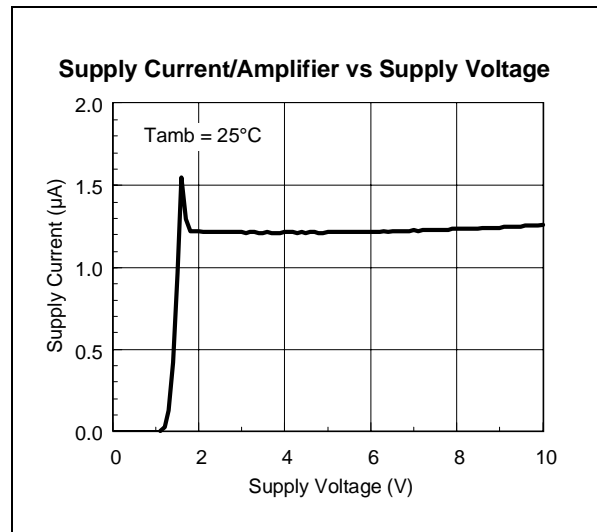


Figure 2:

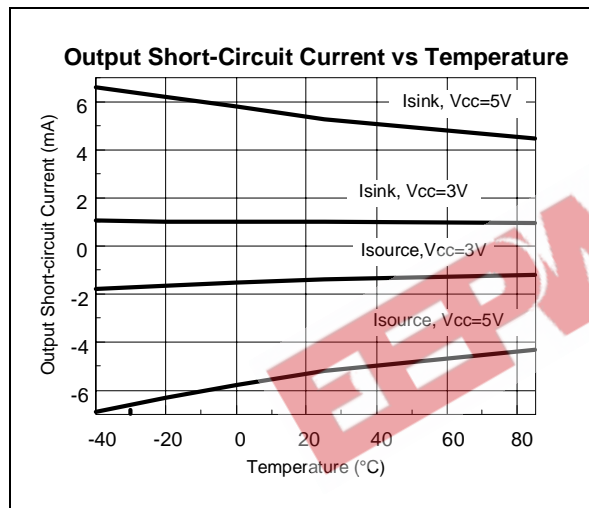


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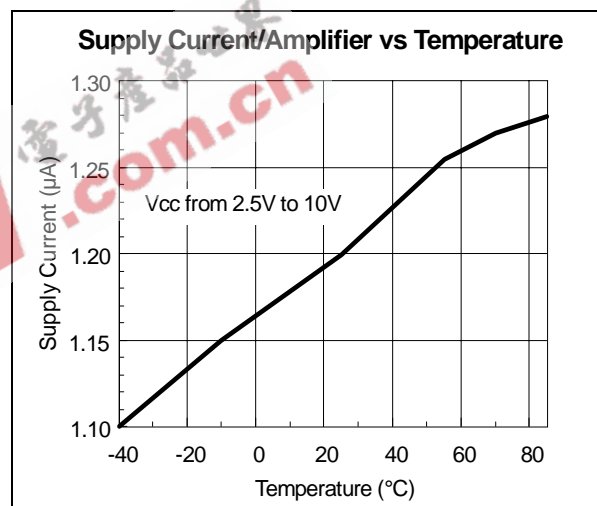


Figure 5:

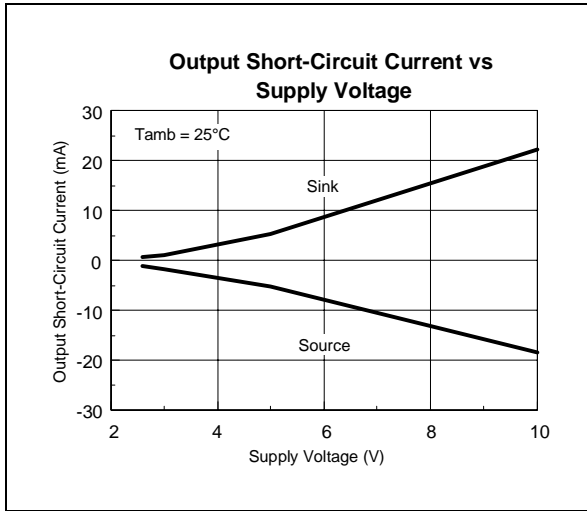


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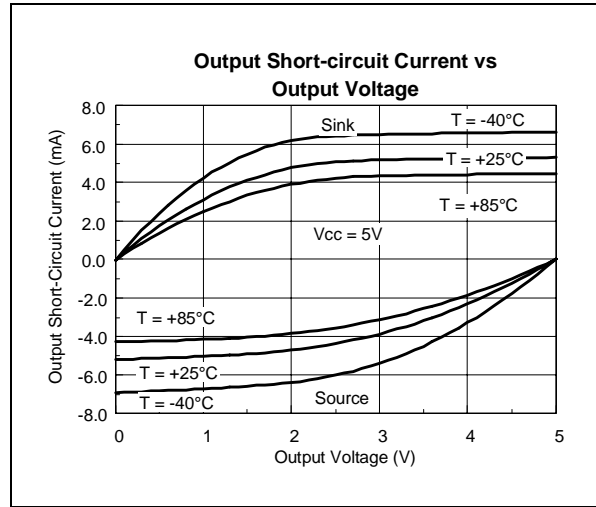


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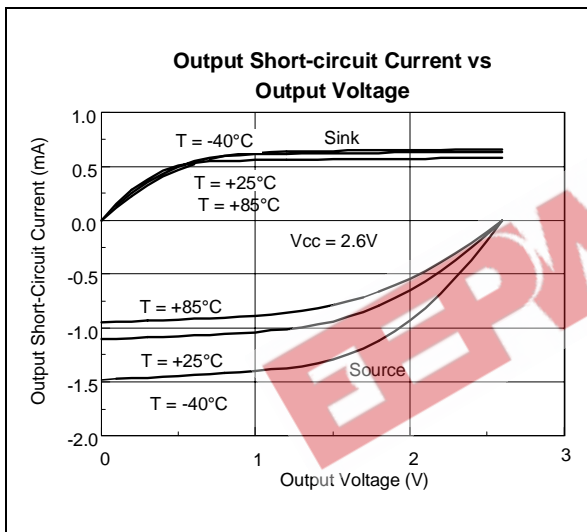


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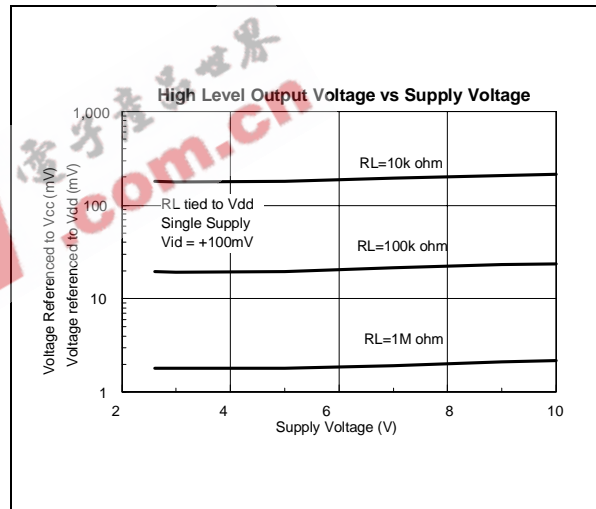


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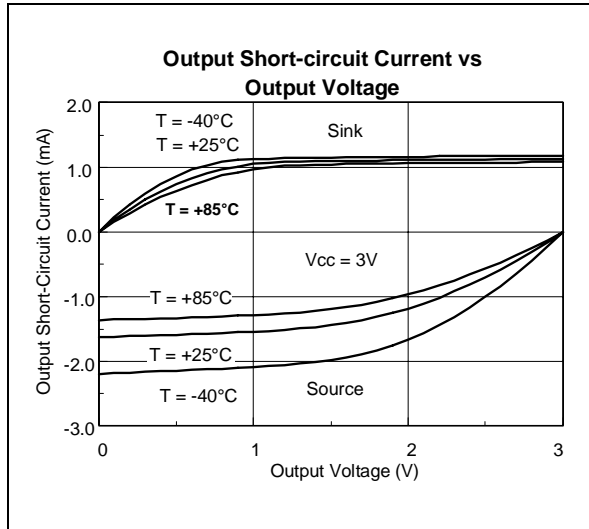


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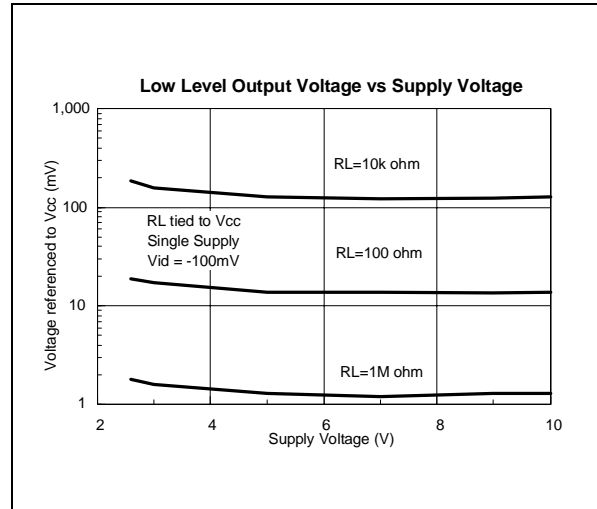


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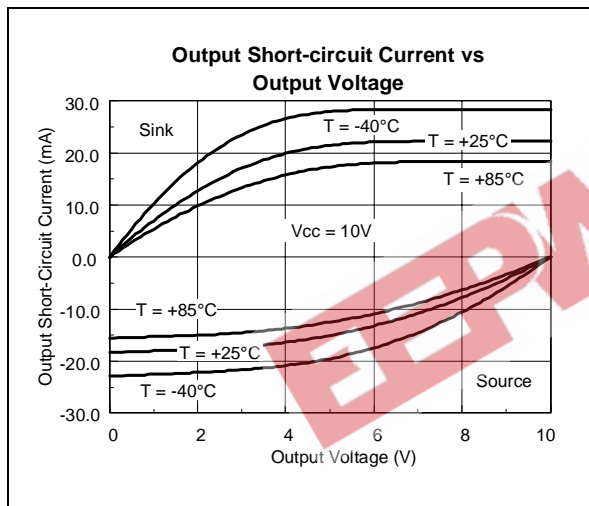


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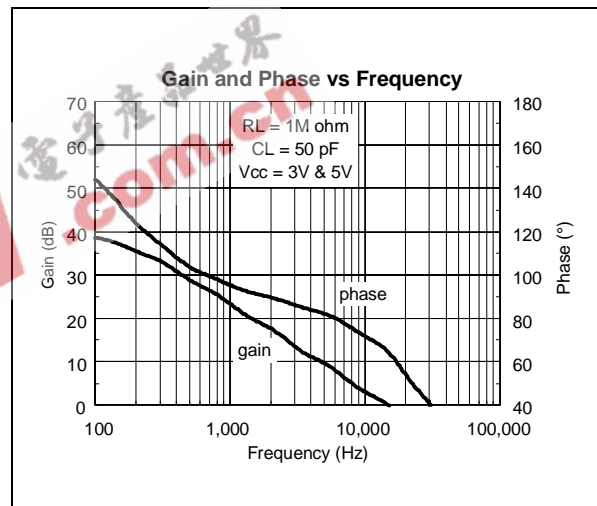


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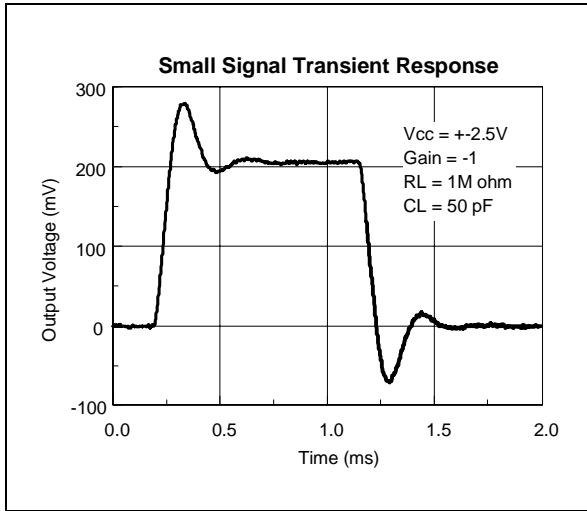


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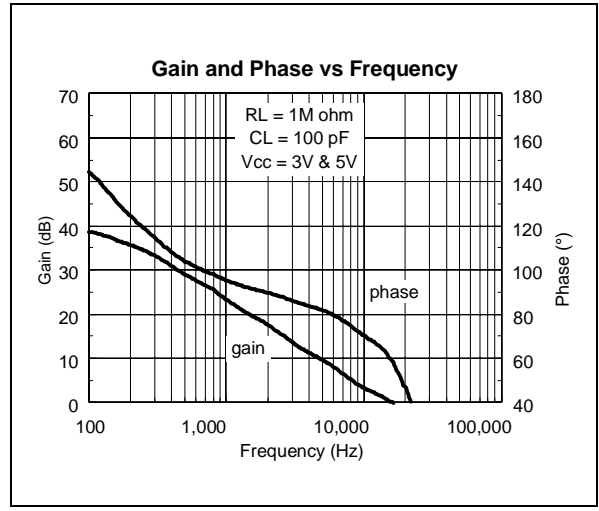


Figure 14:

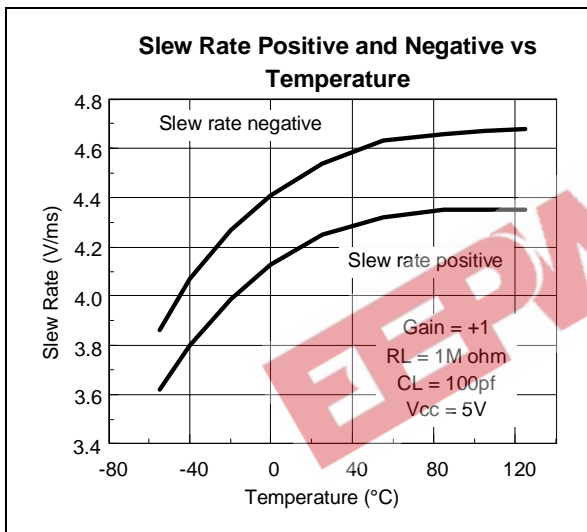
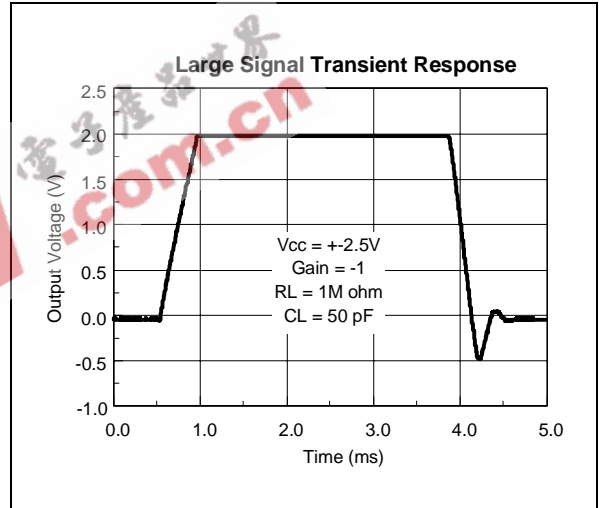


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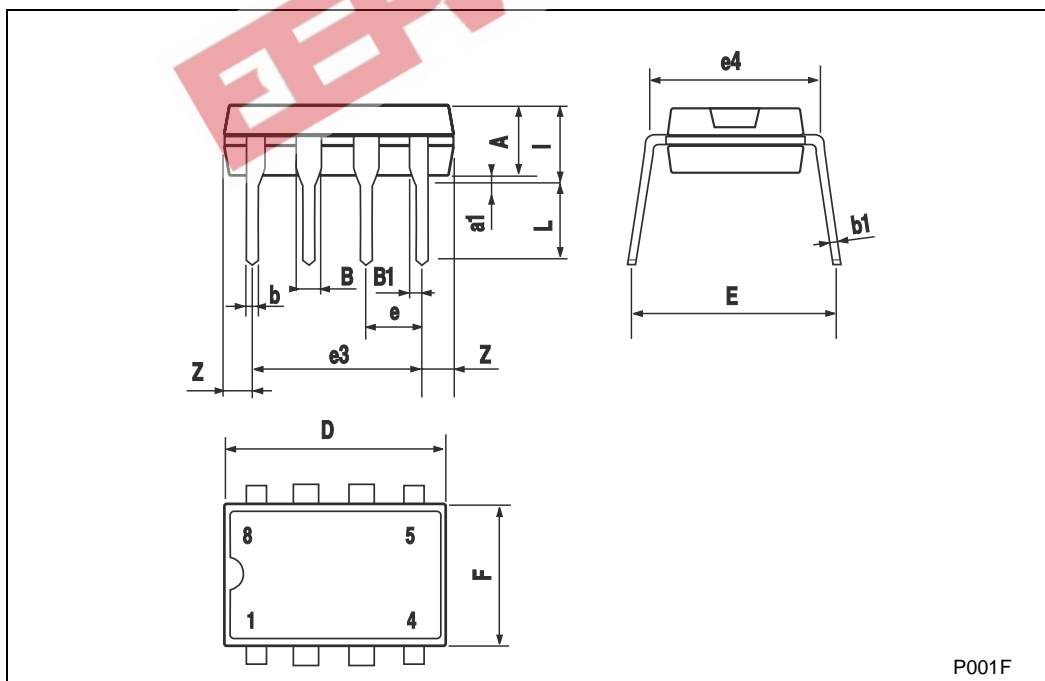


3 Package Mechanical Data

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 |

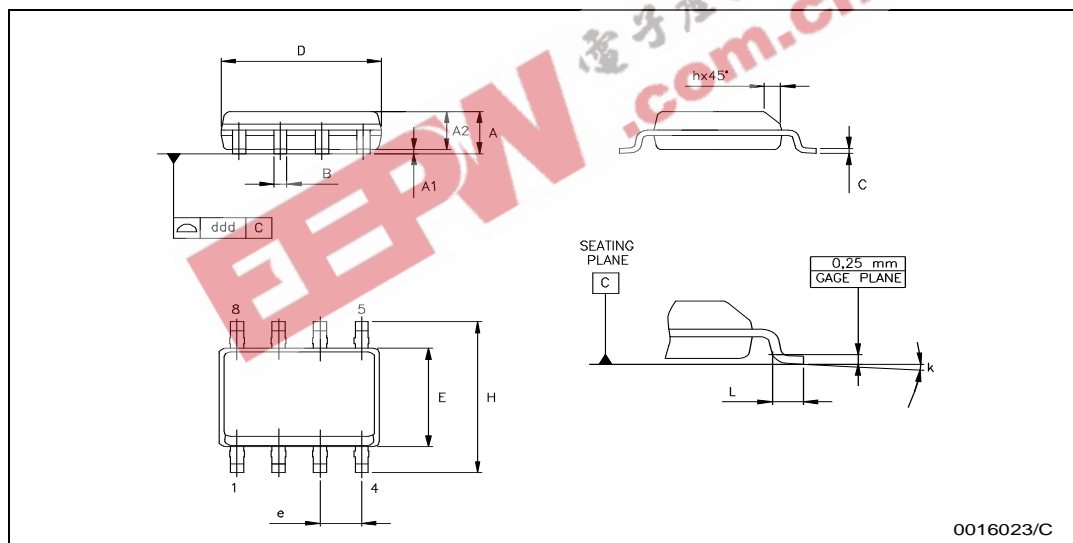


P001F

3.2 SO8 package

SO-8 MECHANICAL DATA

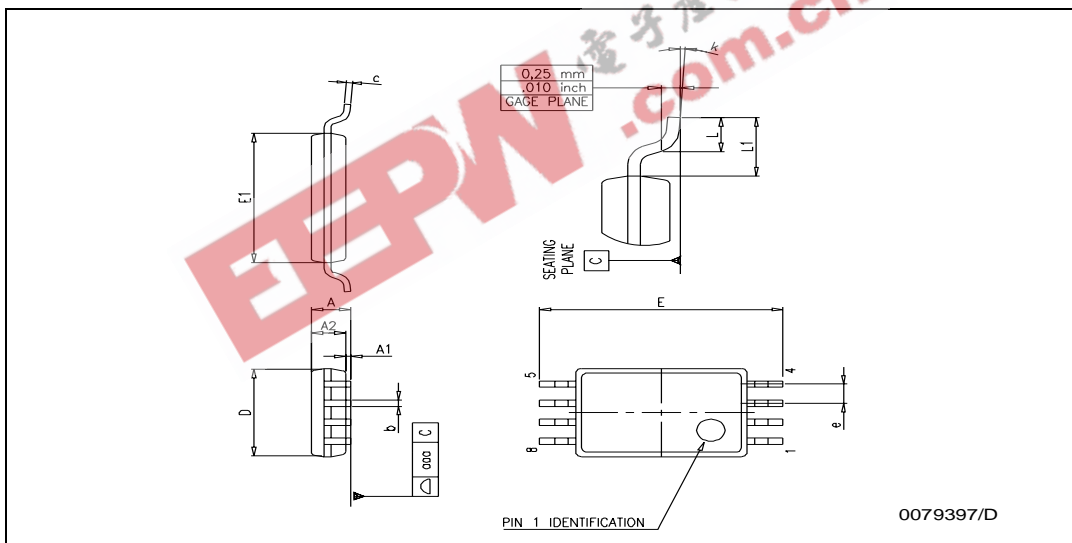
| DIM. | mm. | | | inch | | |
|------|-----------|------|------|-------|-------|-------|
| | MIN. | TYP | MAX. | MIN. | TYP. | MAX. |
| A | 1.35 | | 1.75 | 0.053 | | 0.069 |
| A1 | 0.10 | | 0.25 | 0.04 | | 0.010 |
| A2 | 1.10 | | 1.65 | 0.043 | | 0.065 |
| B | 0.33 | | 0.51 | 0.013 | | 0.020 |
| C | 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

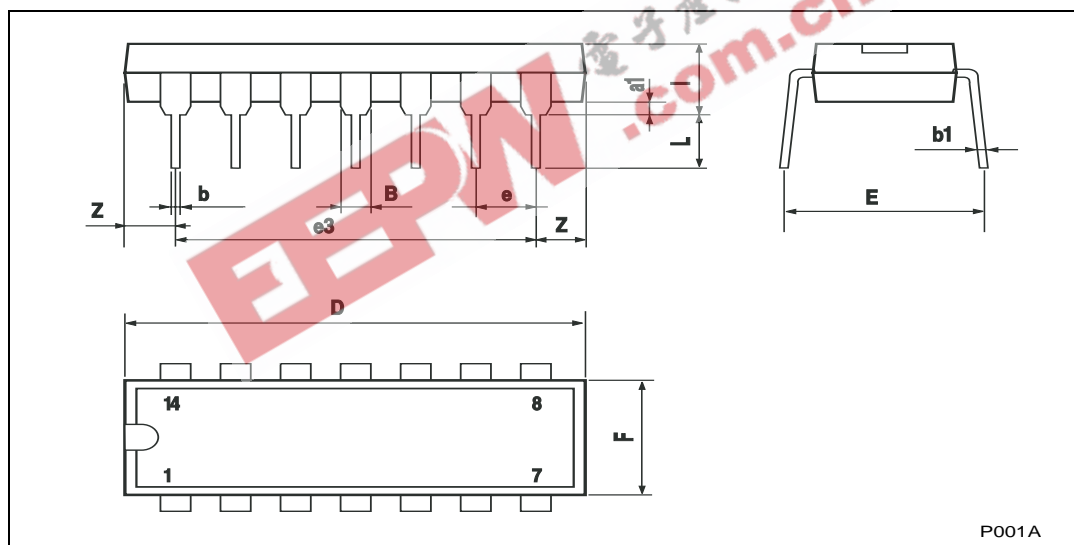
| DIM. | mm. | | | inch | | |
|------|------|------|------|-------|--------|-------|
| | MIN. | TYP | MAX. | MIN. | TYP. | MAX. |
| A | | | 1.2 | | | 0.047 |
| A1 | 0.05 | | 0.15 | 0.002 | | 0.006 |
| A2 | 0.80 | 1.00 | 1.05 | 0.031 | 0.039 | 0.041 |
| b | 0.19 | | 0.30 | 0.007 | | 0.012 |
| c | 0.09 | | 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 |

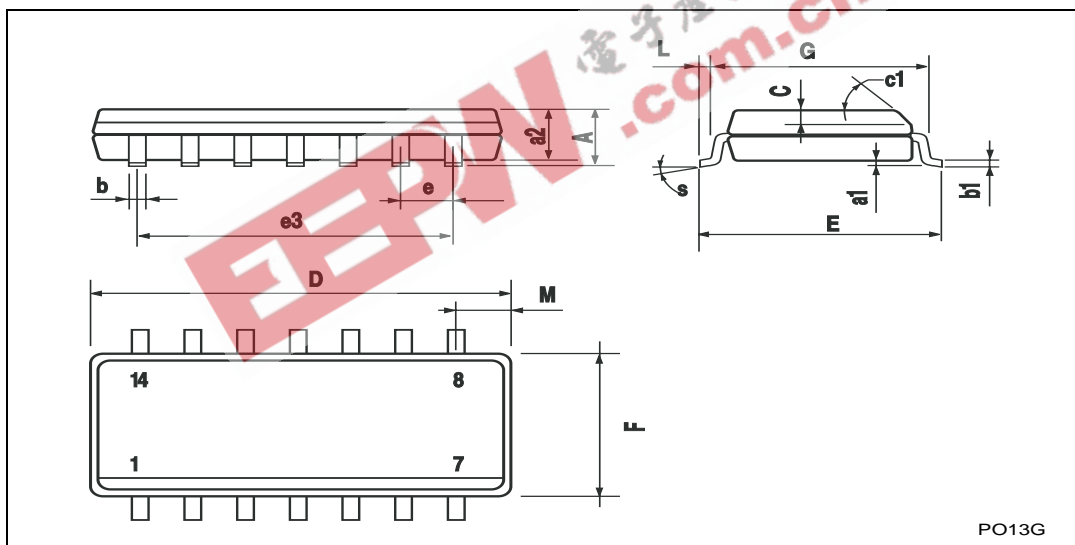


P001A

3.5 SO14 package

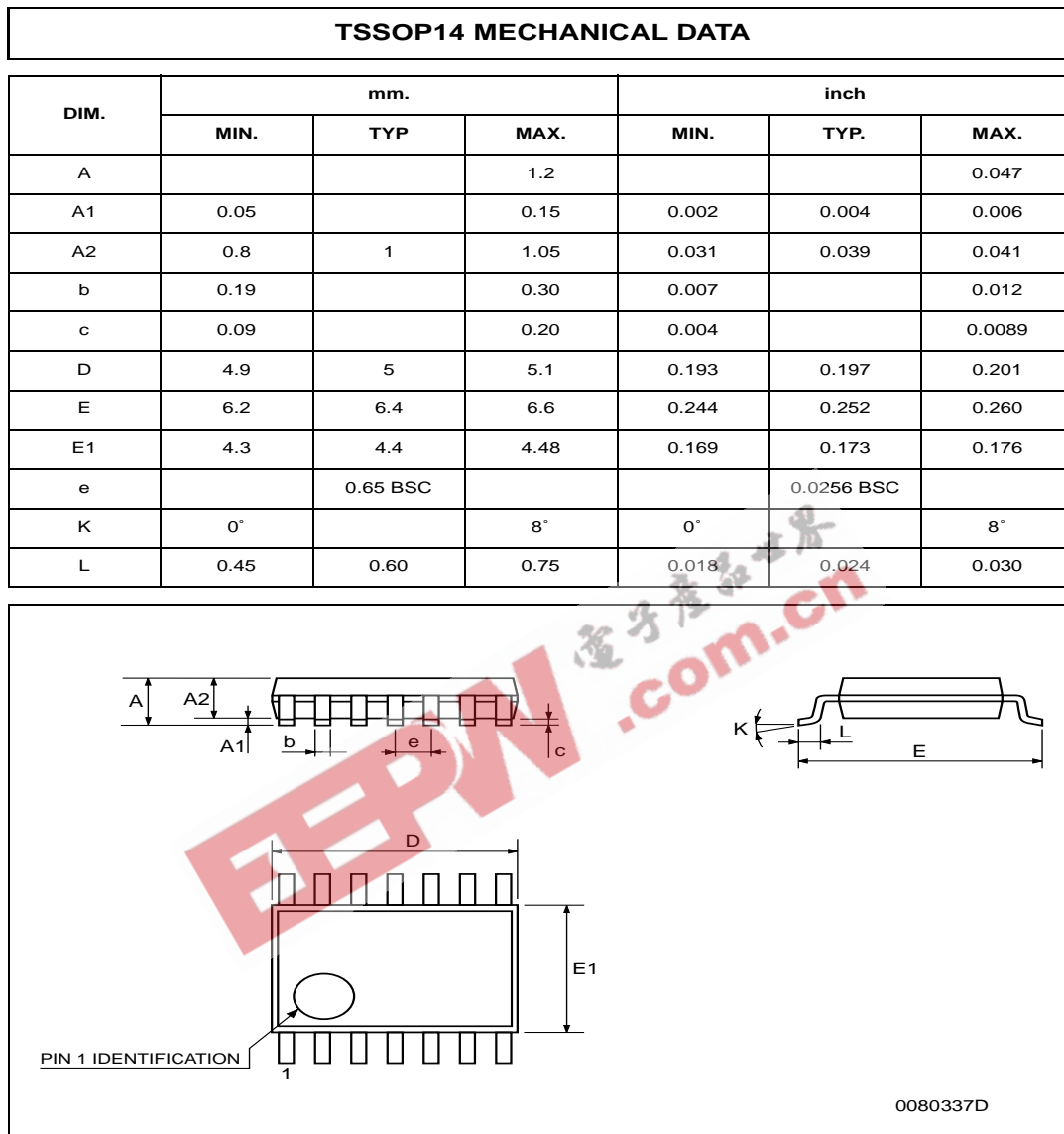
SO-14 MECHANICAL DATA

| 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.) | | | | | |



PO13G

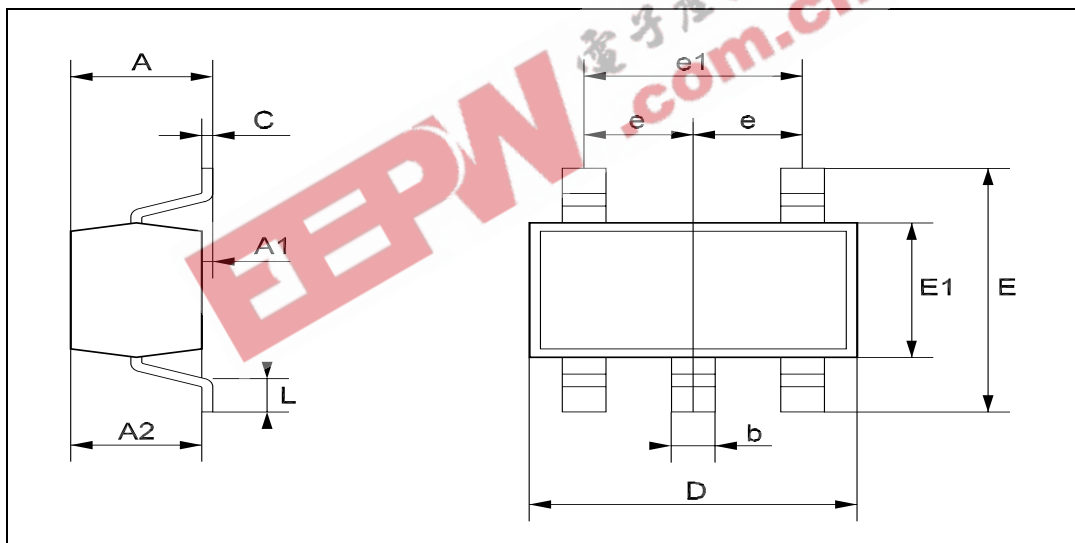
3.6 TSSOP14 package



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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