

Output rail-to-rail micropower operational amplifiers

Features

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

Applications

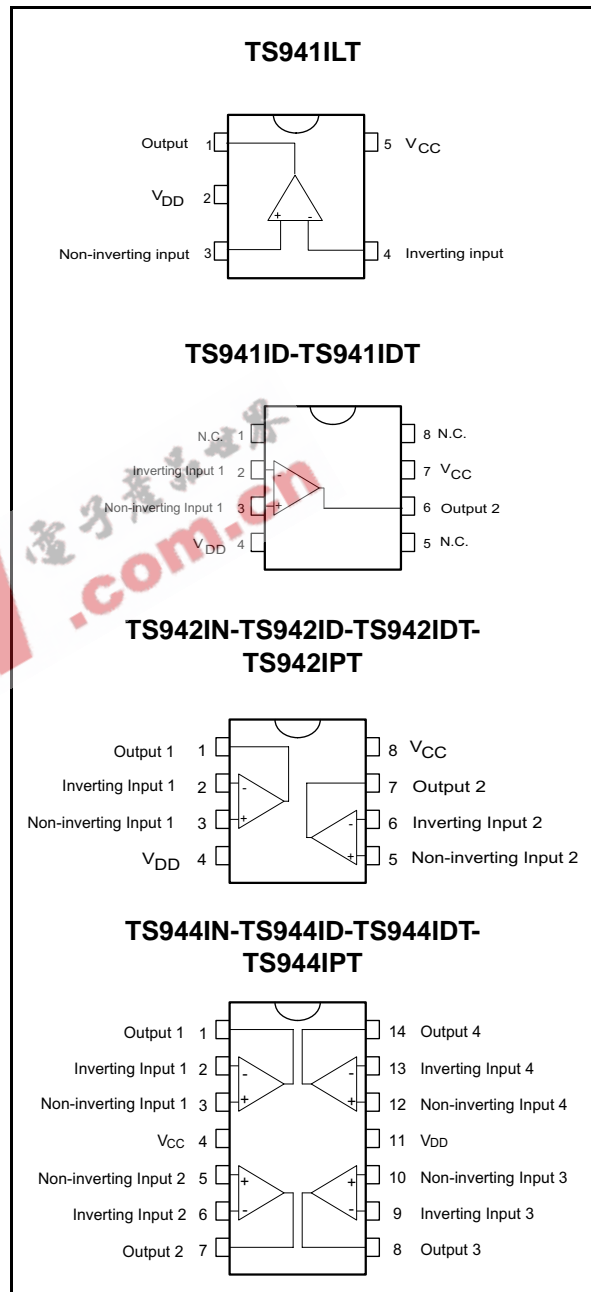
- Battery-powered systems (alarm)
- Portable communication systems (paggers)
- Smoke/gas/fire detectors
- Instrumentation and sensing
- PH meter

Description

The TS94x (single, dual and quad) series are operational amplifiers characterized for 2.5 V to 10 V operation over -40°C to $+85^{\circ}\text{C}$ temperature range.

They exhibit excellent consumption -1.2 μA , while featuring 10 kHz gain bandwidth product, 1.5 mA output capability and output rail-to-rail operation - 2.85 V typ @ 3 V 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 - 1 pA typ input bias current and constant supply current over supply voltage enhance TS94x's performance near the end of the battery charge or battery life.



1 Absolute maximum ratings and operating conditions

Table 1. Absolute maximum ratings (AMR)

| Symbol | Parameter | Value | Unit | |
|------------|---|------------------------------|------|----|
| V_{CC} | Supply voltage ⁽¹⁾ | 12 | V | |
| V_{id} | Differential input voltage ⁽²⁾ | ±12 | V | |
| V_{in} | Input voltage range ⁽³⁾ | $V_{DD}-0.3$ to $V_{CC}+0.3$ | V | |
| T_{stg} | Storage temperature range | -65 to +150 | °C | |
| T_j | Maximum junction temperature | 150 | °C | |
| R_{thja} | Thermal resistance junction to ambient ⁽⁴⁾ | | | |
| | SOT23-5 | 250 | °C/W | |
| | DIP8 | 85 | | |
| | DIP14 | 66 | | |
| | SO-8 | 125 | | |
| | SO-14 | 103 | | |
| | TSSOP8 | 120 | | |
| TSSOP14 | 100 | | | |
| R_{thjc} | Thermal resistance junction to case ⁽⁴⁾ | | | |
| | SOT23-5 | 81 | °C/W | |
| | DIP8 | 41 | | |
| | DIP14 | 33 | | |
| | SO-8 | 40 | | |
| | SO-14 | 31 | | |
| | TSSOP8 | 37 | | |
| TSSOP14 | 32 | | | |
| ESD | HBM: human body model ⁽⁵⁾ | 2 | kV | |
| | MM: machine model ⁽⁶⁾ (TS941, TS942) | 200 | V | |
| | CDM: charged device model ⁽⁷⁾ | TS941 - TS944IDT | 1.5 | kV |
| | | TS942 - TS944IPT | 1 | |
| | Latch-up immunity | 200 | mA | |
| | Lead temperature (soldering, 10sec) | 250 | °C | |

1. All voltage values, except differential voltage are with respect to network terminal.
2. Differential voltages are the 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. R_{th} are typical values.
5. Human body model: A 100 pF capacitor is charged to the specified voltage, then discharged through a 1.5 kΩ resistor between two pins of the device. This is done for all couples of connected pin combinations while the other pins are floating.
6. Machine model: A 200 pF capacitor is charged to the specified voltage, then discharged directly between two pins of the device with no external series resistor (internal resistor < 5 Ω). This is done for all couples of connected pin combinations while the other pins are floating.
7. Charged device model: all pins and the package are charged together to the specified voltage and then discharged directly to the ground through only one pin. This is done for all pins.

Table 2. Operating conditions

| Symbol | Parameter | Value | Unit |
|------------|--------------------------------------|----------------------------------|------|
| V_{CC} | 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 |

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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 include unavoidable inaccuracies of the industrial tests.

Table 4. $V_{CC} = +3V$, $V_{DD} = 0V$, R_L connected to $V_{CC}/2$, $T_{amb} = 25^\circ C$ (unless otherwise specified) ⁽¹⁾

| 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 ⁽²⁾ | | 1 | 100 | pA |
| I_{ib} | Input bias current ⁽²⁾ | | 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. All electrical values are guaranteed with correlation measurements at 2.5 V and 5 V.
2. Maximum values include unavoidable inaccuracies of the industrial tests.

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 3.7 | 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 include unavoidable inaccuracies of the industrial tests.

Figure 1. Supply current per amplifier vs. supply voltage in overdrive

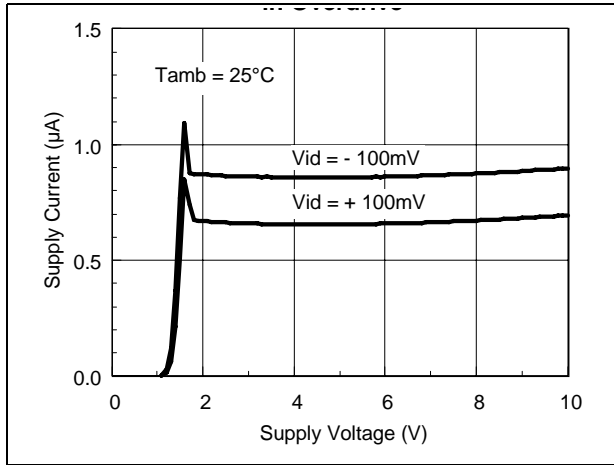


Figure 2. Supply current per amplifier vs. supply voltage

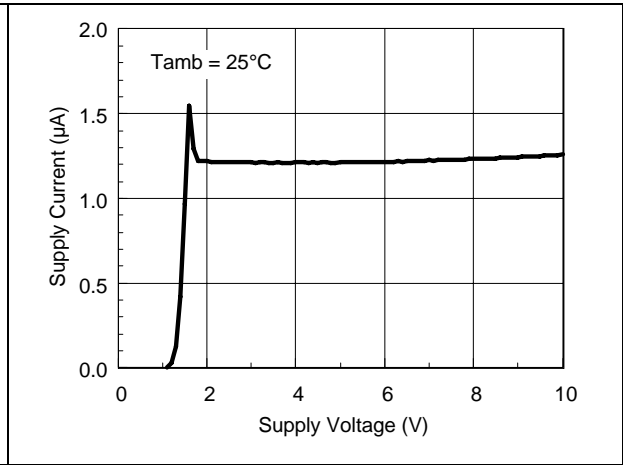


Figure 3. Output short-circuit current vs. temperature

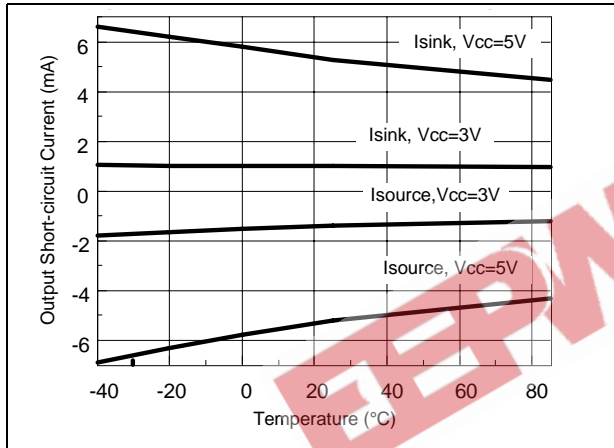


Figure 4. Supply current per amplifier vs. temperature

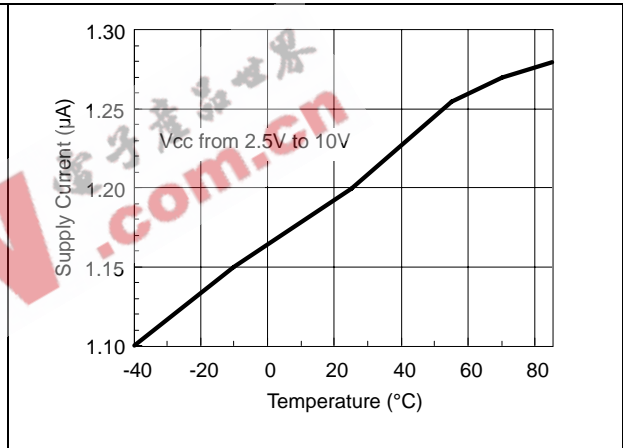


Figure 5. Output short-circuit current vs. supply voltage

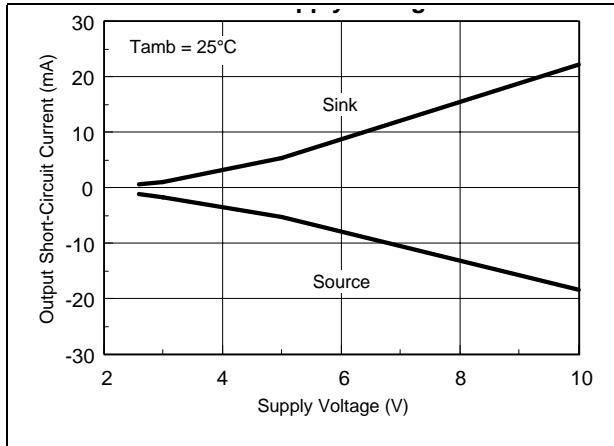


Figure 6. Output short-circuit current vs. output voltage

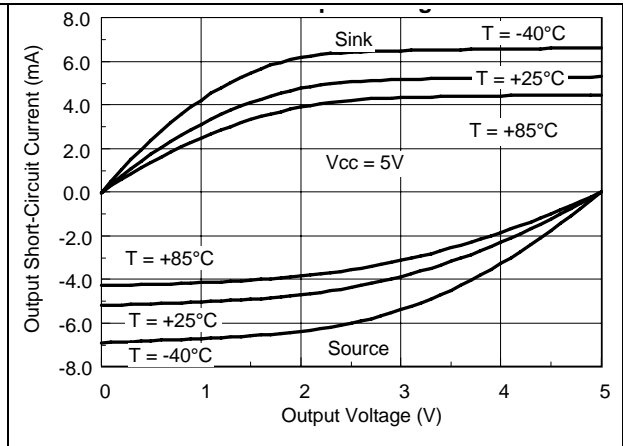


Figure 7. Output short-circuit current vs. output voltage

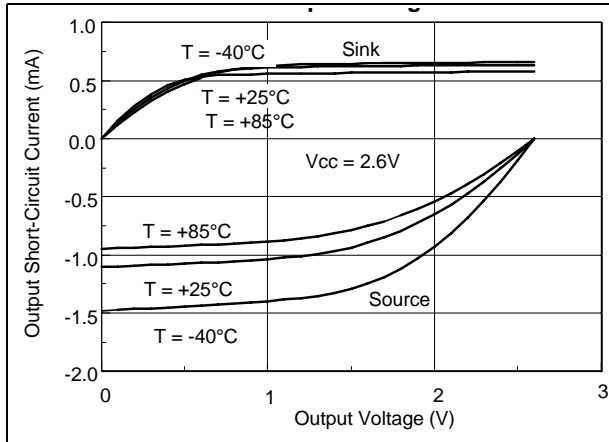


Figure 8. High level output voltage vs. supply voltage

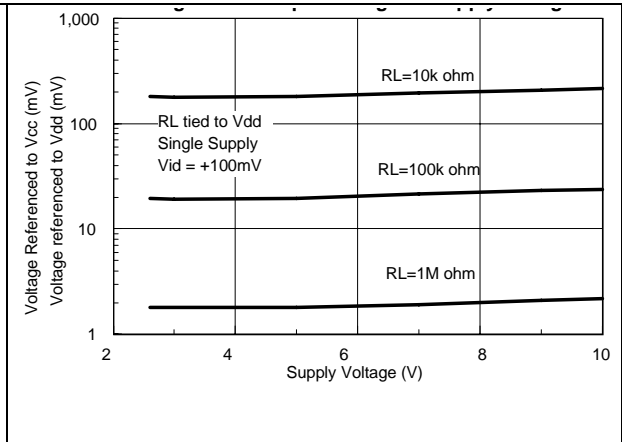


Figure 9. Output short-circuit current vs. output voltage

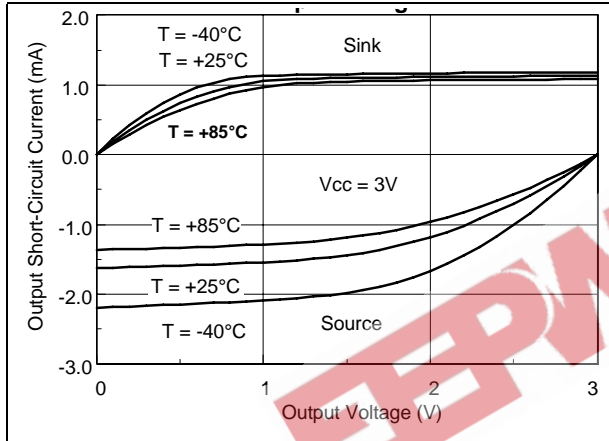


Figure 10. Low level output voltage vs. supply voltage

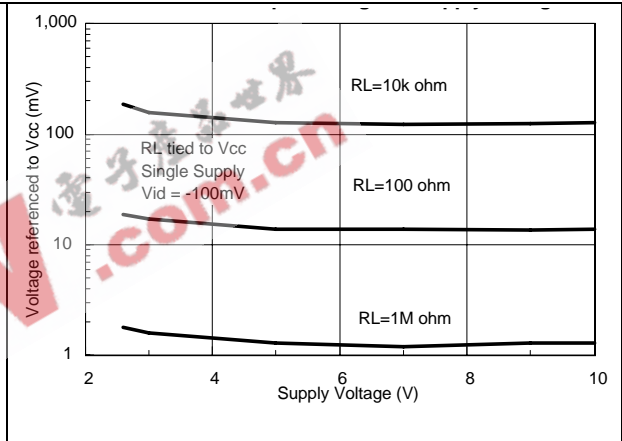


Figure 11. Output short-circuit current vs. output voltage

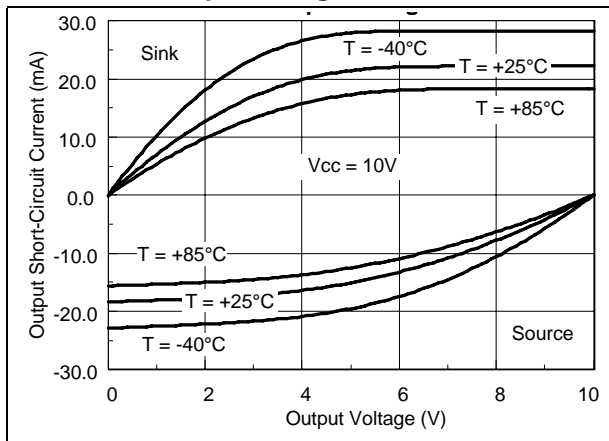


Figure 12. Gain and phase vs. frequency

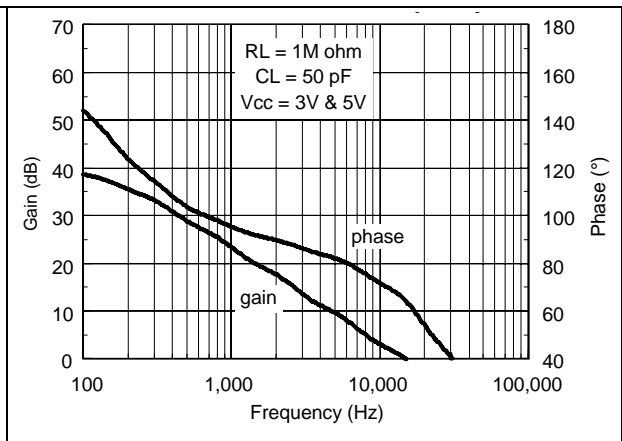


Figure 13. Small signal transient response

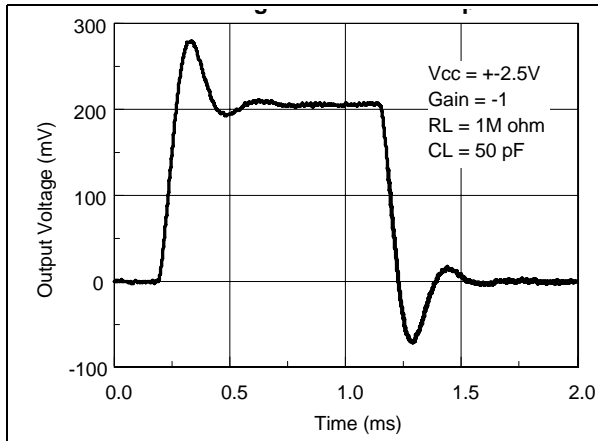


Figure 14. Gain and phase versus frequency

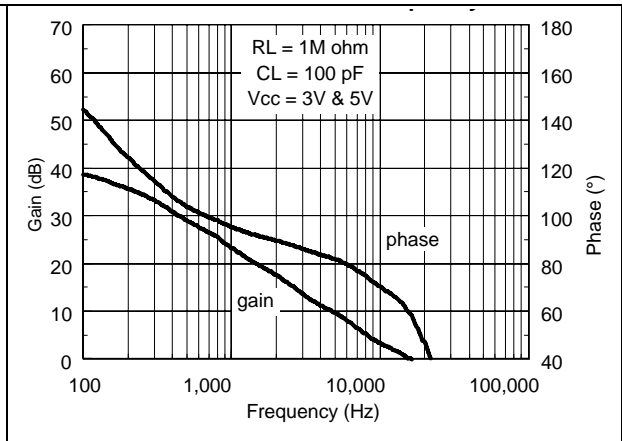


Figure 15. Slew rate positive and negative vs. temperature

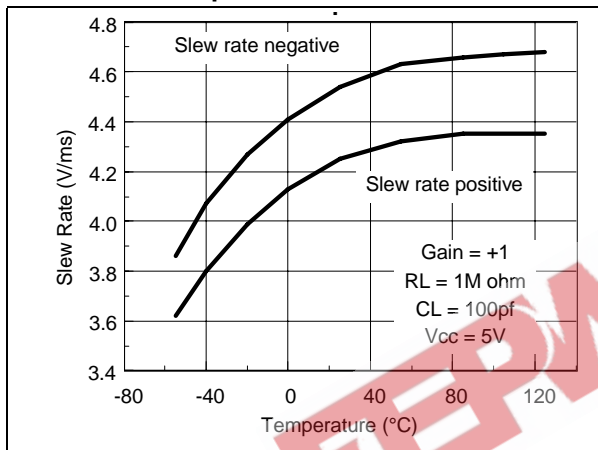
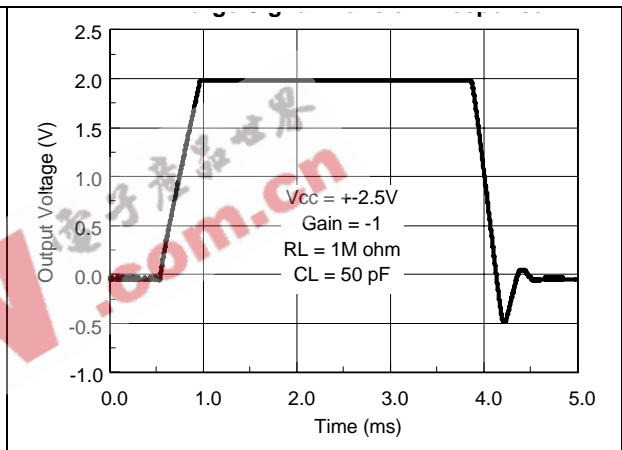


Figure 16. Large signal transient response



3 Package information

In order to meet environmental requirements, STMicroelectronics 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 STMicroelectronics trademark. ECOPACK specifications are available at: www.st.com.

3.1 SOT23-5 package information

Figure 17. SOT23-5 package mechanical drawing

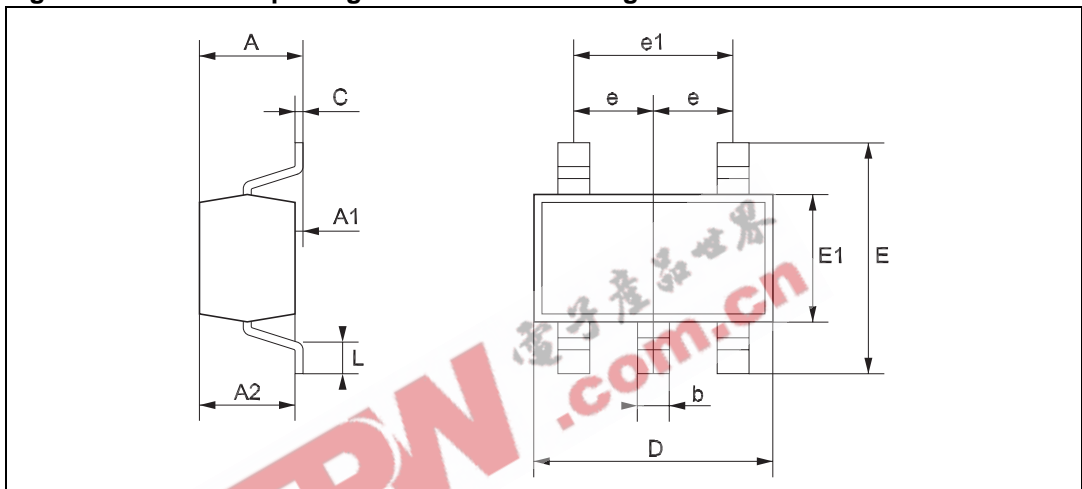


Table 6. SOT23-5 package mechanical data

| Ref. | Dimensions | | | | | |
|------|-------------|------|------|-------|------|-------|
| | Millimeters | | | Mils | | |
| | Min. | Typ. | Max. | Min. | Typ. | Max. |
| A | 0.90 | | 1.45 | 35.4 | | 57.1 |
| A1 | 0.00 | | 0.15 | 0.00 | | 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 |

3.2 DIP8 package information

Figure 18. DIP8 package mechanical drawing

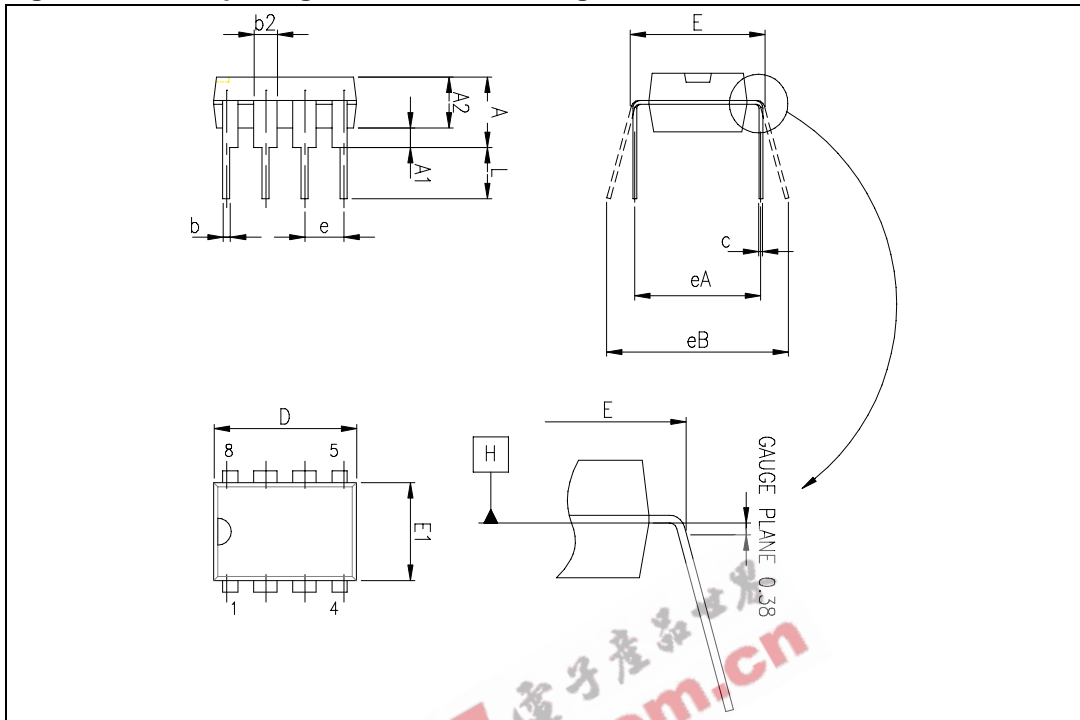


Table 7. DIP8 package mechanical data

| Ref. | Dimensions | | | | | |
|------|-------------|------|-------|--------|-------|-------|
| | Millimeters | | | Inches | | |
| | Min. | Typ. | Max. | Min. | Typ. | Max. |
| A | | | 5.33 | | | 0.210 |
| A1 | 0.38 | | | 0.015 | | |
| A2 | 2.92 | 3.30 | 4.95 | 0.115 | 0.130 | 0.195 |
| b | 0.36 | 0.46 | 0.56 | 0.014 | 0.018 | 0.022 |
| b2 | 1.14 | 1.52 | 1.78 | 0.045 | 0.060 | 0.070 |
| c | 0.20 | 0.25 | 0.36 | 0.008 | 0.010 | 0.014 |
| D | 9.02 | 9.27 | 10.16 | 0.355 | 0.365 | 0.400 |
| E | 7.62 | 7.87 | 8.26 | 0.300 | 0.310 | 0.325 |
| E1 | 6.10 | 6.35 | 7.11 | 0.240 | 0.250 | 0.280 |
| e | | 2.54 | | | 0.100 | |
| eA | | 7.62 | | | 0.300 | |
| eB | | | 10.92 | | | 0.430 |
| L | 2.92 | 3.30 | 3.81 | 0.115 | 0.130 | 0.150 |

3.3 SO-8 package information

Figure 19. SO-8 package mechanical drawing

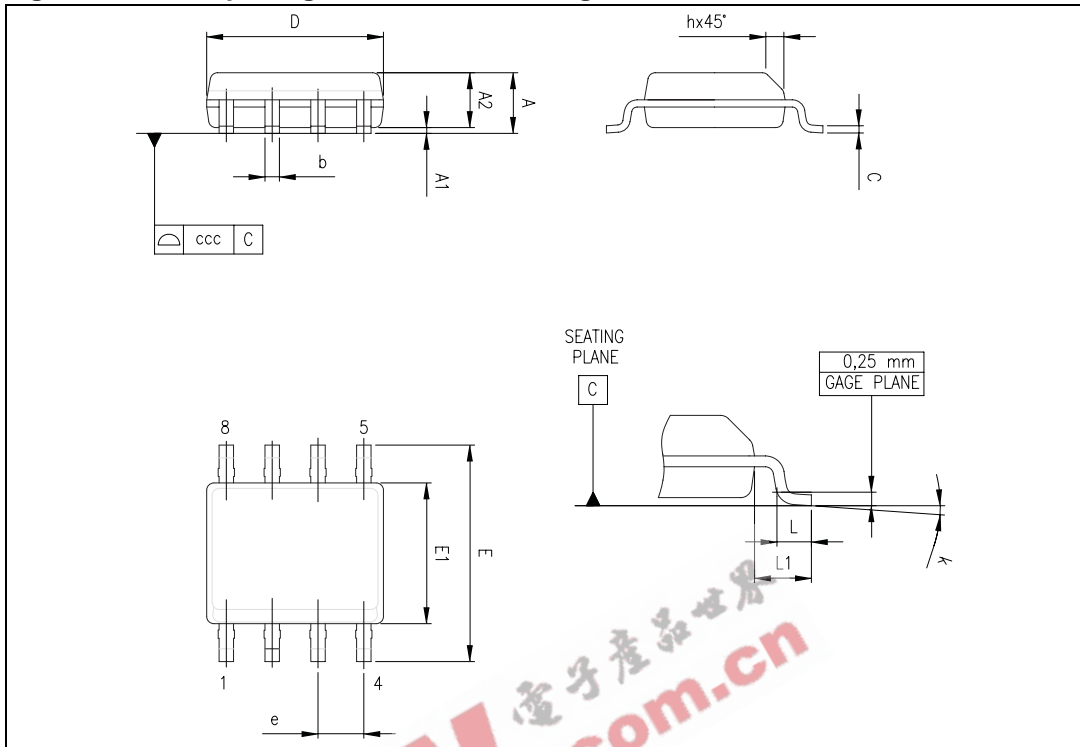


Table 8. SO-8 package mechanical data

| Ref. | Dimensions | | | | | |
|------|-------------|------|------|--------|-------|-------|
| | Millimeters | | | Inches | | |
| | Min. | Typ. | Max. | Min. | Typ. | Max. |
| A | | | 1.75 | | | 0.069 |
| A1 | 0.10 | | 0.25 | 0.004 | | 0.010 |
| A2 | 1.25 | | | 0.049 | | |
| b | 0.28 | | 0.48 | 0.011 | | 0.019 |
| c | 0.17 | | 0.23 | 0.007 | | 0.010 |
| D | 4.80 | 4.90 | 5.00 | 0.189 | 0.193 | 0.197 |
| E | 5.80 | 6.00 | 6.20 | 0.228 | 0.236 | 0.244 |
| E1 | 3.80 | 3.90 | 4.00 | 0.150 | 0.154 | 0.157 |
| e | | 1.27 | | | 0.050 | |
| h | 0.25 | | 0.50 | 0.010 | | 0.020 |
| L | 0.40 | | 1.27 | 0.016 | | 0.050 |
| k | 1° | | 8° | 1° | | 8° |
| ccc | | | 0.10 | | | 0.004 |

3.4 TSSOP8 package information

Figure 20. TSSOP8 package mechanical drawing

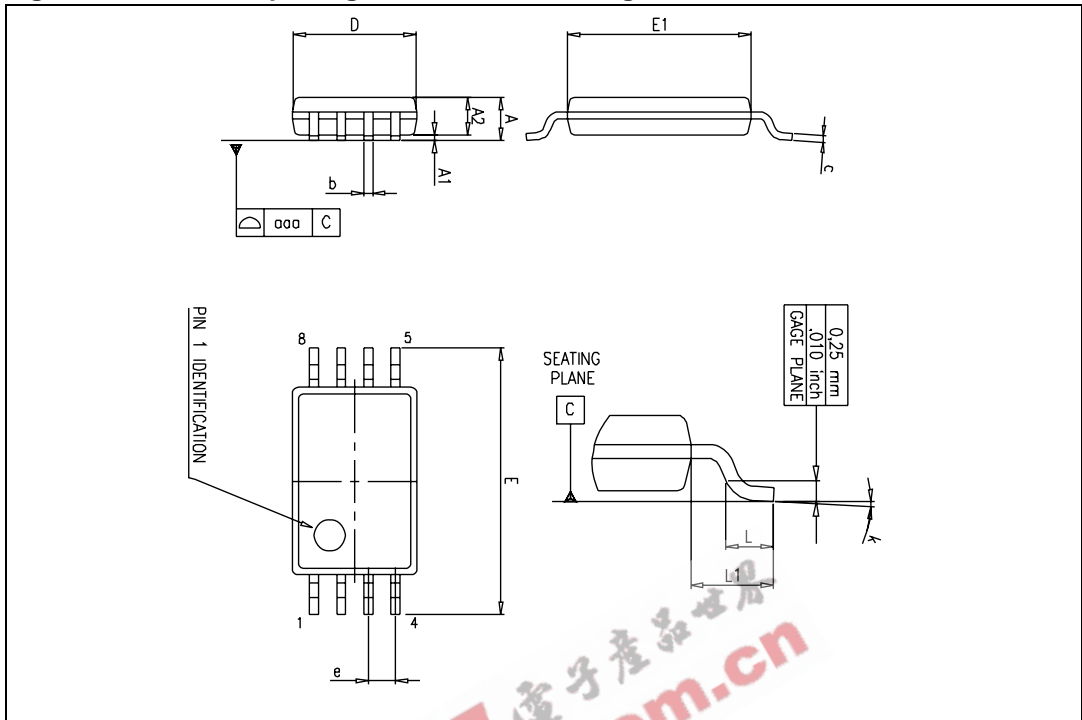


Table 9. TSSOP8 package mechanical data

| Ref. | Dimensions | | | | | |
|------|-------------|------|------|--------|--------|-------|
| | Millimeters | | | Inches | | |
| | 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 | |
| aaa | | 0.1 | | | 0.004 | |

3.5 DIP14 package information

Figure 21. DIP14 package mechanical drawing

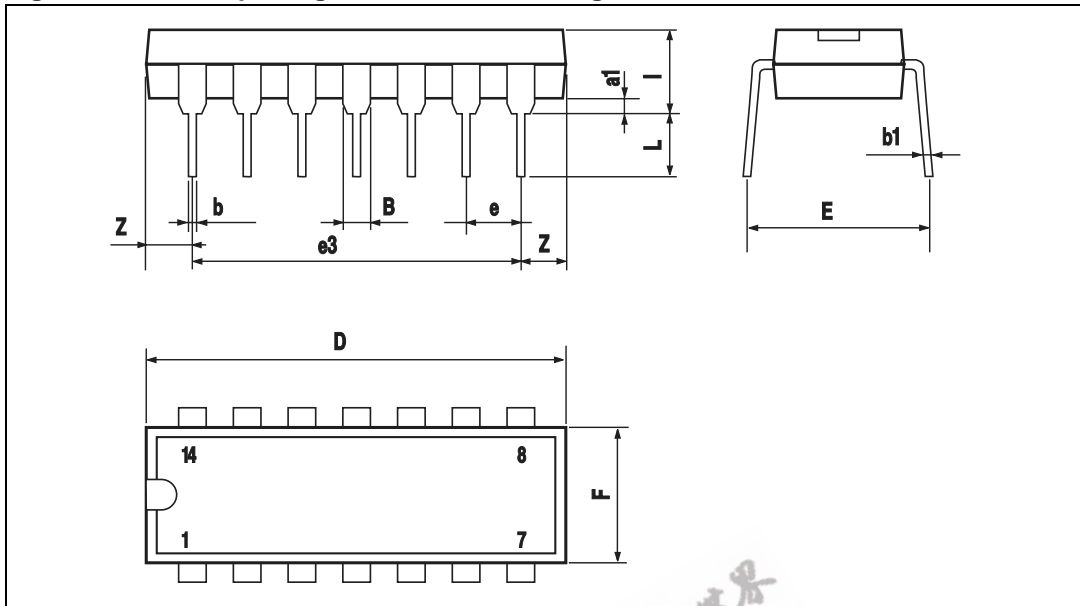


Table 10. DIP14 package mechanical data

| Ref. | Dimensions | | | | | |
|------|-------------|-------|------|--------|-------|-------|
| | 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 |

3.6 SO-14 package information

Figure 22. SO-14 package mechanical drawing

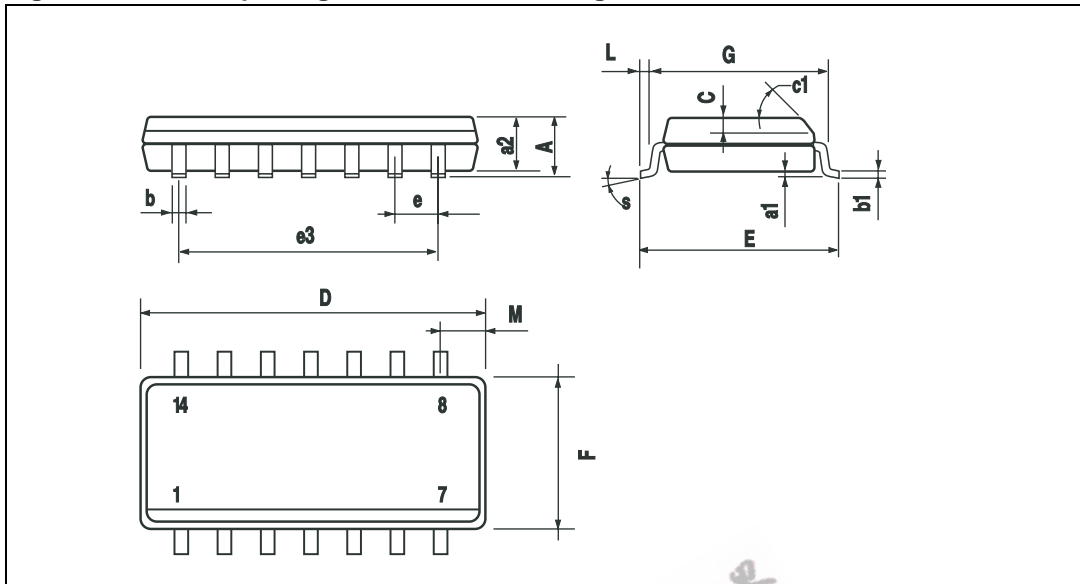


Table 11. SO-14 package mechanical data

| Ref. | Dimensions | | | | | |
|------|-------------|------|------|--------|-------|-------|
| | Millimeters | | | Inches | | |
| | 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.) | | | | | |

3.7 TSSOP14 package information

Figure 23. TSSOP14 package mechanical drawing

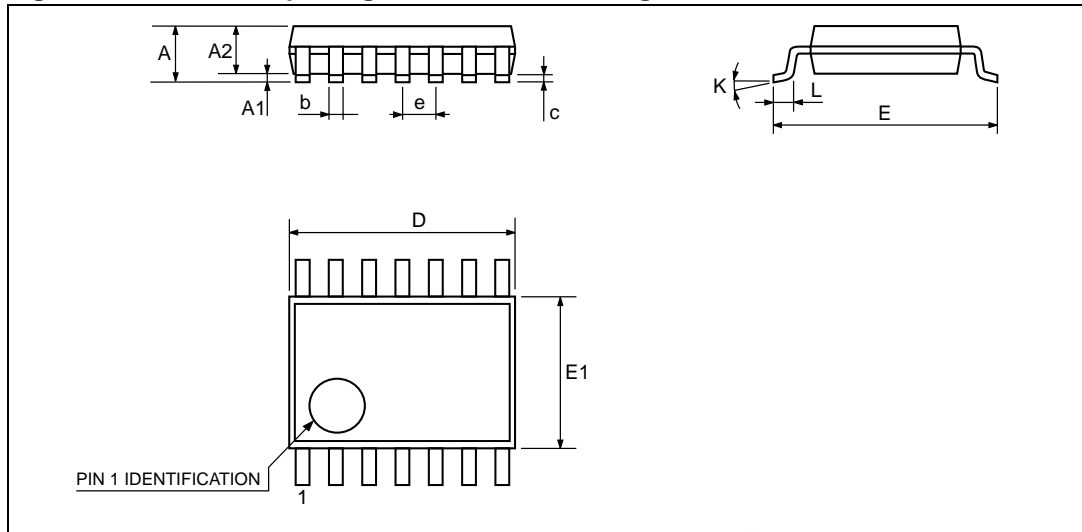


Figure 24. TSSOP14 package mechanical data

| Ref. | Dimensions | | | | | |
|------|-------------|----------|------|--------|------------|--------|
| | Millimeters | | | Inches | | |
| | 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° |
| L1 | 0.45 | 0.60 | 0.75 | 0.018 | 0.024 | 0.030 |

4 Ordering information

Table 12. Order codes

| Order code | Temperature range | Package | Packaging | Marking | | |
|-----------------------|-------------------|---------|------------------------|-----------------------|-------------|----------|
| TS941ID TS941IDT | -40°C to +85°C | SO-8 | Tube or Tape & reel | TS941ID TS941IDT | | |
| TS941AID TS941AIDT | | | | TS941AID | | |
| TS941BID TS941BIDT | | | | TS941BID | | |
| TS941ILT | | | | SOT23-5L | Tape & reel | K201 |
| TS941AILT | | | | | | K202 |
| TS941BILT | | | | | | K203 |
| TS942IN | | DIP-8 | Tube | TS942IN | | |
| TS942AIN | | | | TS942AIN | | |
| TS942BIN | | | | TS942BIN | | |
| TS942ID TS942IDT | | SO-8 | Tube or Tape & reel | TS942ID TS942IDT | | |
| TS942AID TS942AIDT | | | | TS942AID | | |
| TS942BID TS942BIDT | | | | TS942BID | | |
| TS942IPT | | | | TSSOP8 | Tape & reel | TS942 |
| TS942AIPT | | 942AI | | | | |
| TS942BIPT | | 942BI | | | | |
| TS944IN | | DIP14 | Tube | TS944IN | | |
| TS944AIN | | | | TS944AIN | | |
| TS944BIN | | | | TS944BIN | | |
| TS944ID TS944IDT | | SO-14 | Tube or Tape & reel | TS944ID TS944IDT | | |
| TS944AID TS944AIDT | | | | TS944AID TS944AIDT | | |
| TS944BID TS944BIDT | | | | TS944BID TS944BIDT | | |
| TS944IPT | | | | TSSOP14 | Tape & reel | TS944IPT |
| TS944AIPT | | TS944AI | | | | |
| TS944BIPT | | TS944BI | | | | |

5 Revision history

Table 13. Document revision history

| Date | Revision | Changes |
|-------------|----------|---|
| 01-Dec-2001 | 1 | Initial release. |
| 01-Dec-2004 | 2 | Modifications on AMR table (explanation of V_{id} and V_{in} limits). |
| 13-Mar-2008 | 3 | CDM values added for TS944 in SO and TSSOP packages. Document reformatted. |
| 09-Apr-2008 | 4 | Corrected error in power consumption on cover page (1.2 μ A, not 1.2mA). |

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