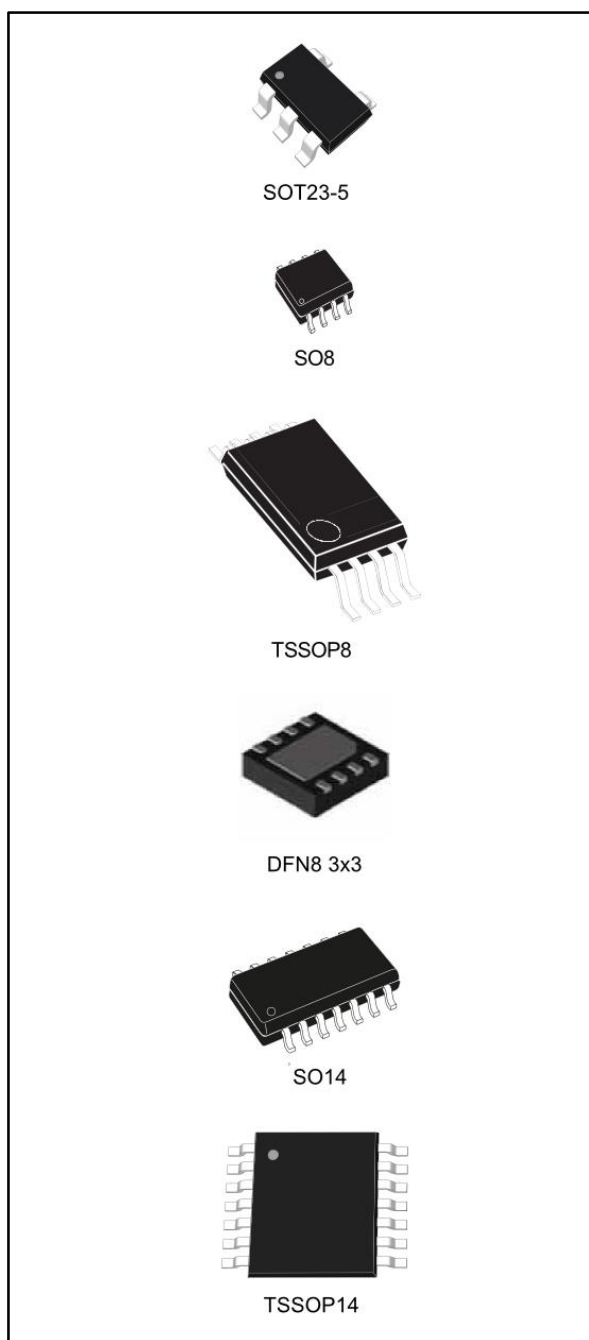


## Output rail-to-rail very low noise operational amplifier

Datasheet - production data



### Features

- Rail-to-rail output voltage swing  $\pm 2.4$  V at  $V_{CC} = \pm 2.5$  V
- Very low noise level: 4 nV/ $\sqrt{\text{Hz}}$
- Ultra low distortion: 0.003 %
- High dynamic features: 12 MHz, 4 V/ $\mu\text{s}$
- Operating range: 2.7 to 10 V
- ESD protection (2 kV)
- Latch-up immunity (class A)

### Applications

- Portable devices (CD players, PDAs)
- Portable communication (cell phones, pagers)
- Instrumentation and sensing technology
- Professional audio circuits

### Description

The TS97x family of operational amplifiers operate with voltages as low as  $\pm 1.35$  V and feature output rail-to-rail signal swing. The TS97x devices are particularly well suited for portable and battery-supplied equipment. Very low noise and low distortion characteristics make them ideal for audio pre-amplification.

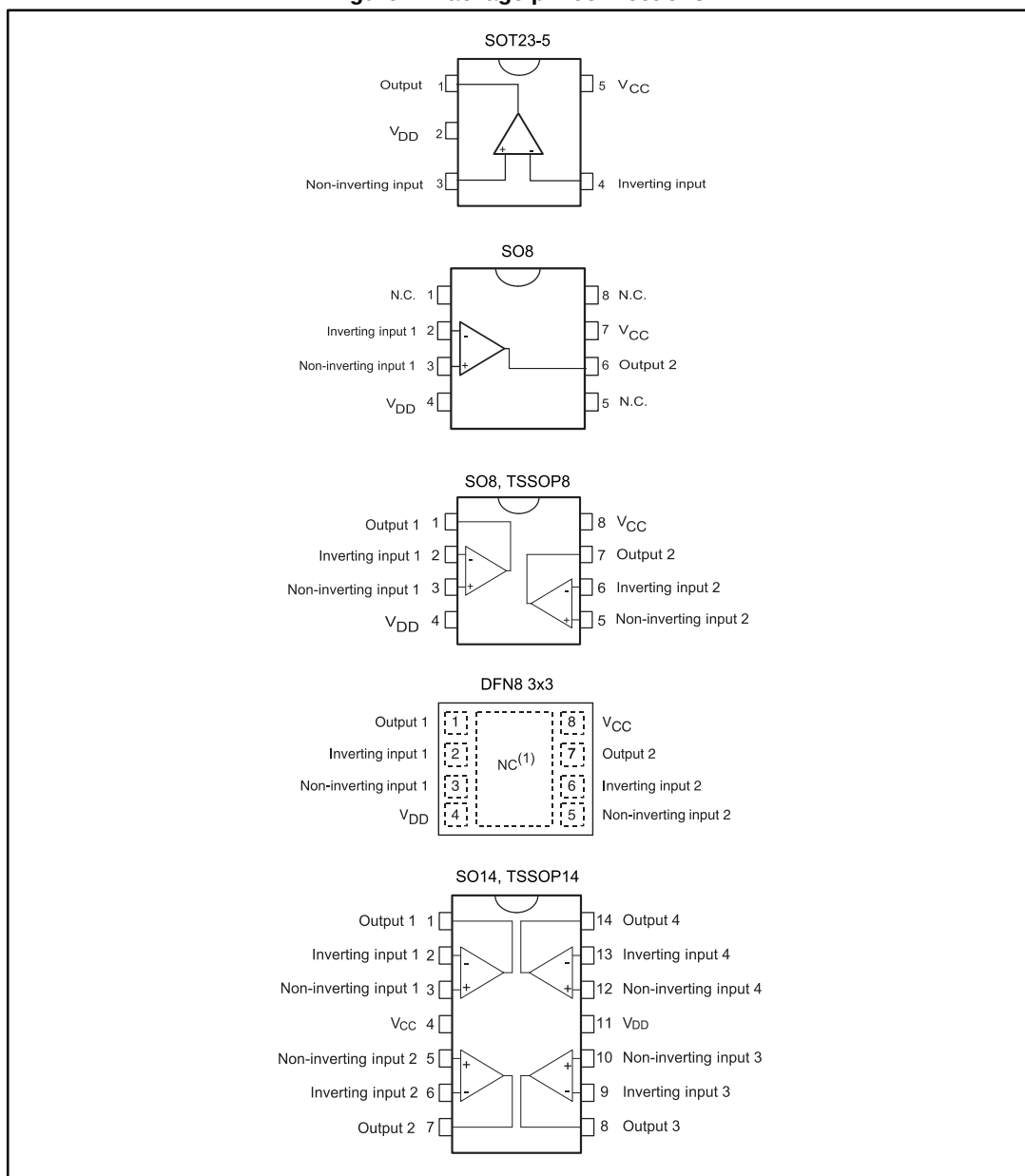
The TS97x devices are available in a variety of packages to suit all types of applications. For applications where space saving is critical, the SOT23-5 package (2.8 x 2.9 mm) or the DFN8 package (3 x 3 mm) simplify the board design because they can be placed anywhere on it.

## Contents

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# 1 Package pin connections

Figure 1: Package pin connections



1. The exposed pad of the DFN8 3x3 can be connected to  $V_{CC}$  or left floating

## 2 Absolute maximum ratings and operating conditions

Table 1: Absolute maximum ratings (AMR)

| Symbol            | Parameter                                             |          | Value                                          | Unit |
|-------------------|-------------------------------------------------------|----------|------------------------------------------------|------|
| V <sub>CC</sub>   | Supply voltage <sup>(1)</sup>                         |          | 12                                             | V    |
| V <sub>id</sub>   | Differential input voltage <sup>(2)</sup>             |          | ±1                                             |      |
| V <sub>in</sub>   | Input voltage <sup>(3)</sup>                          |          | V <sub>DD</sub> - 0.3 to V <sub>CC</sub> + 0.3 |      |
| T <sub>stg</sub>  | Storage temperature range                             |          | -65 to 150                                     | °C   |
| T <sub>j</sub>    | Maximum junction temperature                          |          | 150                                            |      |
| R <sub>thja</sub> | Thermal resistance junction-to-ambient <sup>(4)</sup> | SOT23-5  | 250                                            | °C/W |
|                   |                                                       | SO8      | 125                                            |      |
|                   |                                                       | TSSOP8   | 120                                            |      |
|                   |                                                       | DFN8 3x3 | 40                                             |      |
|                   |                                                       | SO14     | 105                                            |      |
|                   |                                                       | TSSOP14  | 100                                            |      |
| R <sub>thjc</sub> | Thermal resistance junction-to-case <sup>(4)</sup>    | SOT23-5  | 81                                             |      |
|                   |                                                       | SO8      | 40                                             |      |
|                   |                                                       | TSSOP8   | 37                                             |      |
|                   |                                                       | DFN8 3x3 | 5.2                                            |      |
|                   |                                                       | SO14     | 31                                             |      |
|                   |                                                       | TSSOP14  | 32                                             |      |
| ESD               | HBM: human body model <sup>(5)</sup>                  |          | 2                                              | kV   |
|                   | MM: machine model <sup>(6)</sup>                      |          | 200                                            | V    |
|                   | CDM: charged device model <sup>(7) (8)</sup>          |          | 1.5                                            | kV   |
|                   | Lead temperature (soldering, 10 sec.)                 |          | 260                                            | °C   |

### Notes:

<sup>(1)</sup>All voltage values, except the differential voltage are with respect to the network ground terminal.

<sup>(2)</sup>The differential voltage is the non-inverting input terminal with respect to the inverting input terminal.

<sup>(3)</sup>The magnitude of input and output voltages must never exceed V<sub>CC</sub> + 0.3 V.

<sup>(4)</sup>Short-circuits can cause excessive heating and destructive dissipation. Values are typical.

<sup>(5)</sup>Human body model: a 100 pF capacitor is charged to the specified voltage, then discharged through a 1.5kΩ resistor between two pins of the device. This is done for all couples of connected pin combinations while the other pins are floating.

<sup>(6)</sup>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.

<sup>(7)</sup> No value specified for CDM on SOT23-5 package.

<sup>(8)</sup>Charged device model: all pins and package are charged together to the specified voltage and then discharged directly to ground through only one pin. This is done for all pins.

Table 2: Operating conditions

| Symbol            | Parameter                            | Value                                            | Unit |
|-------------------|--------------------------------------|--------------------------------------------------|------|
| V <sub>CC</sub>   | Supply voltage                       | 2.7 to 10                                        | V    |
| V <sub>icm</sub>  | Common mode input voltage range      | V <sub>DD</sub> + 1.15 to V <sub>CC</sub> - 1.15 |      |
| T <sub>oper</sub> | Operating free air temperature range | -40 to 125                                       | °C   |

### 3 Electrical characteristics

Table 3: Electrical characteristics at  $V_{CC} = 2.5\text{ V}$ ,  $V_{DD} = -2.5\text{ V}$ ,  $T_{amb} = 25\text{ }^{\circ}\text{C}$   
(unless otherwise specified)

| Symbol                   | Parameter                       | Conditions                                                                 | Min.  | Typ.  | Max. | Unit                           |
|--------------------------|---------------------------------|----------------------------------------------------------------------------|-------|-------|------|--------------------------------|
| $V_{io}$                 | Input offset voltage            |                                                                            |       | 1     | 5    | mV                             |
|                          |                                 | $T_{min} \leq T_{amb} \leq T_{max}$                                        |       |       | 7    |                                |
| $\Delta V_{io}/\Delta T$ | Input offset voltage drift      | $V_{icm} = 0\text{ V}$ , $V_o = 0\text{ V}$                                |       | 5     |      | $\mu\text{V}/^{\circ}\text{C}$ |
| $I_{io}$                 | Input offset current            | $V_{icm} = 0\text{ V}$ , $V_o = 0\text{ V}$                                |       | 10    | 150  | nA                             |
| $I_{ib}$                 | Input bias current              | $V_{icm} = 0\text{ V}$ , $V_o = 0\text{ V}$                                |       | 200   | 750  |                                |
|                          |                                 | $T_{min} \leq T_{amb} \leq T_{max}$                                        |       | 200   | 1000 |                                |
| $V_{icm}$                | Common mode input voltage range |                                                                            | -1.35 |       | 1.35 | V                              |
| CMR                      | Common mode rejection ratio     | $V_{icm} = \pm 1.35\text{ V}$                                              | 60    | 85    |      | dB                             |
| SVR                      | Supply voltage rejection ratio  | $V_{CC} = \pm 2\text{ V}$ to $\pm 3\text{ V}$                              | 60    | 70    |      |                                |
| $A_{vd}$                 | Large signal voltage gain       | $R_L = 2\text{ k}\Omega$                                                   | 70    | 80    |      |                                |
| $V_{OH}$                 | High-level output voltage       |                                                                            | 2     | 2.4   |      | V                              |
| $V_{OL}$                 | Low-level output voltage        |                                                                            |       | -2.4  | -2   |                                |
| $I_{source}$             | Output source current           |                                                                            |       | 1.5   |      | mA                             |
| $I_{sink}$               | Output sink current             |                                                                            |       | 100   |      |                                |
| $I_{CC}$                 | Supply current per amplifier    | Unity gain, no load                                                        |       | 2     | 2.8  |                                |
| GBP                      | Gain bandwidth product          | $f = 100\text{ kHz}$ , $R_L = 2\text{ k}\Omega$ ,<br>$C_L = 100\text{ pF}$ | 8.5   | 12    |      | MHz                            |
| SR                       | Slew rate                       | $A_v = 1$ , $V_{in} = \pm 1\text{ V}$                                      | 2.8   | 4     |      | $\text{V}/\mu\text{s}$         |
| $\phi_m$                 | Phase margin at unit gain       | $R_L = 2\text{ k}\Omega$ , $C_L = 100\text{ pF}$                           |       | 60    |      | Degrees                        |
| Gm                       | Gain margin                     |                                                                            |       | 10    |      | dB                             |
| $e_n$                    | Equivalent input noise voltage  | $f = 100\text{ kHz}$                                                       |       | 4     |      | $\text{nV}/\sqrt{\text{Hz}}$   |
| $i_n$                    | Equivalent input noise current  | $f = 1\text{ kHz}$                                                         |       | 250   |      | $\text{fA}/\sqrt{\text{Hz}}$   |
| THD                      | Total harmonic distortion       | $f = 1\text{ kHz}$ , $A_v = -1$ , $R_L = 10\text{ k}\Omega$                |       | 0.003 |      | %                              |

## 4 Electrical characteristic curves

Figure 2: Input offset voltage distribution

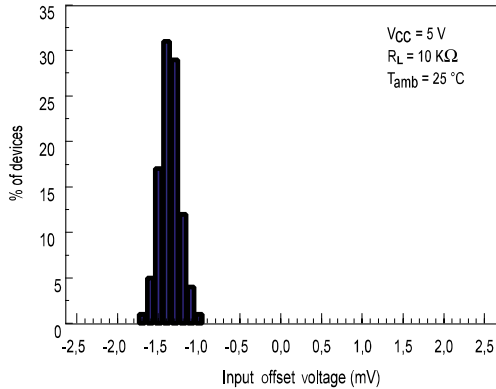
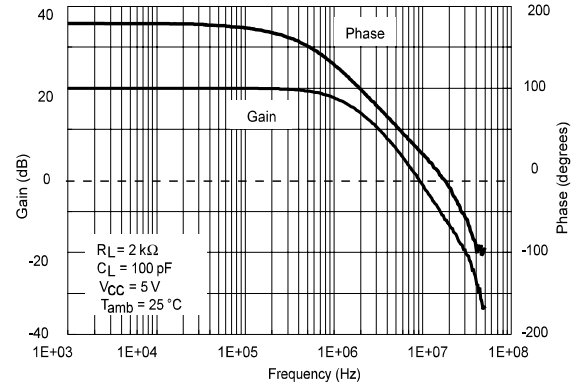
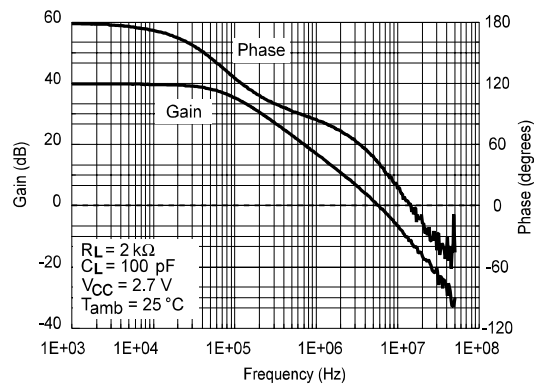
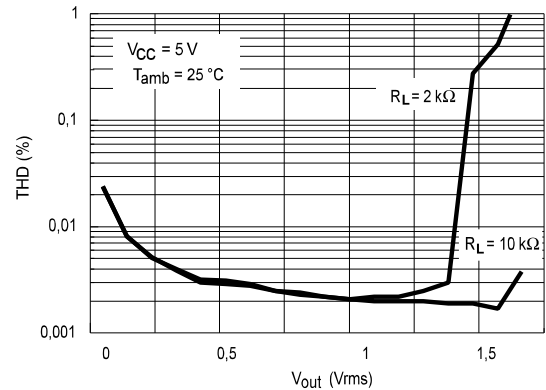
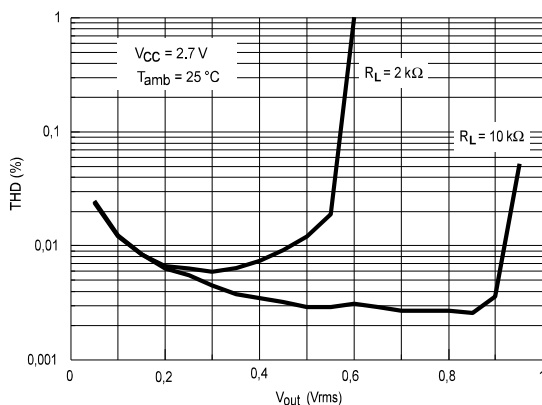
Figure 3: Voltage gain and phase vs. frequency  
 $V_{CC} = 5\text{ V}$ Figure 4: Voltage gain and phase vs. frequency  
 $V_{CC} = 2.7\text{ V}$ Figure 5: THS vs.  $V_{out}$ ,  $V_{CC} = 5\text{ V}$ Figure 6: THD vs.  $V_{out}$ ,  $V_{CC} = 2.7\text{ V}$ 

Figure 7: THD vs. frequency

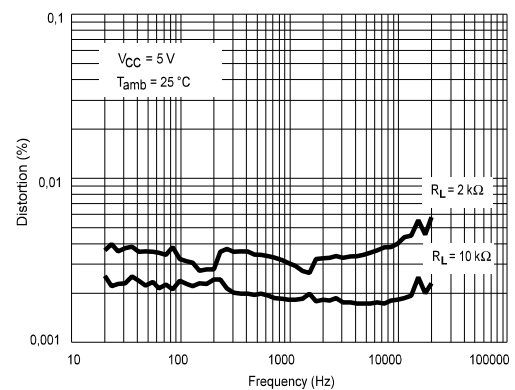
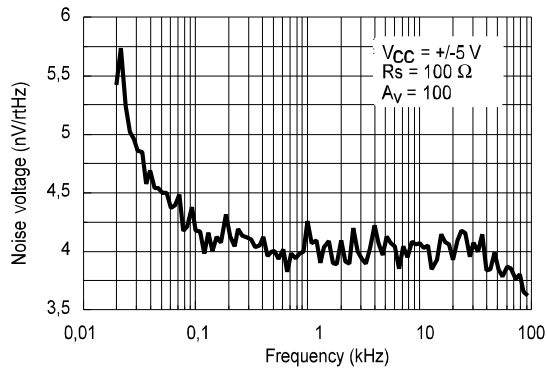
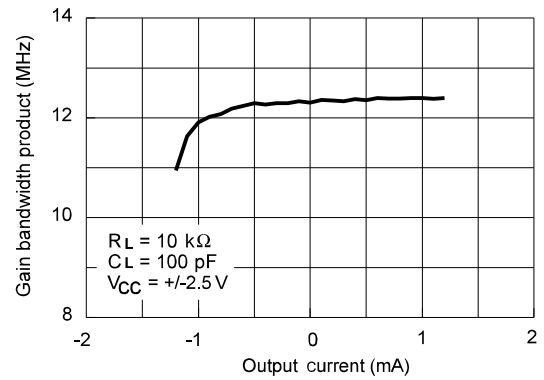
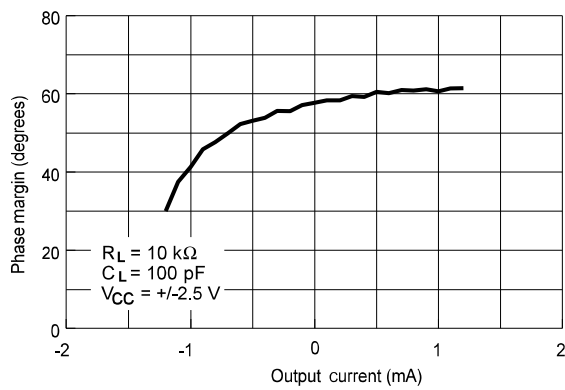
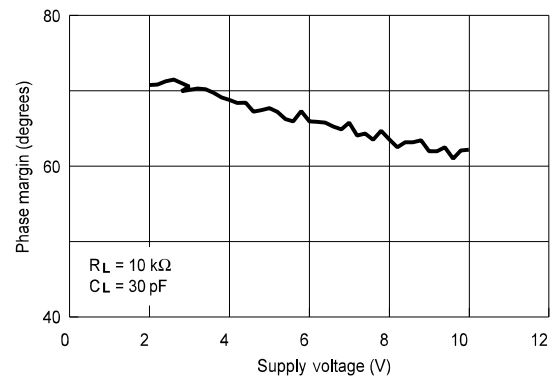
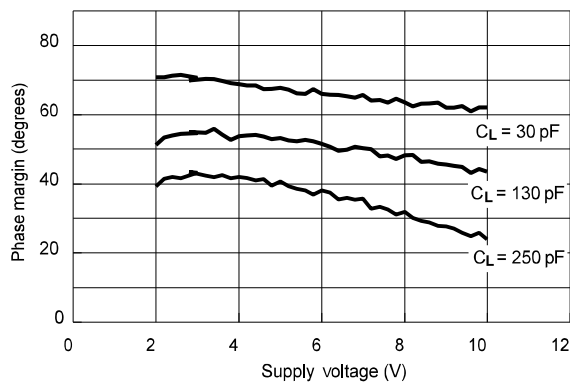
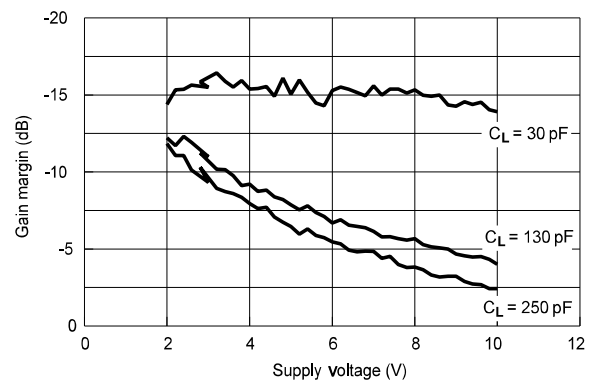


Figure 8: Noise voltage vs. frequency

Figure 9: Gain bandwidth product vs.  $I_{out}$ Figure 10: Phase margin vs.  $I_{out}$ Figure 11: Phase margin vs.  $V_{CC}$   $R_L = 10\text{ k}\Omega$ ,  $C_L = 30\text{ pF}$ Figure 12: Phase margin vs.  $V_{CC}$   $C_L = 30, 130,$  and  $250\text{ pF}$ Figure 13: Gain margin vs.  $V_{CC}$ 

## 5 Package information

In order to meet environmental requirements, ST offers these devices in different grades of ECOPACK® packages, depending on their level of environmental compliance. ECOPACK® specifications, grade definitions and product status are available at: **[www.st.com](http://www.st.com)**. ECOPACK® is an ST trademark.

## 5.1 SOT23-5 package information

Figure 14: SOT23-5 package outline

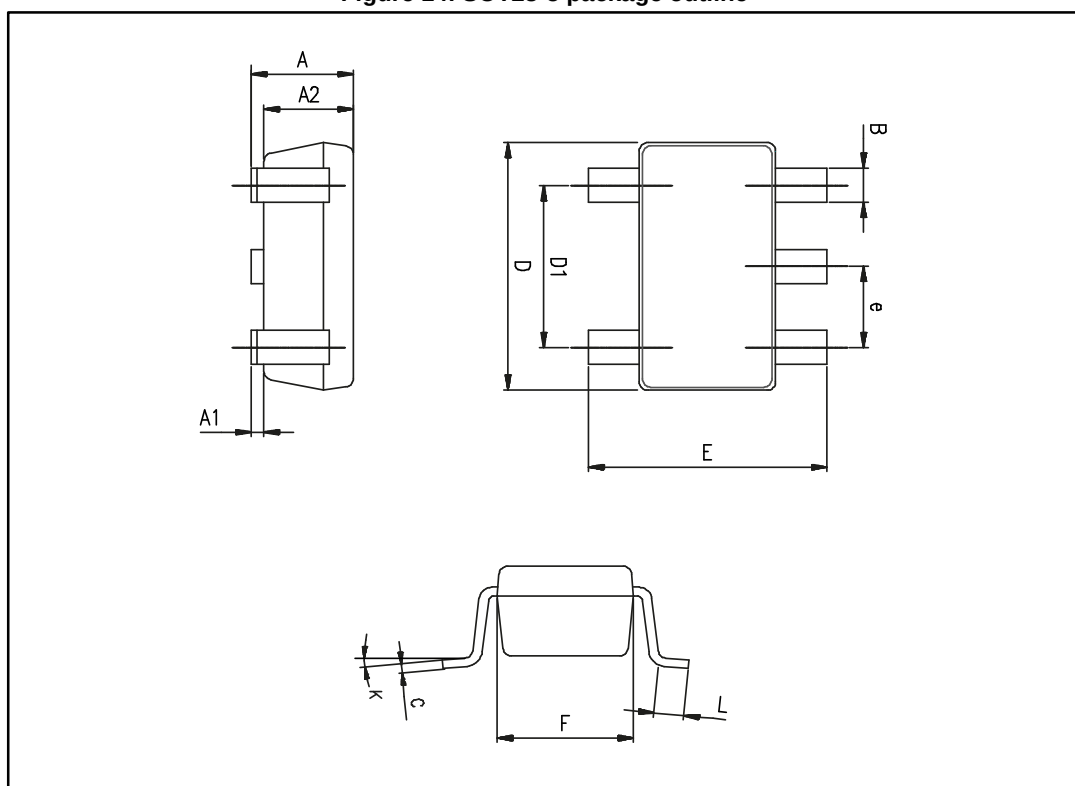


Table 4: SOT23-5 mechanical data

| Ref. | Dimensions  |      |            |           |       |            |
|------|-------------|------|------------|-----------|-------|------------|
|      | Millimeters |      |            | Inches    |       |            |
|      | Min.        | Typ. | Max.       | Min.      | Typ.  | Max.       |
| A    | 0.90        | 1.20 | 1.45       | 0.035     | 0.047 | 0.057      |
| A1   |             |      | 0.15       |           |       | 0.006      |
| A2   | 0.90        | 1.05 | 1.30       | 0.035     | 0.041 | 0.051      |
| B    | 0.35        | 0.40 | 0.50       | 0.014     | 0.016 | 0.020      |
| C    | 0.09        | 0.15 | 0.20       | 0.004     | 0.006 | 0.008      |
| D    | 2.80        | 2.90 | 3.00       | 0.110     | 0.114 | 0.118      |
| D1   |             | 1.90 |            |           | 0.075 |            |
| e    |             | 0.95 |            |           | 0.037 |            |
| E    | 2.60        | 2.80 | 3.00       | 0.102     | 0.110 | 0.118      |
| F    | 1.50        | 1.60 | 1.75       | 0.059     | 0.063 | 0.069      |
| L    | 0.10        | 0.35 | 0.60       | 0.004     | 0.014 | 0.024      |
| K    | 0 degrees   |      | 10 degrees | 0 degrees |       | 10 degrees |

## 5.2 SO8 package information

Figure 15: SO8 package outline

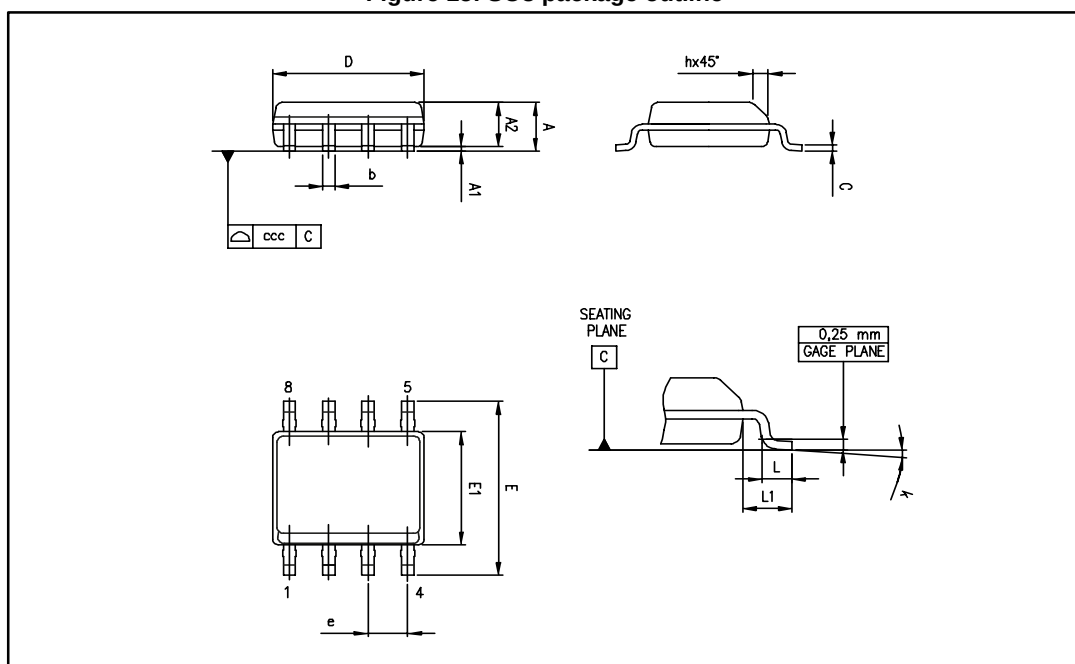


Table 5: SO8 mechanical data

| 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 |
| L1   |             | 1.04 |      |        | 0.040 |       |
| k    | 1°          |      | 8°   | 1°     |       | 8°    |
| ccc  |             |      | 0.10 |        |       | 0.004 |

### 5.3 TSSOP8 package information

Figure 16: TSSOP8 package outline

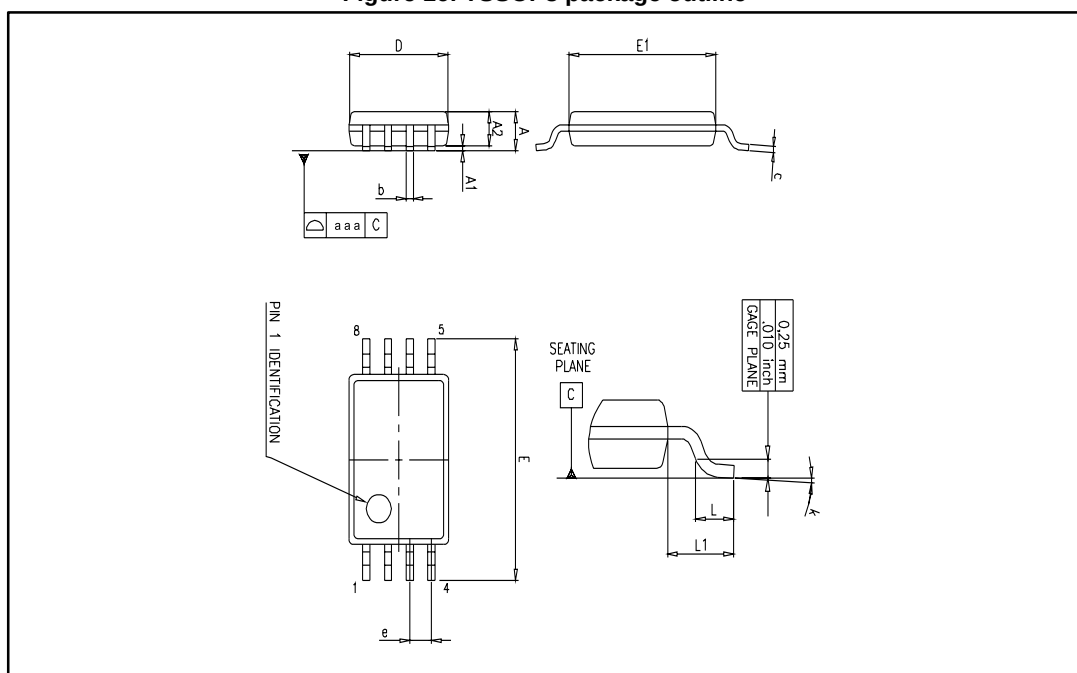


Table 6: TSSOP8 mechanical data

| 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  |       |

## 5.4 DFN8 3x3 exposed pad package information

Figure 17: DFN8 3x3 package outline

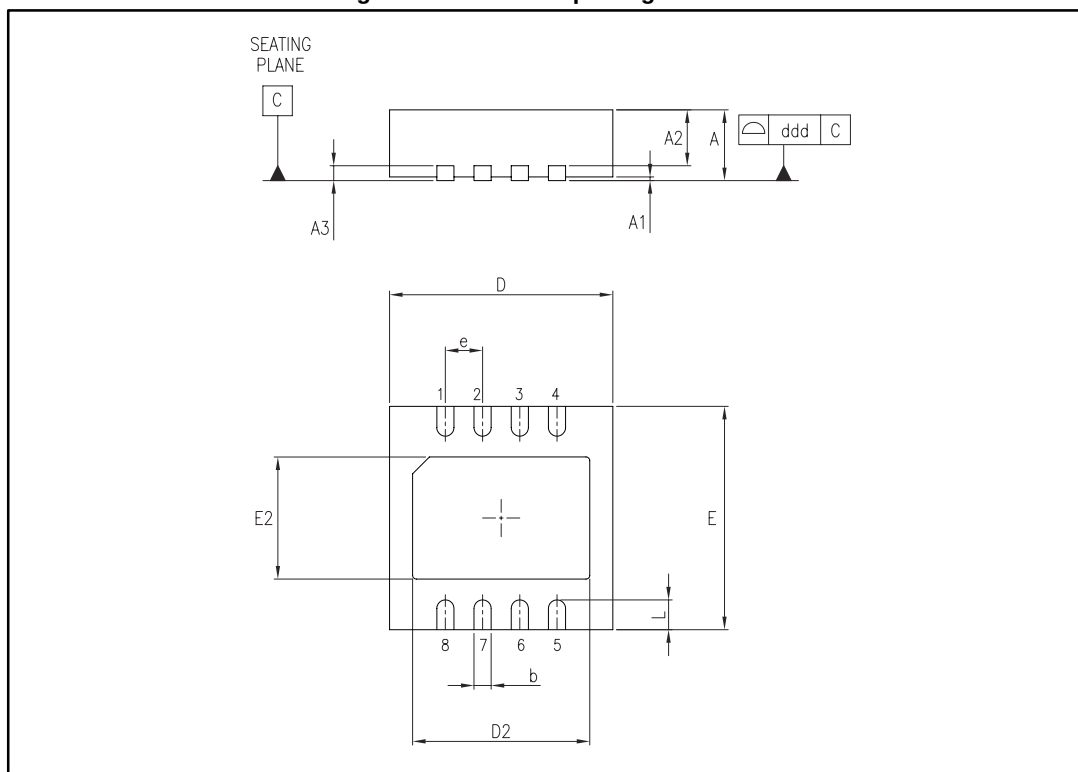


Table 7: DFN8 3x3 mechanical data

| Symbol | Dimensions  |      |      |        |        |        |
|--------|-------------|------|------|--------|--------|--------|
|        | Millimeters |      |      | Inches |        |        |
|        | Min.        | Typ. | Max. | Min.   | Typ.   | Max.   |
| A      | 0.80        | 0.90 | 1.00 | 0.031  | 0.035  | 0.039  |
| A1     |             | 0.02 |      |        | 0.0008 | 0.0019 |
| A2     | 0.55        | 0.65 | 0.80 | 0.021  | 0.025  | 0.031  |
| A3     |             | 0.20 |      |        | 0.008  |        |
| b      | 0.18        | 0.25 | 0.30 | 0.007  | 0.010  | 0.012  |
| D      | 2.85        | 3.00 | 3.15 | 0.112  | 0.118  | 0.124  |
| D2     | 2.20        |      | 2.70 | 0.087  |        | 0.106  |
| E      | 2.85        | 3.00 | 3.15 | 0.112  | 0.118  | 0.124  |
| E2     | 1.40        |      | 1.75 | 0.055  |        | 0.069  |
| e      |             | 0.50 |      |        | 0.020  |        |
| L      | 0.30        | 0.40 | 0.50 | 0.012  | 0.016  | 0.020  |
| ddd    |             |      | 0.08 |        |        | 0.003  |

## 5.5 SO14 package information

Figure 18: SO14 package outline

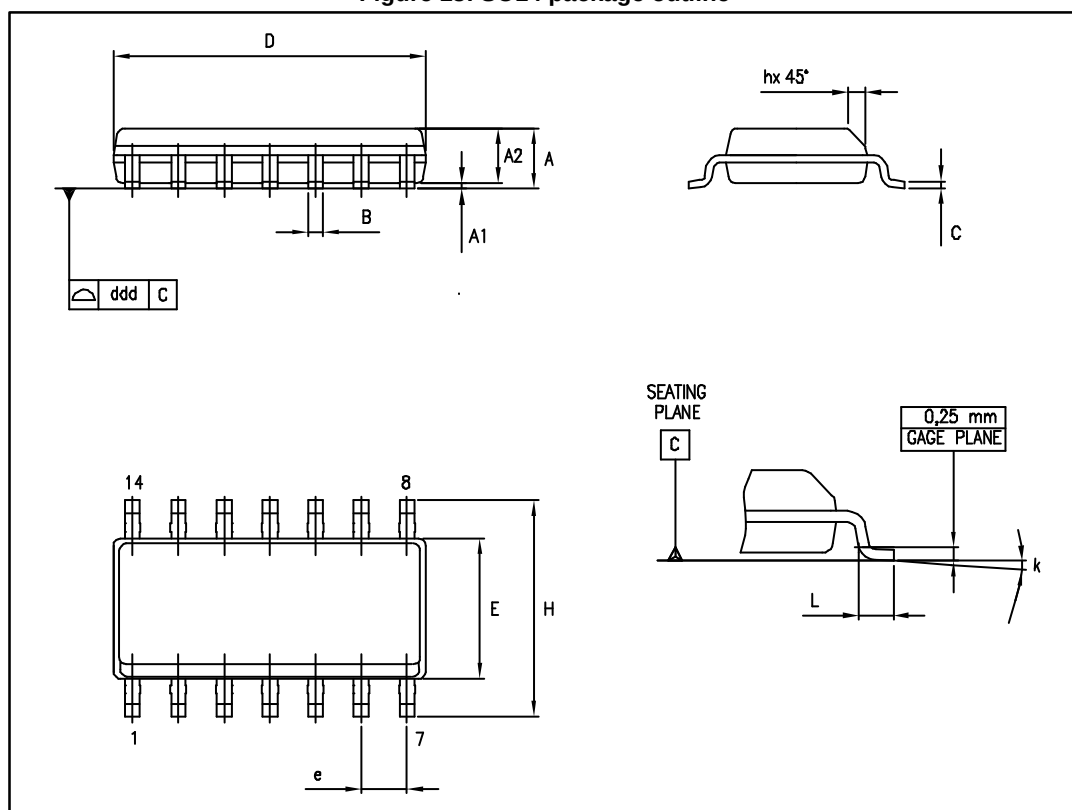


Table 8: SO14 mechanical data

| Ref. | Dimensions  |      |      |        |      |       |
|------|-------------|------|------|--------|------|-------|
|      | Millimeters |      |      | Inches |      |       |
|      | Min.        | Typ. | Max. | Min.   | Typ. | Max.  |
| A    | 1.35        |      | 1.75 | 0.05   |      | 0.068 |
| A1   | 0.10        |      | 0.25 | 0.004  |      | 0.009 |
| A2   | 1.10        |      | 1.65 | 0.04   |      | 0.06  |
| B    | 0.33        |      | 0.51 | 0.01   |      | 0.02  |
| C    | 0.19        |      | 0.25 | 0.007  |      | 0.009 |
| D    | 8.55        |      | 8.75 | 0.33   |      | 0.34  |
| E    | 3.80        |      | 4.0  | 0.15   |      | 0.15  |
| e    |             | 1.27 |      |        | 0.05 |       |
| H    | 5.80        |      | 6.20 | 0.22   |      | 0.24  |
| h    | 0.25        |      | 0.50 | 0.009  |      | 0.02  |
| L    | 0.40        |      | 1.27 | 0.015  |      | 0.05  |
| k    | 8° (max)    |      |      |        |      |       |
| ddd  |             |      | 0.10 |        |      | 0.004 |

## 5.6 TSSOP14 package information

Figure 19: TSSOP14 package outline

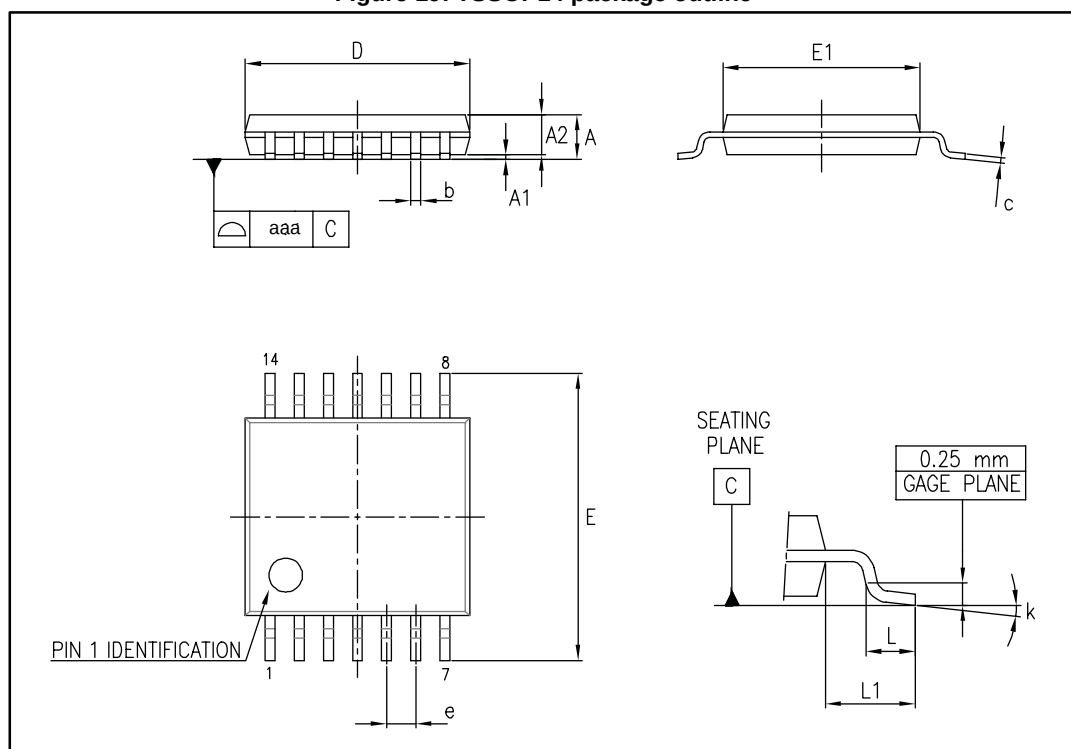


Table 9: TSSOP14 mechanical data

| Ref. | Dimensions  |      |      |        |        |        |
|------|-------------|------|------|--------|--------|--------|
|      | Millimeters |      |      | Inches |        |        |
|      | Min.        | Typ. | Max. | Min.   | Typ.   | Max.   |
| A    |             |      | 1.20 |        |        | 0.047  |
| A1   | 0.05        |      | 0.15 | 0.002  | 0.004  | 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  |        | 0.0089 |
| D    | 4.90        | 5.00 | 5.10 | 0.193  | 0.197  | 0.201  |
| E    | 6.20        | 6.40 | 6.60 | 0.244  | 0.252  | 0.260  |
| E1   | 4.30        | 4.40 | 4.50 | 0.169  | 0.173  | 0.176  |
| e    |             | 0.65 |      |        | 0.0256 |        |
| L    | 0.45        | 0.60 | 0.75 | 0.018  | 0.024  | 0.030  |
| L1   |             | 1.00 |      |        | 0.039  |        |
| k    | 0°          |      | 8°   | 0°     |        | 8°     |
| aaa  |             |      | 0.10 |        |        | 0.004  |

## 6 Ordering information

Table 10: Order codes

| Order code               | Temperature range | Package                           | Packaging     | Marking |
|--------------------------|-------------------|-----------------------------------|---------------|---------|
| TS971IDT                 | -40 °C, 125 °C    | SO8                               | Tape and reel | 971I    |
| TS971ILT                 |                   | SOT23-5                           |               | K120    |
| TS971IYLT <sup>(1)</sup> |                   | SOT23-5 (automotive grade level)  |               | K121    |
| TS972IDT                 |                   | SO8                               |               | 972I    |
| TS972IPT                 |                   | TSSOP8                            |               |         |
| TS972IQT                 |                   | DFN8 3x3                          |               |         |
| TS972IYDT <sup>(1)</sup> |                   | SO8 (automotive grade level)      |               | 972IY   |
| TS972IYPT <sup>(1)</sup> |                   | TSSOP8 (automotive grade level)   |               | 972IY   |
| TS972IYQT <sup>(1)</sup> |                   | DFN8 3x3 (automotive grade level) |               | 972Y    |
| TS974IDT                 |                   | SO14                              |               | 974I    |
| TS974IPT                 |                   | TSSOP14                           |               |         |
| TS974IYPT <sup>(1)</sup> |                   | TSSOP14 (automotive grade level)  |               |         |

**Notes:**

<sup>(1)</sup>Qualified and characterized according to AEC Q100 and Q003 or equivalent, advanced screening according to AEC Q001 and Q 002 or equivalent.

## 7 Revision history

**Table 11: Document revision history**

| Date         | Revision | Changes                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |
|--------------|----------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 15-Nov- 2002 | 1        | First release.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
| 9-May- 2005  | 2        | Modifications on AMR table (explanation of $V_{id}$ and $V_i$ limits)                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
| 31-Aug-2005  | 3        | PPAP references inserted in the datasheet, see Table 1 on page 2.                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
| 9-Dec-2005   | 4        | Thermal resistance junction to case data added in Table 1. on page 3<br>Missing PPAP references inserted in the datasheet, see Table 10: Order codes.                                                                                                                                                                                                                                                                                                                                                                                          |
| 3-Oct-2007   | 5        | Added $R_{thja}$ and $R_{thjc}$ values for DIP8 and DIP14 packages in Table 1.<br>ESD footnotes updated in Table 1: Absolute maximum ratings (AMR).<br>Description section updated on cover page.<br>Markings for automotive grade parts corrected in Table 10: Order codes.                                                                                                                                                                                                                                                                   |
| 20-Dec-2007  | 6        | Reformatted package information in Section 3: Package information.<br>Footnotes for automotive grade parts corrected in Table 10: Order codes.                                                                                                                                                                                                                                                                                                                                                                                                 |
| 06-May-2010  | 7        | Updated package information (drawings and data) in Chapter 3.<br>Removed DIP package order codes from Chapter 4: Ordering information.                                                                                                                                                                                                                                                                                                                                                                                                         |
| 19-Sep-2012  | 8        | Updated "Pin connection" figure on page 1 (removed part numbers).<br>Removed TS971ID, TS971IYD, TS972ID, TS972IYD, TS974ID and TS974IYD order code from Table 10.<br>Qualified status of TS971IYLT and TS974IYPT order code in Table 10.<br>Minor corrections throughout document.                                                                                                                                                                                                                                                             |
| 19-Jul-2013  | 9        | Added footnote regarding NC to the DFN8 3x3 pinout<br>Table 10: Order codes: removed order code TS971IYDT; added automotive qualification to order code TS972IYPT.                                                                                                                                                                                                                                                                                                                                                                             |
| 07-Mar-2014  | 10       | Table 3: Electrical characteristics at $V_{CC} = +2.5\text{ V}$ , $V_{DD} = -2.5\text{ V}$ , $T_{amb} = 25\text{ °C}$ (unless otherwise specified): added parameter "equivalent input noise current"                                                                                                                                                                                                                                                                                                                                           |
| 24-Jun-2016  | 11       | Added package silhouettes to cover page<br>Removed pinouts to <a href="#">Section 1: "Package pin connections"</a><br>Updated document layout<br><a href="#">Table 5</a> : updated "k" parameter in Millimeters, Min. column.<br><a href="#">Table 6</a> : moved "aaa" parameter to Typ. column instead of Max. column.<br><a href="#">Table 7</a> : removed "0.5" from A1, Millimeters, Max column.<br><a href="#">Table 10: "Order codes"</a> : removed obsolete order code TS974IYDT, added order code TS972IYQT, removed "tube" packaging. |

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