



# TS93x, TS93xA, TS93xB

## Output rail-to-rail micropower operational amplifiers

Datasheet —production data

### Features

- Rail-to-rail output voltage swing
- Micropower consumption (20  $\mu$ A)
- Single supply operation (2.7 to 10 V)
- Low offset (2 mV max. for TS93xB)
- CMOS inputs
- Ultra low input bias current (1 pA)
- ESD protection (2 kV)
- Latch-up immunity (class A)
- Available in SO-8, SO-14, SOT23-5, and TSSOP-14 package
- Automotive grade

### Applications

- Battery powered systems
- Portable communication systems
- Alarms, smoke detectors
- Instrumentation and sensing
- PH meters
- Digital scales
- Automotive

### Description

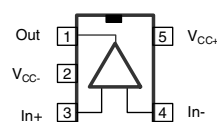
The TS93x (single, dual and quad) series are operational amplifiers that can operate with voltages as low as 2.7 V and reach a 2.9 V<sub>pp</sub> output swing with  $R_L = 100$  k $\Omega$  when supplied at 3 V.

Offering a typical consumption of only 20  $\mu$ A, these devices are particularly well suited to battery powered applications.

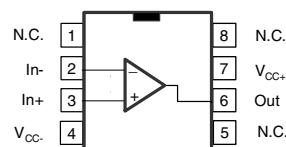
The amplifiers space saving 5-pin SOT23-5 package with outer dimensions of 2.8 mm x 2.9 mm make them very easy to implement on a board design.

#### Pin connections (top view)

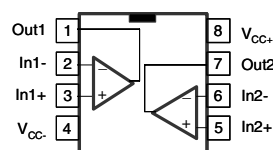
TS931ILT



TS931ID-TS931IDT



TS932ID-TS932IDT



TS934ID-TS934IDT-TS934IPT

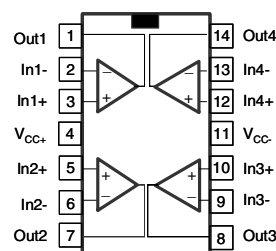


Table 1. Device summary

| Reference | Part number            |
|-----------|------------------------|
| TS93x     | TS931, TS932, TS934    |
| TS93xA    | TS931A, TS932A, TS934A |
| TS93xB    | TS931B, TS932B, TS934B |

# 1 Absolute maximum ratings and operating conditions

**Table 2. Absolute maximum ratings**

| Symbol     | Parameter                                             | Value                              | Unit |
|------------|-------------------------------------------------------|------------------------------------|------|
| $V_{CC}$   | Supply voltage <sup>(1)</sup>                         | 12                                 | V    |
| $V_{id}$   | Differential input voltage <sup>(2)</sup>             | $\pm V_{CC}$                       | V    |
| $V_{in}$   | Input voltage range <sup>(3)</sup>                    | $V_{CC-} - 0.3$ to $V_{CC+} + 0.3$ | V    |
| $I_{in}$   | Input current range <sup>(4)</sup>                    | 10                                 | mA   |
| $T_{std}$  | Storage temperature range                             | -65 to +150                        | °C   |
| $T_j$      | Maximum junction temperature                          | 150                                | °C   |
| $R_{thja}$ | Thermal resistance junction-to-ambient <sup>(5)</sup> |                                    |      |
|            | – SOT23-5                                             | 250                                | °C/W |
|            | – SO8                                                 | 125                                |      |
|            | – SO14                                                | 103                                |      |
|            | – TSSOP14                                             | 100                                |      |
| ESD        | HBM: human body model <sup>(6)</sup>                  | 2                                  | kV   |
|            | MM: machine model <sup>(7)</sup>                      | 200                                | V    |
|            | CDM: charged device model <sup>(8)</sup>              | 2                                  | kV   |
|            | Latch-up immunity                                     | 200                                | mA   |
|            | Soldering temperature (10 sec.), leaded version       | 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  $V_{CC+} + 0.3$  V.
4. Input current must be limited by a resistor in series with the inputs.
5. Short-circuits can cause excessive heating and destructive dissipation.
6. Human body model: 100 pF discharged through a 1.5 k $\Omega$  resistor into pin of device.
7. Machine model ESD: a 200 pF capacitor is charged to the specified voltage, then discharged directly into the IC with no external series resistor (internal resistor < 5  $\Omega$ ), into pin-to-pin of device.
8. Charged device model: all pins and the 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 3. Operating conditions**

| Symbol     | Parameter                            | Value                              | Unit |
|------------|--------------------------------------|------------------------------------|------|
| $V_{CC}$   | Supply voltage                       | 2.7 to 10                          | V    |
| $V_{icm}$  | Common mode input voltage range      | $V_{CC-} - 0.2$ to $V_{CC+} - 1.5$ | V    |
| $T_{oper}$ | Operating free air temperature range | -40 to +105                        | °C   |

## 2 Electrical characteristics

[Table 4](#) and [Table 5](#) give the electrical characteristics at each  $V_{CC}$  value.

**Table 4. Electrical characteristics at  $V_{CC+} = +3\text{ V}$ ,  $V_{CC-} = 0\text{ V}$ ,  $T_{amb} = 25\text{ °C}$  (unless otherwise specified)**

| Symbol          | Parameter                                                                                                        | Min.         | Typ.       | Max.          | Unit                         |
|-----------------|------------------------------------------------------------------------------------------------------------------|--------------|------------|---------------|------------------------------|
| $V_{io}$        | Input offset voltage<br>TS931/2/4<br>TS931/2/4A<br>TS931/2/4B                                                    |              |            | 10<br>5<br>2  | mV                           |
|                 | $T_{min} < T_{op} < T_{max}$<br>TS931/2/4<br>TS931/2/4A<br>TS931/2/4B                                            |              |            | 15<br>10<br>6 |                              |
| $\Delta V_{io}$ | Input offset voltage drift                                                                                       |              | 3          |               | $\mu\text{V}/^\circ\text{C}$ |
| $I_{io}$        | Input offset current <sup>(1)</sup><br>$T_{min} < T_{op} < T_{max}$                                              |              | 1          | 100<br>200    | pA                           |
| $I_{ib}$        | Input bias current <sup>(1)</sup><br>$T_{min} < T_{op} < T_{max}$                                                |              | 1          | 150<br>300    | pA                           |
| CMR             | Common mode rejection ratio, $0 \leq V_{icm} \leq V_{CC+} - 1.7$<br>$T_{min} < T_{op} < T_{max}$                 | 55<br>55     | 85<br>85   |               | dB                           |
| SVR             | Supply voltage rejection ratio <sup>(2)</sup><br>$T_{min} < T_{op} < T_{max}$                                    | 55<br>55     | 85<br>85   |               | dB                           |
| $A_{vd}$        | Large signal voltage gain<br>$V_O = 2\text{ V}_{pp}$ , $R_L = 1\text{ M}\Omega$<br>$R_L = 100\text{ k}\Omega$    |              | 120<br>106 |               | dB                           |
| $V_{OH}$        | High level output voltage, $V_{ID} = 100\text{ mV}$ , $R_L = 100\text{ k}\Omega$<br>$T_{min} < T_{op} < T_{max}$ | 2.95<br>2.95 | 2.99       |               | V                            |
| $V_{OL}$        | Low level output voltage, $V_{ID} = -100\text{ mV}$ , $R_L = 100\text{ k}\Omega$<br>$T_{min} < T_{op} < T_{max}$ |              | 10         | 50<br>50      | mV                           |
| $I_o$           | Output source current<br>$V_{ID} = 100\text{ mV}$ , $V_O = V_{CC-}$                                              |              | 1.5        |               | mA                           |
|                 | Output sink current<br>$V_{ID} = -100\text{ mV}$ , $V_O = V_{CC+}$                                               |              | 1.5        |               |                              |
| $I_{CC}$        | Supply current (per amplifier), $A_{VCL} = 1$ , no load<br>$T_{min} < T_{op} < T_{max}$                          |              | 20         | 31<br>33      | $\mu\text{A}$                |
| GBP             | Gain bandwidth product<br>$R_L = 100\text{ k}\Omega$ , $C_L = 50\text{ pF}$                                      |              | 100        |               | kHz                          |
| SR              | Slew rate<br>$R_L = 100\text{ k}\Omega$ , $C_L = 50\text{ pF}$                                                   |              | 50         |               | V/ms                         |

**Table 4. Electrical characteristics at  $V_{CC+} = +3\text{ V}$ ,  $V_{CC-} = 0\text{ V}$ ,  $T_{amb} = 25\text{ }^{\circ}\text{C}$  (unless otherwise specified) (continued)**

| Symbol   | Parameter                            | Min. | Typ. | Max. | Unit                   |
|----------|--------------------------------------|------|------|------|------------------------|
| $\phi_m$ | Phase margin<br>$C_L = 50\text{ pF}$ |      | 65   |      | Degrees                |
| en       | Input voltage noise                  |      | 75   |      | nV/ $\sqrt{\text{Hz}}$ |

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

2.  $V_{CC}$  has a 0.2 V variation.

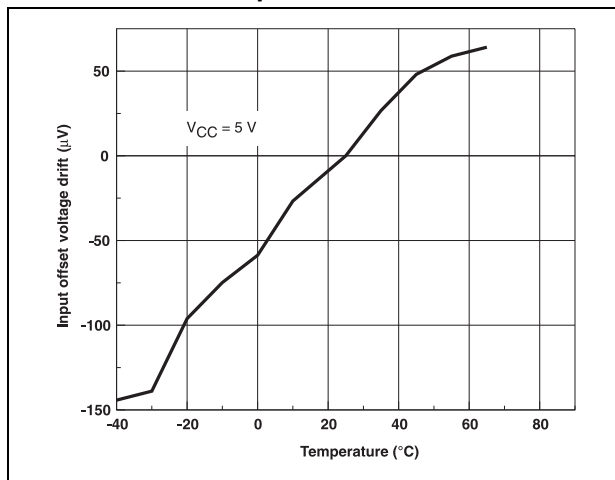
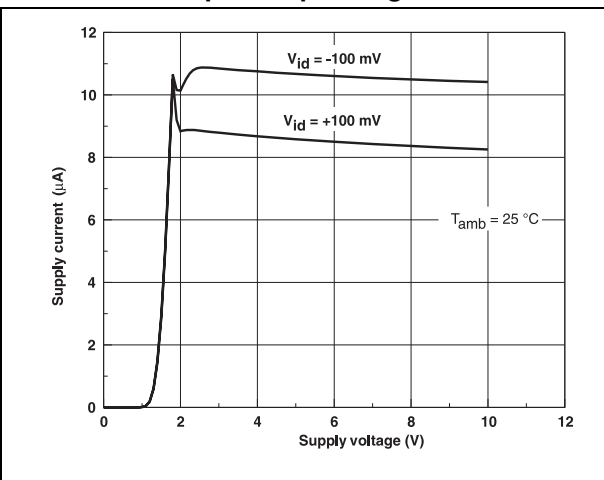
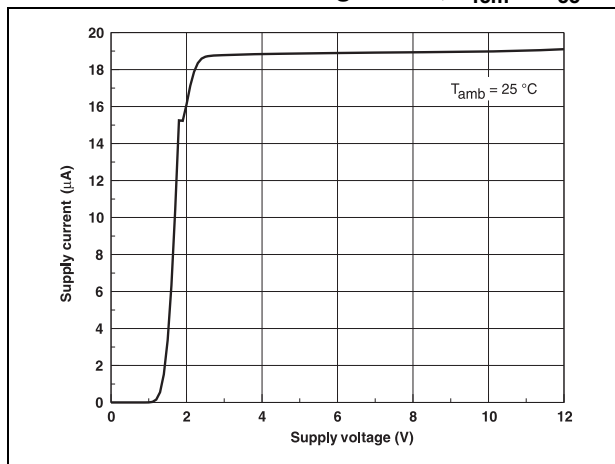
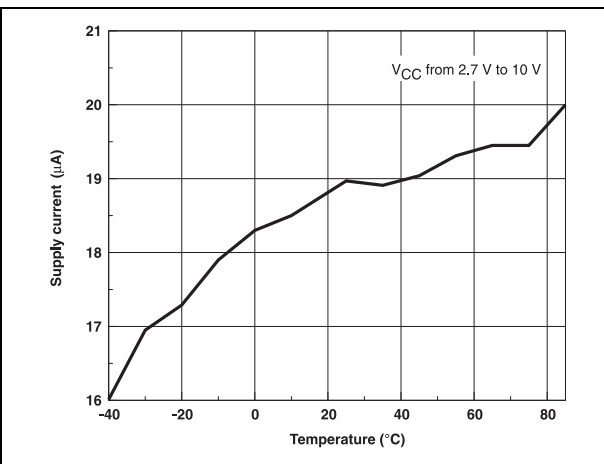
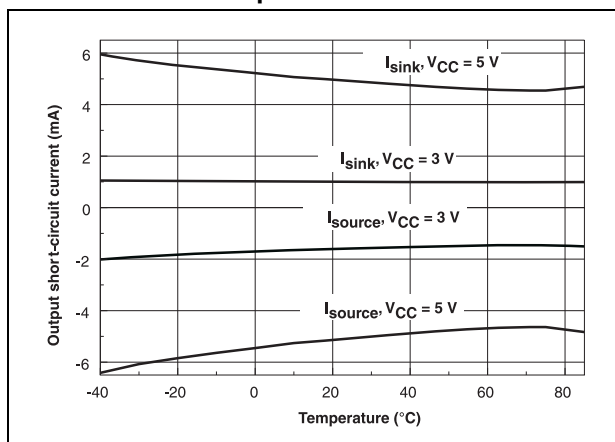
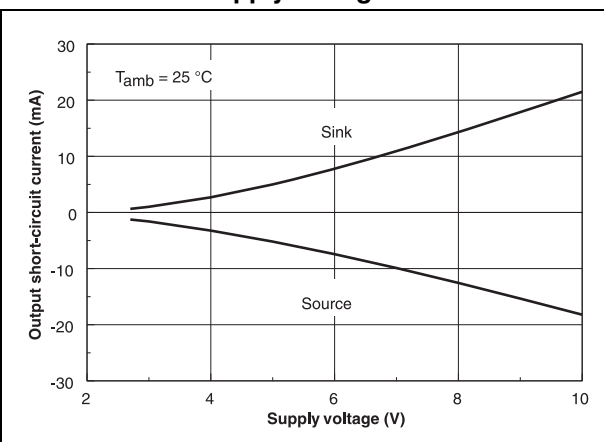
**Table 5. Electrical characteristics at  $V_{CC+} = +5\text{ V}$ ,  $V_{CC-} = 0\text{ V}$ ,  $T_{amb} = 25\text{ }^{\circ}\text{C}$  (unless otherwise specified)**

| Symbol          | Parameter                                                                                                        | Min.         | Typ.       | Max.          | Unit                           |
|-----------------|------------------------------------------------------------------------------------------------------------------|--------------|------------|---------------|--------------------------------|
| $V_{io}$        | Input offset voltage<br>TS931/2/4<br>TS931/2/4A<br>TS931/2/4B                                                    |              |            | 10<br>5<br>2  | mV                             |
|                 | $T_{min} < T_{op} < T_{max}$<br>TS931/2/4<br>TS931/2/4A<br>TS931/2/4B                                            |              |            | 15<br>10<br>6 |                                |
| $\Delta V_{io}$ | Input offset voltage drift                                                                                       |              | 3          |               | $\mu\text{V}/^{\circ}\text{C}$ |
| $I_{io}$        | Input offset current <sup>(1)</sup><br>$T_{min} < T_{op} < T_{max}$                                              |              | 1          | 100<br>200    | pA                             |
| $I_{ib}$        | Input bias current <sup>(1)</sup><br>$T_{min} < T_{op} < T_{max}$                                                |              | 1          | 150<br>300    | pA                             |
| CMR             | Common mode rejection ratio, $0 \leq V_{icm} \leq V_{CC+} - 1.7$<br>$T_{min} < T_{op} < T_{max}$                 | 55<br>55     | 85<br>85   |               | dB                             |
| SVR             | Supply voltage rejection ratio <sup>(2)</sup><br>$T_{min} < T_{op} < T_{max}$                                    | 55<br>55     | 85<br>85   |               | dB                             |
| $A_{vd}$        | Large signal voltage gain<br>$V_O = 4\text{ Vpp}$ , $R_L = 1\text{ M}\Omega$<br>$R_L = 100\text{ k}\Omega$       |              | 120<br>112 |               | dB                             |
| $V_{OH}$        | High level output voltage, $V_{ID} = 100\text{ mV}$ , $R_L = 100\text{ k}\Omega$<br>$T_{min} < T_{op} < T_{max}$ | 4.95<br>4.95 | 4.99       |               | V                              |
| $V_{OL}$        | Low level output voltage, $V_{ID} = -100\text{ mV}$ , $R_L = 100\text{ k}\Omega$<br>$T_{min} < T_{op} < T_{max}$ |              | 10         | 50<br>50      | mV                             |
| $I_o$           | Output source current<br>$V_{ID} = 100\text{ mV}$ , $V_O = V_{DD}$                                               |              | 5          |               | mA                             |
|                 | Output sink current<br>$V_{ID} = -100\text{ mV}$ , $V_O = V_{CC}$                                                |              | 5          |               |                                |
| $I_{CC}$        | Supply current (per amplifier), $A_{VCL} = 1$ , no load<br>$T_{min} < T_{op} < T_{max}$                          |              | 20         | 33<br>35      | $\mu\text{A}$                  |

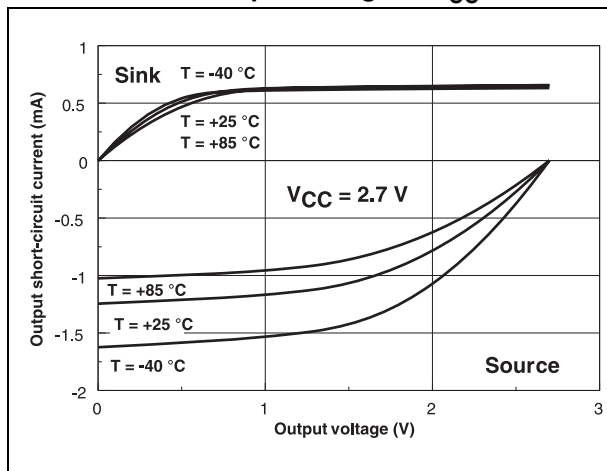
**Table 5. Electrical characteristics at  $V_{CC+} = +5\text{ V}$ ,  $V_{CC-} = 0\text{ V}$ ,  $T_{amb} = 25\text{ °C}$   
(unless otherwise specified) (continued)**

| Symbol   | Parameter                                                                   | Min. | Typ. | Max. | Unit                   |
|----------|-----------------------------------------------------------------------------|------|------|------|------------------------|
| GBP      | Gain bandwidth product<br>$R_L = 100\text{ K}\Omega$ , $C_L = 50\text{ pF}$ |      | 100  |      | kHz                    |
| SR       | Slew rate<br>$R_L = 100\text{ K}\Omega$ , $C_L = 50\text{ pF}$              |      | 50   |      | V/ms                   |
| $\phi_m$ | Phase margin<br>$C_L = 50\text{ pF}$                                        |      | 65   |      | Degrees                |
| en       | Input voltage noise                                                         |      | 76   |      | nV/ $\sqrt{\text{Hz}}$ |

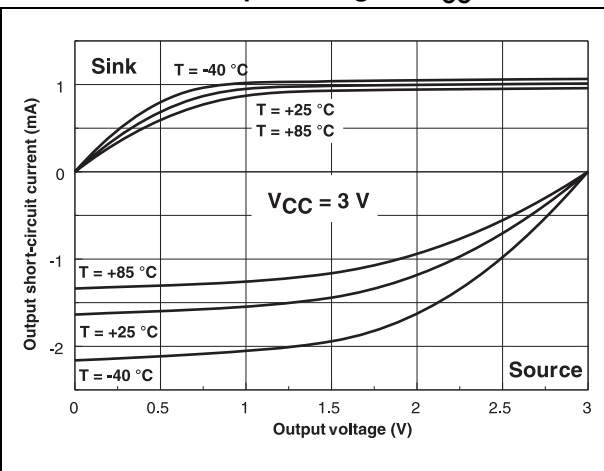
1. Maximum values including unavoidable inaccuracies of the industrial test.
2.  $V_{CC}$  has a 0.2 V variation.

**Figure 1. Input offset voltage vs. temperature****Figure 2. Supply current vs. supply voltage, in open loop configuration****Figure 3. Supply current vs. supply voltage in follower configuration,  $V_{icm} = V_{CC}/2$** **Figure 4. Supply current vs. temperature****Figure 5. Output short-circuit current vs. temperature****Figure 6. Output short-circuit current vs. supply voltage**

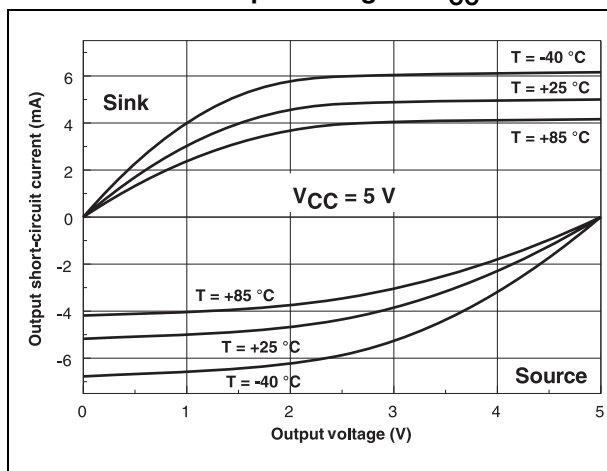
**Figure 7. Output short-circuit current vs. output voltage at  $V_{CC+} = 2.7\text{ V}$**



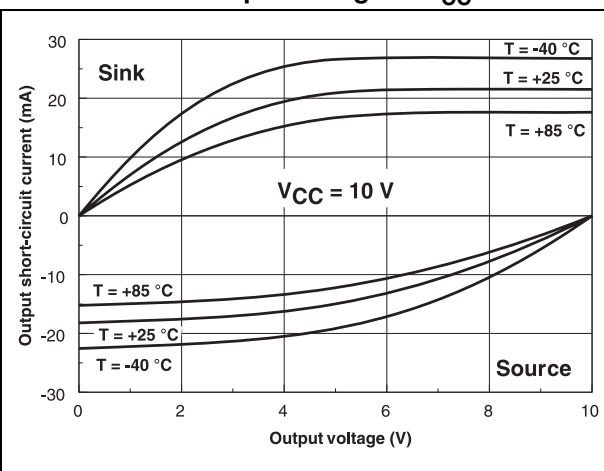
**Figure 8. Output short-circuit current vs. output voltage at  $V_{CC+} = 3\text{ V}$**



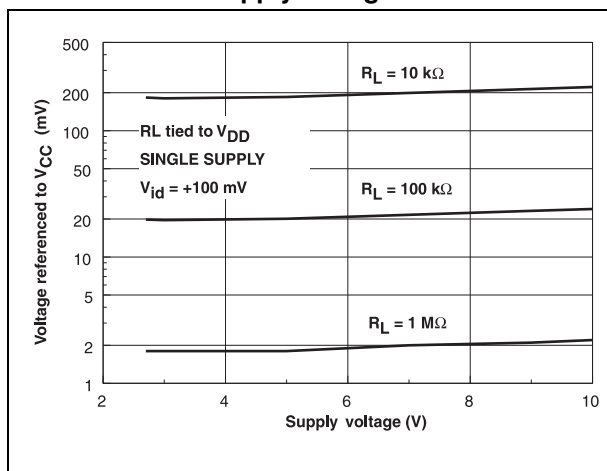
**Figure 9. Output short-circuit current vs. output voltage at  $V_{CC+} = 5\text{ V}$**



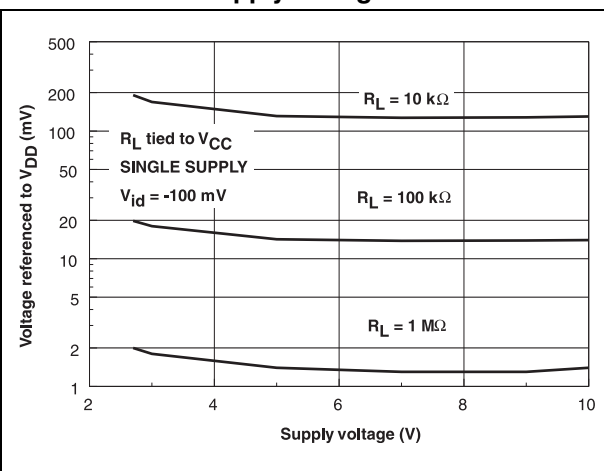
**Figure 10. Output short-circuit current vs. output voltage at  $V_{CC+} = 10\text{ V}$**



**Figure 11. High level output voltage drop vs. supply voltage**



**Figure 12. Low level output voltage drop vs. supply voltage**



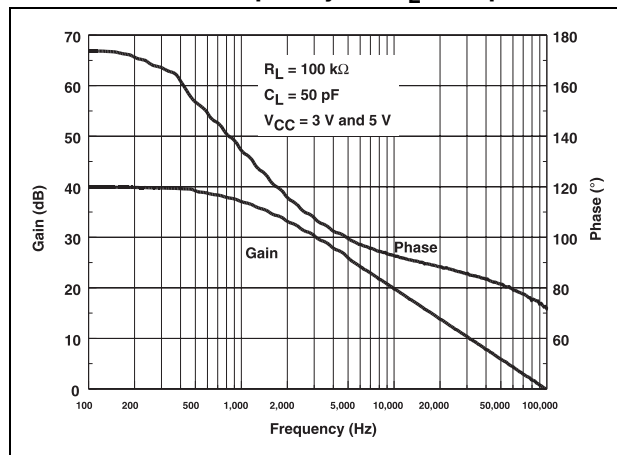
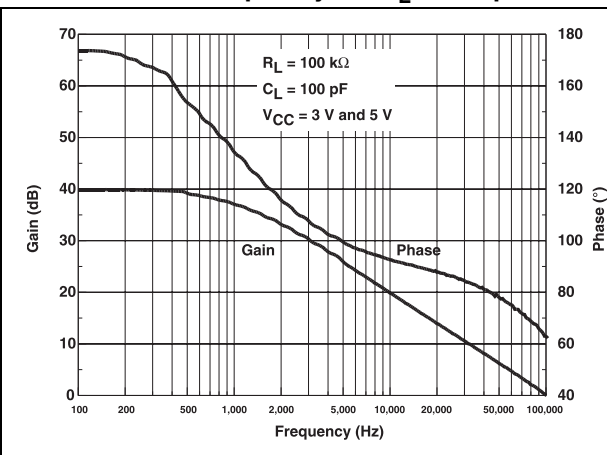
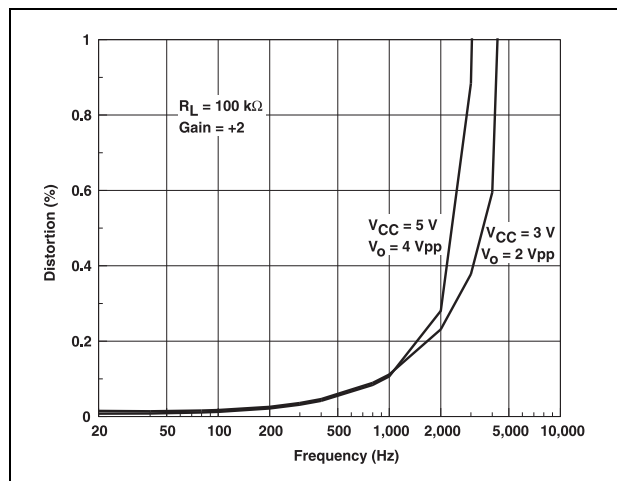
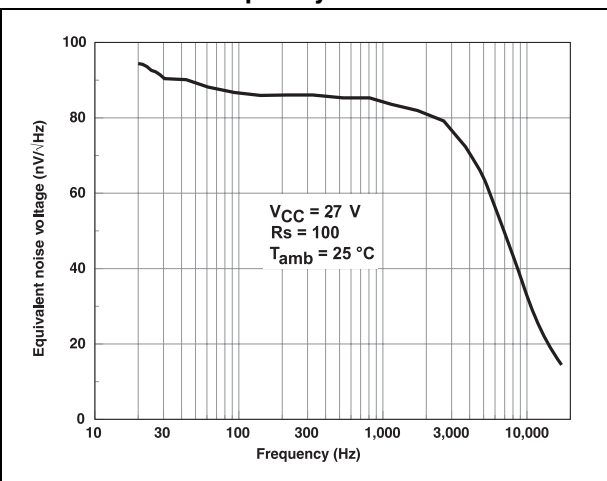
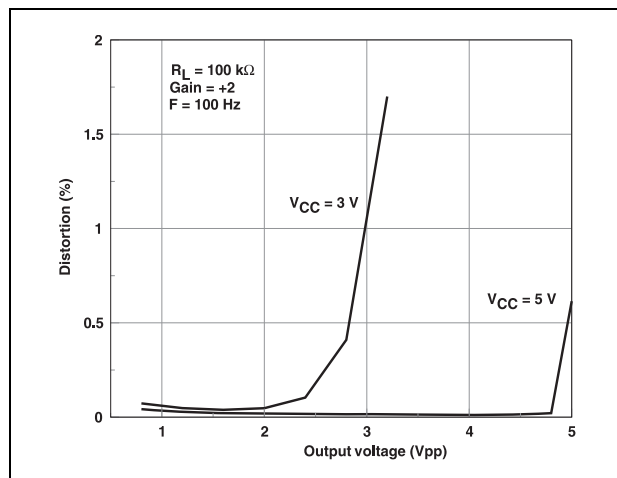
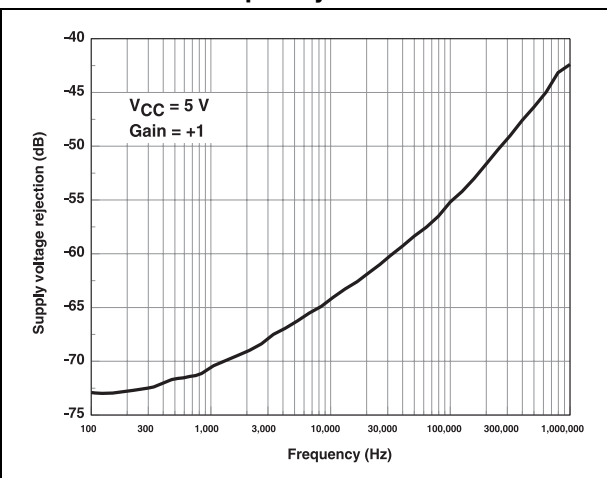
**Figure 13. Voltage gain and phase vs. frequency for  $C_L = 50$  pF****Figure 14. Voltage gain and phase vs. frequency for  $C_L = 100$  pF****Figure 15. Distortion vs. frequency****Figure 16. Equivalent input noise voltage vs. frequency****Figure 17. Distortion vs. output voltage****Figure 18. Supply voltage rejection vs. frequency**

Figure 19. Slew rate vs. time for small input voltage signal

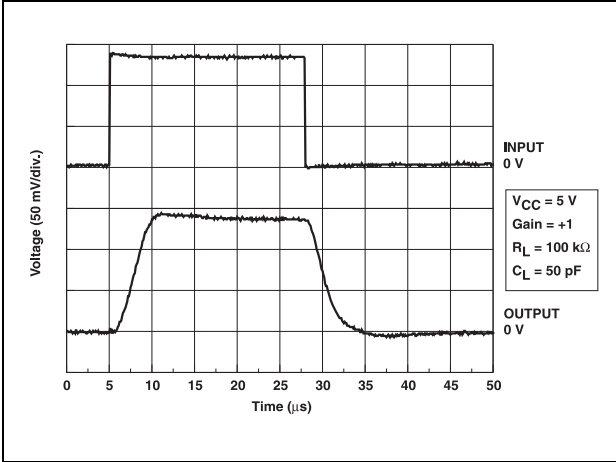
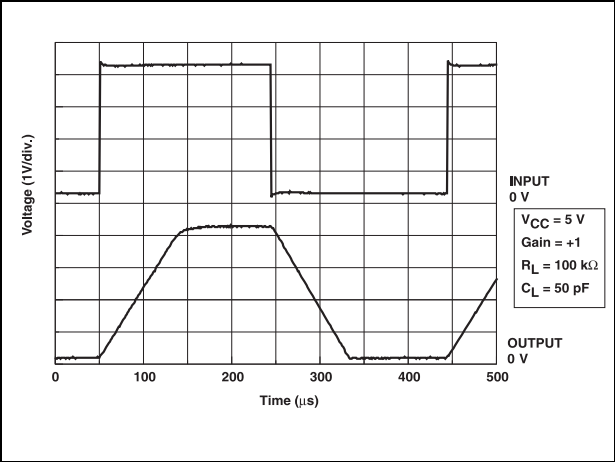


Figure 20. Slew rate vs. time for large input voltage signal



### 3      **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.

### 3.1 SO-8 package information

Figure 21. SO-8 package outline

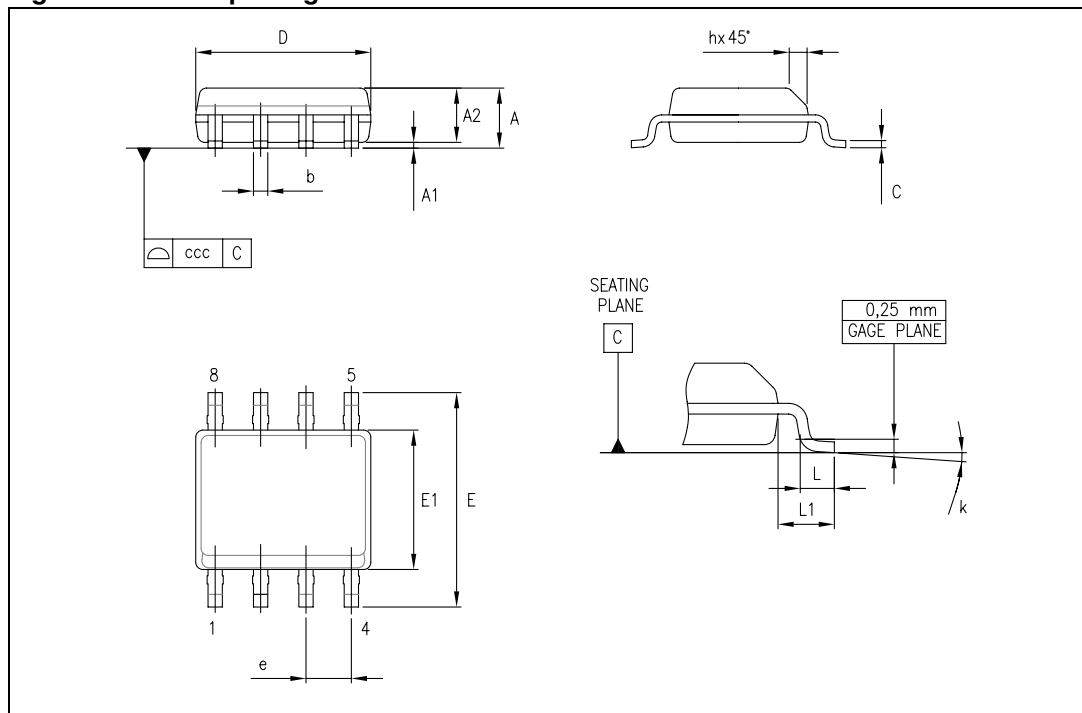


Table 6. SO-8 package mechanical data

| Symbol | 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 |

## 3.2 SO-14 package information

Figure 22. SO-14 package outline

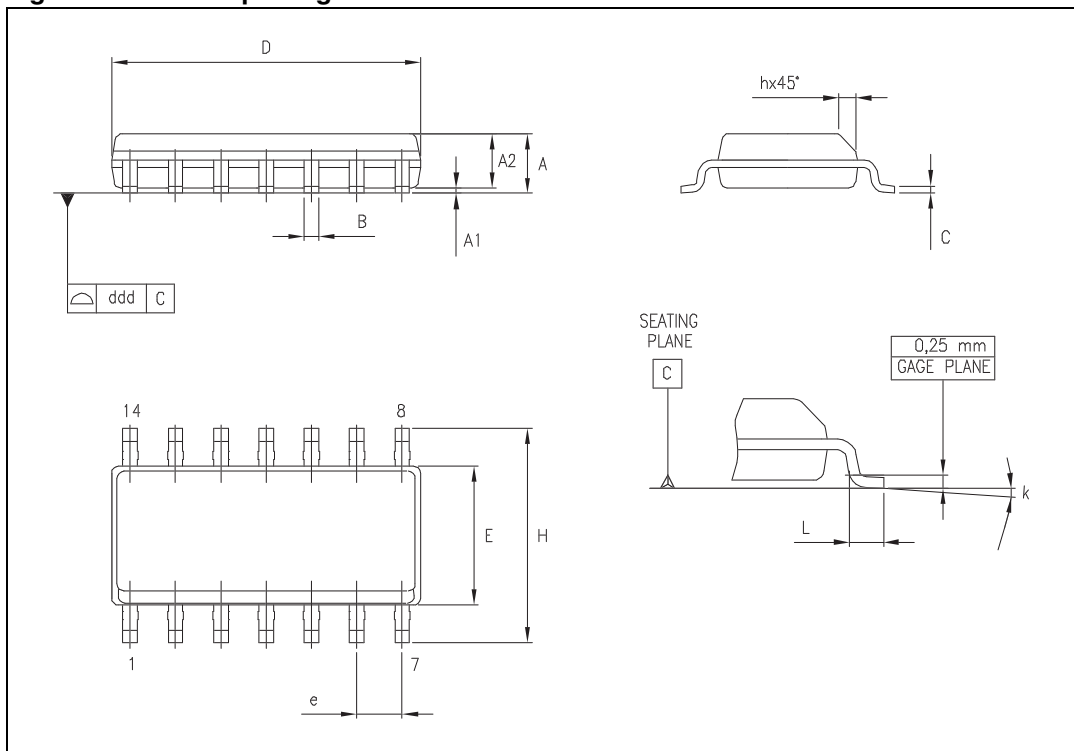


Table 7. SO-14 package mechanical data

| Dimensions |             |      |      |        |      |       |
|------------|-------------|------|------|--------|------|-------|
| Symbol     | 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 |

### 3.3 TSSOP14 package information

Figure 23. TSSOP14 package outline

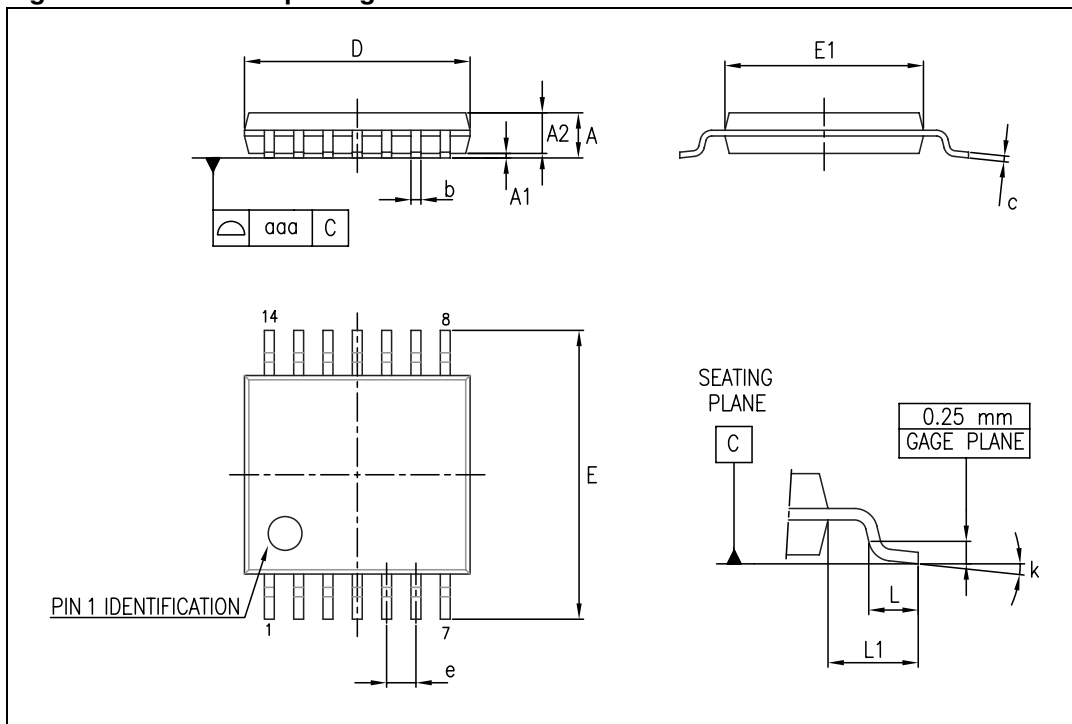


Table 8. TSSOP14 package mechanical data

| Symbol | 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  |

### 3.4 SOT23-5 package information

Figure 24. SOT23-5 package outline

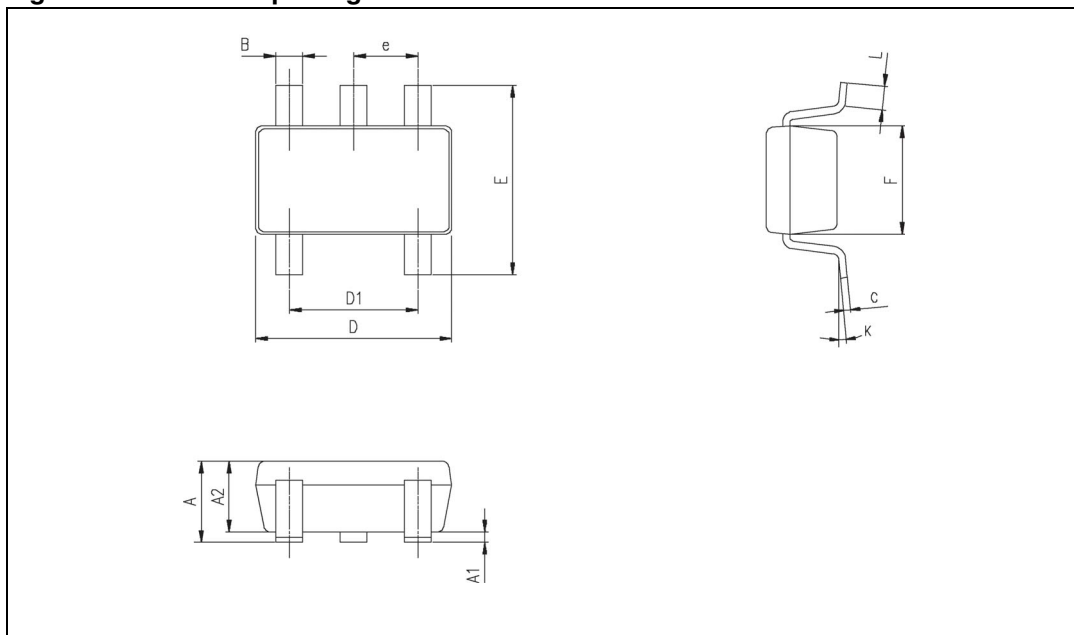


Table 9. SOT23-5 package mechanical data

| Symbol | 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       | 0.013  | 0.015 | 0.019 |
| C      | 0.09        | 0.15 | 0.20       | 0.003  | 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  | 0.013 | 0.023 |
| K      | 0 degrees   |      | 10 degrees |        |       |       |

## 4 Ordering information

**Table 10. Order codes**

| Order code                                                             | Temperature range | Package                                   | Packaging                                                               | Marking                                          |
|------------------------------------------------------------------------|-------------------|-------------------------------------------|-------------------------------------------------------------------------|--------------------------------------------------|
| TS931ID<br>TS931IDT<br>TS931AID<br>TS931AIDT<br>TS931BID<br>TS931BIDT  | -40 °C, +105 °C   | SO-8                                      | Tube<br>Tape and reel<br>Tube<br>Tape and reel<br>Tube<br>Tape and reel | 931I<br>931I<br>931AI<br>931AI<br>931BI<br>931BI |
| TS931ILT<br>TS931AILT<br>TS931BILT                                     |                   | SOT23-5L                                  | Tape and reel                                                           | K205<br>K206<br>K207                             |
| TS932ID<br>TS932IDT<br>TS932AID<br>TS932AIDT<br>TS932BID<br>TS932BIDT  |                   | SO-8                                      | Tube<br>Tape and reel<br>Tube<br>Tape and reel<br>Tube<br>Tape and reel | 932I<br>932I<br>932AI<br>932AI<br>932BI<br>932BI |
| TS934ID<br>TS934IDT<br>TS934AID<br>TS934AIDT<br>TS934BIDT<br>TS934BIDT |                   | SO-14                                     | Tube<br>Tape and reel<br>Tube<br>Tape and reel<br>Tube<br>Tape and reel | 934I<br>934I<br>934AI<br>934AI<br>934BI<br>934BI |
| TS934IPT<br>TS934AIPT<br>TS934BIPT                                     |                   | TSSOP-14<br>(thin shrink outline package) | Tape and reel                                                           | 934I<br>934AI<br>934BI                           |
| TS934IYDT <sup>(1)</sup><br>TS934AIYDT <sup>(1)</sup>                  |                   | SO-14<br>(automotive grade)               | Tape and reel                                                           | 934IY<br>934AIY                                  |

1. Qualified and characterized according to AEC Q100 and Q003 or equivalent, advanced screening according to AEC Q001 and Q 002 or equivalent.

## 5 Revision history

**Table 11. Document revision history**

| Date        | Revision | Changes                                                                                                                                                                                                                                                                                                                                                 |
|-------------|----------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 01-Nov-2001 | 1        | Initial release.                                                                                                                                                                                                                                                                                                                                        |
| 01-Dec-2004 | 2        | Modified AMR values in <a href="#">Table 2</a> (explanation of Vid and Vi limits).                                                                                                                                                                                                                                                                      |
| 04-May-2009 | 3        | Document reformatted.<br>Removed DIP package information and order codes from <a href="#">Chapter 3</a> .<br>Modified temperature range: extended to -40 to +105° C in <a href="#">Table 10: Order codes</a> .<br>Added automotive grade products in <a href="#">Table 10</a> .                                                                         |
| 07-Sep-2009 | 4        | Added root part numbers (TS93xA, TS93xB) and <a href="#">Table 1: Device summary</a> on cover page.<br>Added parameters for full temperature range in <a href="#">Table 4</a> and in <a href="#">Table 5</a> .                                                                                                                                          |
| 07-Nov-2012 | 5        | Updated <a href="#">Features</a> (added SO-8, SO-14, and TSSOP-14 package).<br>Updated <a href="#">Table 2</a> (removed TSSOP8 package).<br>Removed TS934IYD and TS934AIYD order codes from <a href="#">Table 10</a> , qualified status of TS934IYDT and TS934AIYDT order codes in <a href="#">Table 10</a> .<br>Minor corrections throughout document. |

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