

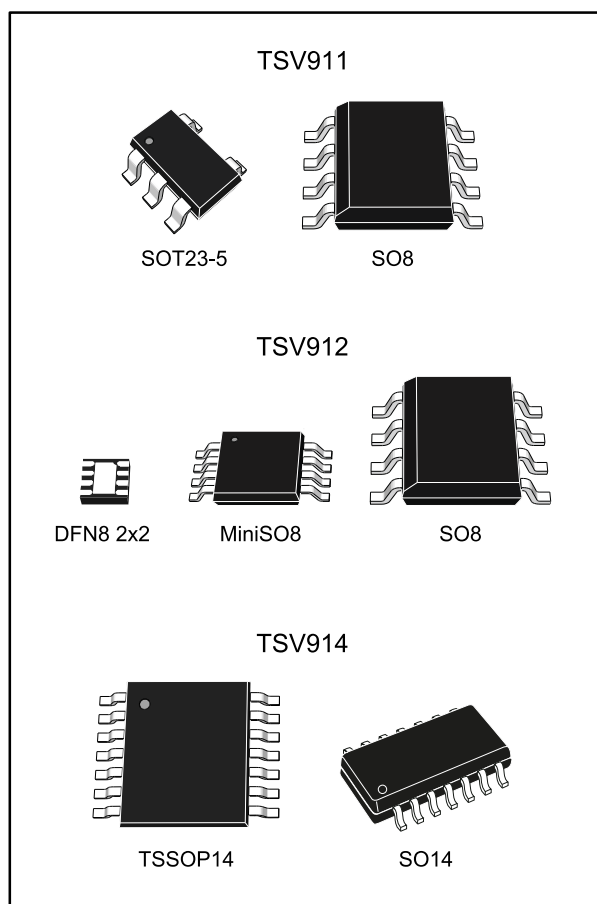


# THE DATASHEET OF TSV911AILT



## Single, dual, and quad rail-to-rail input/output 8 MHz operational amplifiers

Datasheet - production data



### Features

- Rail-to-rail input and output
- Wide bandwidth
- Low power consumption: 820  $\mu$ A typ
- Unity gain stability
- High output current: 35 mA
- Operating from 2.5 V to 5.5 V
- Low input bias current, 1 pA typ
- Low input offset voltage: 1.5 mV max (A grade)
- ESD internal protection  $\geq$  5 kV
- Latch-up immunity

### Applications

- Battery-powered applications
- Portable devices
- Signal conditioning
- Active filtering
- Medical instrumentation
- Automotive applications

### Related products

- See TSV99x, TSV99xA for higher gain bandwidth (not unity gain stable)

### Description

The TSV91x operational amplifiers (op amps) offer low voltage operation and rail-to-rail input and output, as well as an excellent speed/power consumption ratio, providing an 8 MHz gain-bandwidth product while consuming only 1.1 mA maximum at 5 V. The op amps are unity gain stable and feature an ultra-low input bias current.

The devices are ideal for sensor interfaces, battery-supplied and portable applications, as well as active filtering.

**Table 1: Device summary**

| Reference              | Single  | Dual    | Quad    |
|------------------------|---------|---------|---------|
| TSV91x                 | TSV911  | TSV912  | TSV914  |
| TSV91xA <sup>(1)</sup> | TSV911A | TSV912A | TSV914A |

#### Notes:

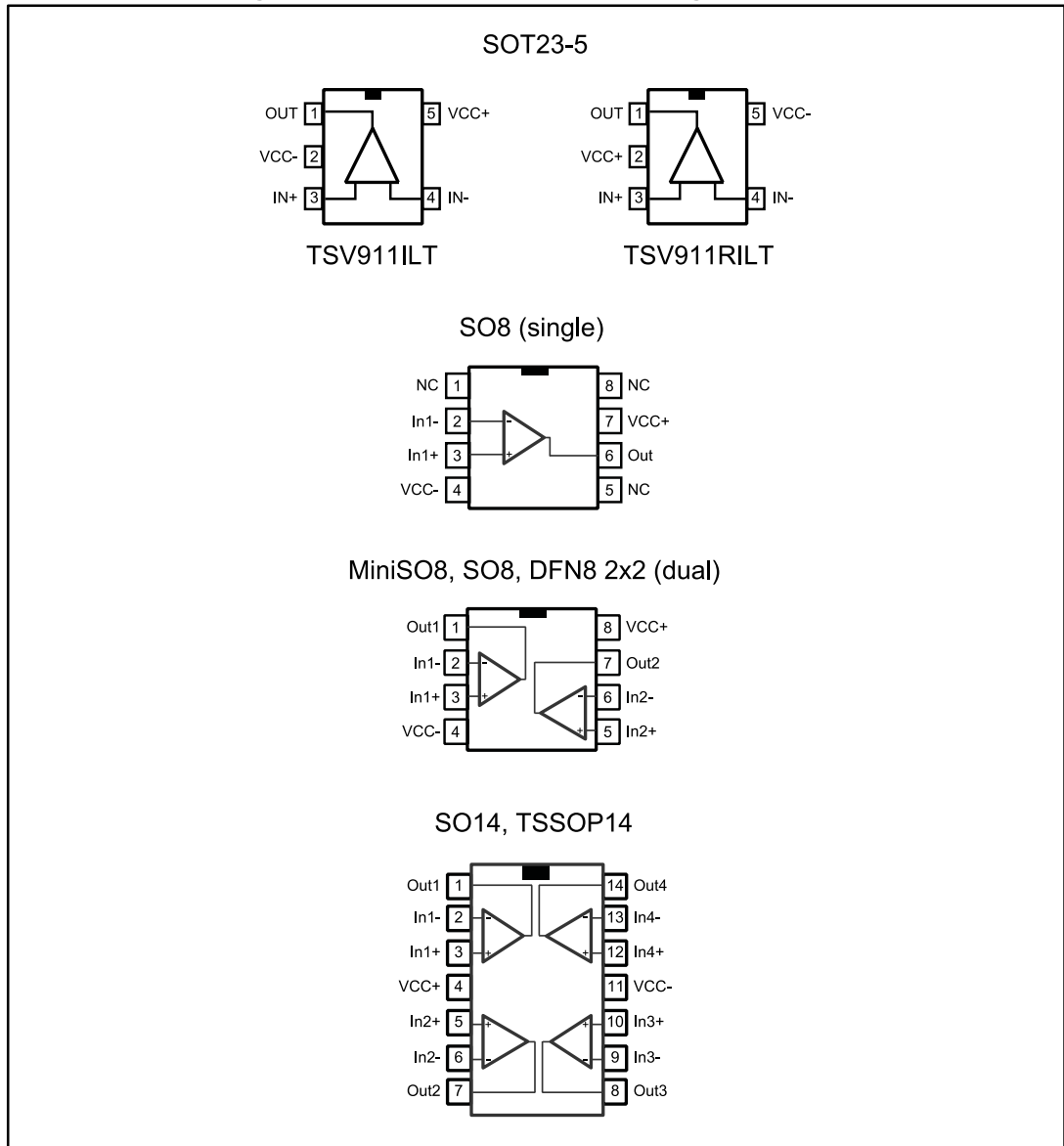
<sup>(1)</sup>Suffix "A" refers to enhanced  $V_{io}$  performance

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# 1 Package pin connections

Figure 1: Pin connections for each package (top view)



1. The exposed pad of the DFN8 2x2 package is not internally connected and can be set to ground or left floating.

## 2 Absolute maximum ratings and operating conditions

Table 2: Absolute maximum ratings (AMR)

| Symbol            | Parameter   |                       | Value  | Unit |
|-------------------|---|-----------------------|--|------|
| V <sub>CC</sub>   | Supply voltage <sup>(1)</sup>                             |                       | 6  | V    |
| V <sub>id</sub>   | Differential input voltage <sup>(2)</sup>                 |                       | ±V <sub>CC</sub>                                       |      |
| V <sub>in</sub>   | Input voltage <sup>(3)</sup>                              |                       | (V <sub>CC-</sub> ) - 0.2 to (V <sub>CC+</sub> ) + 0.2 |      |
| I <sub>in</sub>   | Input current <sup>(4)</sup>                              |                       | 10   | mA   |
| T <sub>stg</sub>  | Storage temperature                                       |                       | -65 to 150   | °C   |
| T <sub>j</sub>    | Maximum junction temperature                              |                       | 150  |      |
| R <sub>thja</sub> | Thermal resistance junction to ambient <sup>(5) (6)</sup> | SOT23-5               | 250  | °C/W |
|                   |   | DFN8 2x2              | 57   |      |
|                   |   | SO8                   | 125  |      |
|                   |   | MiniSO8               | 190  |      |
|                   |   | SO14                  | 103  |      |
|                   |   | TSSOP14               | 100  |      |
| R <sub>thjc</sub> | Thermal resistance junction to case <sup>(5) (6)</sup>    | SOT23-5               | 81   | °C/W |
|                   |   | SO8                   | 40   |      |
|                   |   | MiniSO8               | 39   |      |
|                   |   | SO14                  | 31   |      |
|                   |   | TSSOP14               | 32   |      |
| ESD               | HBM: human body model <sup>(7)</sup>                      |                       | 5  | kV   |
|                   | MM: machine model <sup>(8)</sup>                          |                       | 400  | V    |
|                   | CDM: charged device model <sup>(9)</sup>                  | SOT23-5, SO8, MiniSO8 | 1500   |      |
|                   |   | TSSOP14               | 750  |      |
|                   |   | SO14                  | 500  |      |
|                   | Latch-up immunity   |                       | 200  | mA   |

**Notes:**

- (1) All voltage values, except the differential voltage, are with respect to network ground terminal.
- (2) Differential voltages are the non-inverting input terminal with respect to the inverting input terminal
- (3) V<sub>CC</sub> - V<sub>IN</sub> must not exceed 6 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) R<sub>th</sub> are typical values
- (7) Human body model: 100 pF discharged through a 1.5 kΩ resistor between two pins of the device, done for all couples of pin combinations with other pins floating.
- (8) Machine model: 200 pF charged to the specified voltage, then discharged directly between two pins of the device with no external series resistor (internal resistor < 5 Ω), done for all couples of pin combinations with other pins floating

<sup>(9)</sup>Charged device model: all pins plus packages are charged together to the specified voltage and then discharged directly to the ground.

Table 3: Operating conditions

| Symbol           | Parameter                            | Value  | Unit       |
|------------------|--------------------------------------|--|------------|
| V <sub>CC</sub>  | Supply voltage                       | -40 °C < T <sub>op</sub> < 125 °C                      | 2.5 to 5.5 |
|                  |                                      | 0 °C < T <sub>op</sub> < 125 °C                        | 2.3 to 5.5 |
| V <sub>icm</sub> | Common mode input voltage range      | (V <sub>CC-</sub> ) - 0.1 to (V <sub>CC+</sub> ) + 0.1 | V          |
| T <sub>op</sub>  | Operating free air temperature range | -40 to 125   | °C         |

### 3 Electrical characteristics



In the electrical characteristic tables below, all parameter limits at temperatures other than 25 °C are guaranteed by correlation.

**Table 4: Electrical characteristics at VCC+ = 2.5 V, VCC- = 0 V, Vicm = VCC/2, with RL connected to VCC/2, full temperature range (unless otherwise specified)**

| Symbol                            | Parameter   | Conditions   | Min. | Typ. | Max. | Unit  |
|-----------------------------------|---|--|------|------|------|-------|
| <b>DC performance</b>             |   |  |      |      |      |       |
| V <sub>io</sub>                   | Offset voltage, TSV91x  | T <sub>op</sub> = 25 °C  |      | 0.1  | 4.5  | mV    |
|                                   |   | T <sub>min</sub> < T <sub>op</sub> < T <sub>max</sub>                            |      |      | 7.5  |       |
|                                   | Offset voltage, TSV91xA   | T <sub>op</sub> = 25 °C  |      |      | 1.5  |       |
|                                   |   | T <sub>min</sub> < T <sub>op</sub> < T <sub>max</sub>                            |      |      | 3    |       |
| ΔV <sub>io</sub> /ΔT              | Input offset voltage drift  |  |      | 5    |      | μV/°C |
| i <sub>io</sub>                   | Input offset current <sup>(1)</sup>                                       | T <sub>op</sub> = 25 °C  |      | 1    | 10   | pA    |
|                                   |   | T <sub>min</sub> < T <sub>op</sub> < T <sub>max</sub>                            |      |      | 100  |       |
| i <sub>ib</sub>                   | Input bias current <sup>(1)</sup>   | T <sub>op</sub> = 25 °C  |      | 1    | 10   | pA    |
|                                   |   | T <sub>min</sub> < T <sub>op</sub> < T <sub>max</sub>                            |      |      | 100  |       |
| CMR                               | Common mode rejection ratio, 20 log (ΔV <sub>ic</sub> /ΔV <sub>io</sub> ) | 0 V to 2.5 V, V <sub>out</sub> = 1.25 V, T <sub>op</sub> = 25 °C                 | 58   | 75   |      | dB    |
|                                   |   | T <sub>min</sub> < T <sub>op</sub> < T <sub>max</sub>                            | 53   |      |      |       |
| A <sub>vd</sub>                   | Large signal voltage gain   | R <sub>L</sub> = 10 kΩ, V <sub>out</sub> = 0.5 V to 2 V, T <sub>op</sub> = 25 °C | 80   | 89   |      | dB    |
|                                   |   | T <sub>min</sub> < T <sub>op</sub> < T <sub>max</sub>                            | 75   |      |      |       |
| V <sub>CC</sub> - V <sub>OH</sub> | High-level output voltage   | R <sub>L</sub> = 10 kΩ   |      | 15   | 40   | mV    |
|                                   |   | T <sub>min</sub> < T <sub>op</sub> < T <sub>max</sub>                            |      |      | 40   |       |
|                                   |   | R <sub>L</sub> = 600 Ω   |      | 45   | 150  |       |
|                                   |   | T <sub>min</sub> < T <sub>op</sub> < T <sub>max</sub>                            |      |      | 150  |       |
| V <sub>OL</sub>                   | Low-level output voltage  | R <sub>L</sub> = 10 kΩ   |      | 15   | 40   | mV    |
|                                   |   | T <sub>min</sub> < T <sub>op</sub> < T <sub>max</sub>                            |      |      | 40   |       |
|                                   |   | R <sub>L</sub> = 600 Ω   |      | 45   | 150  |       |
|                                   |   | T <sub>min</sub> < T <sub>op</sub> < T <sub>max</sub>                            |      |      | 150  |       |
| I <sub>out</sub>                  | I <sub>sink</sub>   | V <sub>o</sub> = 2.5 V, T <sub>op</sub> = 25 °C                                  | 18   | 32   |      | mA    |
|                                   |   | T <sub>min</sub> < T <sub>op</sub> < T <sub>max</sub>                            | 16   |      |      |       |
|                                   | I <sub>source</sub>   | V <sub>o</sub> = 0 V, T <sub>op</sub> = 25 °C                                    | 18   | 35   |      |       |
|                                   |   | T <sub>min</sub> < T <sub>op</sub> < T <sub>max</sub>                            | 16   |      |      |       |
| I <sub>CC</sub>                   | Supply current (per channel)  | No load, V <sub>out</sub> = V <sub>CC</sub> /2                                   |      | 0.78 | 1.1  | mA    |
|                                   |   | T <sub>min</sub> < T <sub>op</sub> < T <sub>max</sub>                            |      |      | 1.1  |       |

| Symbol                | Parameter                      | Conditions  | Min. | Typ.  | Max. | Unit                   |
|-----------------------|--------------------------------|---|------|-------|------|------------------------|
| <b>AC performance</b> |                                |   |      |       |      |                        |
| GBP                   | Gain bandwidth product         | $R_L = 2\text{ k}\Omega$ , $C_L = 100\text{ pF}$ ,<br>$f = 100\text{ kHz}$ , $T_{op} = 25\text{ }^\circ\text{C}$  |      | 8     |      | MHz                    |
| $F_u$                 | Unity gain frequency           | $R_L = 2\text{ k}\Omega$ , $C_L = 100\text{ pF}$ ,<br>$T_{op} = 25\text{ }^\circ\text{C}$   |      | 7.2   |      |                        |
| $\phi_m$              | Phase margin                   | $R_L = 2\text{ k}\Omega$ , $C_L = 100\text{ pF}$ ,<br>$T_{op} = 25\text{ }^\circ\text{C}$   |      | 45    |      | Degrees                |
| $G_m$                 | Gain margin                    | $R_L = 2\text{ k}\Omega$ , $C_L = 100\text{ pF}$ ,<br>$T_{op} = 25\text{ }^\circ\text{C}$   |      | 8     |      | dB                     |
| SR                    | Slew rate                      | $R_L = 2\text{ k}\Omega$ , $C_L = 100\text{ pF}$ , $A_v = 1$ ,<br>$T_{op} = 25\text{ }^\circ\text{C}$   |      | 4.5   |      | V/ $\mu\text{s}$       |
| $e_n$                 | Equivalent input noise voltage | $f = 10\text{ kHz}$ , $T_{op} = 25\text{ }^\circ\text{C}$   |      | 21    |      | nV/ $\sqrt{\text{Hz}}$ |
| THD+ $e_n$            | Total harmonic distortion      | $G = 1$ , $f = 1\text{ kHz}$ , $R_L = 2\text{ k}\Omega$ ,<br>$BW = 22\text{ kHz}$ , $T_{op} = 25\text{ }^\circ\text{C}$ ,<br>$V_{icm} = (V_{CC} + 1)/2$ , $V_{out} = 1.1\text{ V}_{pp}$ |      | 0.001 |      | %                      |

**Notes:**<sup>(1)</sup>Guaranteed by design

Table 5: Electrical characteristics at  $V_{CC+} = 3.3\text{ V}$ ,  $V_{CC-} = 0\text{ V}$ ,  $V_{icm} = V_{CC}/2$ , with  $R_L$  connected to  $V_{CC}/2$ , full temperature range (unless otherwise specified)

| Symbol                   | Parameter  | Conditions   | Min. | Typ. | Max. | Unit                           |
|--------------------------|--|--|------|------|------|--------------------------------|
| <b>DC performance</b>    |  |  |      |      |      |                                |
| $V_{io}$                 | Offset voltage, TSV91x   | $T_{op} = 25\text{ }^{\circ}\text{C}$  |      | 0.1  | 4.5  | mV                             |
|                          |  | $T_{min} < T_{op} < T_{max}$   |      |      | 7.5  |                                |
|                          | Offset voltage, TSV91xA  | $T_{op} = 25\text{ }^{\circ}\text{C}$  |      |      | 1.5  |                                |
|                          |  | $T_{min} < T_{op} < T_{max}$   |      |      | 3    |                                |
| $\Delta V_{io}/\Delta T$ | Input offset voltage drift   |  |      | 5    |      | $\mu\text{V}/^{\circ}\text{C}$ |
| $I_{io}$                 | Input offset current <sup>(1)</sup>                                  | $T_{op} = 25\text{ }^{\circ}\text{C}$  |      | 1    | 10   | pA                             |
|                          |  | $T_{min} < T_{op} < T_{max}$   |      |      | 100  |                                |
| $I_{ib}$                 | Input bias current <sup>(1)</sup>                                    | $T_{op} = 25\text{ }^{\circ}\text{C}$  |      | 1    | 10   |                                |
|                          |  | $T_{min} < T_{op} < T_{max}$   |      |      | 100  |                                |
| CMR                      | Common mode rejection ratio, $20 \log (\Delta V_{ic}/\Delta V_{io})$ | 0 V to 3.3 V, $V_{out} = 1.65\text{ V}$ ,<br>$T_{op} = 25\text{ }^{\circ}\text{C}$                                 | 60   | 78   |      | dB                             |
|                          |  | $T_{min} < T_{op} < T_{max}$   | 55   |      |      |                                |
| $A_{vd}$                 | Large signal voltage gain  | $R_L = 10\text{ k}\Omega$ , $V_{out} = 0.5\text{ V to } 2.8\text{ V}$ ,<br>$T_{op} = 25\text{ }^{\circ}\text{C}$   | 80   | 89   |      |                                |
|                          |  | $T_{min} < T_{op} < T_{max}$   | 75   |      |      |                                |
| $V_{CC} - V_{OH}$        | High-level output voltage  | $R_L = 10\text{ k}\Omega$  |      | 15   | 40   | mV                             |
|                          |  | $T_{min} < T_{op} < T_{max}$   |      |      | 40   |                                |
|                          |  | $R_L = 600\text{ }\Omega$  |      | 45   | 150  |                                |
|                          |  | $T_{min} < T_{op} < T_{max}$   |      |      | 150  |                                |
| $V_{OL}$                 | Low-level output voltage   | $R_L = 10\text{ k}\Omega$  |      | 15   | 40   |                                |
|                          |  | $T_{min} < T_{op} < T_{max}$   |      |      | 40   |                                |
|                          |  | $R_L = 600\text{ }\Omega$  |      | 45   | 150  |                                |
|                          |  | $T_{min} < T_{op} < T_{max}$   |      |      | 150  |                                |
| $I_{out}$                | $I_{sink}$   | $V_o = 3.3\text{ V}$ , $T_{op} = 25\text{ }^{\circ}\text{C}$   | 18   | 32   |      | mA                             |
|                          |  | $T_{min} < T_{op} < T_{max}$   | 16   |      |      |                                |
|                          | $I_{source}$   | $V_o = 0\text{ V}$ , $T_{op} = 25\text{ }^{\circ}\text{C}$   | 18   | 35   |      |                                |
|                          |  | $T_{min} < T_{op} < T_{max}$   | 16   |      |      |                                |
| $I_{CC}$                 | Supply current (per channel)   | No load, $V_{out} = V_{CC}/2$  |      | 0.8  | 1.1  |                                |
|                          |  | $T_{min} < T_{op} < T_{max}$   |      |      | 1.1  |                                |
| <b>AC performance</b>    |  |  |      |      |      |                                |
| GBP                      | Gain bandwidth product   | $R_L = 2\text{ k}\Omega$ , $C_L = 100\text{ pF}$ ,<br>$f = 100\text{ kHz}$ , $T_{op} = 25\text{ }^{\circ}\text{C}$ |      | 8    |      | MHz                            |
| $F_u$                    | Unity gain frequency   | $R_L = 2\text{ k}\Omega$ , $C_L = 100\text{ pF}$ ,<br>$T_{op} = 25\text{ }^{\circ}\text{C}$                        |      | 7.2  |      |                                |
| $\phi_m$                 | Phase margin   | $R_L = 2\text{ k}\Omega$ , $C_L = 100\text{ pF}$ ,<br>$T_{op} = 25\text{ }^{\circ}\text{C}$                        |      | 45   |      | Degrees                        |
| $G_m$                    | Gain margin  | $R_L = 2\text{ k}\Omega$ , $C_L = 100\text{ pF}$ ,<br>$T_{op} = 25\text{ }^{\circ}\text{C}$                        |      | 8    |      | dB                             |

| Symbol     | Parameter                      | Conditions   | Min. | Typ.   | Max. | Unit                   |
|------------|--------------------------------|--|------|--------|------|------------------------|
| SR         | Slew rate                      | $R_L = 2 \text{ k}\Omega$ , $C_L = 100 \text{ pF}$ , $A_v = 1$ ,<br>$T_{op} = 25 \text{ }^\circ\text{C}$   |      | 4.5    |      | V/ $\mu\text{s}$       |
| $e_n$      | Equivalent input noise voltage | $f = 10 \text{ kHz}$ , $T_{op} = 25 \text{ }^\circ\text{C}$  |      | 21     |      | nV/ $\sqrt{\text{Hz}}$ |
| THD+ $e_n$ | Total harmonic distortion      | $G = 1$ , $f = 1 \text{ kHz}$ , $R_L = 2 \text{ k}\Omega$ ,<br>$BW = 22 \text{ kHz}$ , $T_{op} = 25 \text{ }^\circ\text{C}$ ,<br>$V_{icm} = (V_{CC} + 1)/2$ , $V_{out} = 1.9 \text{ V}_{pp}$ |      | 0.0007 |      | %                      |

**Notes:**

<sup>(1)</sup>Guaranteed by design

Table 6: Electrical characteristics at  $V_{CC+} = 5\text{ V}$ ,  $V_{CC-} = 0\text{ V}$ ,  $V_{icm} = V_{CC}/2$ , with  $R_L$  connected to  $V_{CC}/2$ , full temperature range (unless otherwise specified)

| Symbol                   | Parameter   | Conditions   | Min. | Typ. | Max. | Unit                           |
|--------------------------|---|--|------|------|------|--------------------------------|
| <b>DC performance</b>    |   |  |      |      |      |                                |
| $V_{io}$                 | Offset voltage, TSV91x  | $T_{op} = 25\text{ }^{\circ}\text{C}$  |      | 0.1  | 4.5  | mV                             |
|                          |   | $T_{min} < T_{op} < T_{max}$   |      |      | 7.5  |                                |
|                          | Offset voltage, TSV91xA   | $T_{op} = 25\text{ }^{\circ}\text{C}$  |      |      | 1.5  |                                |
|                          |   | $T_{min} < T_{op} < T_{max}$   |      |      | 3    |                                |
| $\Delta V_{io}/\Delta T$ | Input offset voltage drift  |  |      | 5    |      | $\mu\text{V}/^{\circ}\text{C}$ |
| $I_{io}$                 | Input offset current <sup>(1)</sup>                                   | $T_{op} = 25\text{ }^{\circ}\text{C}$  |      | 1    | 10   | pA                             |
|                          |   | $T_{min} < T_{op} < T_{max}$   |      |      | 100  |                                |
| $I_{ib}$                 | Input bias current <sup>(1)</sup>                                     | $T_{op} = 25\text{ }^{\circ}\text{C}$  |      | 1    | 10   |                                |
|                          |   | $T_{min} < T_{op} < T_{max}$   |      |      | 100  |                                |
| CMR                      | Common mode rejection ratio, $20\log(\Delta V_{ic}/\Delta V_{io})$    | 0 V to 5 V, $V_{out} = 2.5\text{ V}$ ,<br>$T_{op} = 25\text{ }^{\circ}\text{C}$                                    | 62   | 82   |      | dB                             |
|                          |   | $T_{min} < T_{op} < T_{max}$   | 58   |      |      |                                |
| SVR                      | Supply voltage rejection ratio, $20\log(\Delta V_{CC}/\Delta V_{io})$ | $V_{CC} = 2.5\text{ to }5\text{ V}$  | 70   | 86   |      |                                |
| $A_{vd}$                 | Large signal voltage gain   | $R_L = 10\text{ k}\Omega$ , $V_{out} = 0.5\text{ V to }4.5\text{ V}$ ,<br>$T_{op} = 25\text{ }^{\circ}\text{C}$    | 80   | 91   |      |                                |
|                          |   | $T_{min} < T_{op} < T_{max}$   | 75   |      |      |                                |
| $V_{CC} - V_{OH}$        | High-level output voltage   | $R_L = 10\text{ k}\Omega$  |      | 15   | 40   | mV                             |
|                          |   | $T_{min} < T_{op} < T_{max}$   |      |      | 40   |                                |
|                          |   | $R_L = 600\text{ }\Omega$  |      | 45   | 150  |                                |
|                          |   | $T_{min} < T_{op} < T_{max}$   |      |      | 150  |                                |
| $V_{OL}$                 | Low-level output voltage  | $R_L = 10\text{ k}\Omega$  |      | 15   | 40   | mV                             |
|                          |   | $T_{min} < T_{op} < T_{max}$   |      |      | 40   |                                |
|                          |   | $R_L = 600\text{ }\Omega$  |      | 45   | 150  |                                |
|                          |   | $T_{min} < T_{op} < T_{max}$   |      |      | 150  |                                |
| $I_{out}$                | $I_{sink}$  | $V_o = 5\text{ V}$ , $T_{op} = 25\text{ }^{\circ}\text{C}$   | 18   | 32   |      | mA                             |
|                          |   | $T_{min} < T_{op} < T_{max}$   | 16   |      |      |                                |
|                          | $I_{source}$  | $V_o = 0\text{ V}$ , $T_{op} = 25\text{ }^{\circ}\text{C}$   | 18   | 35   |      |                                |
|                          |   | $T_{min} < T_{op} < T_{max}$   | 16   |      |      |                                |
| $I_{CC}$                 | Supply current (per channel)  | No load, $V_{out} = 2.5\text{ V}$  |      | 0.78 | 1.1  |                                |
|                          |   | $T_{min} < T_{op} < T_{max}$   |      |      | 1.1  |                                |
| <b>AC performance</b>    |   |  |      |      |      |                                |
| GBP                      | Gain bandwidth product  | $R_L = 2\text{ k}\Omega$ , $C_L = 100\text{ pF}$ ,<br>$f = 100\text{ kHz}$ , $T_{op} = 25\text{ }^{\circ}\text{C}$ |      | 8    |      | MHz                            |
| $F_u$                    | Unity gain frequency  | $R_L = 2\text{ k}\Omega$ , $C_L = 100\text{ pF}$ ,<br>$T_{op} = 25\text{ }^{\circ}\text{C}$                        |      | 7.5  |      |                                |
| $\phi_m$                 | Phase margin  | $R_L = 2\text{ k}\Omega$ , $C_L = 100\text{ pF}$ ,<br>$T_{op} = 25\text{ }^{\circ}\text{C}$                        |      | 45   |      | Degrees                        |

| Symbol     | Parameter                      | Conditions  | Min. | Typ.   | Max. | Unit                   |
|------------|--------------------------------|---|------|--------|------|------------------------|
| $G_m$      | Gain margin                    | $R_L = 2\text{ k}\Omega$ , $C_L = 100\text{ pF}$ ,<br>$T_{op} = 25\text{ }^\circ\text{C}$   |      | 8      |      | dB                     |
| SR         | Slew rate                      | $R_L = 2\text{ k}\Omega$ , $C_L = 100\text{ pF}$ , $A_v = 1$ ,<br>$T_{op} = 25\text{ }^\circ\text{C}$   |      | 4.5    |      | V/ $\mu\text{s}$       |
| $e_n$      | Equivalent input noise voltage | $f = 1\text{ kHz}$ , $T_{op} = 25\text{ }^\circ\text{C}$  |      | 27     |      | nV/ $\sqrt{\text{Hz}}$ |
|            |                                | $f = 10\text{ kHz}$ , $T_{op} = 25\text{ }^\circ\text{C}$   |      | 21     |      |                        |
| THD+ $e_n$ | Total harmonic distortion      | $G = 1$ , $f = 1\text{ kHz}$ , $R_L = 2\text{ k}\Omega$ ,<br>$BW = 22\text{ kHz}$ , $T_{op} = 25\text{ }^\circ\text{C}$ ,<br>$V_{icm} = (V_{CC} + 1)/2$ , $V_{out} = 3.6\text{ V}_{pp}$ |      | 0.0004 |      | %                      |

**Notes:**<sup>(1)</sup>Guaranteed by design

### 4 Electrical characteristic curves

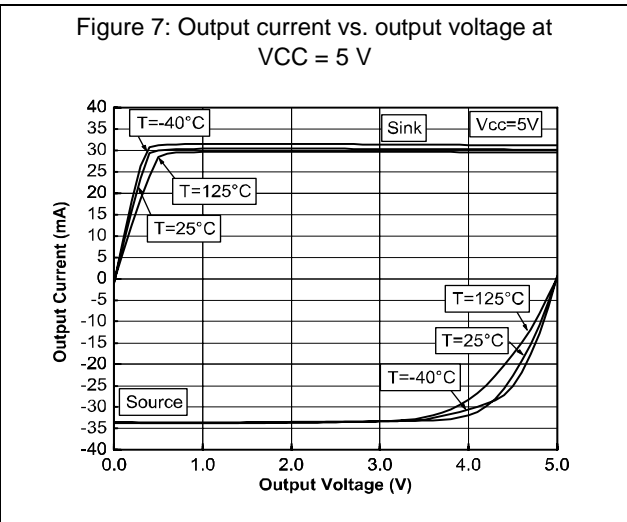
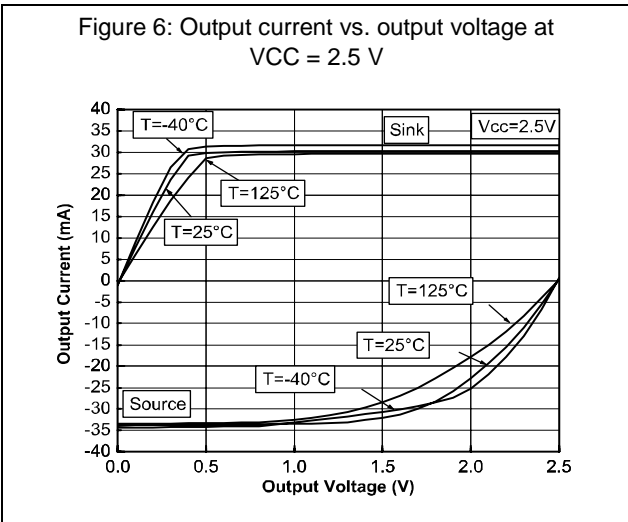
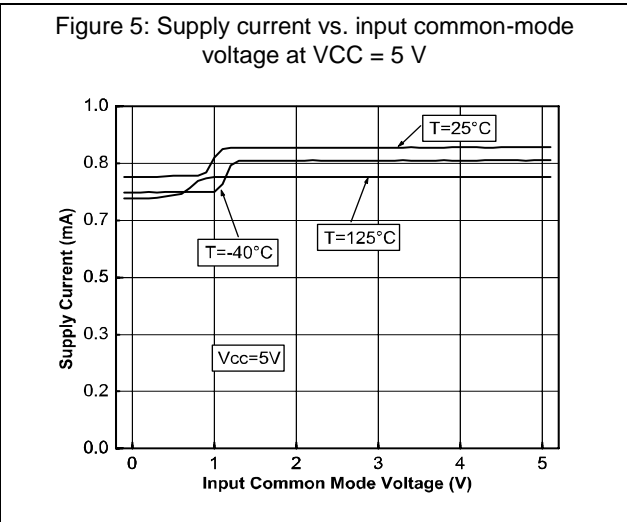
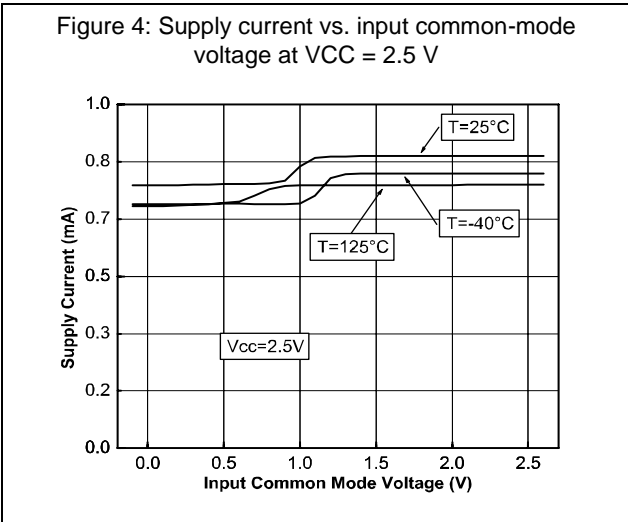
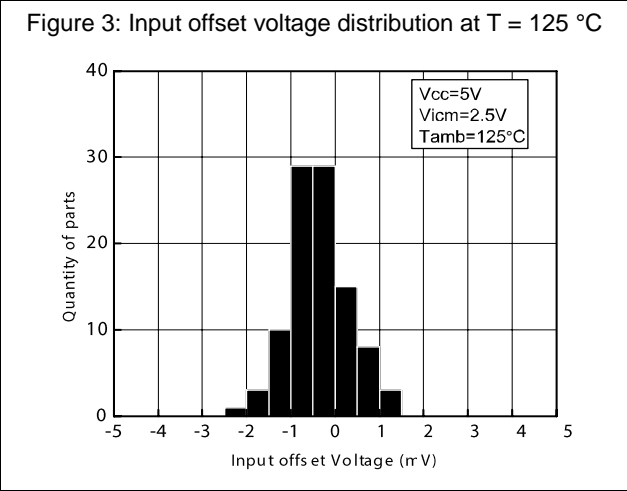
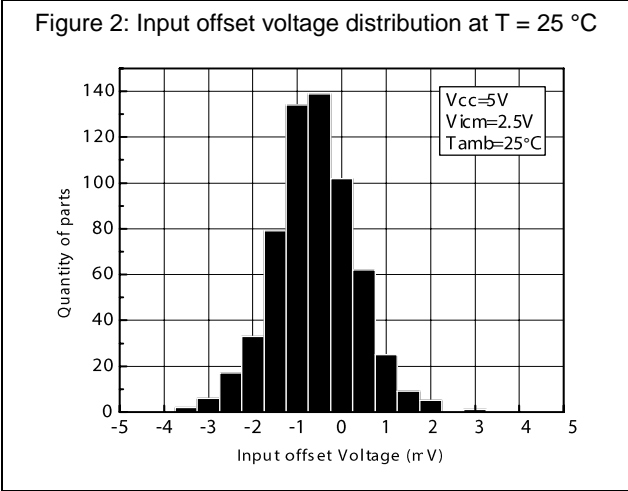


Figure 8: Voltage gain and phase vs. frequency at VCC = 2.5 V and Vicm = 0.5 V

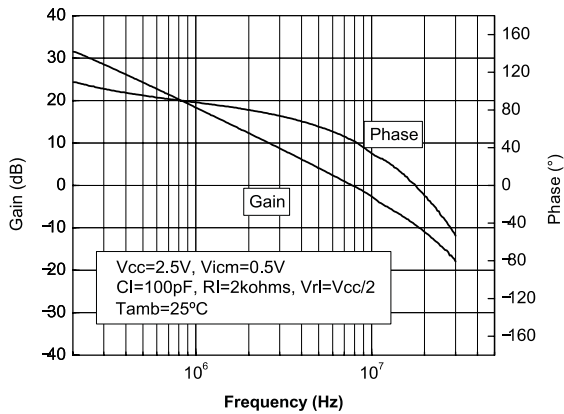


Figure 9: Voltage gain and phase vs. frequency at VCC = 5.5 V and Vicm = 0.5 V

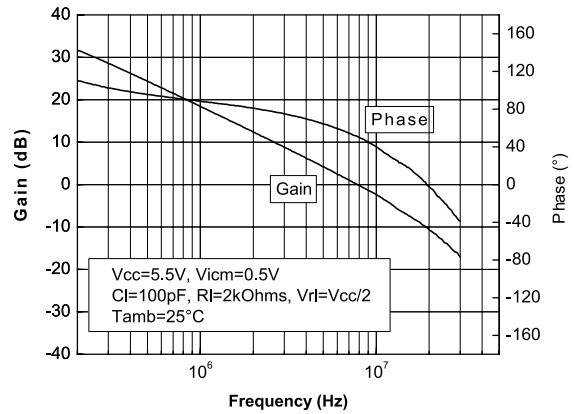


Figure 10: Phase margin vs. capacitive load

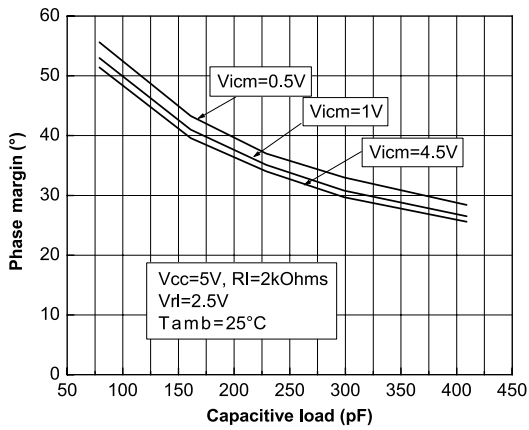


Figure 11: Phase margin vs. output current

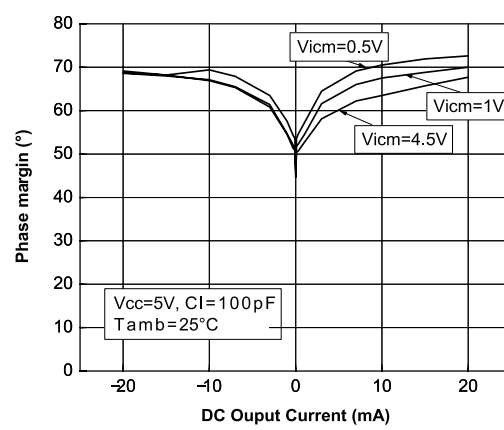


Figure 12: Positive slew rate

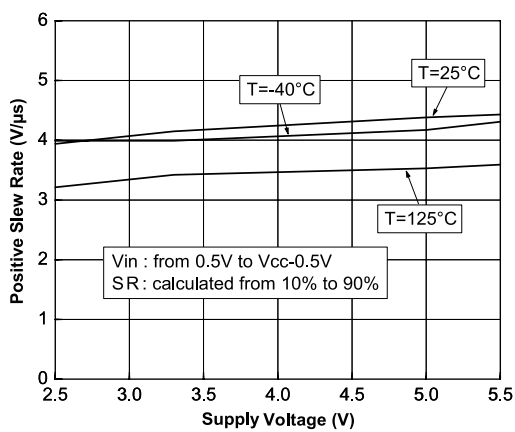
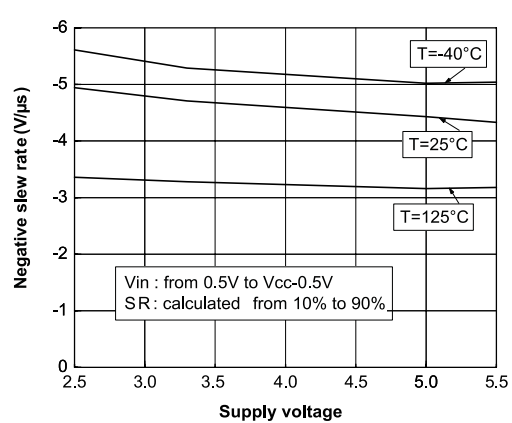
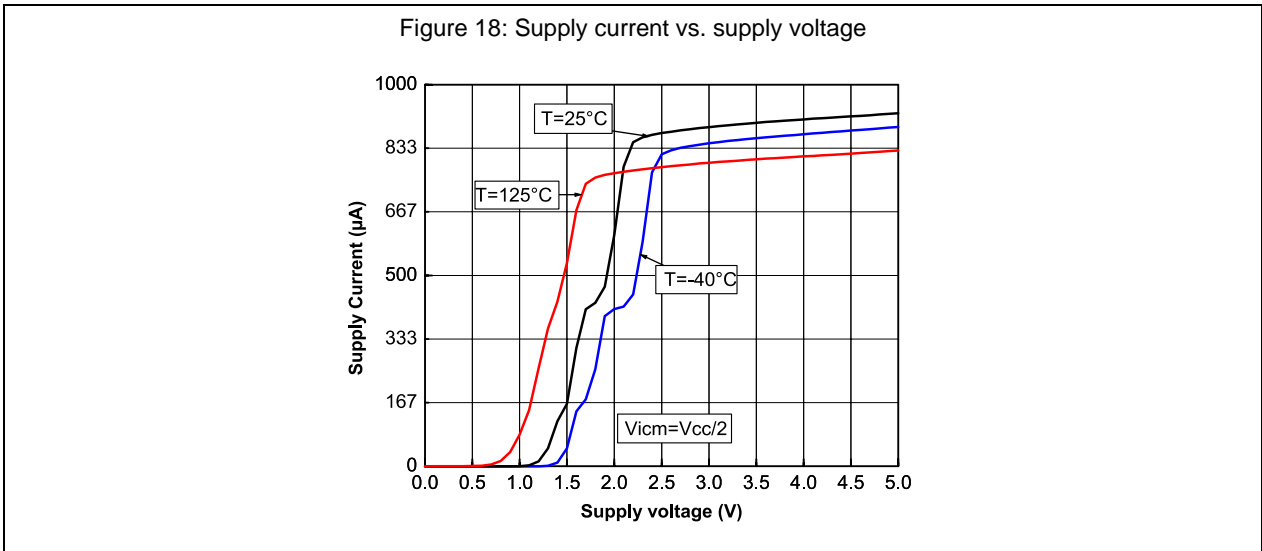
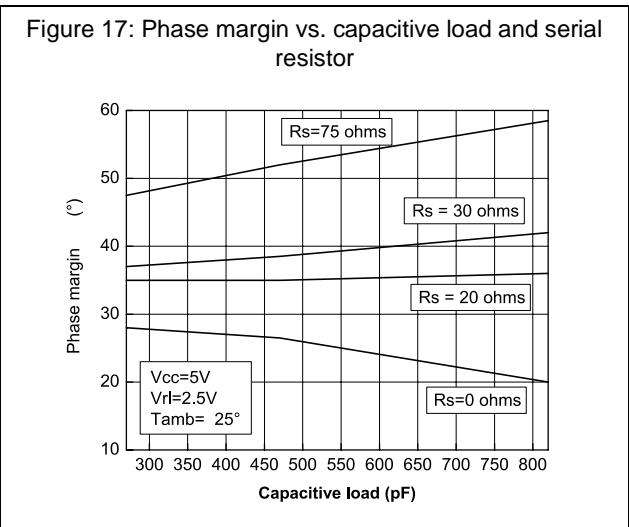
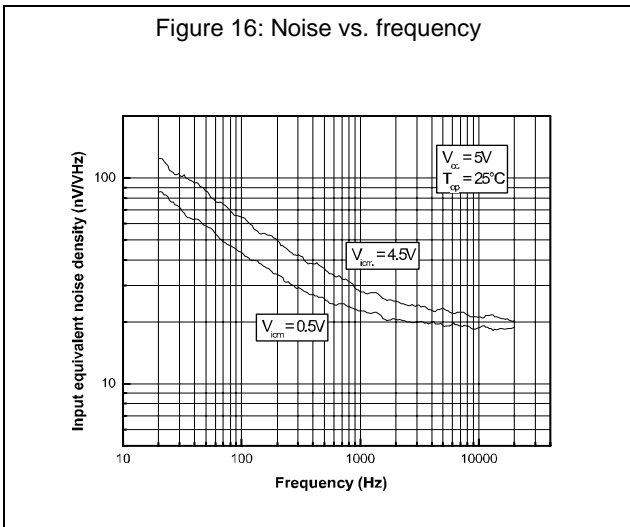
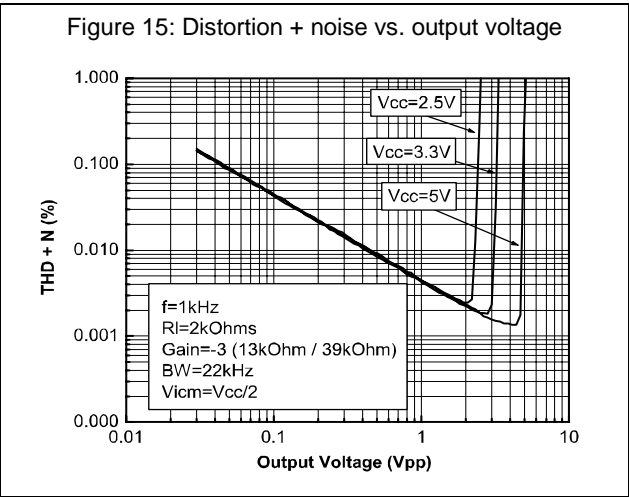
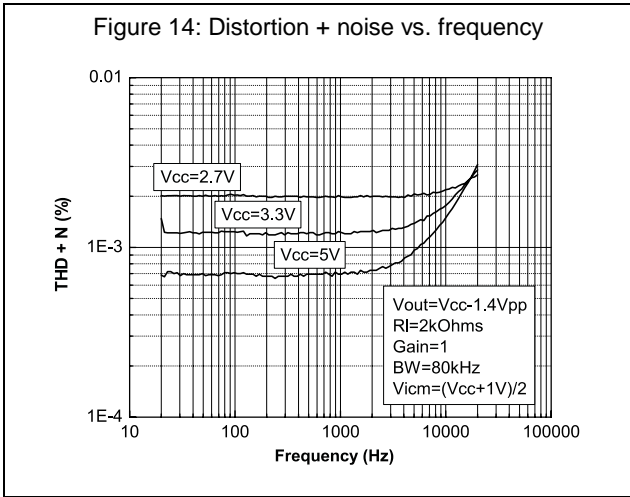


Figure 13: Negative slew rate





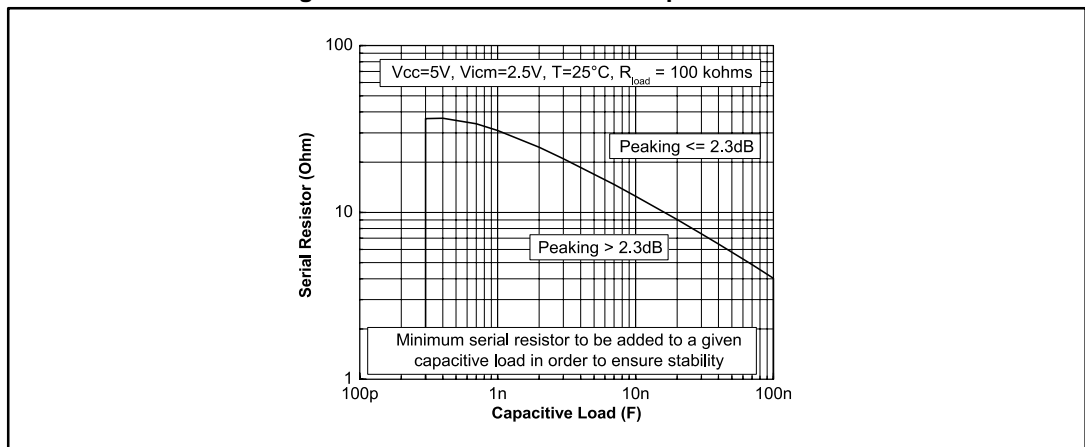
## 5 Application information

### 5.1 Driving resistive and capacitive loads

These products are low-voltage, low-power operational amplifiers optimized to drive rather large resistive loads above 2 k $\Omega$ .

In a *follower* configuration, these operational amplifiers can drive capacitive loads up to 100 pF with no oscillations. When driving larger capacitive loads, adding a small in-series resistor at the output can improve the stability of the device (*Figure 19* shows the recommended in-series resistor values). Once the in-series resistor value has been selected, the stability of the circuit should be tested on bench and simulated with the simulation model.

Figure 19: In-series resistor vs. capacitive load



### 5.2 PCB layouts

For correct operation, it is advised to add 10 nF decoupling capacitors as close as possible to the power supply pins.

### 5.3 Macromodel

An accurate macromodel of the TSV91x is available on STMicroelectronics' web site at: [www.st.com](http://www.st.com). This model is a trade-off between accuracy and complexity (that is, time simulation) of the TSV91x operational amplifiers. It emulates the nominal performances of a typical device within the specified operating conditions mentioned in the datasheet. It helps to validate a design approach and to select the right operational amplifier, *but it does not* replace on-board measurements.

## 6 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.

## 6.1 SOT23-5 package information

Figure 20: SOT23-5 package outline

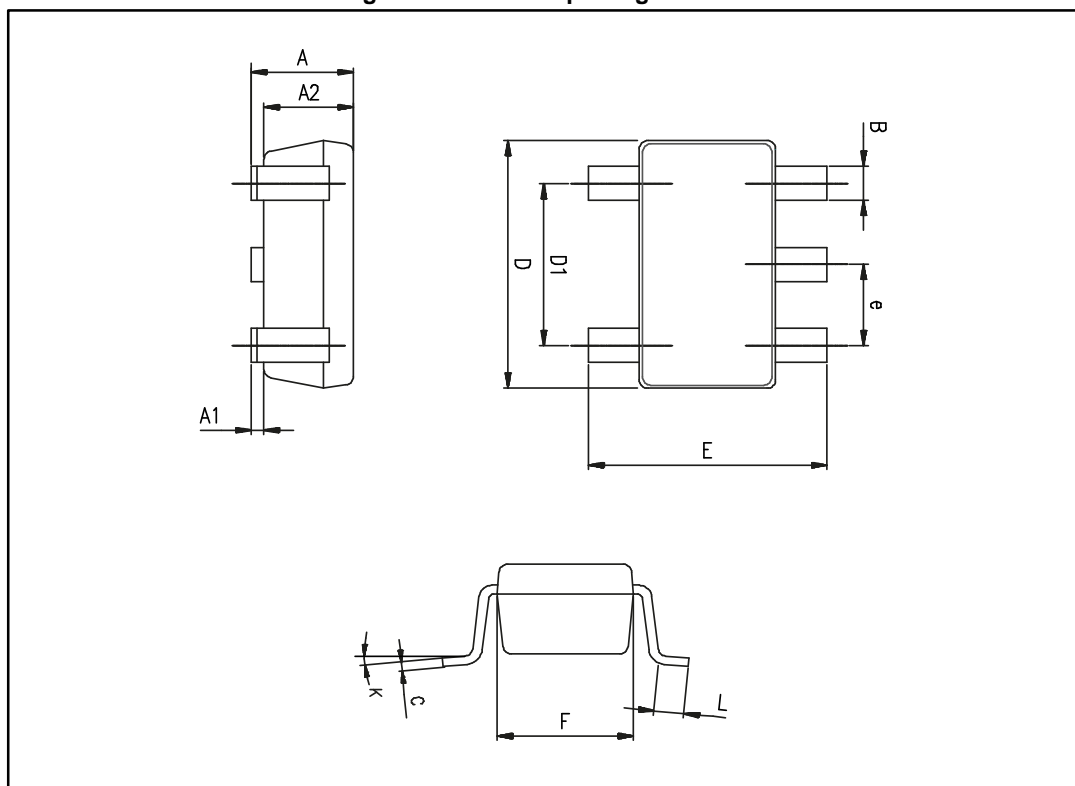


Table 7: SOT23-5 mechanical data

| 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 |

## 6.2 DFN8 2 x 2 package information

Figure 21: DFN8 2 x 2 package outline

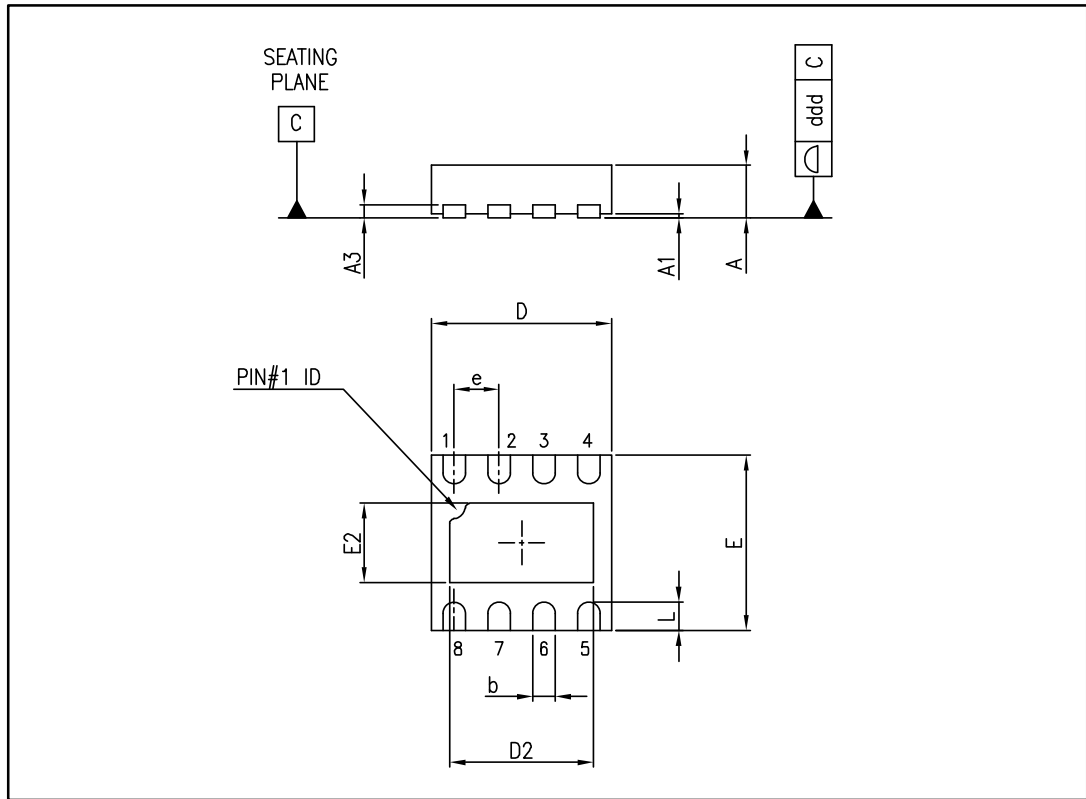
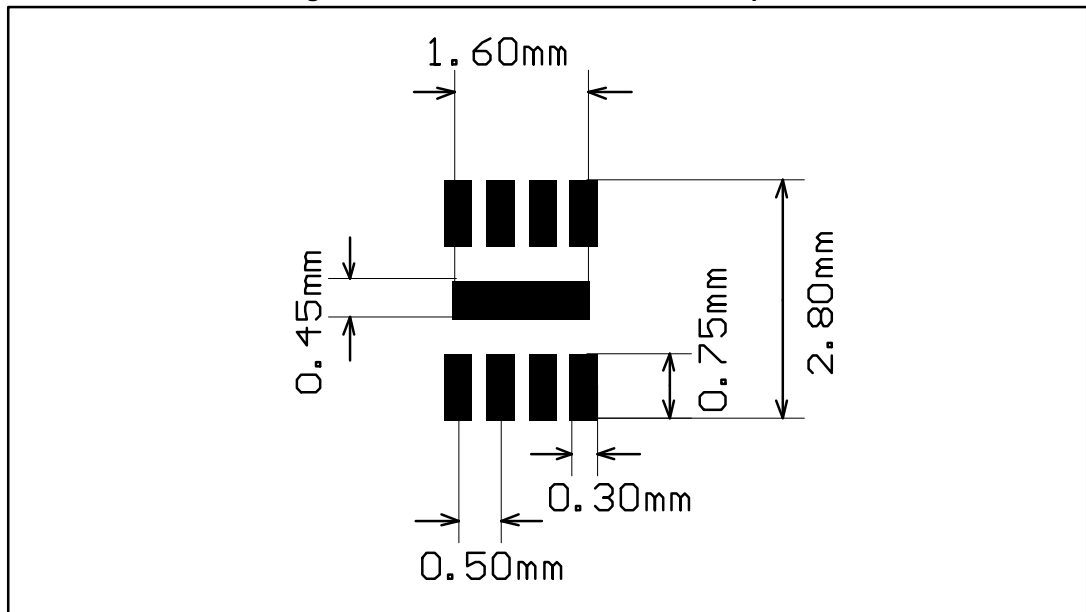


Table 8: DFN8 2 x 2 mechanical data

| Ref. | Dimensions  |      |       |        |       |       |
|------|-------------|------|-------|--------|-------|-------|
|      | Millimeters |      |       | Inches |       |       |
|      | Min.        | Typ. | Max.  | Min.   | Typ.  | Max.  |
| A    | 0.51        | 0.55 | 0.60  | 0.020  | 0.022 | 0.024 |
| A1   |             |      | 0.05  |        |       | 0.002 |
| A3   |             | 0.15 |       |        | 0.006 |       |
| b    | 0.18        | 0.25 | 0.30  | 0.007  | 0.010 | 0.012 |
| D    | 1.85        | 2.00 | 2.15  | 0.073  | 0.079 | 0.085 |
| D2   | 1.45        | 1.60 | 1.70  | 0.057  | 0.063 | 0.067 |
| E    | 1.85        | 2.00 | 2.15  | 0.073  | 0.079 | 0.085 |
| E2   | 0.75        | 0.90 | 1.00  | 0.030  | 0.035 | 0.039 |
| e    |             | 0.50 |       |        | 0.020 |       |
| L    |             |      | 0.425 |        |       | 0.017 |
| ddd  |             |      | 0.08  |        |       | 0.003 |

Figure 22: DFN8 2 x 2 recommended footprint



The exposed pad of the DFN8 2x2 package is not internally connected. It can be set to ground or left floating.

### 6.3 MiniSO8 package information

Figure 23: MiniSO8 package outline

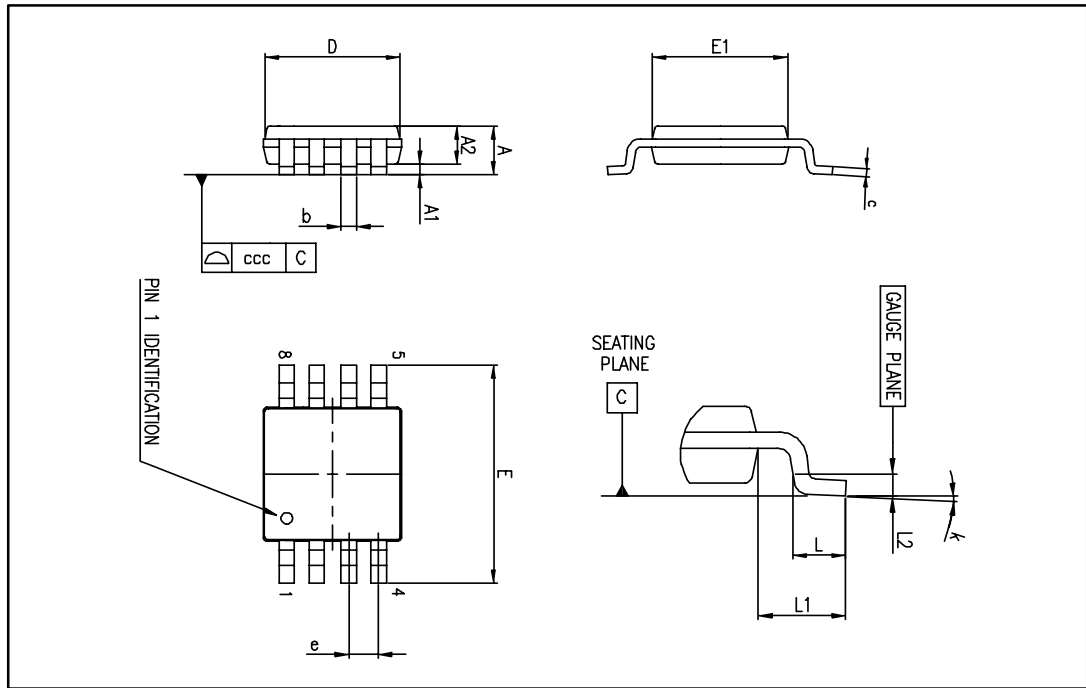


Table 9: MiniSO8 mechanical data

| Ref. | Dimensions  |      |      |        |       |       |
|------|-------------|------|------|--------|-------|-------|
|      | Millimeters |      |      | Inches |       |       |
|      | Min.        | Typ. | Max. | Min.   | Typ.  | Max.  |
| A    |             |      | 1.1  |        |       | 0.043 |
| A1   | 0           |      | 0.15 | 0      |       | 0.006 |
| A2   | 0.75        | 0.85 | 0.95 | 0.030  | 0.033 | 0.037 |
| b    | 0.22        |      | 0.40 | 0.009  |       | 0.016 |
| c    | 0.08        |      | 0.23 | 0.003  |       | 0.009 |
| D    | 2.80        | 3.00 | 3.20 | 0.11   | 0.118 | 0.126 |
| E    | 4.65        | 4.90 | 5.15 | 0.183  | 0.193 | 0.203 |
| E1   | 2.80        | 3.00 | 3.10 | 0.11   | 0.118 | 0.122 |
| e    |             | 0.65 |      |        | 0.026 |       |
| L    | 0.40        | 0.60 | 0.80 | 0.016  | 0.024 | 0.031 |
| L1   |             | 0.95 |      |        | 0.037 |       |
| L2   |             | 0.25 |      |        | 0.010 |       |
| k    | 0°          |      | 8°   | 0°     |       | 8°    |
| ccc  |             |      | 0.10 |        |       | 0.004 |

### 6.4 SO8 package information

Figure 24: SO8 package outline

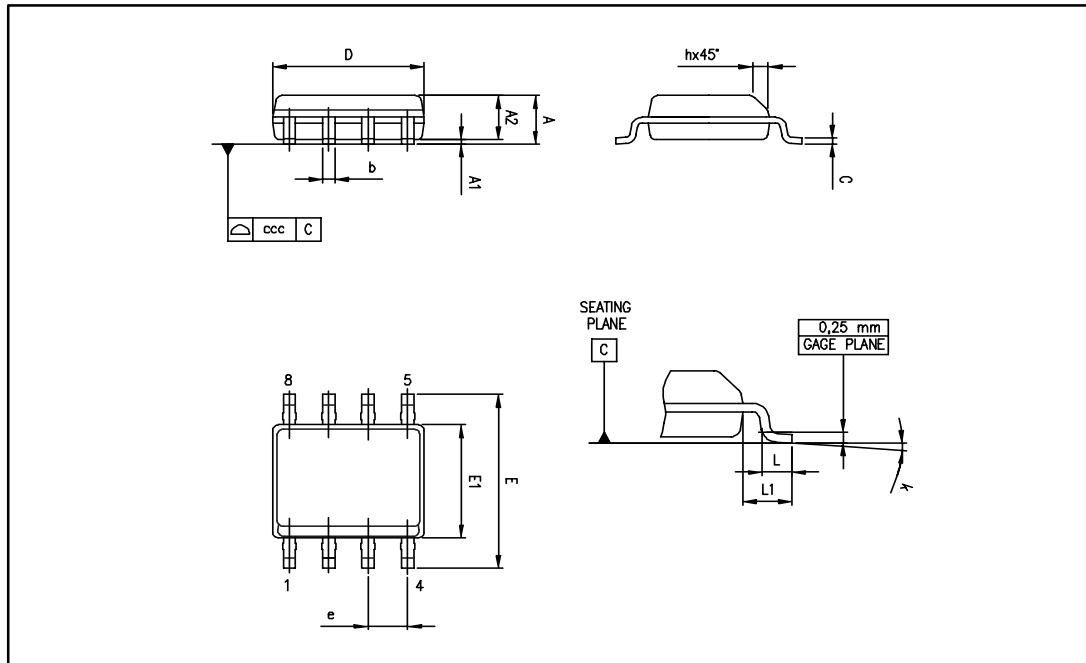


Table 10: SO8 mechanical data

| 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 |

## 6.5 TSSOP14 package information

Figure 25: TSSOP14 package outline

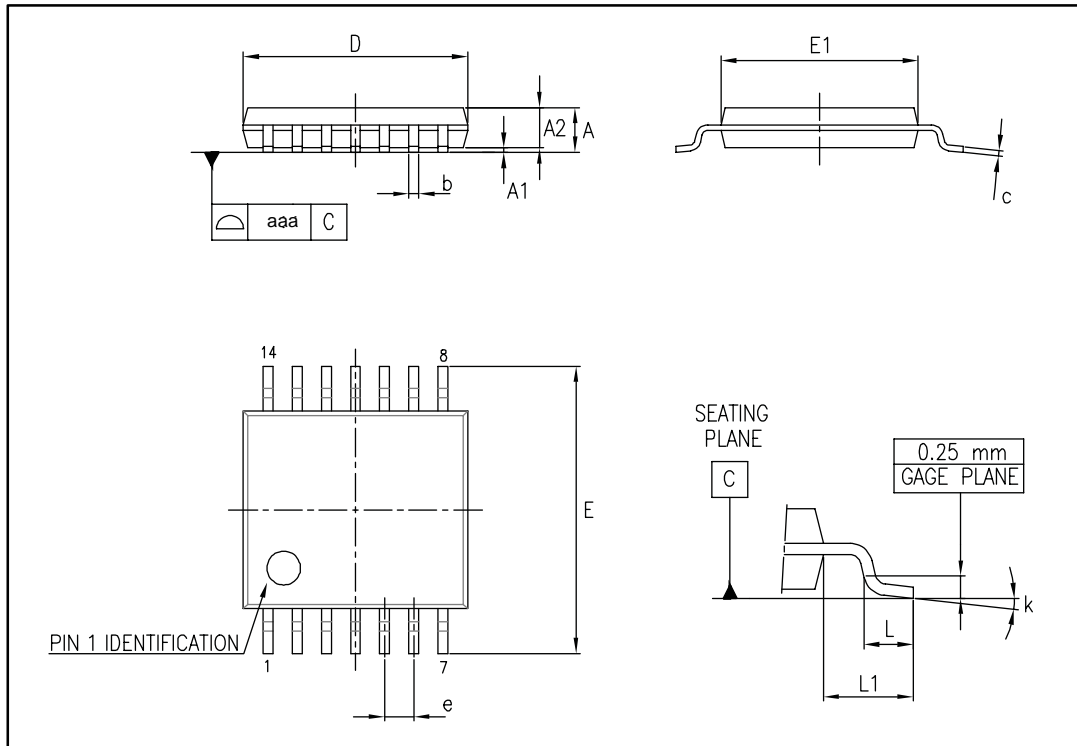


Table 11: TSSOP14 mechanical data

| 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  |

### 6.6 SO14 package information

Figure 26: SO14 package outline

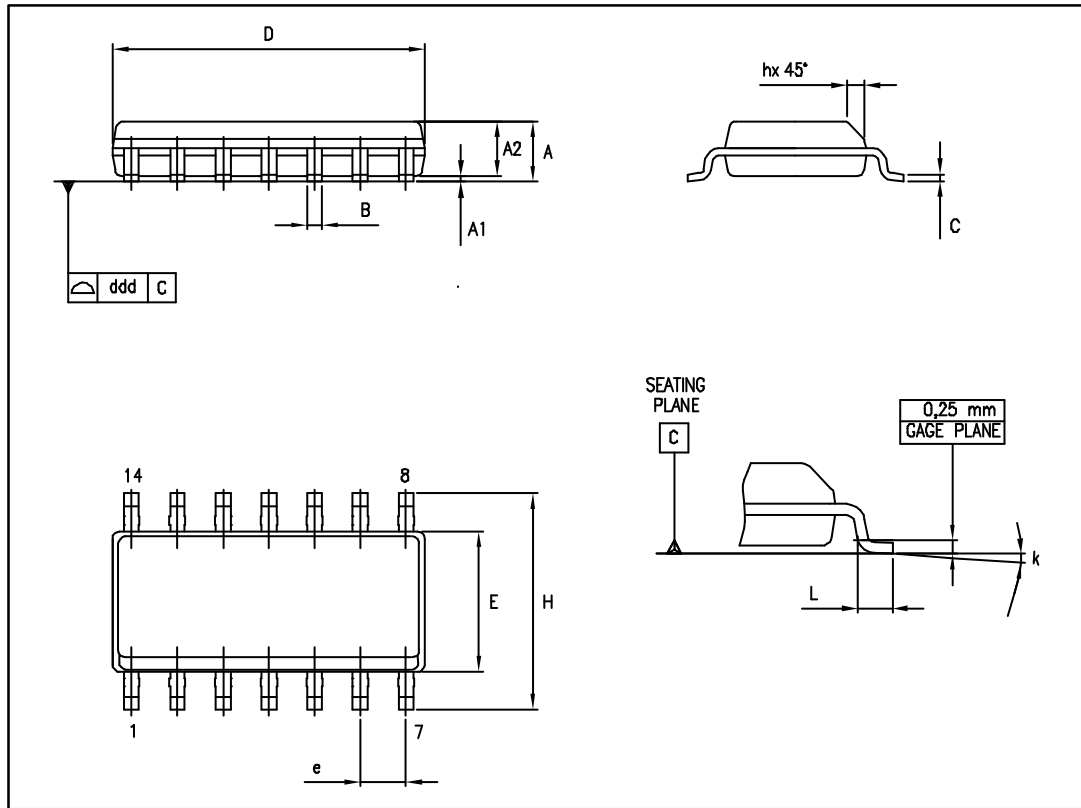


Table 12: SO14 mechanical data

| 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 |

## 7 Ordering information

Table 13: Order codes

| Order code                 | Temperature range | Package                      | Packing               | Marking |
|----------------------------|-------------------|------------------------------|-----------------------|---------|
| TSV911IDT                  | -40 °C to 125 °C  | SO8                          | Tube or tape and reel | V911I   |
| TSV911AIDT                 |                   |                              |                       | V911AI  |
| TSV911ILT                  |                   | SOT23-5                      | Tape and reel         | K127    |
| TSV911AILT                 |                   |                              |                       | K128    |
| TSV911RILT                 |                   |                              |                       | K125    |
| TSV912IST                  |                   | MiniSO8                      |                       | K125    |
| TSV912AIST                 |                   |                              |                       | K126    |
| TSV912IDT                  |                   | SO8                          | Tube or tape and reel | V912I   |
| TSV912AIDT                 |                   |                              |                       | V912AI  |
| TSV912IQ2T                 |                   | DFN8 2x2                     | Tape and reel         | K1Q     |
| TSV914IPT                  |                   | TSSOP14                      |                       | V914I   |
| TSV914AIPT                 |                   |                              | V914AI                |         |
| TSV914IDT                  |                   | SO14                         | Tube or tape and reel | V914I   |
| TSV914AIDT                 |                   |                              |                       | V914AI  |
| TSV911IYLT <sup>(1)</sup>  |                   | SOT23-5,<br>automotive grade |                       | K147    |
| TSV911AIYLT <sup>(1)</sup> |                   |                              |                       | K148    |
| TSV911IYDT <sup>(1)</sup>  |                   | SO-8,<br>automotive grade    | Tape and reel         | V911IY  |
| TSV911AIYDT <sup>(1)</sup> |                   |                              |                       | V911AIY |
| TSV912IYDT <sup>(1)</sup>  |                   |                              |                       | V912IY  |
| TSV912AIYDT <sup>(1)</sup> |                   | MiniSO8,<br>automotive grade |                       | V912AY  |
| TSV912IYST <sup>(1)</sup>  |                   |                              |                       | K147    |
| TSV912AIYST <sup>(1)</sup> |                   | K148                         |                       |         |
| TSV914IYDT <sup>(1)</sup>  |                   | SO14,<br>automotive grade    |                       | V914IY  |
| TSV914AIYDT <sup>(1)</sup> |                   |                              |                       | V914AY  |
| TSV914IYPT <sup>(1)</sup>  |                   | TSSOP14,<br>automotive grade |                       | V914IY  |
| TSV914AIYPT <sup>(1)</sup> |                   |                              |                       | V914AY  |

**Notes:**

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

## 8 Revision history

**Table 14: Document revision history**

| Date        | Revision | Changes   |
|-------------|----------|---|
| 28-Aug-2006 | 1        | First release.  |
| 07-Jun-2007 | 2        | Modified ESD CDM parameter for SO-14 package in Table 2: Absolute maximum ratings.<br>Noise parameters updated in Section 2: Electrical characteristics.<br>Added limits in temperature in Section 2: Electrical characteristics.<br>Added automotive grade level description in Table 13: Order codes.<br>Added footnote about SO-14 package in Table 13: Order codes.<br>Added Figure 16: Phase margin vs. capacitive load and serial resistor. |
| 11-Feb-2008 | 3        | Updated footnotes for ESD parameters in Table 2: Absolute maximum ratings.<br>Corrected MiniSO-8 package information in Table 9: MiniSO-8 package mechanical data.<br>Added missing markings for order codes TSV911AILT and TSV912AILT in Table 13: Order codes.  |
| 22-Jun-2009 | 4        | Added input current information in Table 2: Absolute maximum ratings.<br>Changed Figure 7 and Figure 8.<br>Added Chapter 3: Application information.<br>Updated package information in Chapter 4.<br>Added automotive order codes: TSV911IYLT, TSV911AIYLT, TSV912IYST, TSV912AIYST, TSV914IYPT and TSV914AIYPT in Table 13: Order codes.   |
| 17-Sep-2009 | 5        | Added A versions of devices in title on cover page.<br>Modified ESD value for machine model in Table 2: Absolute maximum ratings.<br>Added Figure 17: Supply current vs. supply voltage on page 10.   |
| 18-Mar-2010 | 6        | Added TSV911RILT in Table 13: Order codes, housed in a SOT23-5 package with a new pinout.   |
| 24-Jun-2010 | 7        | Added pin connections for TSV911ILT and TSV91RILT on cover page.<br>Added Table 1: Device summary on cover page.<br>Modified supply voltage value in Table 3.<br>Corrected typical value of $DV_{io}$ in Table 4, Table 5 and Table 6.<br>Added TSV911RILT, TSV911IYDT and TSV911AIYDT order codes in Table 13.<br>Modified Note 2 under Table 13.  |
| 06-Mar-2012 | 8        | Added DFN8 2x2 package and ordering information for TSV912 device to Chapter 4 and Chapter 5.   |
| 27-Nov-2015 | 9        | Updated layout<br>Section 2: replaced $DV_{io}/DT$ by $\Delta V_{io}/\Delta T$ .<br>Section 5.2: updated name of package and title of drawings and table; added note about exposed pad.<br>Table 13: "Order codes": removed obsolete order codes (TSV911ID, TSV911AID, TSV912ID, TSV912AID, TSV914ID, TSV914AID).   |

## Revision history

TSV91x, TSV91xA

| Date        | Revision | Changes  |
|-------------|----------|--|
| 29-Aug-2016 | 10       | Added silhouettes of packages to cover page<br>Placed pinout diagrams in <i>Section 2: "Package pin connections"</i><br>Added <i>Related products</i><br><i>Description</i> : added footnote 1<br><i>Section 7.2: "DFN8 2 x 2 package information"</i> : modified note about the exposed pad.<br><i>Section 8: "Ordering information"</i> : removed note regarding "moisture sensitivity level 1". |

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