

## Low-power, high-accuracy, general-purpose operational amplifier

Datasheet - production data



### Related products

- See LMV82x series for higher gain bandwidth product (5.5 MHz)

### Applications

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

### Description

The TSV85x, TSV85xA series of single, dual, and quad operational amplifiers offer low voltage operation with a rail-to-rail output swing. The TSV85x, TSV85xA series outperforms the industry standard LMV321, proposing lower supply voltage capability, enhanced input offset voltage, and smaller packages.

The devices are offered with either industry standard pinouts or with a power-saving shutdown feature that reduces the supply current to a maximum of 50 nA at 25 °C.

The wide temperature range, high ESD tolerance, and automotive grade qualification ease the use in harsh automotive applications.

### Features

- Low power consumption: 180  $\mu$ A max at 5 V
- Low power shutdown mode: 50 nA max
- Low offset voltage: 0.8 mV max at 25 °C
- Tiny packages
- Extended temperature range: -40 °C to 125 °C
- Low supply voltage: 2.3 V - 5.5 V
- Gain bandwidth product: 1.3 MHz
- Automotive qualification

### Benefits

- Longer lifetime in battery-powered applications
- Higher accuracy without calibration
- Smaller form factor than equivalent competitor devices
- Application performances guaranteed over wide temperature ranges

**Table 1. Device summary**

|        | Without shutdown feature |              | With shutdown feature |              |
|--------|--------------------------|--------------|-----------------------|--------------|
|        | Standard Vio             | Enhanced Vio | Standard Vio          | Enhanced Vio |
| Single | TSV851                   | TSV851A      | TSV850                | TSV850A      |
| Dual   | TSV852                   | TSV852A      | TSV853                | TSV853A      |
| Quad   | TSV854                   | TSV854A      | TSV855                | TSV855A      |

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# 1 Package pin connections

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



1. The exposed pads of the DFN8 2x2 and QFN16 3x3 can be connected to VCC- or left floating.

## 2 Absolute maximum ratings and operating conditions

**Table 2. Absolute maximum ratings (AMR)**

| Symbol            | Parameter  | Value                              | Unit |
|-------------------|--|------------------------------------|------|
| $V_{CC}$          | Supply voltage <sup>(1)</sup>                              | 6                                  | V    |
| $V_{id}$          | Differential input voltage <sup>(2)</sup>                  | $\pm V_{CC}$                       |      |
| $V_{in}$          | Input pins (IN+ and IN- pins) voltage <sup>(3)</sup>       | $V_{CC-} - 0.3$ to $V_{CC+} + 0.3$ |      |
| $I_{in}$          | Input current <sup>(4)</sup>                               | 10                                 | mA   |
| $\overline{SHDN}$ | Shutdown voltage <sup>(5)</sup>                            | $V_{CC-} - 0.2$ to $V_{CC+} + 0.2$ | V    |
| $T_{stg}$         | Storage temperature  | -65 to +150                        | °C   |
| $R_{thja}$        | Thermal resistance junction to ambient <sup>(6)(7)</sup>   |                                    | °C/W |
|                   | SC70-5   | 205                                |      |
|                   | SOT23-5  | 250                                |      |
|                   | SOT23-6  | 240                                |      |
|                   | DFN8 2x2   | 57                                 |      |
|                   | SO8  | 125                                |      |
|                   | MiniSO8  | 190                                |      |
|                   | MiniSO10   | 113                                |      |
|                   | SO14   | 105                                |      |
|                   | TSSOP14  | 100                                |      |
|                   | TSSOP16  | 95                                 |      |
| QFN16 3x3         | 45   |                                    |      |
| $T_j$             | Maximum junction temperature                               | 150                                | °C   |
| ESD               | HBM: human body model (except shutdown pin) <sup>(8)</sup> | 4                                  | kV   |
|                   | HBM: human body model (shutdown pin) <sup>(8)</sup>        | 3.5                                |      |
|                   | MM: machine model <sup>(9)</sup>                           | 250                                | V    |
|                   | CDM: charged device model <sup>(10)</sup>                  | 1.3                                | kV   |
|                   | CDM: charged device model TSV855 <sup>(10)</sup>           | 1                                  |      |
|                   | Latch-up immunity  | 200                                | mA   |

1. All voltage values, except differential voltage, are with respect to network ground terminal.
2. The differential voltage is the non-inverting input terminal with respect to the inverting input terminal.
3.  $V_{CC-} - V_{in}$  must not exceed 6 V,  $V_{in}$  must not exceed 6 V.
4. Input current must be limited by a resistor in series with the inputs.
5.  $V_{CC-} - V_{shdn}$  must not exceed 6 V,  $V_{in}$  must not exceed 6 V.
6. Short-circuits can cause excessive heating and destructive dissipation.
7.  $R_{th}$  are typical values.
8. 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.
9. Machine model: a 200 pF cap is 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.
10. Charged device model: all pins plus package are charged together to the specified voltage and then discharged directly to the ground.

Table 3. Operating conditions

| Symbol     | Parameter                            | Value                            | Unit |
|------------|--------------------------------------|----------------------------------|------|
| $V_{CC}$   | Supply voltage                       | 2.3 to 5.5                       | V    |
| $V_{icm}$  | Common mode input voltage range      | $V_{CC-} - 0.2$ to $V_{CC+} - 1$ |      |
| $T_{oper}$ | Operating free air temperature range | -40 to +125                      | °C   |

### 3 Electrical characteristics

Table 4. Electrical characteristics at  $V_{CC+} = 2.7\text{ V}$  with  $V_{CC-} = 0\text{ V}$ ,  $V_{icm} = V_{CC}/2$ ,  $T_{amb} = 25\text{ }^{\circ}\text{C}$ , and  $R_L$  connected to  $V_{CC}/2$  (unless otherwise specified)

| Symbol                   | Parameter   | Conditions  | Min. | Typ. | Max. | Unit                           |
|--------------------------|---|---|------|------|------|--------------------------------|
| <b>DC performance</b>    |   |   |      |      |      |                                |
| $V_{io}$                 | Input offset voltage  | TSV85xA, $T = 25\text{ }^{\circ}\text{C}$   |      |      | 0.8  | mV                             |
|                          |   | TSV85x, $T = 25\text{ }^{\circ}\text{C}$  |      |      | 4    |                                |
|                          |   | TSV85xA, $-40\text{ }^{\circ}\text{C} < T < 125\text{ }^{\circ}\text{C}$                    |      |      | 2    |                                |
|                          |   | TSV85x, $-40\text{ }^{\circ}\text{C} < T < 125\text{ }^{\circ}\text{C}$                     |      |      | 6    |                                |
| $\Delta V_{io}/\Delta T$ | Input offset voltage drift <sup>(1)</sup>   | $-40\text{ }^{\circ}\text{C} < T < 125\text{ }^{\circ}\text{C}$                             |      | 1    |      | $\mu\text{V}/^{\circ}\text{C}$ |
| $I_{io}$                 | Input offset current ( $V_{out} = V_{CC}/2$ )   | $T = 25\text{ }^{\circ}\text{C}$  |      | 0.5  | 30   | nA                             |
|                          |   | $-40\text{ }^{\circ}\text{C} < T < 125\text{ }^{\circ}\text{C}$                             |      | 1    | 50   |                                |
| $I_{ib}$                 | Input bias current ( $V_{out} = V_{CC}/2$ )   | $T = 25\text{ }^{\circ}\text{C}$  |      | 27   | 60   | nA                             |
|                          |   | $-40\text{ }^{\circ}\text{C} < T < 125\text{ }^{\circ}\text{C}$                             |      |      | 110  |                                |
| CMR                      | Common mode rejection ratio<br>$20 \log (\Delta V_{icm}/\Delta V_{io})$<br>( $V_{ic} = 0\text{ V}$ to $V_{CC}-1\text{V}$ , $V_{out} = V_{CC}/2$ ) | $T = 25\text{ }^{\circ}\text{C}$  | 70   | 75   |      | dB                             |
|                          |   | $-40\text{ }^{\circ}\text{C} < T < 125\text{ }^{\circ}\text{C}$                             | 68   |      |      |                                |
| $A_{vd}$                 | Large signal voltage gain<br>( $V_{out} = 0.5\text{V}$ to $(V_{CC}-0.5\text{V})$ )  | $R_L = 10\text{ k}\Omega$ , $T = 25\text{ }^{\circ}\text{C}$                                | 100  | 110  |      | dB                             |
|                          |   | $R_L = 10\text{ k}\Omega$ , $-40\text{ }^{\circ}\text{C} < T < 125\text{ }^{\circ}\text{C}$ | 90   |      |      |                                |
|                          |   | $R_L = 2\text{ k}\Omega$ , $T = 25\text{ }^{\circ}\text{C}$                                 | 90   | 100  |      |                                |
|                          |   | $R_L = 2\text{ k}\Omega$ , $-40\text{ }^{\circ}\text{C} < T < 125\text{ }^{\circ}\text{C}$  | 80   |      |      |                                |
| $V_{CC}-V_{OH}$          | High level output voltage   | $R_L = 10\text{ k}\Omega$ , $T = 25\text{ }^{\circ}\text{C}$                                |      | 10   | 100  | mV                             |
|                          |   | $R_L = 10\text{ k}\Omega$ , $-40\text{ }^{\circ}\text{C} < T < 125\text{ }^{\circ}\text{C}$ |      |      | 200  |                                |
|                          |   | $R_L = 2\text{ k}\Omega$ , $T = 25\text{ }^{\circ}\text{C}$                                 |      | 40   | 300  |                                |
|                          |   | $R_L = 2\text{ k}\Omega$ , $-40\text{ }^{\circ}\text{C} < T < 125\text{ }^{\circ}\text{C}$  |      |      | 400  |                                |
| $V_{OL}$                 | Low level output voltage  | $R_L = 10\text{ k}\Omega$ , $T = 25\text{ }^{\circ}\text{C}$                                |      | 65   | 180  | mV                             |
|                          |   | $R_L = 10\text{ k}\Omega$ , $-40\text{ }^{\circ}\text{C} < T < 125\text{ }^{\circ}\text{C}$ |      |      | 280  |                                |
|                          |   | $R_L = 2\text{ k}\Omega$ , $T = 25\text{ }^{\circ}\text{C}$                                 |      | 120  | 300  |                                |
|                          |   | $R_L = 2\text{ k}\Omega$ , $-40\text{ }^{\circ}\text{C} < T < 125\text{ }^{\circ}\text{C}$  |      |      | 400  |                                |
| $I_{out}$                | $I_{sink}$ ( $V_{out} = V_{CC}$ )<br>$V_{id} = -1\text{ V}$   | $T = 25\text{ }^{\circ}\text{C}$  | 15   | 26   |      | mA                             |
|                          |   | $-40\text{ }^{\circ}\text{C} < T < 125\text{ }^{\circ}\text{C}$                             | 15   |      |      |                                |
|                          | $I_{source}$ ( $V_{out} = 0\text{ V}$ )<br>$V_{id} = 1\text{ V}$  | $T = 25\text{ }^{\circ}\text{C}$  | 15   | 21   |      |                                |
|                          |   | $-40\text{ }^{\circ}\text{C} < T < 125\text{ }^{\circ}\text{C}$                             | 12   |      |      |                                |
| $I_{CC}$                 | Supply current (per channel)<br>No load, $V_{out} = V_{CC}/2$   | $T = 25\text{ }^{\circ}\text{C}$  |      | 120  | 180  | $\mu\text{A}$                  |
|                          |   | $-40\text{ }^{\circ}\text{C} < T < 125\text{ }^{\circ}\text{C}$                             |      |      | 180  |                                |

**Table 4. Electrical characteristics at  $V_{CC+} = 2.7\text{ V}$  with  $V_{CC-} = 0\text{ V}$ ,  $V_{icm} = V_{CC}/2$ ,  $T_{amb} = 25\text{ °C}$ , and  $R_L$  connected to  $V_{CC}/2$  (unless otherwise specified) (continued)**

| Symbol                | Parameter                         | Conditions  | Min. | Typ.     | Max. | Unit                                 |
|-----------------------|-----------------------------------|---|------|----------|------|--------------------------------------|
| <b>AC performance</b> |                                   |   |      |          |      |                                      |
| GBP                   | Gain bandwidth product            | $R_L > 1\text{ M}\Omega$ , $C_L = 200\text{ pF}$  |      | 1.3      |      | MHz                                  |
| $F_u$                 | Unity gain frequency              |   |      | 1        |      |                                      |
| $\Phi_m$              | Phase margin                      |   |      | 60       |      | degrees                              |
| $G_m$                 | Gain margin                       |   |      | 10       |      | dB                                   |
| SR                    | Slew rate                         | $R_L > 1\text{ M}\Omega$ , $C_L = 200\text{ pF}$<br>$V_{out} = 0.5\text{ V}$ to $V_{CC} - 0.5\text{ V}$   |      | 0.6      |      | V/ $\mu\text{s}$                     |
| $e_n$                 | Equivalent input noise voltage    | $f = 1\text{ kHz}$<br>$f = 10\text{ kHz}$   |      | 31<br>20 |      | $\frac{\text{nV}}{\sqrt{\text{Hz}}}$ |
| $i_n$                 | Equivalent input noise current    | $f = 1\text{ kHz}$  |      | 0.30     |      | $\frac{\text{pA}}{\sqrt{\text{Hz}}}$ |
| THD+N                 | Total harmonic distortion + noise | $f_{in} = 1\text{ kHz}$ , $A_{CL} = 1$ ,<br>$R_L = 10\text{ k}\Omega$ ,<br>$V_{icm} = V_{CC}/2$ , $BW = 22\text{ kHz}$ ,<br>$V_{out} = 1\text{ V}_{pp}$ |      | 0.002    |      | %                                    |

1. See [Section 4.4: Input offset voltage drift over temperature](#).

**Table 5. Shutdown characteristics  $V_{CC} = 2.7\text{ V}$**

| Symbol                | Parameter                                       | Conditions   | Min.            | Typ. | Max. | Unit |
|-----------------------|---|--|-----------------|------|------|------|
| <b>DC performance</b> |   |  |                 |      |      |      |
| $I_{CC}$              | Supply current in shutdown mode (all operators) | $\overline{\text{SHDN}} = V_{CC-}$   |                 | 2.5  | 50   | nA   |
|                       |   | $-40\text{ °C} < T < 85\text{ °C}$   |                 |      | 200  |      |
|                       |   | $-40\text{ °C} < T < 125\text{ °C}$  |                 |      |      | 1.5  |
| $t_{on}$              | Amplifier turn-on time <sup>(1)</sup>           | $R_L = 2\text{ k}\Omega$ ,<br>$V_{out} = V_{CC-}$ to $V_{CC} - 0.2\text{ V}$               |                 | 300  |      | ns   |
| $t_{off}$             | Amplifier turn-off time <sup>(1)</sup>          | $R_L = 2\text{ k}\Omega$ , $V_{out} = V_{CC+} - 1\text{ V}$<br>to $V_{CC+} - 1.2\text{ V}$ |                 | 20   |      |      |
| $V_{IH}$              | $\overline{\text{SHDN}}$ logic high             |  | $V_{CC-} - 0.5$ |      |      | V    |
| $V_{IL}$              | $\overline{\text{SHDN}}$ logic low              |  |                 |      | 0.5  |      |
| $I_{IH}$              | $\overline{\text{SHDN}}$ current high           | $\overline{\text{SHDN}} = V_{CC+}$   |                 | 10   |      | pA   |
| $I_{IL}$              | $\overline{\text{SHDN}}$ current low            | $\overline{\text{SHDN}} = V_{CC-}$   |                 | 10   |      |      |
| $I_{OLeak}$           | Output leakage in shutdown mode                 | $\overline{\text{SHDN}} = V_{CC-}$   |                 | 50   |      |      |
|                       |   | $-40\text{ °C} < T < 125\text{ °C}$  |                 | 1    |      | nA   |

1. See [Section 4.7: Shutdown function](#).

**Table 6. Electrical characteristics at  $V_{CC+} = 5\text{ V}$  with  $V_{CC-} = 0\text{ V}$ ,  $V_{icm} = V_{CC}/2$ ,  $T_{amb} = 25\text{ °C}$ , and  $R_L$  connected to  $V_{CC}/2$  (unless otherwise specified)**

| Symbol                   | Parameter  | Conditions  | Min. | Typ. | Max. | Unit                    |
|--------------------------|--|---|------|------|------|-------------------------|
| <b>DC performance</b>    |  |   |      |      |      |                         |
| $V_{io}$                 | Input offset voltage   | TSV85xA, $T = 25\text{ °C}$                                     |      |      | 0.8  | mV                      |
|                          |  | TSV85x, $T = 25\text{ °C}$                                      |      |      | 4    |                         |
|                          |  | TSV85xA, $-40\text{ °C} < T < 125\text{ °C}$                    |      |      | 2    |                         |
|                          |  | TSV85x, $-40\text{ °C} < T < 125\text{ °C}$                     |      |      | 6    |                         |
| $\Delta V_{io}/\Delta T$ | Input offset voltage drift <sup>(1)</sup>  | $-40\text{ °C} < T < 125\text{ °C}$                             |      | 1    |      | $\mu\text{V}/\text{°C}$ |
| $I_{io}$                 | Input offset current<br>( $V_{out} = V_{CC}/2$ )   | $T = 25\text{ °C}$  |      | 0.5  | 30   | nA                      |
|                          |  | $-40\text{ °C} < T < 125\text{ °C}$                             |      | 1    | 50   |                         |
| $I_{ib}$                 | Input bias current ( $V_{out} = V_{CC}/2$ )  | $T = 25\text{ °C}$  |      | 27   | 60   | nA                      |
|                          |  | $-40\text{ °C} < T < 125\text{ °C}$                             |      |      | 110  |                         |
| CMR                      | Common mode rejection ratio<br>$20 \log (\Delta V_{icm}/\Delta V_{io})$<br>( $V_{ic} = 0\text{ V}$ to $V_{CC}-1\text{ V}$ , $V_{out} = V_{CC}/2$ ) | $T = 25\text{ °C}$  | 72   | 75   |      | dB                      |
|                          |  | $-40\text{ °C} < T < 125\text{ °C}$                             | 70   |      |      |                         |
| SVR                      | Supply voltage rejection ratio:<br>$20 \log (\Delta V_{CC}/\Delta V_{io})$<br>$V_{CC} = 2.5$ to $5\text{ V}$                                       | $T = 25\text{ °C}$  | 72   | 79   |      | dB                      |
|                          |  | $-40\text{ °C} < T < 125\text{ °C}$                             | 70   |      |      |                         |
| $A_{vd}$                 | Large signal voltage gain<br>( $V_{out} = 0.5\text{ V}$ to $(V_{CC}-0.5\text{ V})$ )   | $R_L = 10\text{ k}\Omega$ , $T = 25\text{ °C}$                  | 100  | 110  |      | dB                      |
|                          |  | $R_L = 10\text{ k}\Omega$ , $-40\text{ °C} < T < 125\text{ °C}$ | 90   |      |      |                         |
|                          |  | $R_L = 2\text{ k}\Omega$ , $T = 25\text{ °C}$                   | 90   | 100  |      |                         |
|                          |  | $R_L = 2\text{ k}\Omega$ , $-40\text{ °C} < T < 125\text{ °C}$  | 80   |      |      |                         |
| $V_{CC}-V_{OH}$          | High level output voltage  | $R_L = 10\text{ k}\Omega$ , $T=25\text{ °C}$                    |      | 10   | 100  | mV                      |
|                          |  | $R_L = 10\text{ k}\Omega$ , $-40\text{ °C} < T < 125\text{ °C}$ |      |      | 200  |                         |
|                          |  | $R_L = 2\text{ k}\Omega$ , $T = 25\text{ °C}$                   |      | 40   | 300  |                         |
|                          |  | $R_L = 2\text{ k}\Omega$ , $-40\text{ °C} < T < 125\text{ °C}$  |      |      | 400  |                         |
| $V_{OL}$                 | Low level output voltage   | $R_L = 10\text{ k}\Omega$ , $T = 25\text{ °C}$                  |      | 65   | 180  | mV                      |
|                          |  | $R_L = 10\text{ k}\Omega$ , $-40\text{ °C} < T < 125\text{ °C}$ |      |      | 280  |                         |
|                          |  | $R_L = 2\text{ k}\Omega$ , $T = 25\text{ °C}$                   |      | 120  | 300  |                         |
|                          |  | $R_L = 2\text{ k}\Omega$ , $-40\text{ °C} < T < 125\text{ °C}$  |      |      | 400  |                         |
| $I_{out}$                | $I_{sink}$ ( $V_{out} = V_{CC}$ )<br>$V_{id} = -1\text{ V}$  | $T = 25\text{ °C}$  | 35   | 43   |      | mA                      |
|                          |  | $-40\text{ °C} < T < 125\text{ °C}$                             | 25   |      |      |                         |
|                          | $I_{source}$ ( $V_{out} = 0\text{ V}$ )<br>$V_{id} = 1\text{ V}$   | $T = 25\text{ °C}$  | 60   | 70   |      |                         |
|                          |  | $-40\text{ °C} < T < 125\text{ °C}$                             | 50   |      |      |                         |
| $I_{CC}$                 | Supply current (per channel)<br>No load, $V_{out} = V_{CC}/2$  | $T = 25\text{ °C}$  |      | 130  | 180  | $\mu\text{A}$           |
|                          |  | $-40\text{ °C} < T < 125\text{ °C}$                             |      |      | 180  |                         |



**Table 6. Electrical characteristics at  $V_{CC+} = 5\text{ V}$  with  $V_{CC-} = 0\text{ V}$ ,  $V_{icm} = V_{CC}/2$ ,  $T_{amb} = 25\text{ }^\circ\text{C}$ , and  $R_L$  connected to  $V_{CC}/2$  (unless otherwise specified) (continued)**

| Symbol                | Parameter                         | Conditions  | Min. | Typ.     | Max. | Unit                                 |
|-----------------------|-----------------------------------|---|------|----------|------|--------------------------------------|
| <b>AC performance</b> |                                   |   |      |          |      |                                      |
| GBP                   | Gain bandwidth product            | $R_L > 1\text{ M}\Omega$ , $C_L = 200\text{ pF}$  |      | 1.3      |      | MHz                                  |
| $F_u$                 | Unity gain frequency              |   |      | 1        |      |                                      |
| $\Phi_m$              | Phase margin                      |   |      | 60       |      | degrees                              |
| $G_m$                 | Gain margin                       |   |      | 10       |      | dB                                   |
| SR                    | Slew rate                         | $R_L > 1\text{ M}\Omega$ , $C_L = 200\text{ pF}$<br>$V_{out} = 0.5\text{ V to } V_{CC} - 0.5\text{ V}$  |      | 0.7      |      | V/ $\mu\text{s}$                     |
| $e_n$                 | Equivalent input noise voltage    | $f = 1\text{ kHz}$<br>$f = 10\text{ kHz}$   |      | 30<br>20 |      | $\frac{\text{nV}}{\sqrt{\text{Hz}}}$ |
| $i_n$                 | Equivalent input noise current    | $f = 1\text{ kHz}$  |      | 0.30     |      | $\frac{\text{pA}}{\sqrt{\text{Hz}}}$ |
| THD+N                 | Total harmonic distortion + noise | $f_{in} = 1\text{ kHz}$ , $A_{CL} = 1$ ,<br>$R_L = 10\text{ k}\Omega$ ,<br>$V_{icm} = V_{CC}/2$ , $BW = 22\text{ kHz}$ ,<br>$V_{out} = 1\text{ V}_{pp}$ |      | 0.002    |      | %                                    |

1. See [Section 4.4: Input offset voltage drift over temperature.](#)

**Table 7. Shutdown characteristics  $V_{CC} = 5\text{ V}$**

| Symbol                | Parameter                                     | Conditions   | Min.            | Typ. | Max. | Unit |
|-----------------------|---|--|-----------------|------|------|------|
| <b>DC performance</b> |   |  |                 |      |      |      |
| $I_{CC}$              | Supply current in shutdown mode (per channel) | $\overline{\text{SHDN}} = V_{CC-}$   |                 | 2.5  | 50   | nA   |
|                       |   | $-40\text{ }^\circ\text{C} < T < 85\text{ }^\circ\text{C}$                             |                 |      | 200  |      |
|                       |   | $-40\text{ }^\circ\text{C} < T < 125\text{ }^\circ\text{C}$                            |                 |      |      | 1.5  |
| $t_{on}$              | Amplifier turn-on time <sup>(1)</sup>         | $R_L = 2\text{ k}\Omega$ ,<br>$V_{out} = V_{CC-}$ to $V_{CC+} + 0.2\text{ V}$          |                 | 300  |      | ns   |
| $t_{off}$             | Amplifier turn-off time <sup>(1)</sup>        | $R_L = 2\text{ k}\Omega$ , $V_{out} = V_{CC+} - 1\text{ V to } V_{CC+} - 1.2\text{ V}$ |                 | 20   |      |      |
| $V_{IH}$              | $\overline{\text{SHDN}}$ logic high           |  | $V_{CC-} - 0.5$ |      |      | V    |
| $V_{IL}$              | $\overline{\text{SHDN}}$ logic low            |  |                 |      | 0.5  |      |
| $I_{IH}$              | $\overline{\text{SHDN}}$ current high         | $\overline{\text{SHDN}} = V_{CC+}$   |                 | 10   |      | pA   |
| $I_{IL}$              | $\overline{\text{SHDN}}$ current low          | $\overline{\text{SHDN}} = V_{CC-}$   |                 | 10   |      |      |
| $I_{OLeak}$           | Output leakage in shutdown mode               | $\overline{\text{SHDN}} = V_{CC-}$   |                 | 50   |      |      |
|                       |   | $-40\text{ }^\circ\text{C} < T < 125\text{ }^\circ\text{C}$                            |                 | 1    |      | nA   |

1. See [Section 4.7: Shutdown function.](#)

Figure 2. Supply current vs. supply voltage at  $V_{icm} = V_{CC}/2$



Figure 3. Vio distribution at  $V_{CC} = 5 V$



Figure 4. Input offset voltage vs. input common mode voltage at  $V_{CC} = 5 V$



Figure 5. Output current vs. output voltage at  $V_{CC} = 2.7 V$



Figure 6. Output current vs. output voltage at  $V_{CC} = 5 V$



Figure 7. Output current vs. supply voltage at  $V_{icm} = V_{CC}/2$



Figure 8. Voltage gain and phase with  $C_I = 100 \text{ pF}$



Figure 9. Voltage gain and phase with  $C_I = 200 \text{ pF}$

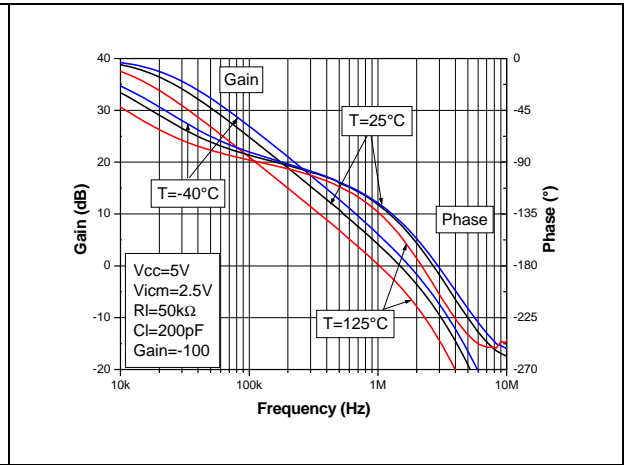


Figure 10. Gain margin vs. load capacitor at  $V_{CC} = 5 \text{ V}$



Figure 11. Phase margin vs. load capacitor at  $V_{CC} = 5 \text{ V}$

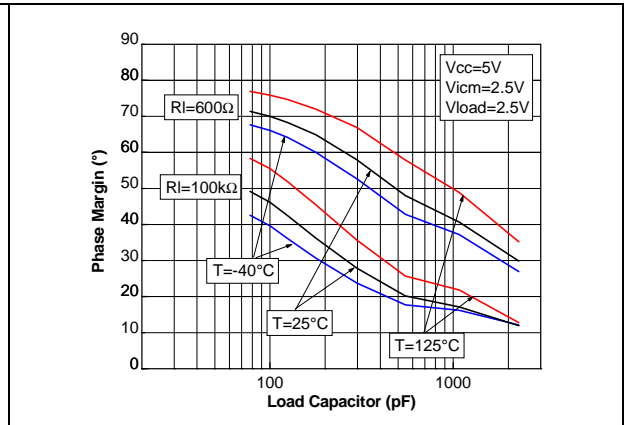


Figure 12. Closed-loop gain in voltage follower configuration for different capacitive loads



Figure 13. Phase margin vs. output current at  $V_{CC} = 5 \text{ V}$

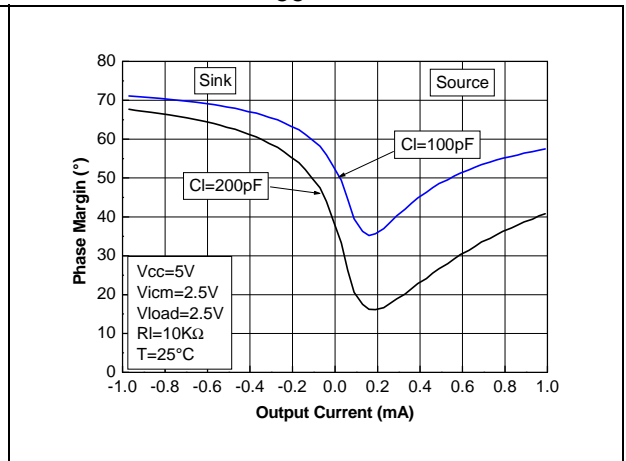


Figure 14. Positive and negative slew rate vs. supply voltage



Figure 15. Positive slew rate at V<sub>CC</sub> = 5 V with CI = 100 pF



Figure 16. Negative slew rate at V<sub>CC</sub> = 5 V with CI = 100 pF



Figure 17. Noise vs. frequency



Figure 18. 0.1 Hz to 10 Hz noise at V<sub>CC</sub> = 5 V



Figure 19. Distortion + noise vs. frequency



Figure 20. Distortion + noise vs. output voltage



## 4 Application information

### 4.1 Operating voltages

The TSV85x, TSV85xA can operate from 2.3 to 5.5 V. The devices' parameters are fully specified for 2.7 V and 5 V power supplies. Additionally, the main specifications are guaranteed in extended temperature ranges from -40 °C to +125 °C.

### 4.2 Input common-mode range

The TSV85x, TSV85xA has an input common-mode range that includes ground. The input common-mode range is extended from  $V_{CC-} - 0.2$  V to  $V_{CC+} - 1$  V, with no output phase reversal.

### 4.3 Rail-to-rail output

The operational amplifiers' output levels can go close to the rails: 180 mV maximum above and below the rail when connected to a 10 kΩ resistive load to  $V_{CC}/2$ .

### 4.4 Input offset voltage drift over temperature

The maximum input voltage drift over the temperature variation is defined as follows.

$$\frac{\Delta V_{io}}{\Delta T} = \max \left| \frac{V_{io}(T) - V_{io}(25^{\circ}\text{C})}{T - 25^{\circ}\text{C}} \right|$$

for  $T_{\min} < T < T_{\max}$ .

### 4.5 PCB layouts

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

### 4.6 Macromodel

Accurate macromodels of the TSV85x, TSV85xA are available on STMicroelectronics' web site at [www.st.com](http://www.st.com). These models are a trade-off between accuracy and complexity (that is, time simulation) of the TSV85x, TSV85xA operational amplifiers. They emulate the nominal performances of a typical device within the specified operating conditions mentioned in the datasheet. They also help to validate a design approach and to select the right operational amplifier, *but they do not replace on-board measurements*.

### 4.7 Shutdown function

The operational amplifier is enabled when the  $\overline{\text{SHDN}}$  pin is pulled high. To disable the amplifier, the SHDN pin must be pulled down to  $V_{CC-}$ . When in shutdown mode, the amplifier output is in a high impedance state. The SHDN pin must never be left floating but tied to  $V_{CC+}$  or  $V_{CC-}$ .

The turn-on and turn-off times are calculated for an output variation of  $\pm 200$  mV (Figure 21 and Figure 22 show the test configurations). Figure 23 and Figure 24 show the respective results with these test configurations.

Figure 21. Test configuration for turn-on time (Vout pulled down)



Figure 22. Test configuration for turn-off time (Vout pulled down)



Figure 23. Turn-on time,  $V_{CC} = 5$  V, Vout pulled down,  $T = 25$  °C



Figure 24. Turn-off time,  $V_{CC} = 5$  V, Vout pulled down,  $T = 25$  °C



## 5 Package information

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



### 5.1 SC70-5 (or SOT323-5) package information

Figure 25. SC70-5 (or SOT323-5) package mechanical drawing



Table 8. SC70-5 (or SOT323-5) package mechanical data

| Ref | Dimensions  |      |      |        |       |       |
|-----|-------------|------|------|--------|-------|-------|
|     | Millimeters |      |      | Inches |       |       |
|     | Min         | Typ  | Max  | Min    | Typ   | Max   |
| A   | 0.80        |      | 1.10 | 0.032  |       | 0.043 |
| A1  |             |      | 0.10 |        |       | 0.004 |
| A2  | 0.80        | 0.90 | 1.00 | 0.032  | 0.035 | 0.039 |
| b   | 0.15        |      | 0.30 | 0.006  |       | 0.012 |
| c   | 0.10        |      | 0.22 | 0.004  |       | 0.009 |
| D   | 1.80        | 2.00 | 2.20 | 0.071  | 0.079 | 0.087 |
| E   | 1.80        | 2.10 | 2.40 | 0.071  | 0.083 | 0.094 |
| E1  | 1.15        | 1.25 | 1.35 | 0.045  | 0.049 | 0.053 |
| e   |             | 0.65 |      |        | 0.025 |       |
| e1  |             | 1.30 |      |        | 0.051 |       |
| L   | 0.26        | 0.36 | 0.46 | 0.010  | 0.014 | 0.018 |
| <   | 0°          |      | 8°   |        |       |       |

## 5.2 SOT23-5 package information

Figure 26. SOT23-5 package mechanical drawing



Table 9. SOT23-5 package 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       | 0.013  | 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 |        |       |       |

### 5.3 SOT23-6 package information

Figure 27. SOT23-6 package mechanical drawing



Table 10. SOT23-6 package mechanical data

| Ref. | Dimensions  |      |      |        |       |       |
|------|-------------|------|------|--------|-------|-------|
|      | Millimeters |      |      | Inches |       |       |
|      | Min.        | Typ. | Max. | Min.   | Typ.  | Max.  |
| A    | 0.90        |      | 1.45 | 0.035  |       | 0.057 |
| A1   |             |      | 0.10 |        |       | 0.004 |
| A2   | 0.90        |      | 1.30 | 0.035  |       | 0.051 |
| b    | 0.35        |      | 0.50 | 0.013  |       | 0.019 |
| c    | 0.09        |      | 0.20 | 0.003  |       | 0.008 |
| D    | 2.80        |      | 3.05 | 0.110  |       | 0.120 |
| E    | 1.50        |      | 1.75 | 0.060  |       | 0.069 |
| e    |             | 0.95 |      |        | 0.037 |       |
| H    | 2.60        |      | 3.00 | 0.102  |       | 0.118 |
| L    | 0.10        |      | 0.60 | 0.004  |       | 0.024 |
| °    | 0 °         |      | 10 ° | 0 °    |       | 10 °  |

### 5.4 DFN8 package information

Figure 28. DFN8 2x2 mm package mechanical drawing (pitch 0.5 mm)



Table 11. DFN8 2x2 mm package mechanical data (pitch 0.5 mm)

| 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 | 0.040 |
| e    |             | 0.50 |       |        | 0.020 |       |
| L    |             |      | 0.425 |        |       | 0.017 |
| ddd  |             |      | 0.08  |        |       | 0.003 |

### 5.5 SO8 package information

Figure 29. SO8 package mechanical drawing



Table 12. SO8 package mechanical data

| Ref. | Dimensions  |      |      |        |       |       |
|------|-------------|------|------|--------|-------|-------|
|      | Millimeters |      |      | Inches |       |       |
|      | Min.        | Typ. | Max. | Min.   | Typ.  | Max.  |
| A    |             |      | 1.75 |        |       | 0.069 |
| A1   | 0.10        |      | 0.25 | 0.004  |       | 0.010 |
| A2   | 1.25        |      |      | 0.049  |       |       |
| b    | 0.28        |      | 0.48 | 0.011  |       | 0.019 |
| c    | 0.17        |      | 0.23 | 0.007  |       | 0.010 |
| D    | 4.80        | 4.90 | 5.00 | 0.189  | 0.193 | 0.197 |
| E    | 5.80        | 6.00 | 6.20 | 0.228  | 0.236 | 0.244 |
| E1   | 3.80        | 3.90 | 4.00 | 0.150  | 0.154 | 0.157 |
| e    |             | 1.27 |      |        | 0.050 |       |
| h    | 0.25        |      | 0.50 | 0.010  |       | 0.020 |
| L    | 0.40        |      | 1.27 | 0.016  |       | 0.050 |
| L1   |             | 1.04 |      |        | 0.040 |       |
| k    | 1°          |      | 8°   | 1°     |       | 8°    |
| ccc  |             |      | 0.10 |        |       | 0.004 |

### 5.6 MiniSO8 package information

Figure 30. MiniSO8 package mechanical drawing



Table 13. MiniSO8 package 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 |

### 5.7 MiniSO10 package information

Figure 31. MiniSO10 package mechanical drawing



Table 14. MiniSO10 package mechanical data

| Ref. | Dimensions  |      |      |        |       |       |
|------|-------------|------|------|--------|-------|-------|
|      | Millimeters |      |      | Inches |       |       |
|      | Min.        | Typ. | Max. | Min.   | Typ.  | Max.  |
| A    |             |      | 1.10 |        |       | 0.043 |
| A1   | 0.05        | 0.10 | 0.15 | 0.002  | 0.004 | 0.006 |
| A2   | 0.78        | 0.86 | 0.94 | 0.031  | 0.034 | 0.037 |
| b    | 0.25        | 0.33 | 0.40 | 0.010  | 0.013 | 0.016 |
| c    | 0.15        | 0.23 | 0.30 | 0.006  | 0.009 | 0.012 |
| D    | 2.90        | 3.00 | 3.10 | 0.114  | 0.118 | 0.122 |
| E    | 4.75        | 4.90 | 5.05 | 0.187  | 0.193 | 0.199 |
| E1   | 2.90        | 3.00 | 3.10 | 0.114  | 0.118 | 0.122 |
| e    |             | 0.50 |      |        | 0.020 |       |
| L    | 0.40        | 0.55 | 0.70 | 0.016  | 0.022 | 0.028 |
| L1   |             | 0.95 |      |        | 0.037 |       |
| k    | 0°          | 3°   | 6°   | 0°     | 3°    | 6°    |
| aaa  |             |      | 0.10 |        |       | 0.004 |

### 5.8 SO14 package information

Figure 32. SO14 package mechanical drawing

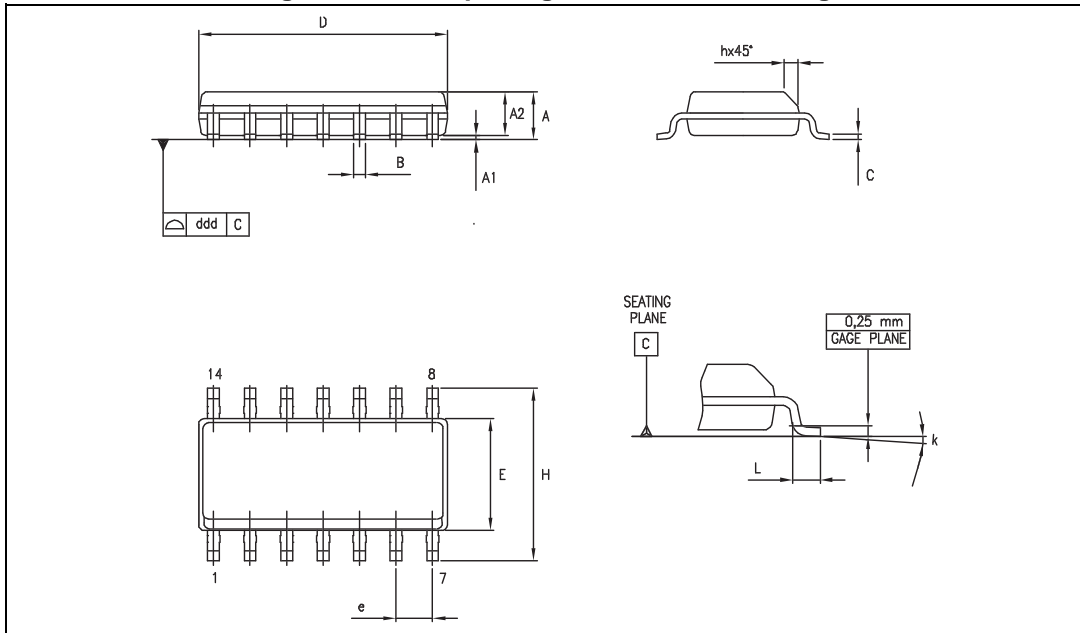


Table 15. SO14 package mechanical data

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



### 5.9 TSSOP14 package information

Figure 33. TSSOP14 package mechanical drawing



Table 16. TSSOP14 package 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  |

### 5.10 TSSOP16 package information

Figure 34. TSSOP16 package mechanical drawing



Table 17. TSSOP16 package mechanical data

| Ref. | Dimensions  |      |      |        |        |       |
|------|-------------|------|------|--------|--------|-------|
|      | Millimeters |      |      | Inches |        |       |
|      | Min.        | Typ. | Max. | Min.   | Typ.   | Max.  |
| A    |             |      | 1.20 |        |        | 0.047 |
| A1   | 0.05        |      | 0.15 | 0.002  |        | 0.006 |
| 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    | 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  | 0.177 |
| e    |             | 0.65 |      |        | 0.0256 |       |
| k    | 0°          |      | 8°   | 0°     |        | 8°    |
| L    | 0.45        | 0.60 | 0.75 | 0.018  | 0.024  | 0.030 |
| L1   |             | 1.00 |      |        | 0.039  |       |
| aaa  |             |      | 0.10 |        |        | 0.004 |

### 5.11 QFN16 3x3 package information

Figure 35. QFN16 3x3 package mechanical drawing



Table 18. QFN16 3x3 mm package mechanical data (pitch 0.5 mm)

| Ref. | Dimensions  |      |      |        |       |       |
|------|-------------|------|------|--------|-------|-------|
|      | Millimeters |      |      | Inches |       |       |
|      | Min.        | Typ. | Max. | Min.   | Typ.  | Max.  |
| A    | 0.80        | 0.90 | 1.00 | 0.031  | 0.035 | 0.039 |
| A1   | 0           |      | 0.05 | 0      |       | 0.002 |
| A3   |             | 0.20 |      |        | 0.008 |       |
| b    | 0.18        |      | 0.30 | 0.007  |       | 0.012 |
| D    | 2.90        | 3.00 | 3.10 | 0.114  | 0.118 | 0.122 |
| D2   | 1.50        |      | 1.80 | 0.059  |       | 0.071 |
| E    | 2.90        | 3.00 | 3.10 | 0.114  | 0.118 | 0.122 |
| E2   | 1.50        |      | 1.80 | 0.059  |       | 0.071 |
| e    |             | 0.50 |      |        | 0.020 |       |
| L    | 0.30        |      | 0.50 | 0.012  |       | 0.020 |

Figure 36. QFN16 3x3 footprint recommendation



## 6 Ordering information

**Table 19. Order codes for devices without shutdown feature**

| Order code | Temperature range | Package   | Packing       | Marking  |
|------------|-------------------|-----------|---------------|----------|
| TSV851ICT  | -40 °C to 125 °C  | SC70-5    | Tape and reel | K5E      |
| TSV851ILT  |                   | SOT23-5   |               | K153     |
| TSV852IQ2T |                   | DFN8 2x2  |               | K5E      |
| TSV852IST  |                   | MiniSO8   |               | K153     |
| TSV852IDT  |                   | SO8       |               | TSV852I  |
| TSV854IPT  |                   | TSSOP14   |               | TSV854I  |
| TSV854IDT  |                   | SO14      |               |          |
| TSV854IQ4T |                   | QFN16 3x3 |               | K157     |
| TSV851AICT |                   | SC70-5    |               | K5F      |
| TSV851AILT |                   | SOT23-5   |               | K154     |
| TSV852AIST |                   | MiniSO8   |               |          |
| TSV852AIDT |                   | SO8       |               | TSV852AI |
| TSV854AIPT |                   | TSSOP14   |               | TSV854AI |
| TSV854AIDT |                   | SO14      |               |          |

**Table 20. Order codes for devices with shutdown feature**

| Order code | Temperature range | Package  | Packing       | Marking  |
|------------|-------------------|----------|---------------|----------|
| TSV850ILT  | -40 °C to 125 °C  | SOT23-6  | Tape and reel | K153     |
| TSV853IST  |                   | MiniSO10 |               |          |
| TSV855IPT  |                   | TSSOP16  |               | TSV855I  |
| TSV850AILT |                   | SOT23-6  |               | K154     |
| TSV853AIST |                   | MiniSO10 |               |          |
| TSV855AIPT |                   | TSSOP16  |               | TSV855AI |

Table 21. Order codes (automotive grade parts)

| Order code  | Temperature range                                      | Package | Packing       | Marking   |
|-------------|--|---------|---------------|-----------|
| TSV851IYLT  | -40 °C to 125 °C<br>automotive<br>grade <sup>(1)</sup> | SOT23-5 | Tape and reel | K165      |
| TSV852IYST  |  | MiniSO8 |               |           |
| TSV852IYDT  |  | SO8     |               | TSV852IY  |
| TSV854IYPT  |  | TSSOP14 |               | TSV854IY  |
| TSV851AIYLT |  | SOT23-5 |               | K166      |
| TSV852AIYST |  | MiniSO8 |               |           |
| TSV852AIYDT |  | SO8     |               | TSV852AY  |
| TSV854AIYPT |  | TSSOP14 |               | TSV854AIY |

1. Qualified and characterized according to AEC Q100 and Q003 or equivalent, advanced screening according to AEC Q001 and Q002 or equivalent.

## 7 Revision history

Table 22. Document revision history

| Date        | Revision | Changes  |
|-------------|----------|--|
| 10-Nov-2011 | 1        | Initial release.   |
| 06-Jul-2012 | 2        | Added QFN16 package with related information.<br>Minimum supply voltage decreased down to 2.3 V.<br>Modified Figure 2, Figure 7 and Figure 14.<br>Addition of automotive grade parts.  |
| 02-Oct-2013 | 3        | Figure 1: Pin connections for each package (top view): added DFN8 2x2 pin connection to show exposed pad; added footnote 1.<br>Section 4.7: Shutdown function: added explanation of Figure 23 and Figure 23.<br>Table 21: Order codes (automotive grade parts): updated footnote 1.<br>Updated disclaimer. |
| 24-Apr-2017 | 4        | Updated <a href="#">Table 11</a> : "L" dimension changed from 0.5 mm to 0.425 mm.<br>Minor text edits throughout the document.   |

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