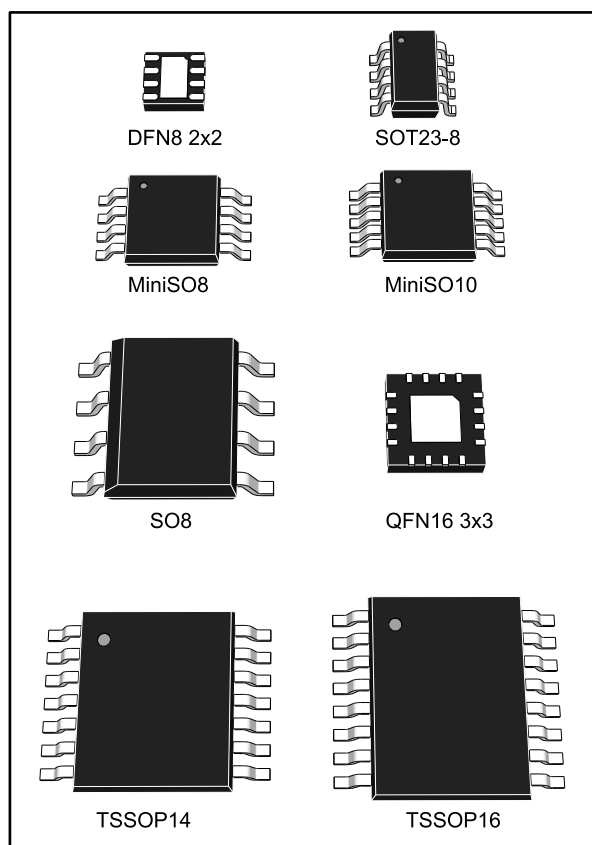


## Dual and quad, rail-to-rail input/output, 60 $\mu$ A, 880 kHz operational amplifiers

Datasheet - production data



### Features

- Rail-to-rail input and output
- Low power consumption: 60  $\mu$ A typ at 5 V
- Low supply voltage: 1.5 V - 5.5 V
- Gain bandwidth product: 880 kHz typ
- Unity gain stable on 100 pF capacitor
- Low power shutdown mode: 5 nA typ
- Low offset voltage: 800  $\mu$ V max (A version)
- Low input bias current: 1 pA typ
- EMI hardened op amps
- Automotive qualification

### Related products

- See the TSV52x series for higher merit factor (1.15 MHz for 45  $\mu$ A)
- See the TSV61x (120 kHz for 9  $\mu$ A) or TSV62x (420 kHz for 29  $\mu$ A) for more power savings

### Applications

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

### Description

The TSV63x and TSV63xA series of dual and quad operational amplifiers offers low voltage operation and rail-to-rail input and output.

This family features an excellent speed/power consumption ratio, offering an 880 kHz gain-bandwidth product while consuming only 60  $\mu$ A at 5 V supply voltage. The devices also feature an ultralow input bias current and TSV633 and TSV635 have a shutdown mode.

These features make the TSV63x and TSV63xA family ideal for sensor interfaces, battery-supplied and portable applications, and active filtering.

Table 1: Device summary

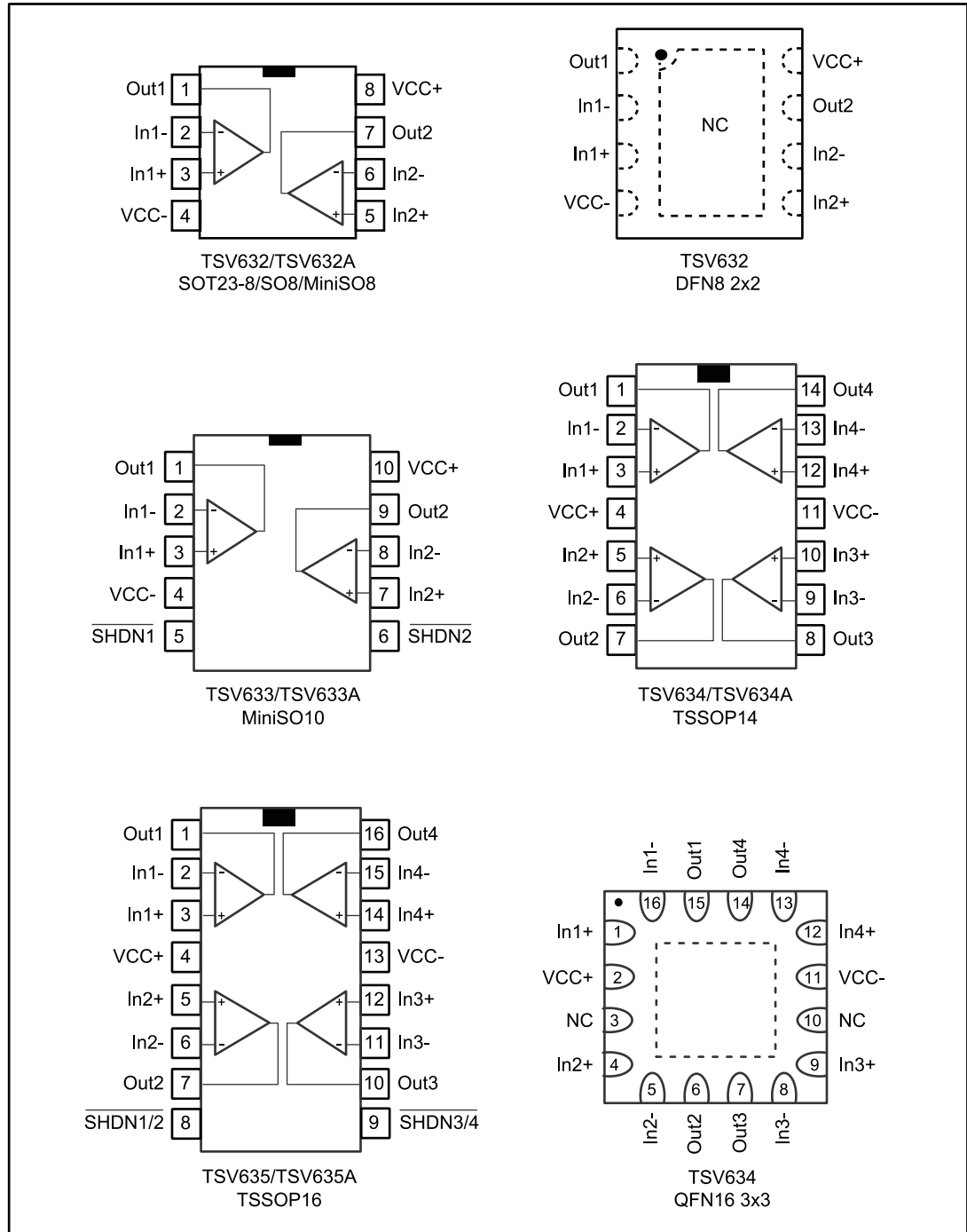
| Reference | Dual version    |              | Quad version    |              |
|-----------|-----------------|--------------|-----------------|--------------|
|           | Without standby | With standby | Without standby | With standby |
| TSV63x    | TSV632          | TSV633       | TSV634          | TSV635       |
| TSV63xA   | TSV632A         | TSV633A      | TSV634A         | TSV635A      |

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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 the QFN16 3x3 can be connected to V<sub>CC-</sub> 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   |
| $\overline{\text{SHDN}}$<br>SHDN | Shutdown voltage <sup>(3)</sup>                         |           | (V <sub>CC-</sub> ) - 0.2 to (V <sub>CC+</sub> ) + 0.2 | V    |
| T <sub>stg</sub>                 | Storage temperature                                     |           | -65 to 150                                             | °C   |
| R <sub>thja</sub>                | Thermal resistance junction to ambient <sup>(5/6)</sup> | DFN8 2x2  | 57                                                     | °C/W |
|                                  |                                                         | SOT23-8   | 105                                                    |      |
|                                  |                                                         | MiniSO8   | 190                                                    |      |
|                                  |                                                         | MiniSO10  | 113                                                    |      |
|                                  |                                                         | SO8       | 125                                                    |      |
|                                  |                                                         | QFN16 3x3 | 39                                                     |      |
|                                  |                                                         | TSSOP14   | 100                                                    |      |
|                                  |                                                         | TSSOP16   | 95                                                     |      |
| T <sub>j</sub>                   | Maximum junction temperature                            |           | 150                                                    | °C   |
| ESD                              | HBM: human body model <sup>(7)</sup>                    |           | 4000                                                   | V    |
|                                  | MM: machine model <sup>(8)</sup>                        |           | 300                                                    |      |
|                                  | CDM: charged device model <sup>(9)</sup>                |           | 1500                                                   |      |
|                                  | Latch-up immunity                                       |           | 200                                                    | mA   |

### Notes:

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

<sup>(2)</sup> Differential voltages are the non-inverting input terminal with respect to the inverting input terminal.

<sup>(3)</sup> V<sub>CC</sub> - V<sub>IN</sub> must not exceed 6 V, V<sub>IN</sub> must not exceed 6 V.

<sup>(4)</sup> Input current must be limited by a resistor in series with the inputs

<sup>(5)</sup> R<sub>th</sub> are typical values

<sup>(6)</sup> Short-circuits can cause excessive heating and destructive dissipation

<sup>(7)</sup> 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.

<sup>(8)</sup> 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

<sup>(9)</sup> 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                       | 1.5 to 5.5                             | V    |
| $V_{ICM}$  | Common-mode input voltage range      | $(V_{CC-}) - 0.1$ to $(V_{CC+}) + 0.1$ |      |
| $T_{oper}$ | Operating free-air temperature range | -40 to 125                             | °C   |

### 3 Electrical characteristics

Table 4: Electrical characteristics at VCC+ = 1.8 V with VCC- = 0 V, Vicm = VCC/2, Tamb = 25° C, and RL connected to VCC/2 (unless otherwise specified)

| Symbol               | Parameter                                                                          | Conditions                                                         | Min. | Typ. | Max.              | Unit    |
|----------------------|------------------------------------------------------------------------------------|--------------------------------------------------------------------|------|------|-------------------|---------|
| DC performance       |                                                                                    |                                                                    |      |      |                   |         |
| V <sub>io</sub>      | Offset voltage                                                                     | TSV63x                                                             |      |      | 3                 | mV      |
|                      |                                                                                    | TSV63xA                                                            |      |      | 0.8               |         |
|                      |                                                                                    | TSV633AIST (MiniSO10)                                              |      |      | 1                 |         |
|                      |                                                                                    | T <sub>min</sub> < T <sub>op</sub> < T <sub>max</sub> - TSV63x     |      |      | 4.5               |         |
|                      |                                                                                    | T <sub>min</sub> < T <sub>op</sub> < T <sub>max</sub> - TSV63xA    |      |      | 2                 |         |
|                      |                                                                                    | T <sub>min</sub> < T <sub>op</sub> < T <sub>max</sub> - TSV633AIST |      |      | 2.2               |         |
| ΔV <sub>io</sub> /ΔT | Input offset voltage drift                                                         |                                                                    |      | 2    |                   | μV/°C   |
| I <sub>io</sub>      | Input offset current                                                               | (V <sub>out</sub> = V <sub>CC</sub> /2)                            |      | 1    | 10 <sup>(1)</sup> | pA      |
|                      |                                                                                    | T <sub>min</sub> < T <sub>op</sub> < T <sub>max</sub>              |      | 1    | 100               |         |
| I <sub>ib</sub>      | Input bias current                                                                 | (V <sub>out</sub> = V <sub>CC</sub> /2)                            |      | 1    | 10 <sup>(1)</sup> |         |
|                      |                                                                                    | T <sub>min</sub> < T <sub>op</sub> < T <sub>max</sub>              |      | 1    | 100               |         |
| CMR                  | Common mode rejection ratio 20 log (ΔV <sub>ic</sub> /ΔV <sub>io</sub> )           | 0 V to 1.8 V, V <sub>out</sub> = 0.9 V                             | 53   | 74   |                   | dB      |
|                      |                                                                                    | T <sub>min</sub> < T <sub>op</sub> < T <sub>max</sub>              | 51   |      |                   |         |
| A <sub>vd</sub>      | Large signal voltage gain                                                          | R <sub>L</sub> = 10 kΩ, V <sub>out</sub> = 0.5 V to 1.3 V          | 85   | 95   |                   |         |
|                      |                                                                                    | T <sub>min</sub> < T <sub>op</sub> < T <sub>max</sub>              | 80   |      |                   |         |
| V <sub>OH</sub>      | High level output voltage, (V <sub>OH</sub> = V <sub>CC</sub> - V <sub>out</sub> ) | R <sub>L</sub> = 10 kΩ                                             |      | 5    | 35                | mV      |
|                      |                                                                                    | T <sub>min</sub> < T <sub>op</sub> < T <sub>max</sub>              |      |      | 50                |         |
| V <sub>OL</sub>      | Low level output voltage                                                           | R <sub>L</sub> = 10 kΩ                                             |      | 4    | 35                |         |
|                      |                                                                                    | T <sub>min</sub> < T <sub>op</sub> < T <sub>max</sub>              |      |      | 50                |         |
| I <sub>out</sub>     | I <sub>sink</sub>                                                                  | V <sub>o</sub> = 1.8 V                                             | 6    | 12   |                   | mA      |
|                      |                                                                                    | T <sub>min</sub> < T <sub>op</sub> < T <sub>max</sub>              | 4    |      |                   |         |
|                      | I <sub>source</sub>                                                                | V <sub>o</sub> = 0 V                                               | 6    | 10   |                   |         |
|                      |                                                                                    | T <sub>min</sub> < T <sub>op</sub> < T <sub>max</sub>              | 4    |      |                   |         |
| I <sub>CC</sub>      | Supply current (per channel)                                                       | No load, V <sub>out</sub> = V <sub>CC</sub> /2                     | 40   | 50   | 60                | μA      |
|                      |                                                                                    | T <sub>min</sub> < T <sub>op</sub> < T <sub>max</sub>              |      |      | 62                |         |
| AC performance       |                                                                                    |                                                                    |      |      |                   |         |
| GBP                  | Gain bandwidth product                                                             | R <sub>L</sub> = 2 kΩ, C <sub>L</sub> = 100 pF, f = 100 kHz        | 700  | 790  |                   | kHz     |
| φ <sub>m</sub>       | Phase margin                                                                       | R <sub>L</sub> = 2 kΩ, C <sub>L</sub> = 100 pF                     |      | 45   |                   | Degrees |
| G <sub>m</sub>       | Gain margin                                                                        | R <sub>L</sub> = 2 kΩ, C <sub>L</sub> = 100 pF                     |      | 13   |                   | dB      |
| SR                   | Slew rate                                                                          | R <sub>L</sub> = 2 kΩ, C <sub>L</sub> = 100 pF, A <sub>v</sub> = 1 | 0.2  | 0.27 |                   | V/μs    |
| e <sub>n</sub>       | Equivalent input noise voltage                                                     | f = 1 kHz                                                          |      | 60   |                   | nV/√Hz  |
|                      |                                                                                    | f = 10 kHz                                                         |      | 33   |                   |         |

**Notes:**

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

Table 5: Shutdown characteristics VCC = 1.8 V

| Symbol             | Parameter                                      | Conditions                                                                                           | Min. | Typ. | Max. | Unit |
|--------------------|------------------------------------------------|------------------------------------------------------------------------------------------------------|------|------|------|------|
| DC performance     |                                                |                                                                                                      |      |      |      |      |
| I <sub>CC</sub>    | Supply current in shutdown mode (all channels) | $\overline{\text{SHDN}} = V_{CC-}$                                                                   |      | 2.5  | 50   | nA   |
|                    |                                                | $T_{\min} < T_{\text{op}} < 85^{\circ} \text{C}$                                                     |      |      | 200  |      |
|                    |                                                | $T_{\min} < T_{\text{op}} < 125^{\circ} \text{C}$                                                    |      |      | 1.5  | μA   |
| t <sub>on</sub>    | Amplifier turn-on time                         | R <sub>L</sub> = 2 kΩ, V <sub>out</sub> = (V <sub>CC-</sub> ) to (V <sub>CC-</sub> ) + 0.2 V         |      | 200  |      | ns   |
| t <sub>off</sub>   | Amplifier turn-off time                        | R <sub>L</sub> = 2 kΩ, V <sub>out</sub> = (V <sub>CC+</sub> ) - 0.5 V to (V <sub>CC+</sub> ) - 0.7 V |      | 20   |      |      |
| V <sub>IH</sub>    | $\overline{\text{SHDN}}$ logic high            |                                                                                                      | 1.35 |      |      | V    |
| V <sub>IL</sub>    | $\overline{\text{SHDN}}$ logic low             |                                                                                                      |      |      | 0.6  |      |
| I <sub>IH</sub>    | $\overline{\text{SHDN}}$ current high          | $\overline{\text{SHDN}} = V_{CC+}$                                                                   |      | 10   |      | pA   |
| I <sub>IL</sub>    | $\overline{\text{SHDN}}$ current low           | $\overline{\text{SHDN}} = V_{CC-}$                                                                   |      | 10   |      |      |
| I <sub>OLeak</sub> | Output leakage in shutdown mode                | $\overline{\text{SHDN}} = V_{CC-}$                                                                   |      | 50   |      |      |
|                    |                                                | $T_{\min} < T_{\text{op}} < 125^{\circ} \text{C}$                                                    |      | 1    |      | nA   |

Table 6:  $V_{CC+} = 3.3\text{ V}$ ,  $V_{CC-} = 0\text{ V}$ ,  $V_{icm} = V_{CC}/2$ ,  $T_{amb} = 25^\circ\text{C}$ ,  $R_L$  connected to  $V_{CC}/2$   
(unless otherwise specified)

| Symbol               | Parameter                                                                          | Conditions                                                         | Min. | Typ. | Max.              | Unit    |
|----------------------|------------------------------------------------------------------------------------|--------------------------------------------------------------------|------|------|-------------------|---------|
| DC performance       |                                                                                    |                                                                    |      |      |                   |         |
| V <sub>io</sub>      | Offset voltage                                                                     | TSV63x                                                             |      |      | 3                 | mV      |
|                      |                                                                                    | TSV63xA                                                            |      |      | 0.8               |         |
|                      |                                                                                    | TSV633AIST (MiniSO10)                                              |      |      | 1                 |         |
|                      |                                                                                    | T <sub>min</sub> < T <sub>op</sub> < T <sub>max</sub> - TSV63x     |      |      | 4.5               |         |
|                      |                                                                                    | T <sub>min</sub> < T <sub>op</sub> < T <sub>max</sub> - TSV63xA    |      |      | 2                 |         |
|                      |                                                                                    | T <sub>min</sub> < T <sub>op</sub> < T <sub>max</sub> - TSV633AIST |      |      | 2.2               |         |
| ΔV <sub>io</sub> /ΔT | Input offset voltage drift                                                         |                                                                    |      | 2    |                   | μV/°C   |
| I <sub>io</sub>      | Input offset current                                                               | V <sub>out</sub> = V <sub>CC</sub> /2                              |      | 1    | 10 <sup>(1)</sup> | pA      |
|                      |                                                                                    | T <sub>min</sub> < T <sub>op</sub> < T <sub>max</sub>              |      | 1    | 100               |         |
| I <sub>ib</sub>      | Input bias current                                                                 | V <sub>out</sub> = V <sub>CC</sub> /2                              |      | 1    | 10 <sup>(1)</sup> |         |
|                      |                                                                                    | T <sub>min</sub> < T <sub>op</sub> < T <sub>max</sub>              |      | 1    | 100               |         |
| CMR                  | Common mode rejection ratio 20 log (ΔV <sub>ic</sub> /ΔV <sub>io</sub> )           | 0 V to 3.3 V, V <sub>out</sub> = 1.65 V                            | 57   | 79   |                   | 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 2.8 V          | 88   | 98   |                   |         |
|                      |                                                                                    | T <sub>min</sub> < T <sub>op</sub> < T <sub>max</sub>              | 83   |      |                   |         |
| V <sub>OH</sub>      | High level output voltage, (V <sub>OH</sub> = V <sub>CC</sub> - V <sub>out</sub> ) | R <sub>L</sub> = 10 kΩ                                             |      | 5    | 35                | mV      |
|                      |                                                                                    | T <sub>min</sub> < T <sub>op</sub> < T <sub>max</sub>              |      |      | 50                |         |
| V <sub>OL</sub>      | Low level output voltage                                                           | R <sub>L</sub> = 10 kΩ                                             |      | 4    | 35                |         |
|                      |                                                                                    | T <sub>min</sub> < T <sub>op</sub> < T <sub>max</sub>              |      |      | 50                |         |
| I <sub>out</sub>     | I <sub>sink</sub>                                                                  | V <sub>o</sub> = 3.3 V                                             | 23   | 45   |                   | mA      |
|                      |                                                                                    | T <sub>min</sub> < T <sub>op</sub> < T <sub>max</sub>              | 20   |      |                   |         |
|                      | I <sub>source</sub>                                                                | V <sub>o</sub> = 0 V                                               | 23   | 38   |                   |         |
|                      |                                                                                    | T <sub>min</sub> < T <sub>op</sub> < T <sub>max</sub>              | 20   |      |                   |         |
| I <sub>CC</sub>      | Supply current, (per channel)                                                      | No load, V <sub>out</sub> = 1.75 V                                 | 43   | 55   | 64                | μA      |
|                      |                                                                                    | T <sub>min</sub> < T <sub>op</sub> < T <sub>max</sub>              |      |      | 66                |         |
| AC performance       |                                                                                    |                                                                    |      |      |                   |         |
| GBP                  | Gain bandwidth product                                                             | R <sub>L</sub> = 2 kΩ, C <sub>L</sub> = 100 pF, f = 100 kHz        | 710  | 860  |                   | kHz     |
| φ <sub>m</sub>       | Phase margin                                                                       | R <sub>L</sub> = 2 kΩ, C <sub>L</sub> = 100 pF                     |      | 46   |                   | Degrees |
| G <sub>m</sub>       | Gain margin                                                                        | R <sub>L</sub> = 2 kΩ, C <sub>L</sub> = 100 pF                     |      | 13   |                   | dB      |
| SR                   | Slew rate                                                                          | R <sub>L</sub> = 2 kΩ, C <sub>L</sub> = 100 pF, A <sub>v</sub> = 1 | 0.22 | 0.29 |                   | V/μs    |

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

Table 7: Electrical characteristics at VCC+ = 5 V with VCC- = 0 V, Vicm = VCC/2, Tamb = 25° C, and RL connected to VCC/2 (unless otherwise specified)

| Symbol               | Parameter                                                                          | Conditions                                                         | Min. | Typ. | Max.              | Unit    |  |
|----------------------|------------------------------------------------------------------------------------|--------------------------------------------------------------------|------|------|-------------------|---------|--|
| DC performance       |                                                                                    |                                                                    |      |      |                   |         |  |
| V <sub>io</sub>      | Offset voltages                                                                    | TSV63x                                                             |      |      | 3                 | mV      |  |
|                      |                                                                                    | TSV63xA                                                            |      |      | 0.8               |         |  |
|                      |                                                                                    | TSV633AIST ( MiniSO10)                                             |      |      | 1                 |         |  |
|                      |                                                                                    | T <sub>min</sub> < T <sub>op</sub> < T <sub>max</sub> - TSV63x     |      |      | 4.5               |         |  |
|                      |                                                                                    | T <sub>min</sub> < T <sub>op</sub> < T <sub>max</sub> - TSV63xA    |      |      | 2                 |         |  |
|                      |                                                                                    | T <sub>min</sub> < T <sub>op</sub> < T <sub>max</sub> - TSV633AIST |      |      | 2.2               |         |  |
| ΔV <sub>io</sub> /ΔT | Input offset voltage drift                                                         |                                                                    |      | 2    |                   | μV/°C   |  |
| I <sub>io</sub>      | Input offset current                                                               | (V <sub>out</sub> = V <sub>CC</sub> /2)                            |      | 1    | 10 <sup>(1)</sup> | pA      |  |
|                      |                                                                                    | T <sub>min</sub> < T <sub>op</sub> < T <sub>max</sub>              |      | 1    | 100               |         |  |
| I <sub>ib</sub>      | Input bias current                                                                 | (V <sub>out</sub> = V <sub>CC</sub> /2)                            |      | 1    | 10 <sup>(1)</sup> |         |  |
|                      |                                                                                    | T <sub>min</sub> < T <sub>op</sub> < T <sub>max</sub>              |      | 1    | 100               |         |  |
| CMR                  | Common mode rejection ratio 20 log (ΔV <sub>ic</sub> /ΔV <sub>io</sub> )           | 0 V to 5 V, V <sub>out</sub> = 2.5 V                               | 60   | 80   |                   | dB      |  |
|                      |                                                                                    | T <sub>min</sub> < T <sub>op</sub> < T <sub>max</sub>              | 55   |      |                   |         |  |
| SVR                  | Supply voltage rejection ratio 20 log (ΔV <sub>CC</sub> /ΔV <sub>io</sub> )        | V <sub>CC</sub> = 1.8 to 5 V                                       | 75   | 102  |                   |         |  |
|                      |                                                                                    | T <sub>min</sub> < T <sub>op</sub> < T <sub>max</sub>              | 73   |      |                   |         |  |
| A <sub>vd</sub>      | Large signal voltage gain                                                          | R <sub>L</sub> = 10 kΩ, V <sub>out</sub> = 0.5 V to 4.5 V          | 89   | 98   |                   |         |  |
|                      |                                                                                    | T <sub>min</sub> < T <sub>op</sub> < T <sub>max</sub>              | 84   |      |                   |         |  |
| EMIRR                | EMI rejection ratio, EMIRR = -20 log (V <sub>RFpeak</sub> /ΔV <sub>io</sub> )      | V <sub>RF</sub> = 100 mV <sub>rms</sub> , f = 400 MHz              |      | 61   |                   |         |  |
|                      |                                                                                    | V <sub>RF</sub> = 100 mV <sub>rms</sub> , f = 900 MHz              |      | 85   |                   |         |  |
|                      |                                                                                    | V <sub>RF</sub> = 100 mV <sub>rms</sub> , f = 1800 MHz             |      | 92   |                   |         |  |
|                      |                                                                                    | V <sub>RF</sub> = 100 mV <sub>rms</sub> , f = 2400 MHz             |      | 83   |                   |         |  |
| V <sub>OH</sub>      | High level output voltage, (V <sub>OH</sub> = V <sub>CC</sub> - V <sub>out</sub> ) | R <sub>L</sub> = 10 kΩ                                             |      | 7    | 35                | mV      |  |
|                      |                                                                                    | T <sub>min</sub> < T <sub>op</sub> < T <sub>max</sub>              |      |      | 50                |         |  |
| V <sub>OL</sub>      | Low level output voltage                                                           | R <sub>L</sub> = 10 kΩ                                             |      | 6    | 35                |         |  |
|                      |                                                                                    | T <sub>min</sub> < T <sub>op</sub> < T <sub>max</sub>              |      |      | 50                |         |  |
| I <sub>out</sub>     | I <sub>sink</sub>                                                                  | V <sub>o</sub> = 5 V                                               | 40   | 69   |                   | mA      |  |
|                      |                                                                                    | T <sub>min</sub> < T <sub>op</sub> < T <sub>max</sub>              | 35   |      |                   |         |  |
|                      | I <sub>source</sub>                                                                | V <sub>o</sub> = 0 V                                               | 40   | 74   |                   |         |  |
|                      |                                                                                    | T <sub>min</sub> < T <sub>op</sub> < T <sub>max</sub>              | 35   |      |                   |         |  |
| I <sub>CC</sub>      | Supply current, (per channel)                                                      | No load, V <sub>out</sub> = V <sub>CC</sub> /2                     | 50   | 60   | 69                | μA      |  |
|                      |                                                                                    | T <sub>min</sub> < T <sub>op</sub> < T <sub>max</sub>              |      |      | 72                |         |  |
| AC performance       |                                                                                    |                                                                    |      |      |                   |         |  |
| GBP                  | Gain bandwidth product                                                             | R <sub>L</sub> = 2 kΩ, C <sub>L</sub> = 100 pF, f = 100 kHz        | 730  | 880  |                   | kHz     |  |
| F <sub>u</sub>       | Unity gain frequency                                                               | R <sub>L</sub> = 2 kΩ, C <sub>L</sub> = 100 pF                     |      | 830  |                   |         |  |
| φ <sub>m</sub>       | Phase margin                                                                       | R <sub>L</sub> = 2 kΩ, C <sub>L</sub> = 100 pF                     |      | 48   |                   | Degrees |  |

# Electrical characteristics

# TSV632, TSV632A, TSV633, TSV633A, TSV634, TSV634A, TSV635, TSV635A

| Symbol     | Parameter                         | Conditions                                                                                                                       | Min. | Typ.  | Max. | Unit                   |
|------------|-----------------------------------|----------------------------------------------------------------------------------------------------------------------------------|------|-------|------|------------------------|
| $G_m$      | Gain margin                       | $R_L = 2\text{ k}\Omega$ , $C_L = 100\text{ pF}$                                                                                 |      | 13    |      | dB                     |
| SR         | Slew rate                         | $R_L = 2\text{ k}\Omega$ , $C_L = 100\text{ pF}$ , $A_v = 1$                                                                     | 0.25 | 0.34  |      | V/ $\mu$ s             |
| $e_n$      | Equivalent input noise voltage    | $f = 1\text{ kHz}$                                                                                                               |      | 60    |      | nV/ $\sqrt{\text{Hz}}$ |
|            |                                   | $f = 10\text{ kHz}$                                                                                                              |      | 33    |      |                        |
| THD+ $e_n$ | Total harmonic distortion + noise | $V_{CC} = 5\text{ V}$ , $f = 1\text{ kHz}$ , $A_v = 1$ , $R_L = 100\text{ k}\Omega$ , $V_{icm} = V_{CC}/2$ , $V_{out} = 2V_{pp}$ |      | 0.002 |      | %                      |

## Notes:

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

Table 8: Shutdown characteristics at  $V_{CC} = 5\text{ V}$

| Symbol         | Parameter                                      | Conditions                                                                                    | Min. | Typ. | Max. | Unit    |
|----------------|------------------------------------------------|-----------------------------------------------------------------------------------------------|------|------|------|---------|
| DC performance |                                                |                                                                                               |      |      |      |         |
| $I_{CC}$       | Supply current in shutdown mode (all channels) | $\overline{\text{SHDN}} = V_{CC-}$                                                            |      | 5    | 50   | nA      |
|                |                                                | $T_{min} < T_{op} < 85^\circ\text{ C}$                                                        |      |      | 200  |         |
|                |                                                | $T_{min} < T_{op} < 125^\circ\text{ C}$                                                       |      |      | 1.5  | $\mu$ A |
| $t_{on}$       | Amplifier turn-on time                         | $R_L = 2\text{ k}\Omega$ , $V_{out} = (V_{CC-})$ to $(V_{CC-}) + 0.2\text{ V}$                |      | 200  |      | ns      |
| $t_{off}$      | Amplifier turn-off time                        | $R_L = 2\text{ k}\Omega$ , $V_{out} = (V_{CC+}) - 0.5\text{ V}$ to $(V_{CC+}) - 0.7\text{ V}$ |      | 20   |      |         |
| $V_{IH}$       | $\overline{\text{SHDN}}$ logic high            |                                                                                               | 2    |      |      | V       |
| $V_{IL}$       | $\overline{\text{SHDN}}$ logic low             |                                                                                               |      |      | 0.8  |         |
| $I_{IH}$       | $\overline{\text{SHDN}}$ 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   |      |         |
|                |                                                | $T_{min} < T_{op} < 125^\circ\text{ C}$                                                       |      | 1    |      | nA      |

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

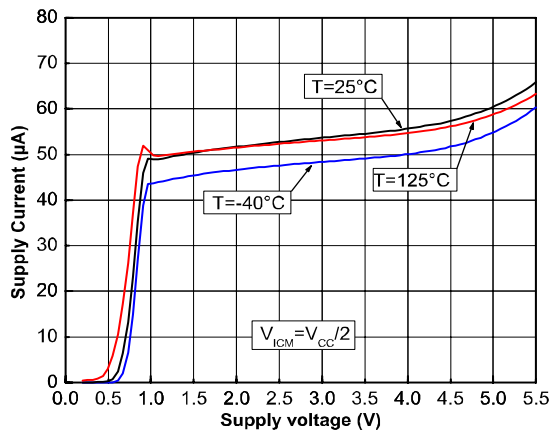


Figure 3: Output current vs. output voltage  
at  $V_{CC} = 1.5\text{ V}$

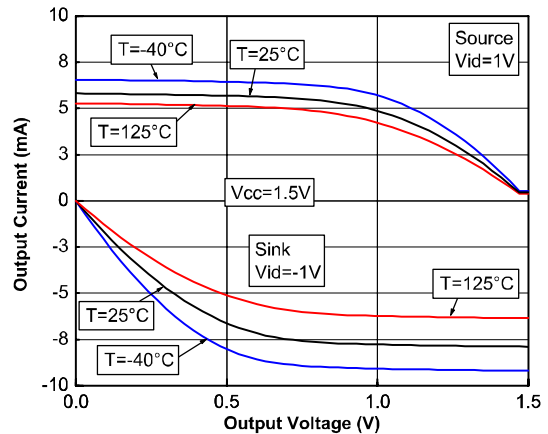


Figure 4: Output current vs. output voltage  
at  $V_{CC} = 5\text{ V}$

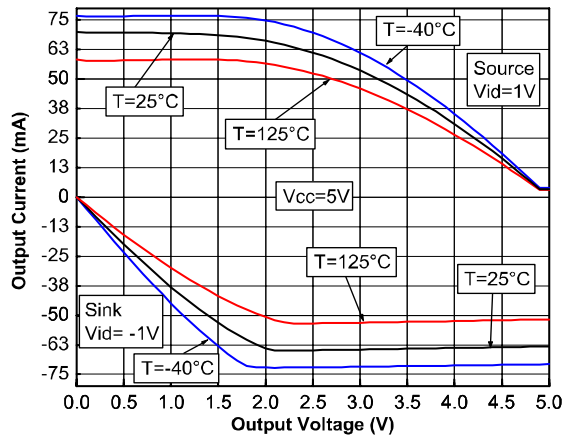


Figure 5: Voltage gain and phase vs. frequency  
at  $V_{CC} = 1.5\text{ V}$

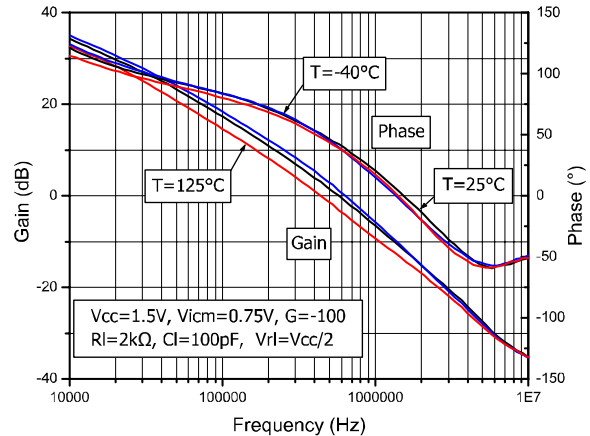


Figure 6: Voltage gain and phase vs. frequency  
at  $V_{CC} = 5\text{ V}$

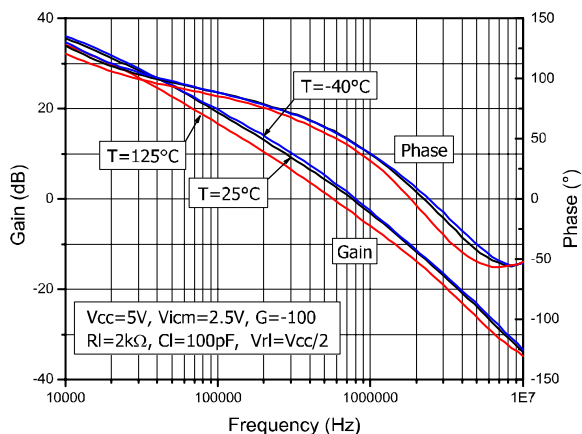


Figure 7: Phase margin vs. output current  
at  $V_{CC} = 5\text{ V}$

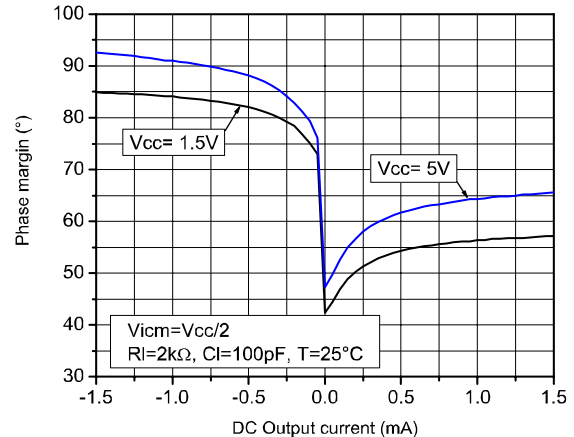


Figure 8: Positive slew rate vs. time

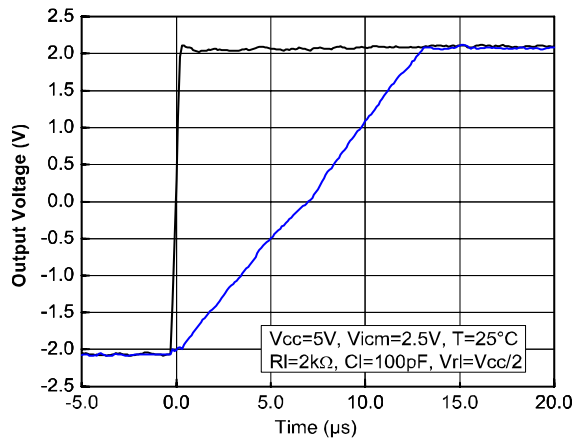


Figure 9: Negative slew rate vs. time

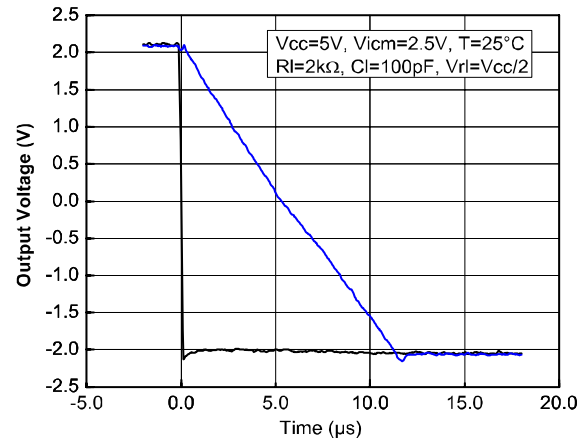


Figure 10: Positive slew rate vs. supply voltage

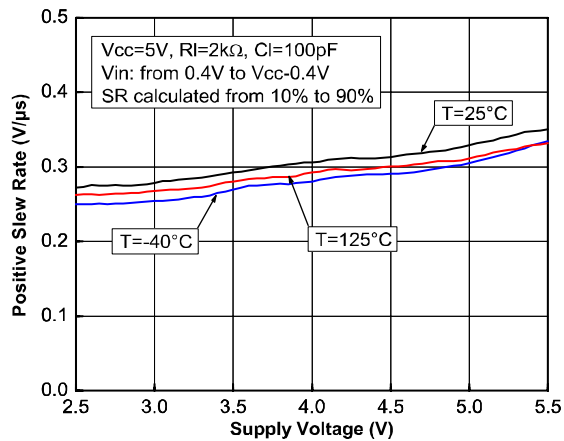


Figure 11: Negative slew rate vs. supply voltage

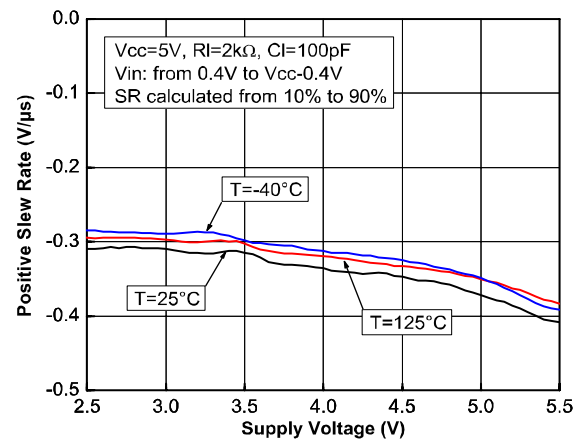


Figure 12: Distortion + noise vs. output voltage

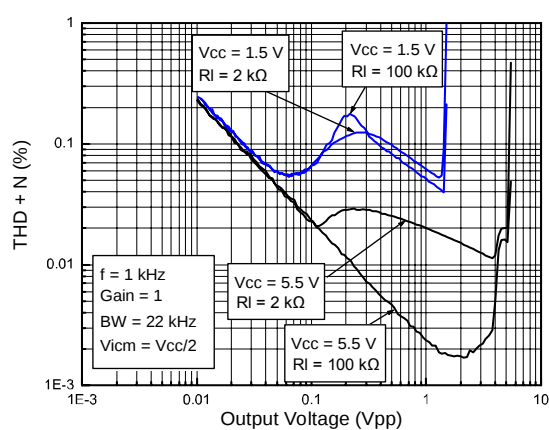


Figure 13: Distortion + noise vs. frequency

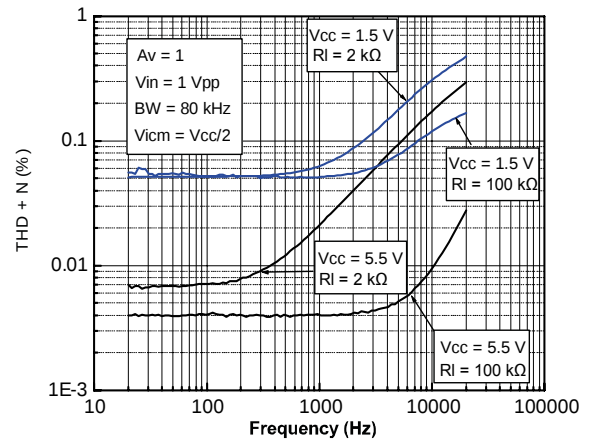


Figure 14: Noise vs. frequency

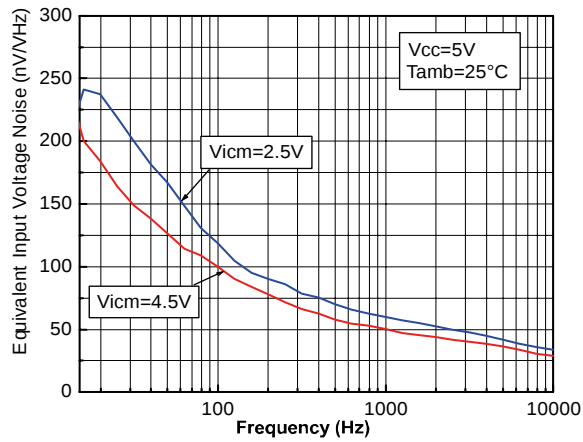
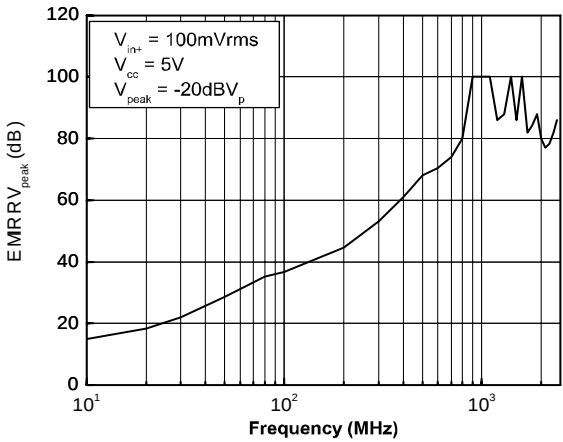


Figure 15: EMIRR vs. frequency at  $V_{CC} = 5V$ ,  
 $T = 25^{\circ}C$



## 4 Application information

### 4.1 Operating voltages

The TSV63x and TSV63xA can operate from 1.5 to 5.5 V. Their parameters are fully specified for 1.8 V, 3.3 V, and 5 V power supplies. However, the parameters are very stable in the full  $V_{CC}$  range and several characterization curves show the TSV63x and TSV63xA characteristics at 1.5 V. Additionally, the main specifications are guaranteed in extended temperature ranges from  $-40^{\circ}\text{C}$  to  $125^{\circ}\text{C}$ .

### 4.2 Rail-to-rail input

The TSV63x and TSV63xA are built with two complementary PMOS and NMOS input differential pairs. The devices have a rail-to-rail input and the input common mode range is extended from  $(V_{CC-}) - 0.1\text{ V}$  to  $(V_{CC+}) + 0.1\text{ V}$ . The transition between the two pairs appears at  $(V_{CC+}) - 0.7\text{ V}$ . In the transition region, the performance of CMRR, PSRR,  $V_{io}$  (Figure 16 and Figure 17), and THD is slightly degraded.

Figure 16: Input offset voltage vs input common mode voltage at  $V_{CC} = 1.5\text{ V}$

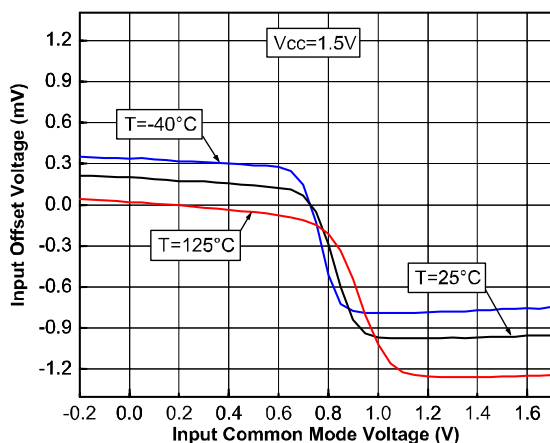
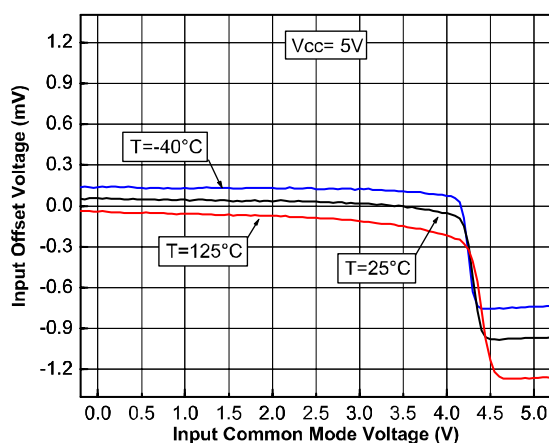


Figure 17: Input offset voltage vs input common mode voltage at  $V_{CC} = 5\text{ V}$



The devices are guaranteed without phase reversal.

### 4.3 Rail-to-rail output

The operational amplifiers' output levels can go close to the rails: 35 mV maximum above and below the rail when connected to a  $10\text{ k}\Omega$  resistive load to  $V_{CC}/2$ .

## 4.4 Shutdown function (TSV633, TSV635)

The operational amplifiers are enabled when the  $\overline{\text{SHDN}}$  pin is pulled high. To disable the amplifiers, the  $\overline{\text{SHDN}}$  must be pulled down to  $V_{CC-}$ . When in shutdown mode, the amplifiers' output is in a high impedance state. The  $\overline{\text{SHDN}}$  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 18](#) and [Figure 19](#) show the test configurations. [Figure 20](#) shows the time it takes the product to come out of shutdown mode and [Figure 21](#) shows the time it takes the product to enter shutdown mode.

Figure 18: Test configuration for turn-on time (Vout pulled down)

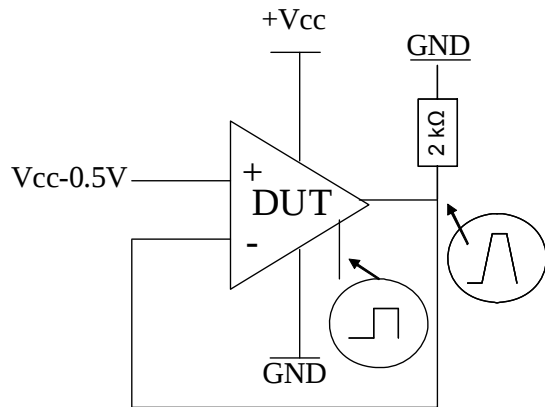


Figure 19: Test configuration for turn-off time (Vout pulled down)

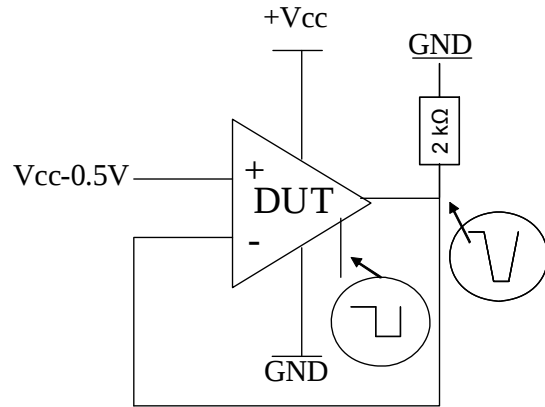


Figure 20: Turn-on time,  $V_{CC} = 5$  V, Vout pulled down,  $T = 25^\circ\text{C}$

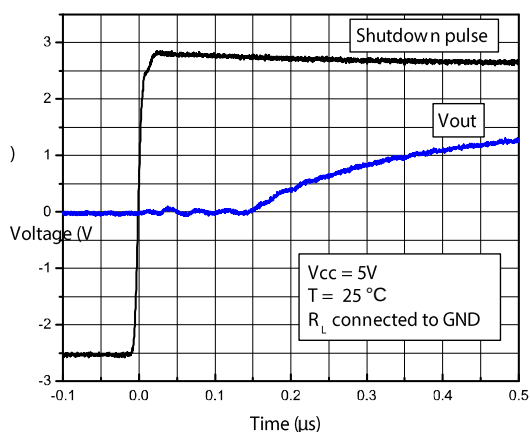
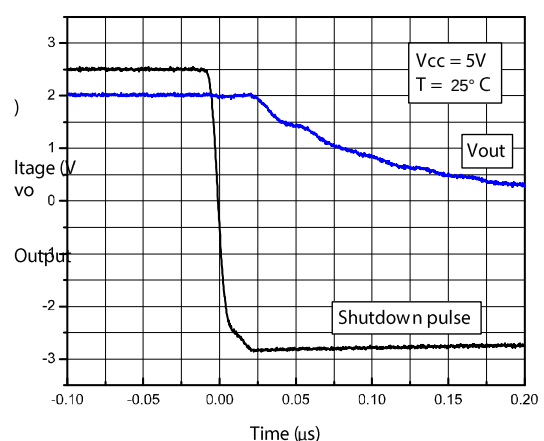


Figure 21: Turn-off time,  $V_{CC} = 5$  V, Vout pulled down,  $T = 25^\circ\text{C}$



## 4.5 Optimization of DC and AC parameters

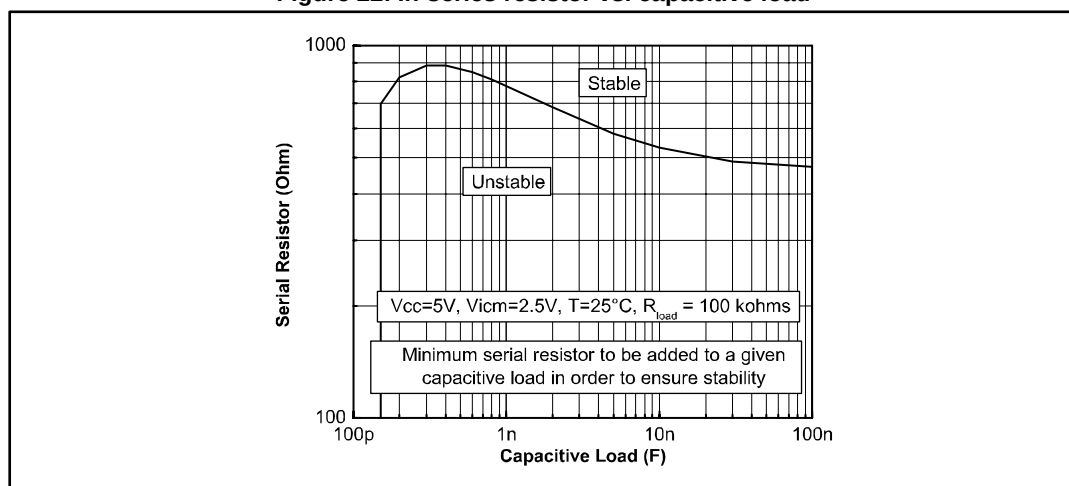
These devices use an innovative approach to reduce the spread of the main DC and AC parameters. An internal adjustment achieves a very narrow spread of the current consumption (60  $\mu\text{A}$  typical, min/max at  $\pm 17\%$ ). Parameters linked to the current consumption value, such as GBP, SR, and  $A_{vd}$ , benefit from this narrow dispersion. All parts present a similar speed and the same behavior in terms of stability. In addition, the minimum values of GBP and SR are guaranteed (GBP = 730 kHz minimum and SR = 0.25 V/ $\mu\text{s}$  minimum).

## 4.6 Driving resistive and capacitive loads

These products are micropower, low-voltage, operational amplifiers optimized to drive rather large resistive loads, above 2 k $\Omega$ . For lower resistive loads, the THD level may significantly increase.

In a *follower* configuration, these operational amplifiers can drive capacitive loads up to 100 pF with no oscillations. When driving larger capacitive loads, adding an in-series resistor at the output can improve the stability of the devices (see [Figure 22](#) for recommended in-series resistor values). Once the in-series resistor value has been selected, the stability of the circuit should be tested on the bench and simulated with the simulation model.

Figure 22: In-series resistor vs. capacitive load



## 4.7 PCB layouts

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

## 4.8 Macromodel

Two accurate macromodels (with or without the shutdown feature) of the TSV63x and TSV63xA 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 TSV63x and TSV63xA 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*.

## 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 DFN8 2 x 2 (NB) package information

Figure 23: DFN8 2 x 2 mm (NB) package outline

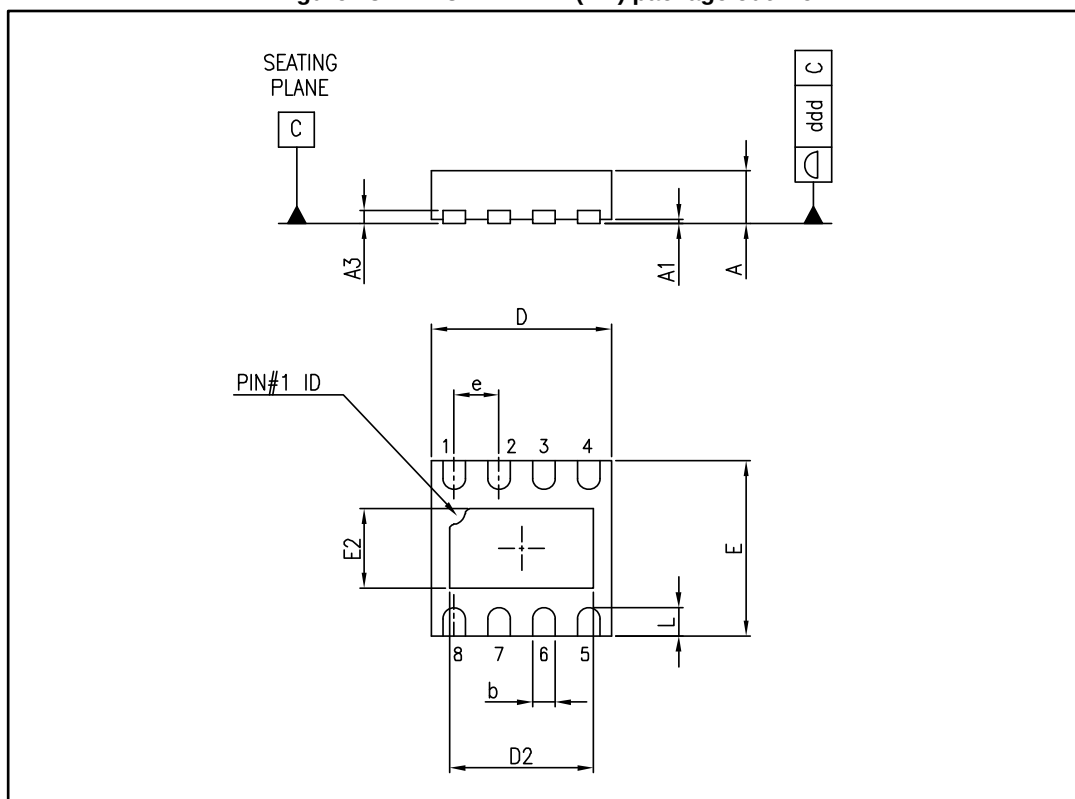
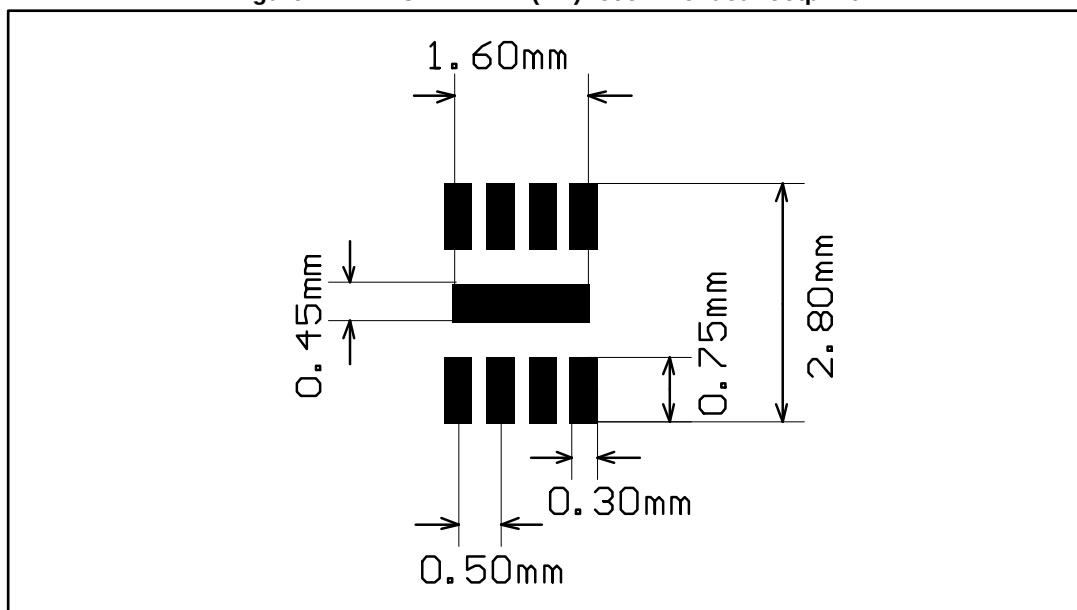


Table 9: DFN8 2 x 2 x 0.6 mm (NB) package mechanical data (pitch 0.5 mm)

| 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 | 0.039 |
| e    |             | 0.50 |       |        | 0.020 |       |
| L    |             |      | 0.425 |        |       | 0.017 |
| ddd  |             |      | 0.08  |        |       | 0.003 |

Figure 24: DFN8 2 x 2 mm (NB) recommended footprint



## 5.2 SOT23-8 package information

Figure 25: SOT23-8 package outline

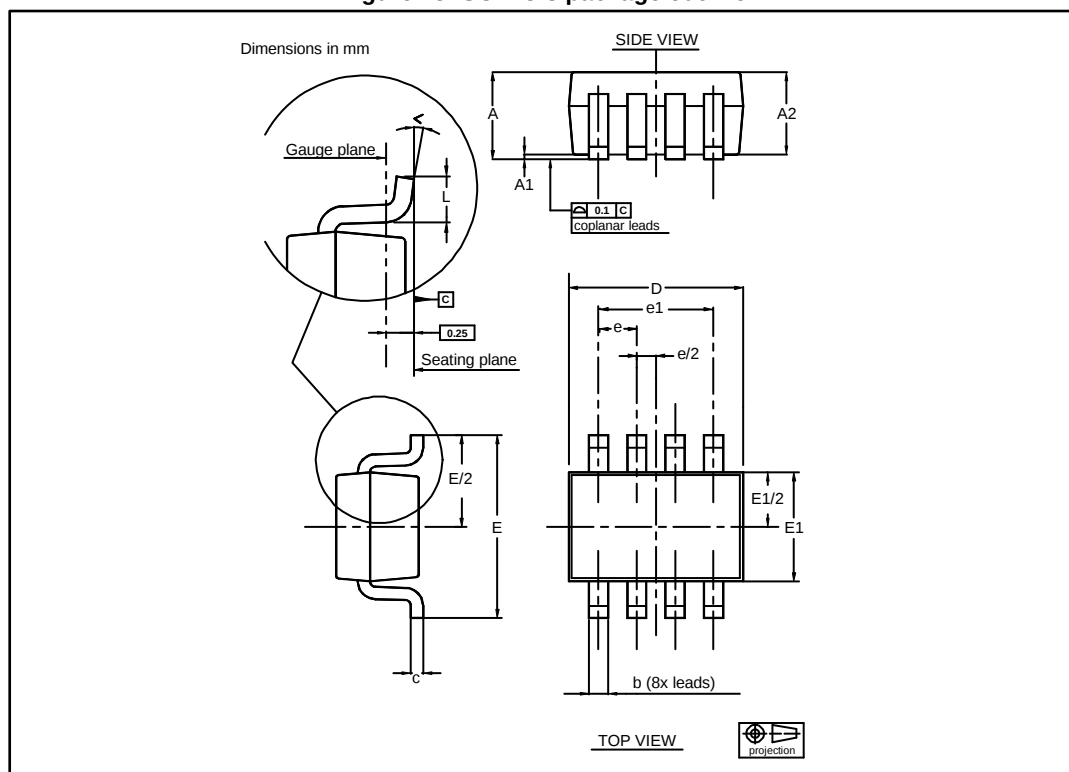


Table 10: SOT23-8 package mechanical data

| Ref. | Dimensions  |      |      |        |       |       |
|------|-------------|------|------|--------|-------|-------|
|      | Millimeters |      |      | Inches |       |       |
|      | Min.        | Typ. | Max. | Min.   | Typ.  | Max.  |
| A    |             |      | 1.45 |        |       | 0.057 |
| A1   |             |      | 0.15 |        |       | 0.006 |
| A2   | 0.90        |      | 1.30 | 0.035  |       | 0.051 |
| b    | 0.22        |      | 0.38 | 0.009  |       | 0.015 |
| c    | 0.08        |      | 0.22 | 0.003  |       | 0.009 |
| D    | 2.80        |      | 3.00 | 0.110  |       | 0.118 |
| E    | 2.60        |      | 3.00 | 0.102  |       | 0.118 |
| E1   | 1.50        |      | 1.75 | 0.059  |       | 0.069 |
| e    |             | 0.65 |      |        | 0.026 |       |
| e1   |             | 1.95 |      |        | 0.077 |       |
| L    | 0.30        |      | 0.60 | 0.012  |       | 0.024 |
| <    | 0°          |      | 8°   | 0°     |       | 8°    |

## 5.3 MiniSO8 package information

Figure 26: MiniSO8 package outline

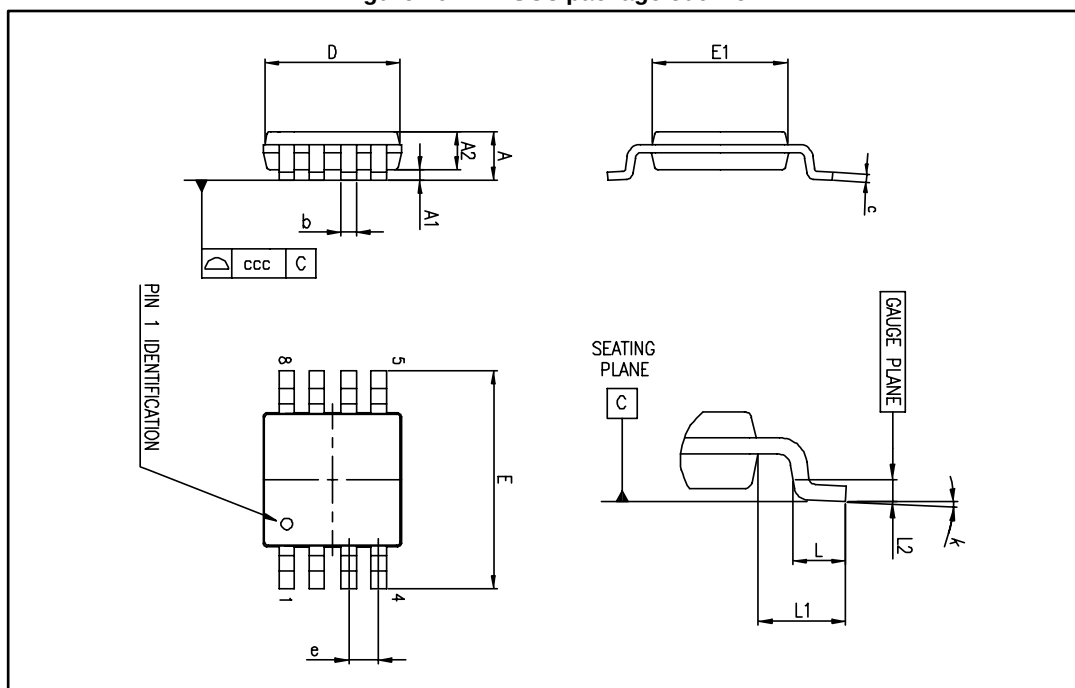


Table 11: MiniSO8 package mechanical data

| 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 |

## 5.4 MiniSO10 package information

Figure 27: MiniSO10 package outline

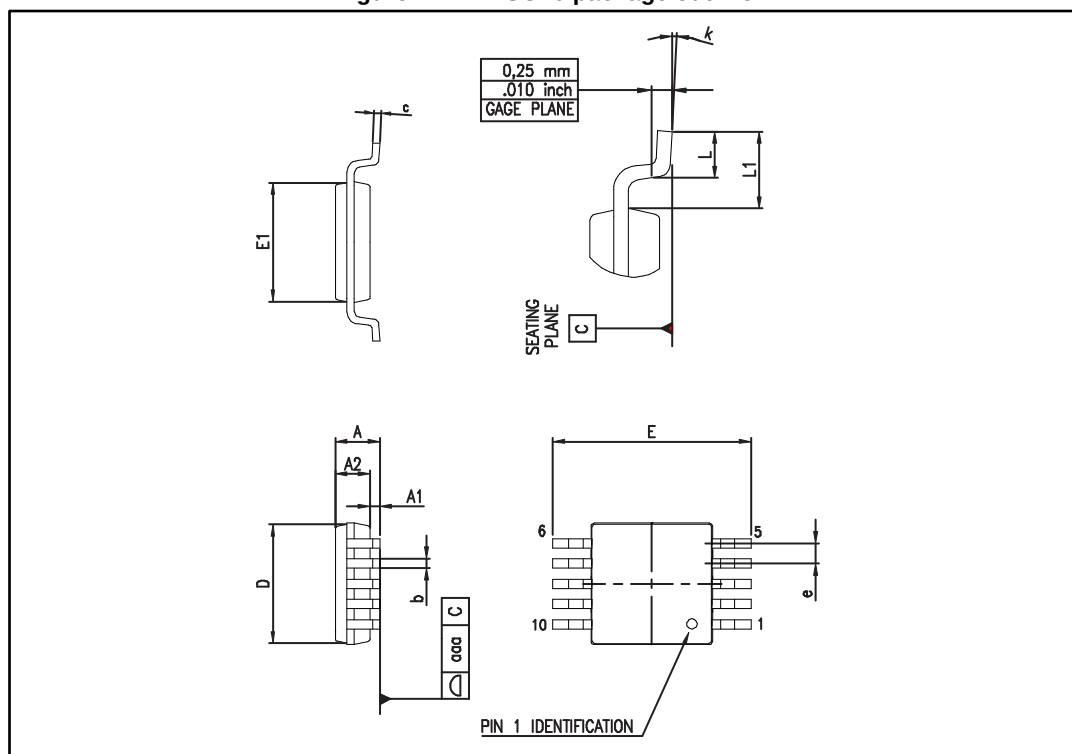


Table 12: MiniSO-10 package mechanical data

| 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 |

## 5.5 SO8 package information

Figure 28: SO8 package outline

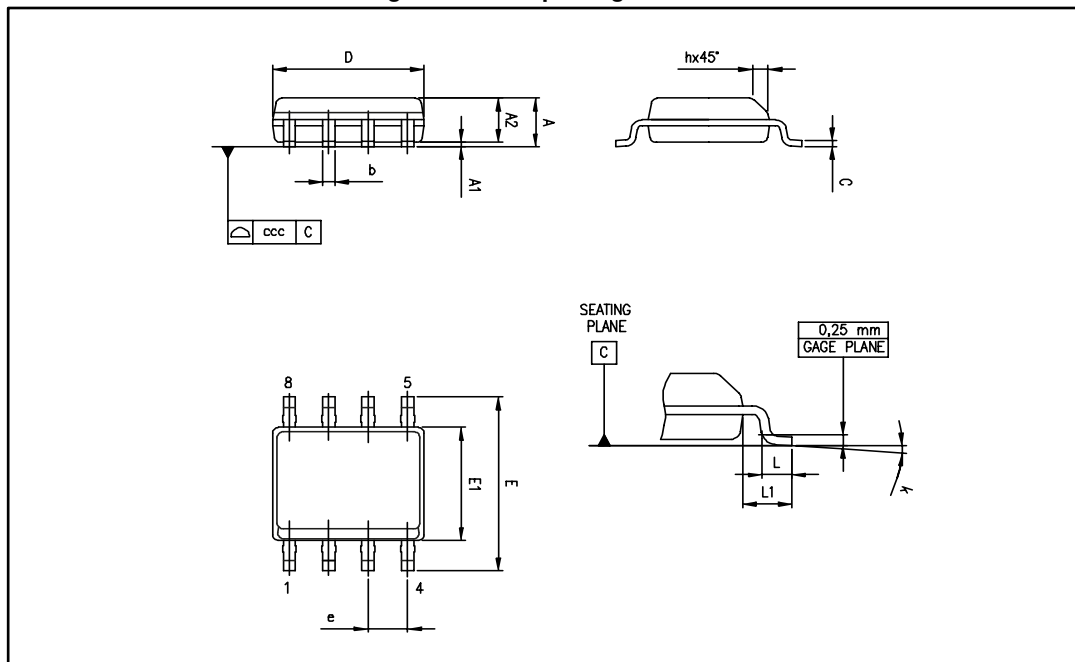


Table 13: SO8 package mechanical data

| 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 QFN16 3x3 package information

Figure 29: QFN16 3x3 mm package outline

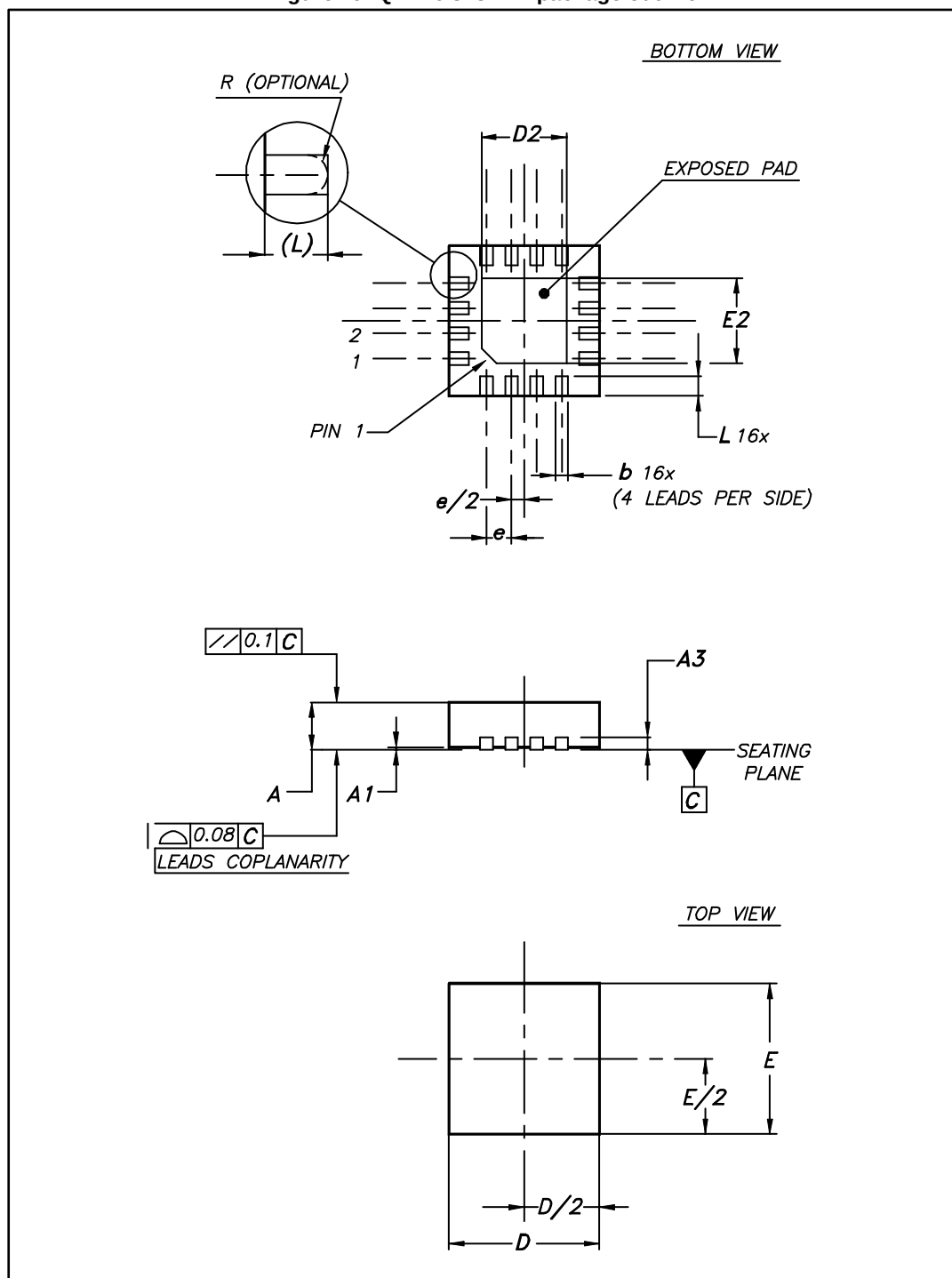
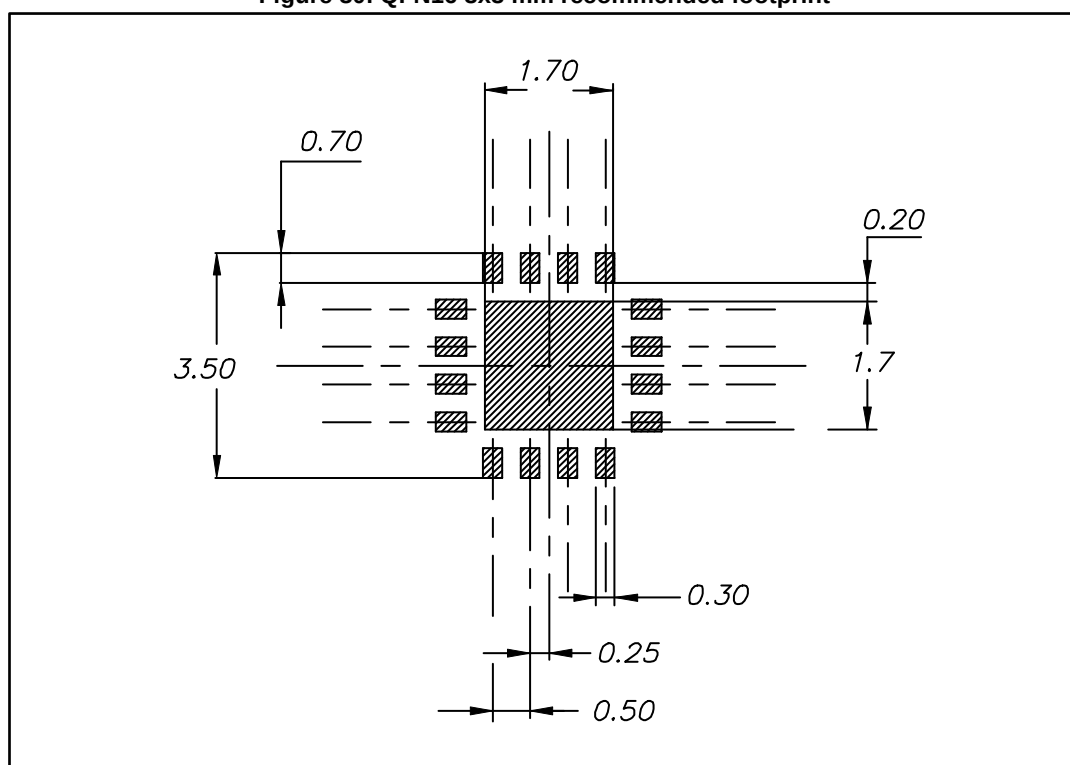


Table 14: QFN16 3x3 mm package mechanical data

| 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 30: QFN16 3x3 mm recommended footprint



## 5.7 TSSOP14 package information

Figure 31: TSSOP14 package outline

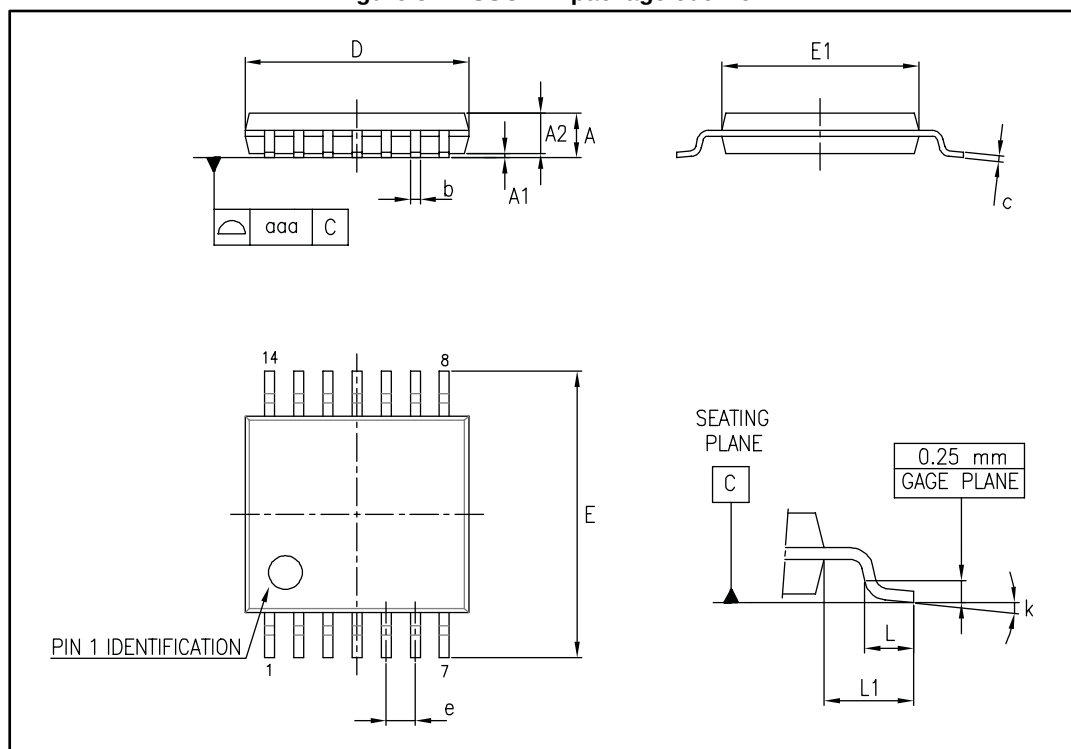


Table 15: TSSOP14 package mechanical data

| 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  |

## 5.8 TSSOP16 package information

Figure 32: TSSOP16 package outline

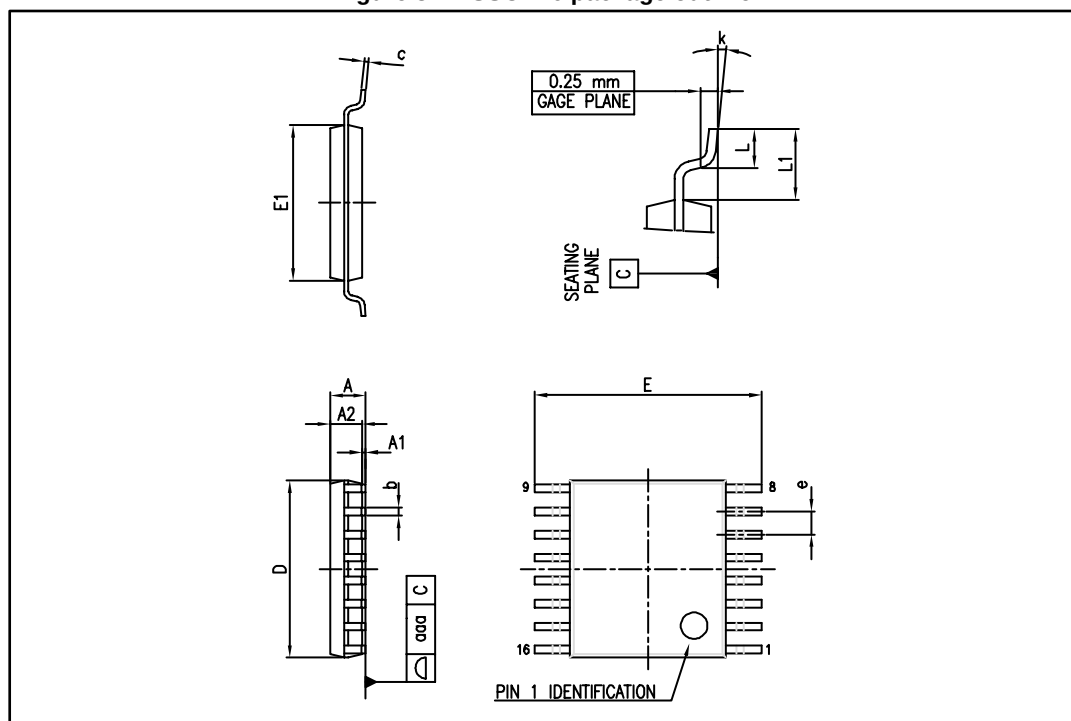


Table 16: TSSOP16 package mechanical data

| 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 |      |        | 0.026 |       |
| 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 |

## 6 Ordering information

Table 17: Order codes

| Order code  | Temperature range                                    | Package <sup>(1)</sup> | Marking |
|-------------|------------------------------------------------------|------------------------|---------|
| TSV632AIDT  | -40 °C to 125 °C                                     | SO8                    | TV632A  |
| TSV632AILT  |                                                      | SOT23-8                | K145    |
| TSV632AIQ2T |                                                      | DFN8 2x2               | K1P     |
| TSV632AIST  |                                                      | MiniSO8                | K145    |
| TSV632IDT   |                                                      | SO8                    | TSV632  |
| TSV632ILT   |                                                      | SOT23-8                | K110    |
| TSV632IQ2T  |                                                      | DFN8 2x2               | K1N     |
| TSV632IST   |                                                      | MiniSO8                | K110    |
| TSV632IYDT  | -40 °C to 125 °C,<br>automotive grade <sup>(2)</sup> | SO8                    | V632IY  |
| TSV633AIST  | -40 °C to 125 °C                                     | MiniSO10               | K146    |
| TSV633IST   |                                                      |                        | K111    |
| TSV634AIPT  |                                                      | TSSOP14                | TSV634A |
| TSV634IQ4T  |                                                      | QFN16 3x3              | K112    |
| TSV634IPT   |                                                      | TSSOP14                | TSV634  |
| TSV634IYPT  | -40 °C to 125 °C,<br>automotive grade <sup>(2)</sup> |                        | V634IY  |
| TSV635AIPT  | -40 °C to 125 °C                                     | TSSOP16                | TSV635A |
| TSV635IPT   |                                                      |                        | TSV635  |

**Notes:**

<sup>(1)</sup>All devices are in tape and reel packing

<sup>(2)</sup>Qualified and characterized according to AEC Q100 and Q003 or equivalent, advanced screening according to AEC Q001 and Q002.

## 7 Revision history

Table 18: Document revision history

| Date        | Revision | Changes                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
|-------------|----------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 25-May-2009 | 1        | Initial release.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
| 15-Jun-2009 | 2        | Corrected pin connection diagram in <a href="#">Figure 1</a> .                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |
| 03-Sep-2009 | 3        | Added root part numbers (TSV63xA) and <a href="#">Table 1: "Device summary"</a> on cover page.<br>Added order code TSV632AILT in <a href="#">Table 17: "Order codes"</a> .                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
| 07-Nov-2011 | 4        | Added DFN8 2x2 package mechanical drawing.<br>Added ordering information for DFN package to <a href="#">Table 17: "Order codes"</a> .<br>Corrected unit on Y axis of <a href="#">Figure 16</a> and <a href="#">Figure 17</a> .                                                                                                                                                                                                                                                                                                                                                                                                                                                            |
| 13-Dec-2012 | 5        | Updated <a href="#">Features</a><br>Added QFN16 3x3 package<br>Updated <a href="#">Figure 1: "Pin connections for each package (top view)"</a> .<br><a href="#">Table 4</a> , <a href="#">Table 6</a> , and <a href="#">Table 7</a> : replaced $DV_{IO}$ symbol with $\Delta V_{IO}/\Delta T$<br><a href="#">Table 4</a> , <a href="#">Table 5</a> , <a href="#">Table 6</a> , <a href="#">Table 7</a> and <a href="#">Table 8</a> : for supply current parameter, replaced "operator" with "channel".<br><a href="#">Table 17: "Order codes"</a> : added automotive order codes and updated footnote<br>Deleted TSV632ID/AID from order codes in <a href="#">Table 17: "Order codes"</a> |
| 29-May-2015 | 6        | <a href="#">Table 4</a> , <a href="#">Table 6</a> , and <a href="#">Table 7</a> : $V_{OH}$ "min" values changed to "max" values.<br><a href="#">Table 17: "Order codes"</a> : added order code TSV632AIQ2T, updated footnote 1.                                                                                                                                                                                                                                                                                                                                                                                                                                                           |

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