



## TSV632, TSV633, TSV634, TSV635

Rail-to-rail input/output 60  $\mu$ A 880 kHz operational amplifiers

### 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 stability
- 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
- High tolerance to ESD: 4 kV HBM
- Extended temperature range: -40° C to +125° C

### Applications

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

### Description

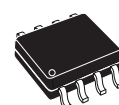
The TSV63x series of dual and quad operational amplifiers offers low voltage operation and rail-to-rail input and output.

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

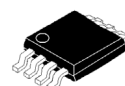
These features make the TSV63x family ideal for sensor interfaces, battery-supplied and portable applications, as well as active filtering.



SOT23-8



SO-8



MiniSO-8



TSSOP-14



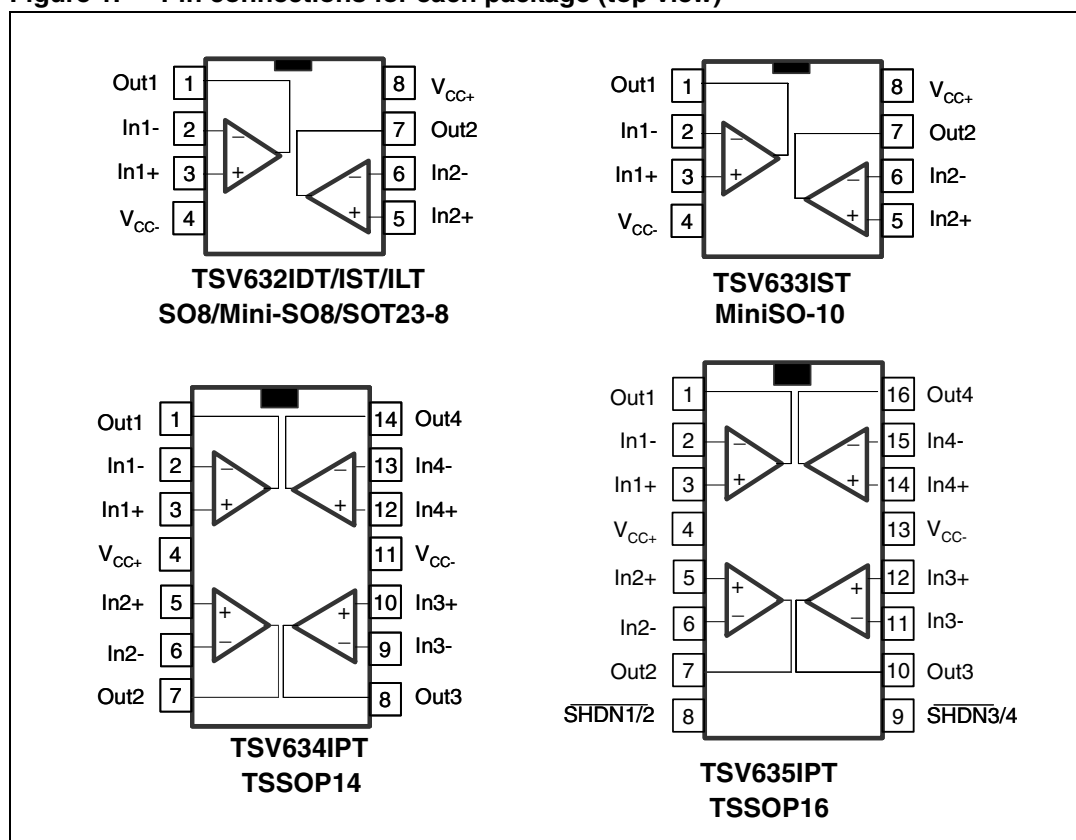
TSSOP-16

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# 1 Package pin connections

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



## 2 Absolute maximum ratings and operating conditions

**Table 1. 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    |
| $V_{in}$          | Input voltage <sup>(3)</sup>                                                                                               | $V_{CC-} - 0.2$ to $V_{CC+} + 0.2$    | V    |
| $I_{in}$          | Input current <sup>(4)</sup>                                                                                               | 10                                    | mA   |
| $\overline{SHDN}$ | Shutdown voltage <sup>(3)</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>(5)(6)</sup><br>SOT23-8<br>MiniSO-8<br>SO-8<br>MiniSO-10<br>TSSOP14<br>TSSOP16 | 105<br>190<br>125<br>113<br>100<br>95 | °C/W |
| $T_j$             | Maximum junction temperature                                                                                               | 150                                   | °C   |
| ESD               | HBM: human body model <sup>(7)</sup>                                                                                       | 4                                     | kV   |
|                   | MM: machine model <sup>(8)</sup>                                                                                           | 300                                   | V    |
|                   | CDM: charged device model <sup>(9)</sup>                                                                                   | 1.5                                   | kV   |
|                   | Latch-up immunity                                                                                                          | 200                                   | mA   |

1. All voltage values, except differential voltage are with respect to network ground terminal.
2. Differential voltages are the non-inverting input terminal with respect to the inverting input terminal.
3.  $V_{CC-}$ - $V_{in}$  must not exceed 6 V,  $V_{in}$  must not exceed 6V.
4. Input current must be limited by a resistor in series with the inputs.
5. Short-circuits can cause excessive heating and destructive dissipation.
6.  $R_{th}$  are typical values.
7. Human body model: 100 pF discharged through a 1.5 k $\Omega$  resistor between two pins of the device, done for all couples of pin combinations with other pins floating.
8. 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  $\Omega$ ), done for all couples of pin combinations with other pins floating.
9. Charged device model: all pins plus package are charged together to the specified voltage and then discharged directly to the ground.

**Table 2. 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 $V_{CC+} + 0.1$ | V    |
| $T_{oper}$ | Operating free air temperature range | -40 to +125                        | °C   |

### 3 Electrical characteristics

**Table 3. Electrical characteristics at  $V_{CC+} = +1.8\text{ V}$  with  $V_{CC-} = 0\text{ V}$ ,  $V_{icm} = V_{CC}/2$ ,  $T_{amb} = 25^\circ\text{C}$ , and  $R_L$  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               | mV                     |
| 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      |      |                   |                        |
| DV <sub>io</sub>                                                   | Input offset voltage drift                                                  |                                                                                 |          | 2    |                   | μV/°C                  |
| I <sub>io</sub>                                                    | Input offset current<br>(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               | pA                     |
| I <sub>ib</sub>                                                    | Input bias current<br>(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               | pA                     |
| CMR                                                                | Common mode rejection<br>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       |      |                   | dB                     |
| 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   |                   | dB                     |
|                                                                    |                                                                             | T <sub>min</sub> < T <sub>op</sub> < T <sub>max</sub>                           | 80       |      |                   | dB                     |
| V <sub>OH</sub>                                                    | High level output voltage                                                   | R <sub>L</sub> = 10 kΩ<br>T <sub>min</sub> < T <sub>op</sub> < T <sub>max</sub> | 35<br>50 | 5    |                   | mV                     |
| V <sub>OL</sub>                                                    | Low level output voltage                                                    | R <sub>L</sub> = 10 kΩ<br>T <sub>min</sub> < T <sub>op</sub> < T <sub>max</sub> |          | 4    | 35<br>50          | mV                     |
| 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   |                   | mA                     |
|                                                                    |                                                                             | T <sub>min</sub> < T <sub>op</sub> < T <sub>max</sub>                           | 4        |      |                   |                        |
| I <sub>CC</sub>                                                    | Supply current (per<br>operator)                                            | 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                | μA                     |
| 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<br>voltage                                           | f = 1 kHz                                                                       |          | 60   |                   | $\frac{nV}{\sqrt{Hz}}$ |
|                                                                    |                                                                             | f = 10 kHz                                                                      |          | 33   |                   |                        |

1. Guaranteed by design.

Table 4. Shutdown characteristics  $V_{CC} = 1.8\text{ V}$ 

| 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            |
|                       |                                                 | $T_{\min} < T_{\text{op}} < 85^{\circ}\text{ C}$                                                         |      |      | 200  | nA            |
|                       |                                                 | $T_{\min} < T_{\text{op}} < 125^{\circ}\text{ C}$                                                        |      |      | 1.5  | $\mu\text{A}$ |
| $t_{\text{on}}$       | Amplifier turn-on time                          | $R_L = 2\text{ k}\Omega$<br>$V_{\text{out}} = V_{CC-} \text{ to } V_{CC-} + 0.2\text{ V}$                |      | 200  |      | ns            |
| $t_{\text{off}}$      | Amplifier turn-off time                         | $R_L = 2\text{ k}\Omega$<br>$V_{\text{out}} = V_{CC+} - 0.5\text{ V} \text{ to } V_{CC+} - 0.7\text{ V}$ |      | 20   |      | ns            |
| $V_{\text{IH}}$       | $\overline{\text{SHDN}}$ logic high             |                                                                                                          | 1.35 |      |      | V             |
| $V_{\text{IL}}$       | $\overline{\text{SHDN}}$ logic low              |                                                                                                          |      |      | 0.6  | V             |
| $I_{\text{IH}}$       | $\overline{\text{SHDN}}$ current high           | $\overline{\text{SHDN}} = V_{CC+}$                                                                       |      | 10   |      | $\mu\text{A}$ |
| $I_{\text{IL}}$       | $\overline{\text{SHDN}}$ current low            | $\overline{\text{SHDN}} = V_{CC-}$                                                                       |      | 10   |      | $\mu\text{A}$ |
| $I_{\text{OLeak}}$    | Output leakage in shutdown mode                 | $\overline{\text{SHDN}} = V_{CC-}$                                                                       |      | 50   |      | $\mu\text{A}$ |
|                       |                                                 | $T_{\min} < T_{\text{op}} < 125^{\circ}\text{ C}$                                                        |      | 1    |      | nA            |

**Table 5.**  $V_{CC+} = +3.3\text{ V}$ ,  $V_{CC-} = 0\text{ V}$ ,  $V_{icm} = V_{CC}/2$ ,  $T_{amb} = 25^{\circ}\text{ C}$ ,  $R_L$  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               | mV      |
| 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      |      |                   |         |
| DV <sub>io</sub>                                                   | Input offset voltage drift                                               |                                                                                 |          | 2    |                   | μV/°C   |
| I <sub>io</sub>                                                    | Input offset current                                                     |                                                                                 |          | 1    | 10 <sup>(1)</sup> | pA      |
|                                                                    |                                                                          | T <sub>min</sub> < T <sub>op</sub> < T <sub>max</sub>                           |          | 1    | 100               | pA      |
| I <sub>ib</sub>                                                    | Input bias current                                                       |                                                                                 |          | 1    | 10 <sup>(1)</sup> | pA      |
|                                                                    |                                                                          | T <sub>min</sub> < T <sub>op</sub> < T <sub>max</sub>                           |          | 1    | 100               | pA      |
| 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   |                   | dB      |
|                                                                    |                                                                          | T <sub>min</sub> < T <sub>op</sub> < T <sub>max</sub>                           | 83       |      |                   |         |
| V <sub>OH</sub>                                                    | High level output voltage                                                | R <sub>L</sub> = 10 kΩ<br>T <sub>mi.</sub> < T <sub>op</sub> < T <sub>max</sub> | 35<br>50 | 5    |                   | mV      |
| V <sub>OL</sub>                                                    | Low level output voltage                                                 | R <sub>L</sub> = 10 kΩ<br>T <sub>min</sub> < T <sub>op</sub> < T <sub>max</sub> |          | 4    | 35<br>50          | mV      |
| 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   |                   | mA      |
|                                                                    |                                                                          | T <sub>min</sub> < T <sub>op</sub> < T <sub>max</sub>                           | 20       |      |                   |         |
| I <sub>CC</sub>                                                    | Supply current (per operator)                                            | 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                | μA      |
| AC performance                                                     |                                                                          |                                                                                 |          |      |                   |         |
| GBP                                                                | Gain bandwidth product                                                   | R <sub>L</sub> = 2 kΩ C <sub>L</sub> = 100 pF,<br>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    |

1. Guaranteed by design.

**Table 6. Electrical characteristics at  $V_{CC+} = +5\text{ V}$  with  $V_{CC-} = 0\text{ V}$ ,  $V_{icm} = V_{CC}/2$ ,  $T_{amb} = 25^\circ\text{C}$ , and  $R_L$  connected to  $V_{CC}/2$  (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               | mV    |
| 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      |      |                   |       |
| DV <sub>io</sub>                                                   | Input offset voltage drift                                                      |                                                                                 |          | 2    |                   | μV/°C |
| I <sub>io</sub>                                                    | Input offset current<br>(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               | pA    |
| I <sub>ib</sub>                                                    | Input bias current<br>(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               | pA    |
| 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       |      |                   | dB    |
| 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  |                   | dB    |
|                                                                    |                                                                                 | 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   |                   | dB    |
|                                                                    |                                                                                 | T <sub>min</sub> < T <sub>op</sub> < T <sub>max</sub>                           | 84       |      |                   | dB    |
| EMIRR                                                              | EMI Rejection Ratio<br>EMIRR = -20 log (V <sub>RFpeak</sub> /ΔV <sub>io</sub> ) | V <sub>RF</sub> = 100 mV <sub>rms</sub> , f = 400 MHz                           |          | 61   |                   | dB    |
|                                                                    |                                                                                 | 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                                                       | R <sub>L</sub> = 10 kΩ<br>T <sub>min</sub> < T <sub>op</sub> < T <sub>max</sub> | 35<br>50 | 7    |                   | mV    |
| V <sub>OL</sub>                                                    | Low level output voltage                                                        | R <sub>L</sub> = 10 kΩ<br>T <sub>min</sub> < T <sub>op</sub> < T <sub>max</sub> |          | 6    | 35<br>50          | mV    |
| 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   |                   | mA    |
|                                                                    |                                                                                 | T <sub>min</sub> < T <sub>op</sub> < T <sub>max</sub>                           | 35       |      |                   |       |
| I <sub>CC</sub>                                                    | Supply current (per operator)                                                   | 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                | μA    |
| 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  |                   | kHz   |

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

| Symbol     | Parameter                         | Conditions                                                                                                                       | Min. | Typ.     | Max. | Unit                                 |
|------------|-----------------------------------|----------------------------------------------------------------------------------------------------------------------------------|------|----------|------|--------------------------------------|
| $\phi_m$   | Phase margin                      | $R_L = 2\text{ k}\Omega$ $C_L = 100\text{ pF}$                                                                                   |      | 48       |      | Degrees                              |
| $G_m$      | 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/ $\mu\text{s}$                     |
| $e_n$      | Equivalent input noise voltage    | $f = 1\text{ kHz}$<br>$f = 10\text{ kHz}$                                                                                        |      | 60<br>33 |      | $\frac{\text{nV}}{\sqrt{\text{Hz}}}$ |
| 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    |      | %                                    |

1. Guaranteed by design.

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

| Symbol                | Parameter                                       | Conditions                                                                                 | Min. | Typ. | Max. | Unit          |
|-----------------------|-------------------------------------------------|--------------------------------------------------------------------------------------------|------|------|------|---------------|
| <b>DC performance</b> |                                                 |                                                                                            |      |      |      |               |
| $I_{CC}$              | Supply current in shutdown mode (all operators) | $\overline{\text{SHDN}} = V_{CC-}$                                                         |      | 5    | 50   | nA            |
|                       |                                                 | $T_{min} < T_{op} < 85^\circ\text{ C}$                                                     |      |      | 200  | nA            |
|                       |                                                 | $T_{min} < T_{op} < 125^\circ\text{ C}$                                                    |      |      | 1.5  | $\mu\text{A}$ |
| $t_{on}$              | Amplifier turn-on time                          | $R_L = 2\text{ k}\Omega$<br>$V_{out} = V_{CC-} - V$ to $V_{CC+} + 0.2\text{ V}$            |      | 200  |      | ns            |
| $t_{off}$             | Amplifier turn-off time                         | $R_L = 2\text{ k}\Omega$<br>$V_{out} = V_{CC+} - 0.5\text{ V}$ to $V_{CC+} - 0.7\text{ V}$ |      | 20   |      | ns            |
| $V_{IH}$              | $\overline{\text{SHDN}}$ logic high             |                                                                                            | 2    |      |      | V             |
| $V_{IL}$              | $\overline{\text{SHDN}}$ logic low              |                                                                                            |      |      | 0.8  | V             |
| $I_{IH}$              | $\overline{\text{SHDN}}$ current high           | $\overline{\text{SHDN}} = V_{CC+}$                                                         |      | 10   |      | pA            |
| $I_{IL}$              | $\overline{\text{SHDN}}$ current low            | $\overline{\text{SHDN}} = V_{CC-}$                                                         |      | 10   |      | pA            |
| $I_{OLeak}$           | Output leakage in shutdown mode                 | $\overline{\text{SHDN}} = V_{CC-}$                                                         |      | 50   |      | pA            |
|                       |                                                 | $T_{min} < T_{op} < 125^\circ\text{ C}$                                                    |      | 1    |      | nA            |

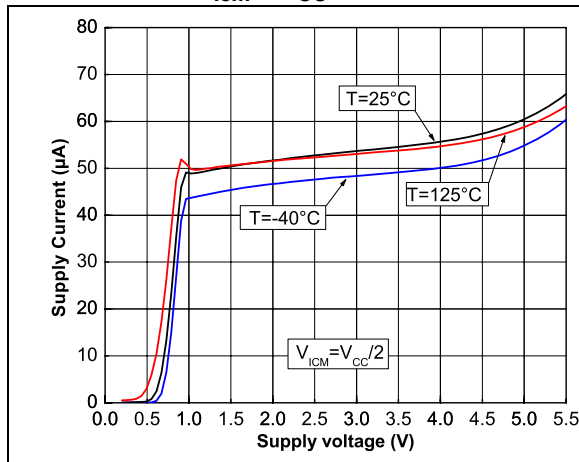
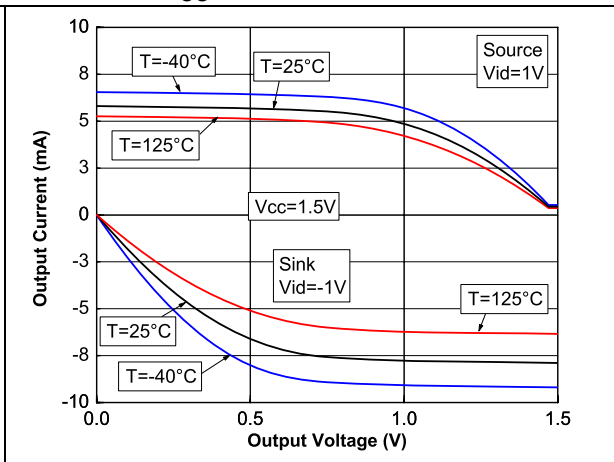
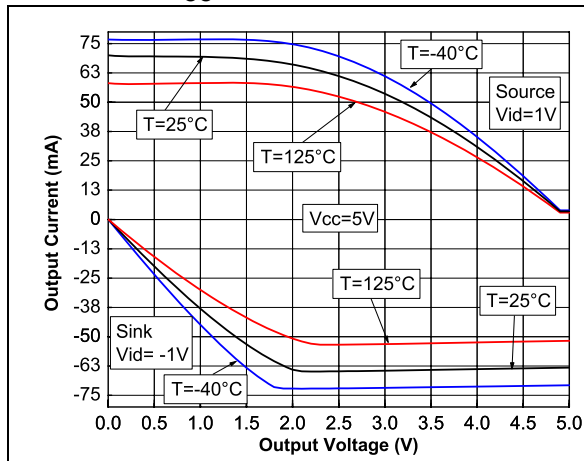
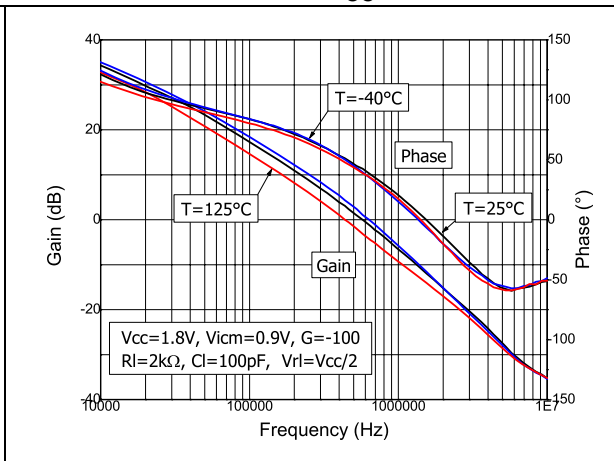
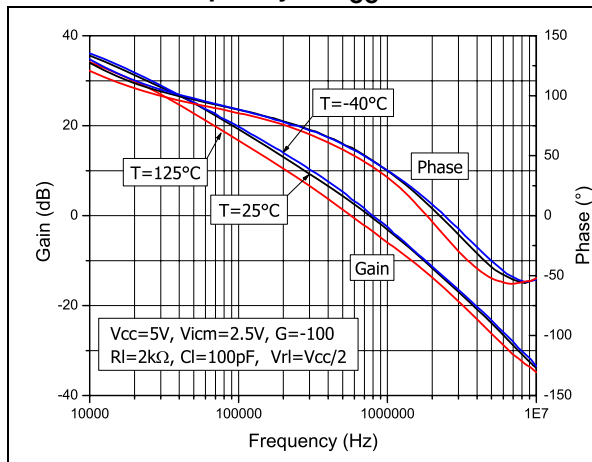
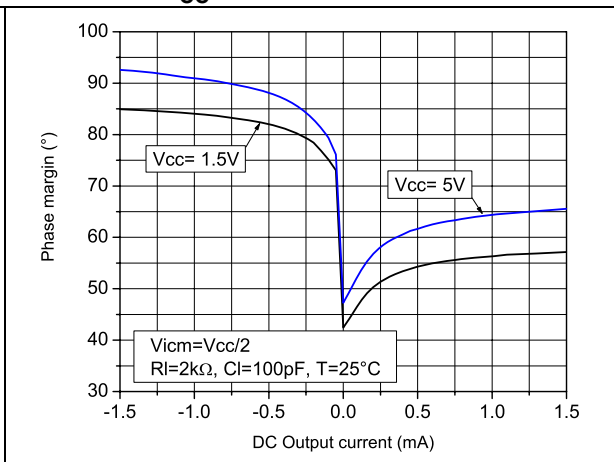
**Figure 2. Supply current vs. supply voltage at  $V_{icm} = V_{CC}/2$** **Figure 3. Output current vs. output voltage at  $V_{CC} = 1.5V$** **Figure 4. Output current vs. output voltage at  $V_{CC} = 5V$** **Figure 5. Voltage gain and phase vs. frequency at  $V_{CC} = 1.5V$** **Figure 6. Voltage gain and phase vs. frequency at  $V_{CC} = 5V$** **Figure 7. Phase margin vs. output current at  $V_{CC} = 5V$** 

Figure 8. Positive slew rate vs. time

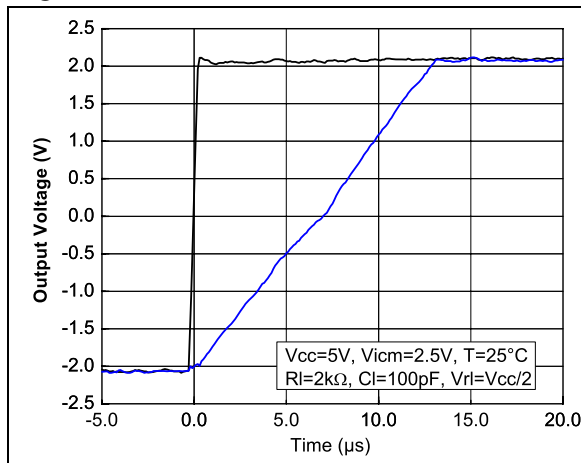


Figure 9. Negative slew rate vs. time

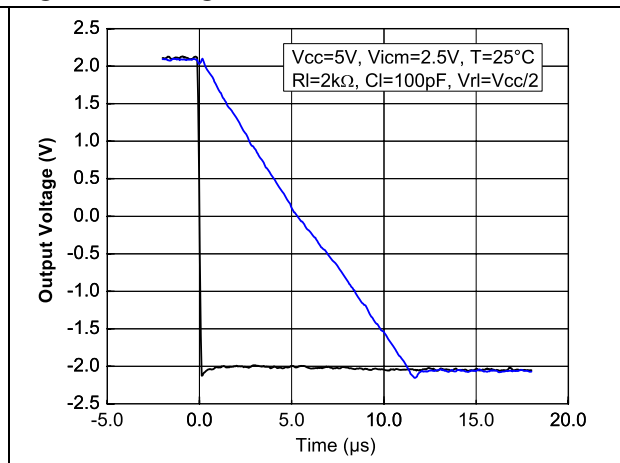


Figure 10. Positive slew rate vs. supply voltage

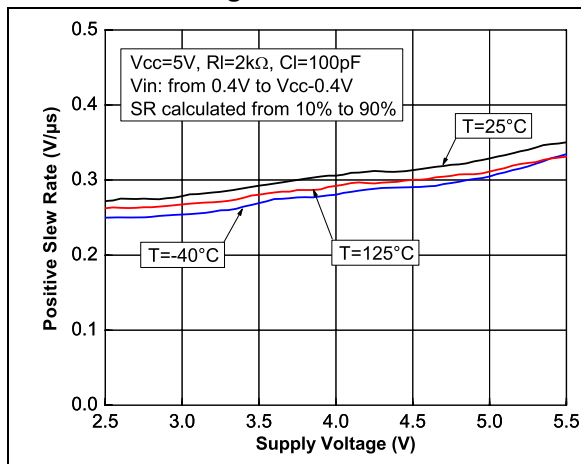


Figure 11. Negative slew rate vs. supply voltage

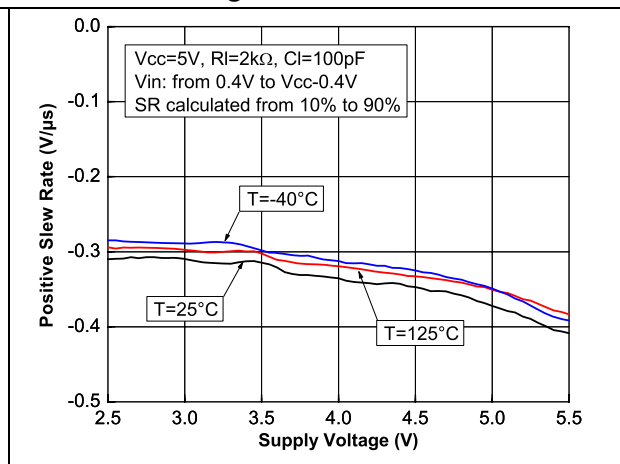


Figure 12. Distortion + noise vs. output voltage

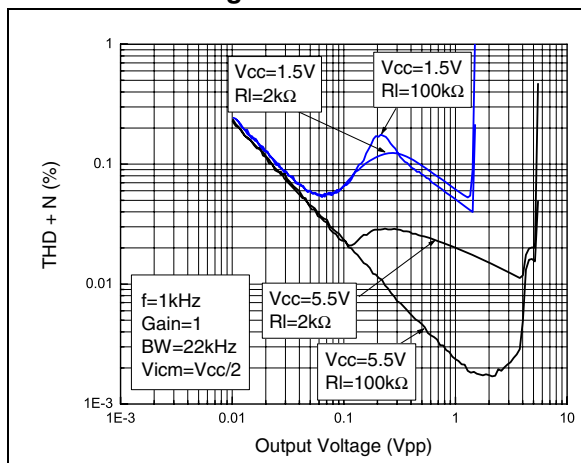


Figure 13. Distortion + noise vs. frequency

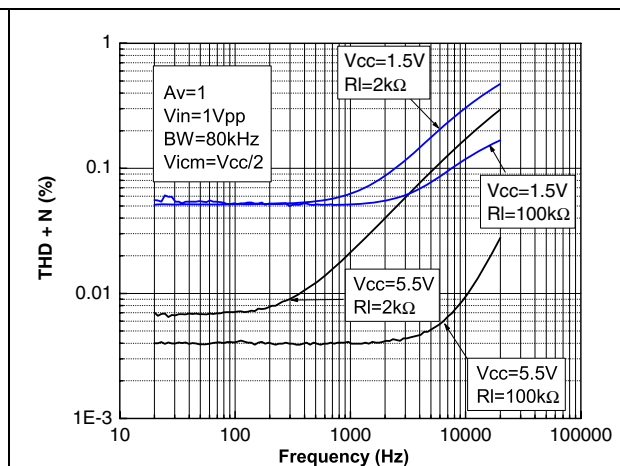


Figure 14. Noise vs. frequency

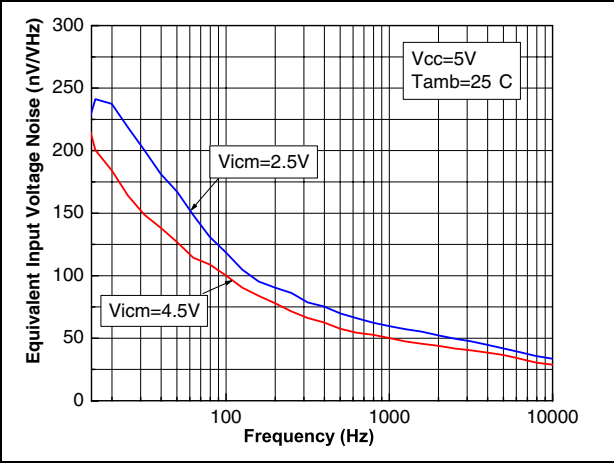
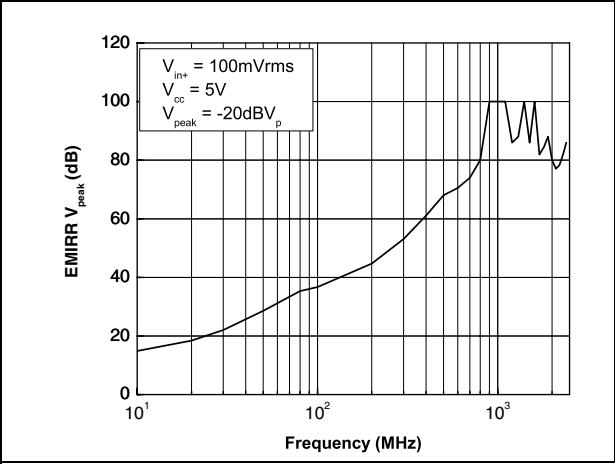


Figure 15. EMIRR vs. frequency at  $V_{cc} = 5V$ ,  $T = 25^{\circ}C$



## 4 Application information

### 4.1 Operating voltages

The TSV63x can operate from 1.5 to 5.5 V. Their parameters are fully specified for 1.8-, 3.3- and 5-V power supplies. However, the parameters are very stable in the full  $V_{CC}$  range and several characterization curves show the TSV63x 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 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 at  $V_{CC} = 1.5\text{ V}$

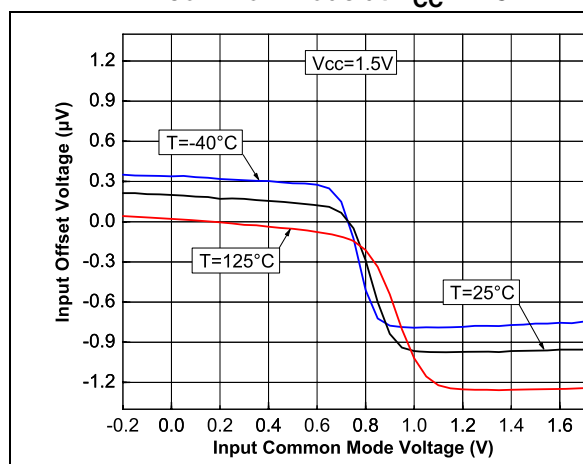
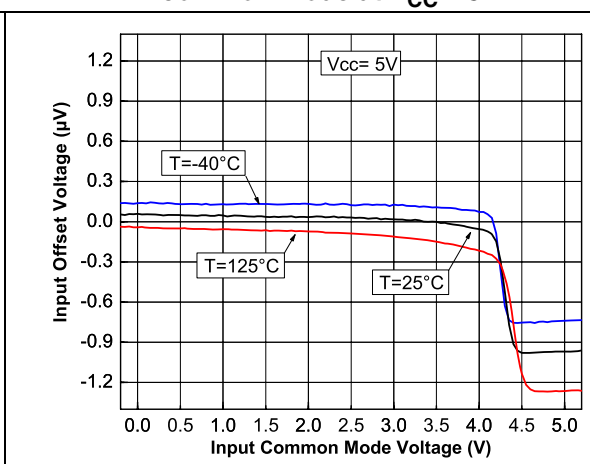


Figure 17. Input offset voltage vs input common mode at  $V_{CC} = 5\text{ V}$



The devices are guaranteed without phase reversal.

### 4.3 Rail-to-rail output

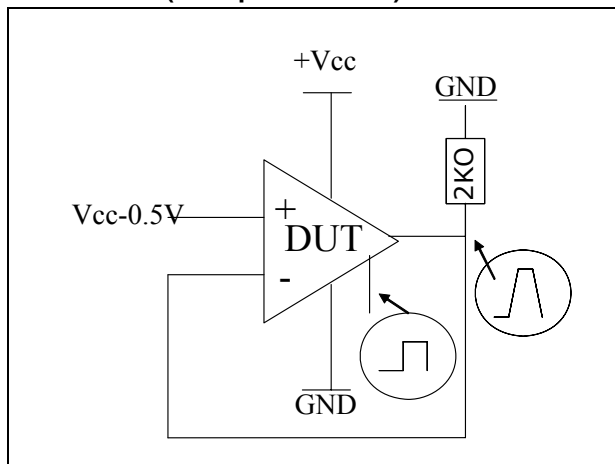
The operational amplifiers' output levels can go close to the rails: 35 mV maximum above and below the rail when connected to a  $10\text{ k}\Omega$  resistive load to  $V_{CC}/2$ .

### 4.4 Shutdown function (TSV633 - TSV635)

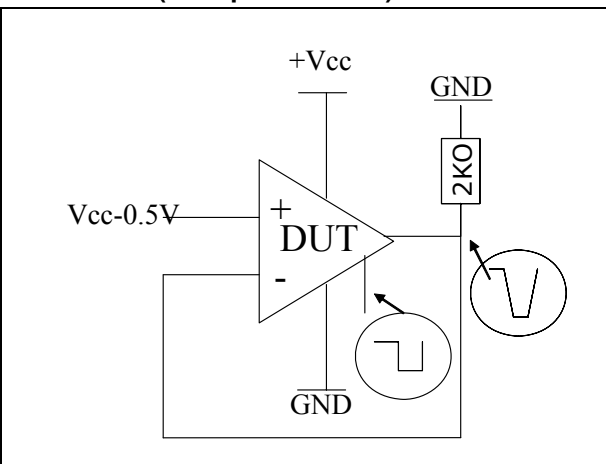
The operational amplifiers are enabled when the  $\overline{\text{SHDN}}$  pin is pulled high. To disable the amplifiers, the  $\overline{\text{SHDN}}$  must be pulled down to  $V_{CC-}$ . When in shutdown mode, the amplifiers' output is in a high impedance state. The  $\overline{\text{SHDN}}$  pin must 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).

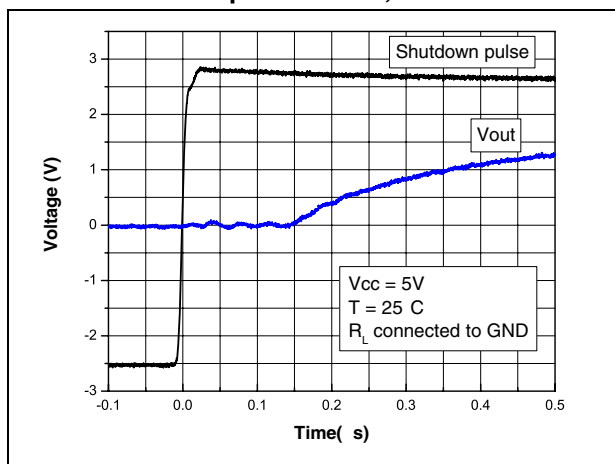
**Figure 18. Test configuration for turn-on time**  
(Vout pulled down)



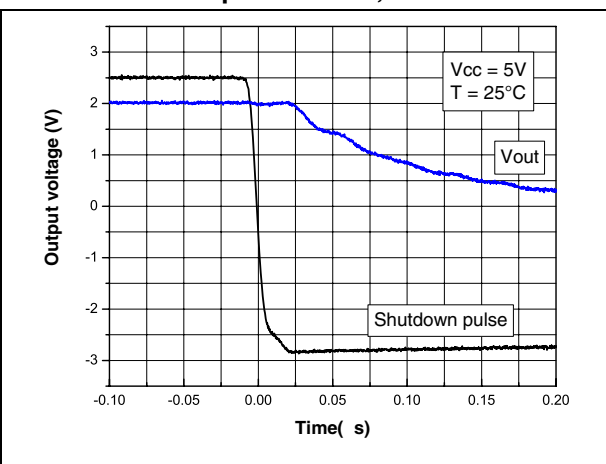
**Figure 19. Test configuration for turn-off time**  
(Vout pulled down)



**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

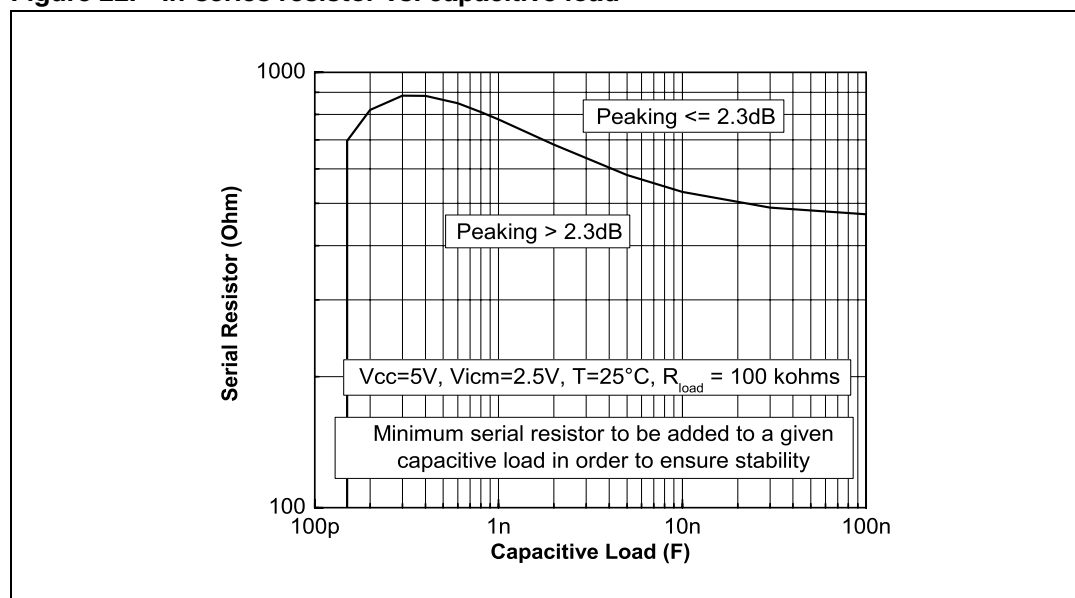
These devices use an innovative approach to reduce the spread of the main DC and AC parameters. An internal adjustment achieves a very narrow spread of the current consumption (60  $\mu$ A typical, min/max at  $\pm 17\%$ ). Parameters linked to the current consumption value, such as GBP, SR and AVd, 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/ $\mu$ s minimum).

## 4.6 Driving resistive and capacitive loads

These products are micro-power, 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 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 shutdown feature) of the TSV63x is available on STMicroelectronics' web site at [www.st.com](http://www.st.com). This model is a trade-off between accuracy and complexity (that is, time simulation) of the TSV63x operational amplifiers. It emulates the nominal performances of a typical device within the specified operating conditions mentioned in the datasheet. It also helps to validate a design approach and to select the right operational amplifier, *but it does 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 SOT23-8 package information

Figure 23. SOT23-8 package mechanical drawing

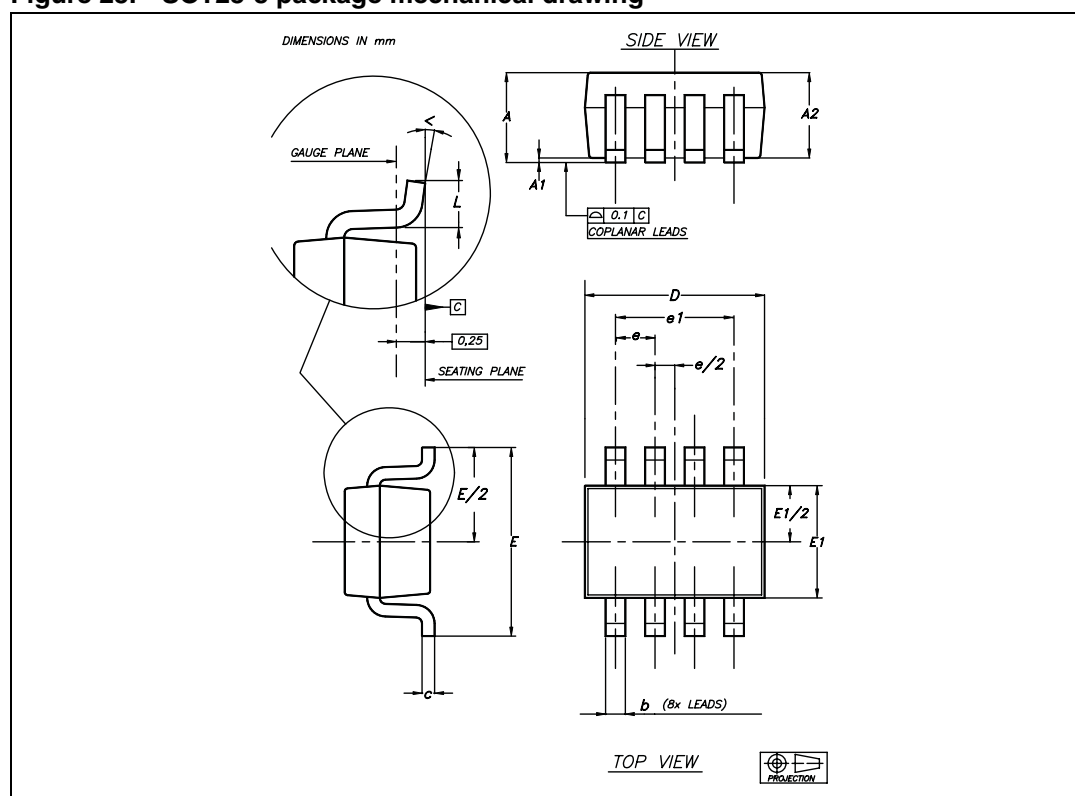


Table 8. SOT23-8 package mechanical data

| 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    | 0.110  |       | 0.118 |
| E    | 2.60        |      | 3    | 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°   |        |       |       |

## 5.2 SO-8 package information

Figure 24. SO-8 package mechanical drawing

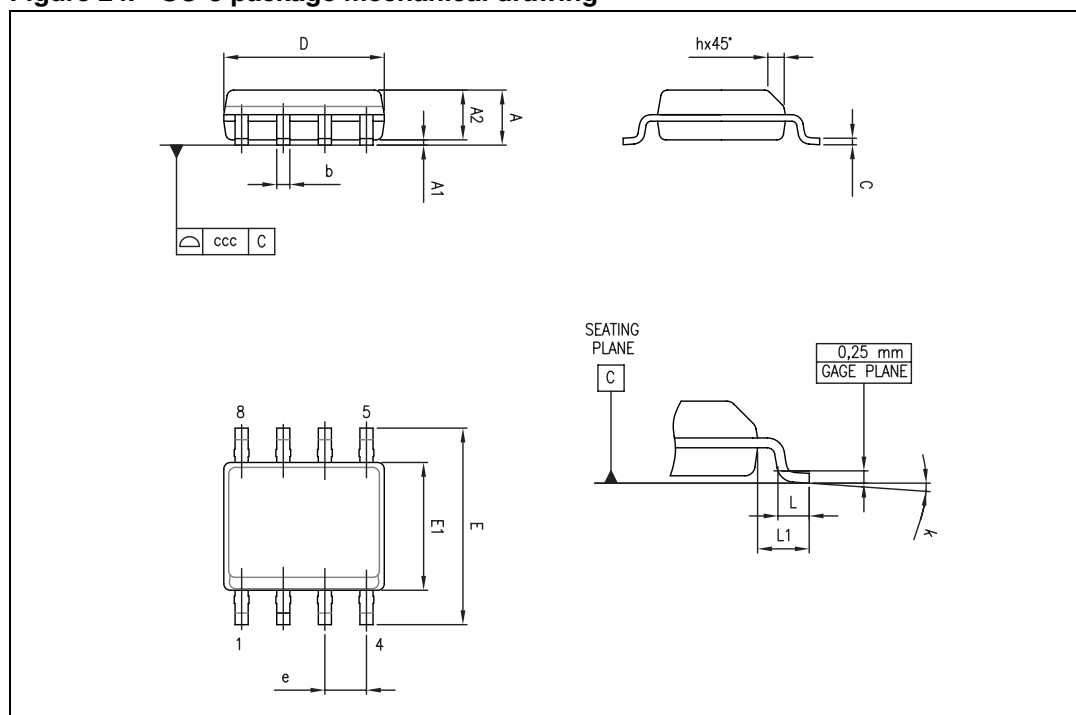


Table 9. SO-8 package mechanical data

| 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    | 0           |      | 8°   | 1°     |       | 8°    |
| ccc  |             |      | 0.10 |        |       | 0.004 |

### 5.3 MiniSO-8 package information

Figure 25. MiniSO-8 package mechanical drawing

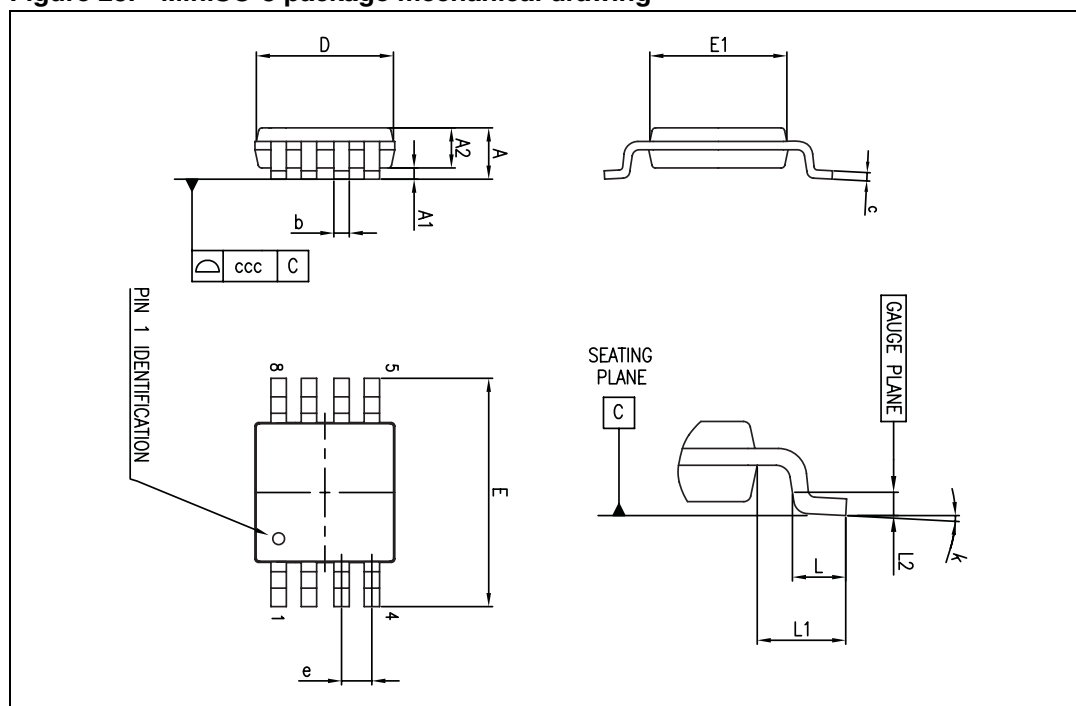


Table 10. MiniSO-8 package mechanical data

| 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 MiniSO-10 package information

Figure 26. MiniSO-10 package mechanical drawing

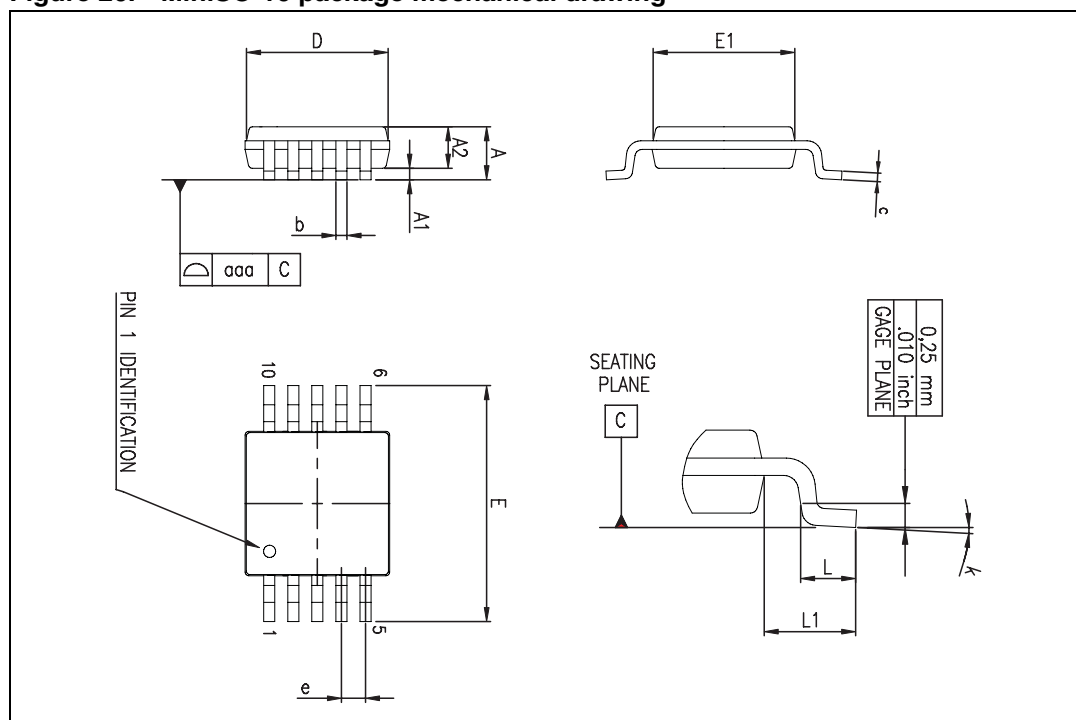


Table 11. MiniSO-10 package mechanical data

| 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 TSSOP14 package information

Figure 27. TSSOP14 package mechanical drawing

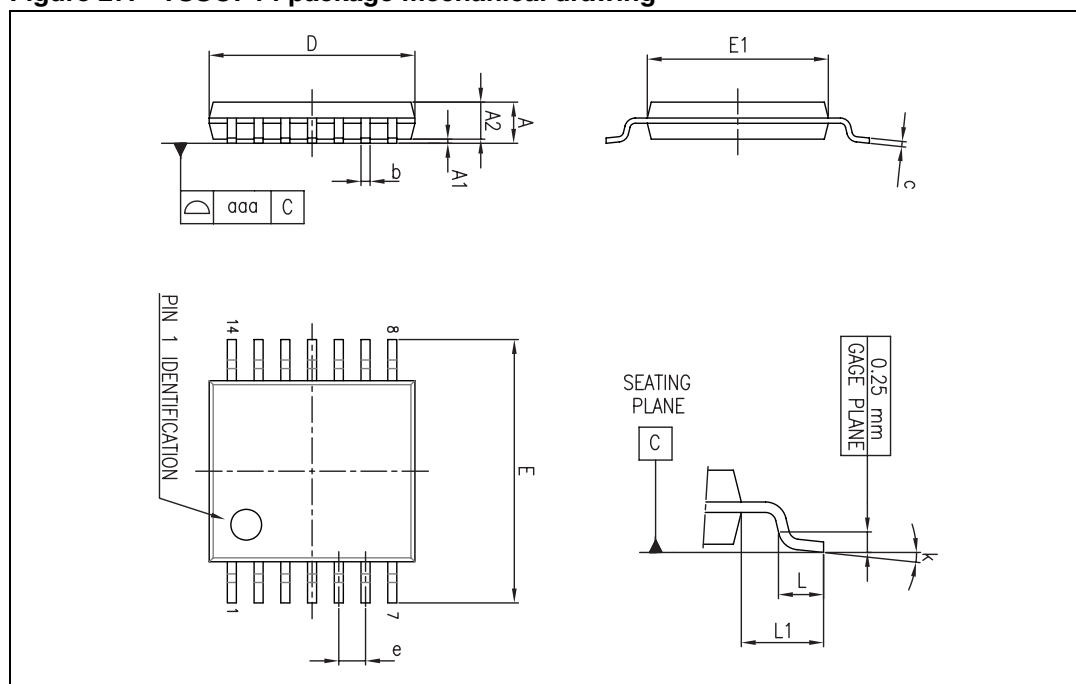


Table 12. TSSOP14 package mechanical data

| 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  |

## 5.6 TSSOP16 package information

Figure 28. TSSOP16 package mechanical drawing

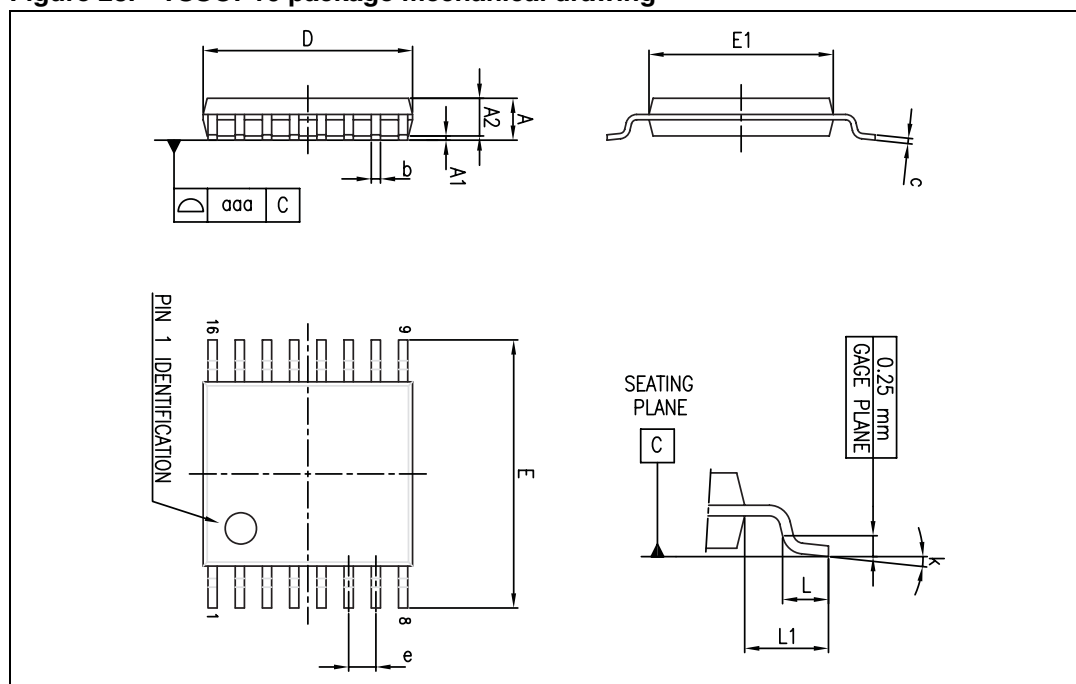


Table 13. TSSOP16 package mechanical data

| 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 |

## 6 Ordering information

**Table 14. Order codes**

| Order code   | Temperature range | Package   | Packing              | Marking |
|--------------|-------------------|-----------|----------------------|---------|
| TSV632ID/DT  | -40° C to +125° C | SO-8      | Tube and tape & reel | TSV632  |
| TSV632AID/DT |                   |           |                      | TV632A  |
| TSV632IST    |                   | MiniSO-8  | Tape & reel          | K110    |
| TSV632AIST   |                   |           |                      | K145    |
| TSV632ILT    |                   | SOT23-8   | Tape & reel          | K110    |
| TSV633IST    |                   | MiniSO-10 | Tape & reel          | K111    |
| TSV633AIST   |                   |           |                      | K146    |
| TSV634IPT    |                   | TSSOP-14  | Tape & reel          | TSV634  |
| TSV634AIPT   |                   |           |                      | TSV634A |
| TSV635IPT    |                   | TSSOP-16  | Tape & reel          | TSV635  |
| TSV635AIPT   |                   |           |                      | TSV635A |

## 7 Revision history

**Table 15. Document revision history**

| Date        | Revision | Changes          |
|-------------|----------|------------------|
| 25-May-2009 | 1        | Initial release. |

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