



# TSV6390, TSV6390A, TSV6391, TSV6391A

Micropower (60  $\mu$ A), wide bandwidth (2.4 MHz) CMOS op-amps

## Features

- Low offset voltage: 500  $\mu$ V max (A version)
- Low power consumption: 60  $\mu$ A typ at 5 V
- Low supply voltage: 1.5 V – 5.5 V
- Gain bandwidth product: 2.4 MHz typical
- Stable in gain configuration (-3 or +4)
- Low power shutdown mode: 5 nA typical
- High output current: 63 mA at  $V_{CC} = 5$  V
- Low input bias current: 1 pA typical
- Rail-to-rail input and output
- Extended temperature range: -40°C to +125°C
- 4 kV human body model

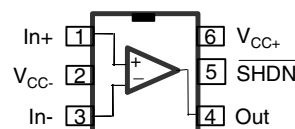
## Applications

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

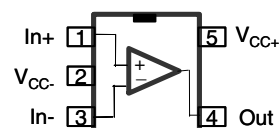
## Description

The TSV6390 and TSV6391 devices are single operational amplifiers offering low voltage, low power operation and rail-to-rail input and output.

With a very low input bias current and low offset voltage (500  $\mu$ V maximum for the A version), the TSV6390 and TSV6391 are ideal for applications requiring precision. The devices can operate at power supplies ranging from 1.5 to 5.5 V, and are therefore ideal for battery-powered devices, extending battery life.



**TSV6390ICT/ILT**  
**SC70-6/SOT23-6**



**TSV6391ICT/ILT**  
**SC70-5/SOT23-5**

When used with a gain (above -3 or +4), these products feature an excellent speed/power consumption ratio, offering a 2.4 MHz gain bandwidth product while consuming only 60  $\mu$ A at a 5 V supply voltage.

The TSV6390 comes with a shutdown function.

Both the TSV6390 and TSV6391 have a high tolerance to ESD, sustaining 4 kV for the human body model.

Additionally, they are offered in micropackages, SC70-6 and SOT23-6 for the TSV6390 and SC70-5 and SOT23-5 for the TSV6391. They are guaranteed for industrial temperature ranges from -40° C to +125° C.

All these features combined make the TSV6390 and TSV6391 ideal for sensor interfaces, battery-supplied and portable applications, as well as active filtering.

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# 1 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>SC70-5<br>SOT23-5<br>SOT23-6<br>SC70-6 | 205<br>250<br>240<br>232          | °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 voltages, 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 6 V.
4. Input current must be limited by a resistor in series with the inputs.
5. Short-circuits can cause excessive heating and destructive dissipation.
6.  $R_{th}$  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 capacitor 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   |

## 2 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                                                                 | TSV6390-TSV6391<br>TSV6390A-TSV6391A                                                          |      |          | 3<br>0.5 | mV                     |
|                  |                                                                                | T <sub>min</sub> < T <sub>op</sub> < T <sub>max</sub><br>TSV6390-TSV6391<br>TSV6390A-TSV6391A |      |          | 4.5<br>2 |                        |
| DV <sub>io</sub> | Input offset voltage drift                                                     |                                                                                               |      | 2        |          | μV/°C                  |
| I <sub>io</sub>  | Input offset current <sup>(1)</sup><br>(V <sub>out</sub> = V <sub>CC</sub> /2) |                                                                                               |      | 1        | 10       | pA                     |
|                  |                                                                                | T <sub>min</sub> < T <sub>op</sub> < T <sub>max</sub>                                         |      | 1        | 100      |                        |
| I <sub>ib</sub>  | Input bias current <sup>(1)</sup><br>(V <sub>out</sub> = V <sub>CC</sub> /2)   |                                                                                               |      | 1        | 10       | pA                     |
|                  |                                                                                | T <sub>min</sub> < T <sub>op</sub> < T <sub>max</sub>                                         |      | 1        | 100      |                        |
| CMR              | Common mode rejection ratio<br>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       |          | dB                     |
|                  |                                                                                | T <sub>min</sub> < T <sub>op</sub> < T <sub>max</sub>                                         | 80   |          |          |                        |
| V <sub>OH</sub>  | High level output voltage                                                      | R <sub>L</sub> = 10 kΩ                                                                        | 35   | 5        |          | 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       | mV                     |
|                  |                                                                                | T <sub>min</sub> < T <sub>op</sub> < T <sub>max</sub>                                         |      |          | 50       |                        |
| I <sub>out</sub> | I <sub>sink</sub>                                                              | V <sub>out</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>out</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<br>SHDN = V <sub>CC</sub>                                       | 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> = 10 kΩ, C <sub>L</sub> = 100 pF                                               |      | 2        |          | MHz                    |
| Gain             | Minimum gain for stability                                                     | Phase margin = 60°, R <sub>f</sub> = 10 kΩ,<br>R <sub>L</sub> = 10 kΩ, C <sub>L</sub> = 20 pF |      | +4<br>-3 |          | V/V                    |
| SR               | Slew rate                                                                      | R <sub>L</sub> = 10 kΩ, C <sub>L</sub> = 100 pF,<br>V <sub>out</sub> = 0.5 V to 1.3 V         |      | 0.7      |          | V/μs                   |
| e <sub>n</sub>   | Equivalent input noise voltage                                                 | f = 1 kHz<br>f = 10 kHz                                                                       |      | 60<br>33 |          | $\frac{nV}{\sqrt{Hz}}$ |

1. Guaranteed by design.

Table 4. Shutdown characteristics  $V_{CC} = 1.8\text{ V}$  (TSV6390)

| 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>$V_{\text{out}} = V_{CC-} \text{ to } V_{CC-} + 0.2\text{ V}$      |      | 300  |      | ns            |
| $t_{\text{off}}$      | Amplifier turn-off time                         | $R_L = 2\text{ k}\Omega$ $V_{\text{out}} = V_{CC+} - 0.5\text{ V}$ to $V_{CC+} - 0.7\text{ V}$ |      | 20   |      | ns            |
| $V_{\text{IH}}$       | $\overline{\text{SHDN}}$ logic high             |                                                                                                | 1.3  |      |      | V             |
| $V_{\text{IL}}$       | $\overline{\text{SHDN}}$ logic low              |                                                                                                |      |      | 0.5  | V             |
| $I_{\text{IH}}$       | $\overline{\text{SHDN}}$ current high           | $\overline{\text{SHDN}} = V_{CC+}$                                                             |      | 10   |      | pA            |
| $I_{\text{IL}}$       | $\overline{\text{SHDN}}$ current low            | $\overline{\text{SHDN}} = V_{CC-}$                                                             |      | 10   |      | pA            |
| $I_{\text{OLeak}}$    | Output leakage in shutdown mode                 | $\overline{\text{SHDN}} = V_{CC-}$                                                             |      | 50   |      | pA            |
|                       |                                                 | $T_{\min} < T_{\text{op}} < T_{\max}$                                                          |      | 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                                                           | TSV6390-TSV6391<br>TSV6390A-TSV6391A                                                          |      |          | 3<br>0.5 | mV                     |
|                  |                                                                          | T <sub>min</sub> < T <sub>op</sub> < T <sub>max</sub><br>TSV6390-TSV6391<br>TSV6390A-TSV6391A |      |          | 4.5<br>2 |                        |
|                  |                                                                          |                                                                                               |      |          |          |                        |
| DV <sub>io</sub> | Input offset voltage drift                                               |                                                                                               |      | 2        |          | μV/°C                  |
| I <sub>io</sub>  | Input offset current <sup>(1)</sup>                                      |                                                                                               |      | 1        | 10       | pA                     |
|                  |                                                                          | T <sub>min</sub> < T <sub>op</sub> < T <sub>max</sub>                                         |      | 1        | 100      |                        |
| I <sub>ib</sub>  | Input bias current <sup>(1)</sup>                                        |                                                                                               |      | 1        | 10       | pA                     |
|                  |                                                                          | 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       |          | 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                                                                        | 35   | 6        |          | 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                                                                        |      | 7        | 35       | mV                     |
|                  |                                                                          | T <sub>min</sub> < T <sub>op</sub> < T <sub>max</sub>                                         |      |          | 50       |                        |
| I <sub>out</sub> | I <sub>sink</sub>                                                        | V <sub>out</sub> = 3.3 V                                                                      | 23   | 45       |          | mA                     |
|                  |                                                                          | T <sub>min</sub> < T <sub>op</sub> < T <sub>max</sub>                                         | 20   | 42       |          |                        |
|                  | I <sub>source</sub>                                                      | V <sub>out</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<br>SHDN = V <sub>CC</sub>                                 | No load, V <sub>out</sub> = V <sub>CC</sub> /2                                                | 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> = 10 kΩ C <sub>L</sub> = 100 pF                                                |      | 2.2      |          | MHz                    |
| Gain             | Minimum gain for stability                                               | Phase margin = 60°, R <sub>f</sub> = 10 kΩ,<br>R <sub>L</sub> = 10 kΩ C <sub>L</sub> = 20 pF, |      | +4<br>-3 |          | V/V                    |
| SR               | Slew rate                                                                | R <sub>L</sub> = 10 kΩ, C <sub>L</sub> = 100 pF,<br>V <sub>out</sub> = 0.5 V to 2.8 V         |      | 0.9      |          | V/μs                   |
| e <sub>n</sub>   | Equivalent input noise voltage                                           | f = 1 kHz                                                                                     |      | 65       |          | $\frac{nV}{\sqrt{Hz}}$ |

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 voltage                                                                 | TSV6390-TSV6391<br>TSV6390A-TSV6391A                                                           |      |          | 3<br>0.5 | mV    |
|                  |                                                                                | T <sub>min</sub> < T <sub>op</sub> < T <sub>max</sub><br>TSV6390-TSV6391<br>TSV6390A-TSV6391A  |      |          | 4.5<br>2 | mV    |
| DV <sub>io</sub> | Input offset voltage drift                                                     |                                                                                                |      | 2        |          | μV/°C |
| I <sub>io</sub>  | Input offset current <sup>(1)</sup><br>(V <sub>out</sub> = V <sub>CC</sub> /2) |                                                                                                |      | 1        | 10       | pA    |
|                  |                                                                                | T <sub>min</sub> < T <sub>op</sub> < T <sub>max</sub>                                          |      | 1        | 100      |       |
| I <sub>ib</sub>  | Input bias current <sup>(1)</sup><br>(V <sub>out</sub> = V <sub>CC</sub> /2)   |                                                                                                |      | 1        | 10       | pA    |
|                  |                                                                                | T <sub>min</sub> < T <sub>op</sub> < T <sub>max</sub>                                          |      | 1        | 100      |       |
| CMR              | Common mode rejection ratio<br>20 log (ΔV <sub>io</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<br>20 log (ΔV <sub>CC</sub> /ΔV <sub>io</sub> ) | V <sub>CC</sub> = 1.8 to 5 V                                                                   | 75   | 93       |          | 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   |          |          |       |
| V <sub>OH</sub>  | High level output voltage                                                      | R <sub>L</sub> = 10 kΩ                                                                         | 35   | 7        |          | 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       | mV    |
|                  |                                                                                | T <sub>min</sub> < T <sub>op</sub> < T <sub>max</sub>                                          |      |          | 50       |       |
| I <sub>out</sub> | I <sub>sink</sub>                                                              | V <sub>out</sub> = 5 V                                                                         | 40   | 65       |          | mA    |
|                  |                                                                                | T <sub>min</sub> < T <sub>op</sub> < T <sub>max</sub>                                          | 35   |          |          |       |
|                  | I <sub>source</sub>                                                            | V <sub>out</sub> = 0 V                                                                         | 40   | 72       |          | mA    |
|                  |                                                                                | T <sub>min</sub> < T <sub>op</sub> < T <sub>max</sub>                                          | 35   |          |          |       |
| I <sub>CC</sub>  | Supply current<br>SHDN = V <sub>CC</sub>                                       | 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> = 10 kΩ, C <sub>L</sub> = 100 pF                                                |      | 2.4      |          | MHz   |
| Gain             | Minimum gain for stability                                                     | Phase margin = 60°, R <sub>f</sub> = 10 kΩ,<br>R <sub>L</sub> = 10 kΩ, C <sub>L</sub> = 20 pF, |      | +4<br>-3 |          | V/V   |
| SR               | Slew rate                                                                      | R <sub>L</sub> = 10 kΩ, C <sub>L</sub> = 100 pF                                                |      | 1.1      |          | V/μs  |

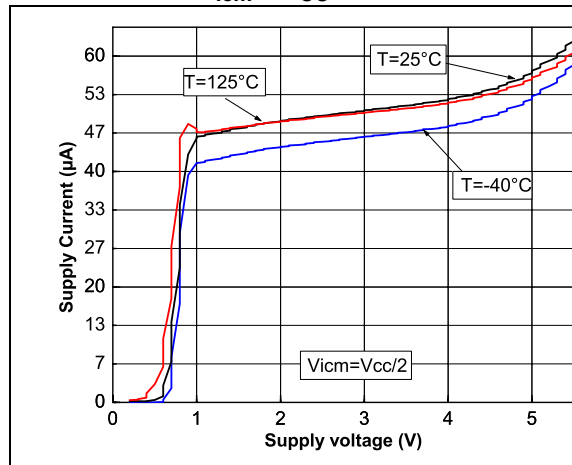
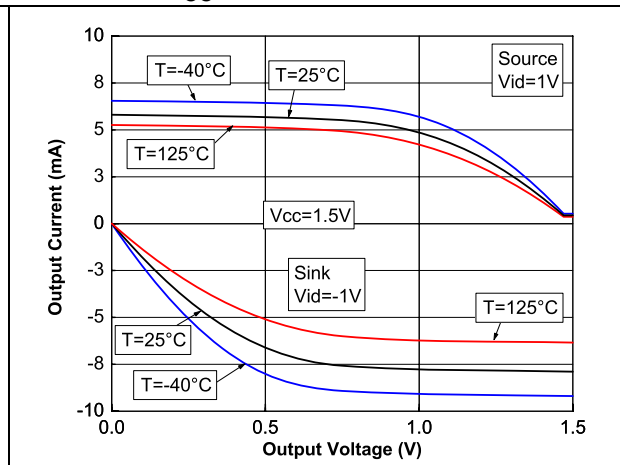
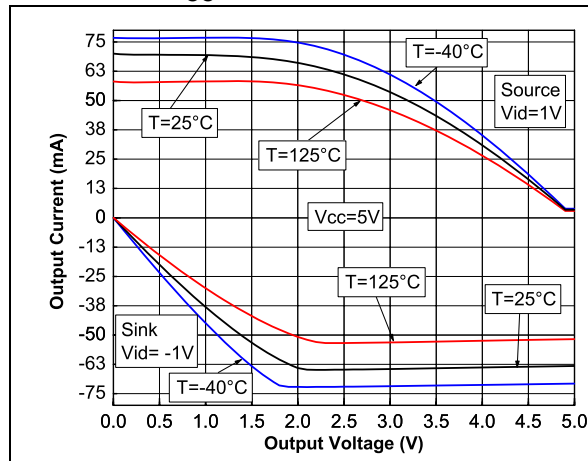
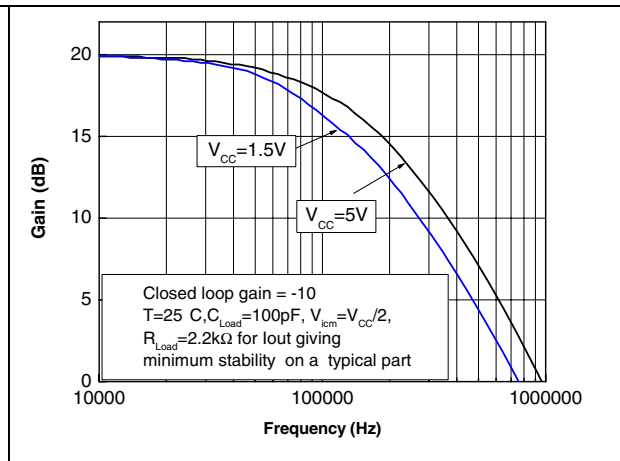
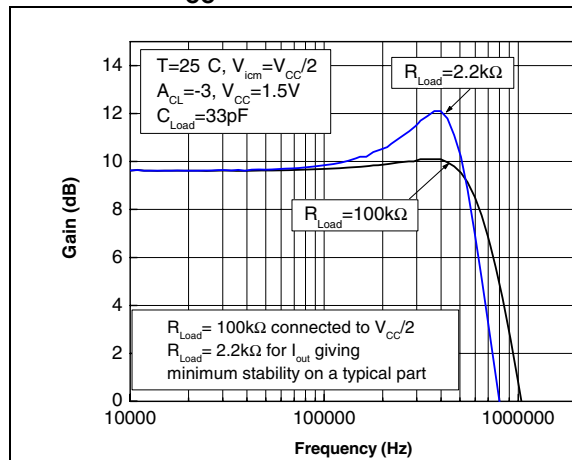
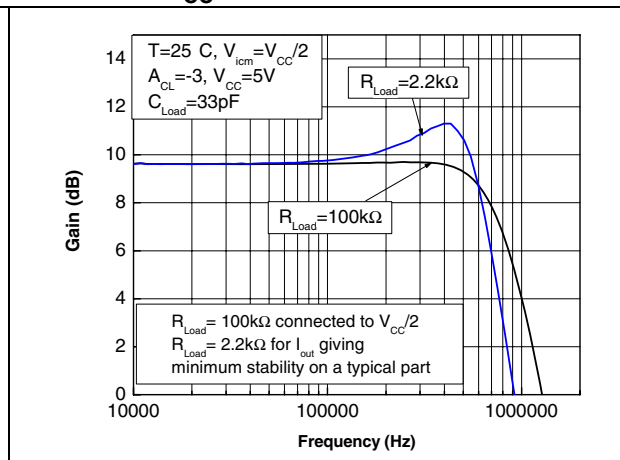
**Table 6. Electrical characteristics at  $V_{CC+} = +5\text{ V}$  with  $V_{CC-} = 0\text{ V}$ ,  $V_{icm} = V_{CC}/2$ ,  $T_{amb} = 25^\circ\text{ C}$  and  $R_L$  connected to  $V_{CC}/2$  (unless otherwise specified) (continued)**

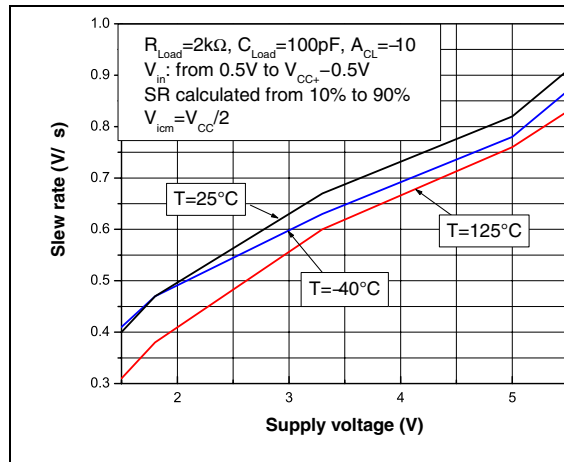
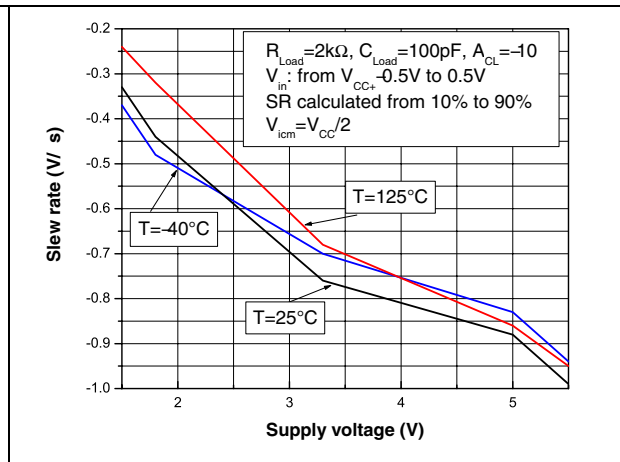
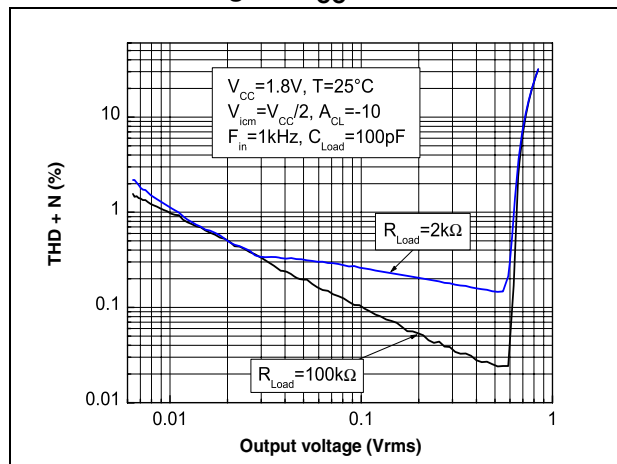
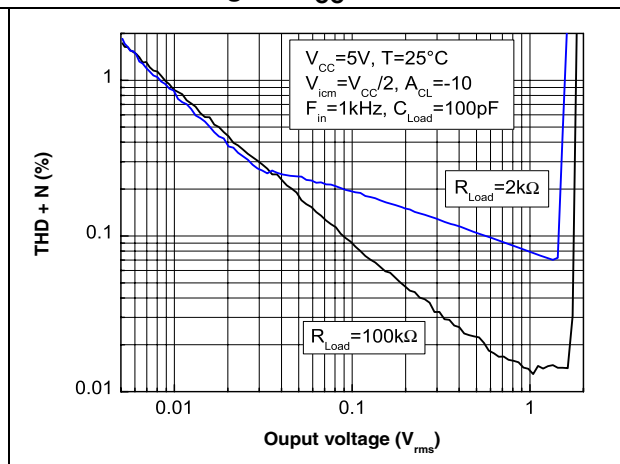
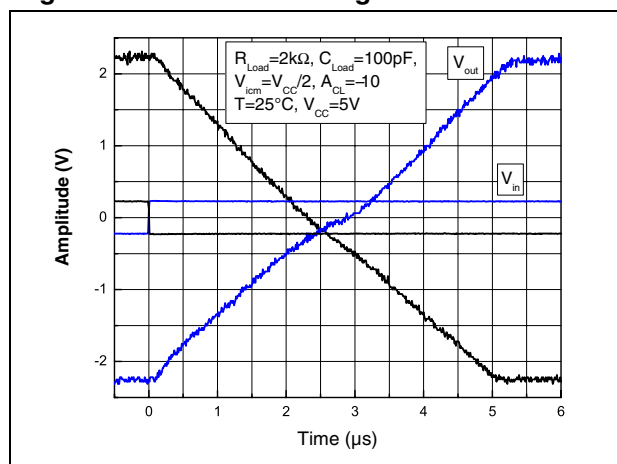
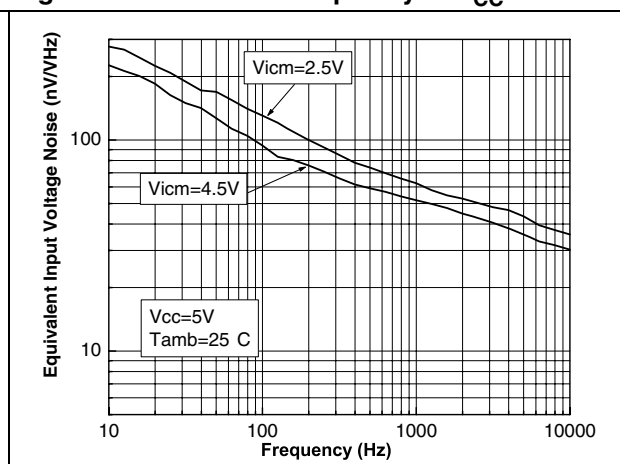
| Symbol | Parameter                         | Conditions                                                                                                             | Min. | Typ.     | Max. | Unit                                 |
|--------|-----------------------------------|------------------------------------------------------------------------------------------------------------------------|------|----------|------|--------------------------------------|
| $e_n$  | Equivalent input noise voltage    | $f = 1\text{ kHz}$<br>$f = 10\text{ kHz}$                                                                              |      | 60<br>33 |      | $\frac{\text{nV}}{\sqrt{\text{Hz}}}$ |
| THD+N  | Total harmonic distortion + noise | $A_v = -10$ , $f_{in} = 1\text{ kHz}$ , $R = 100\text{ k}\Omega$ ,<br>$V_{icm} = V_{CC}/2$ , $V_{in} = 40\text{ mVpp}$ |      | 0.11     |      | %                                    |

1. Guaranteed by design.

**Table 7. Shutdown characteristics  $V_{CC} = 5\text{ V}$  (TSV6390)**

| 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>$V_{out} = V_{CC-}$ to $V_{CC+} + 0.2\text{ V}$               |      | 300  |      | ns            |
| $t_{off}$             | Amplifier turn-off time                         | $R_L = 2\text{ k}\Omega$ , $V_{out} = V_{CC+} - 0.5\text{ V}$ to $V_{CC+} - 0.7\text{ V}$ |      | 30   |      | ns            |
| $V_{IH}$              | $\overline{\text{SHDN}}$ logic high             |                                                                                           | 4.5  |      |      | V             |
| $V_{IL}$              | $\overline{\text{SHDN}}$ logic low              |                                                                                           |      |      | 0.5  | 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            |
|                       |                                                 | $T_{min} < T_{op} < T_{max}$                                                              |      | 1    |      | nA            |

**Figure 1. Supply current vs. supply voltage at  $V_{icm} = V_{CC}/2$** **Figure 2. Output current vs. output voltage at  $V_{CC} = 1.5V$** **Figure 3. Output current vs. output voltage at  $V_{CC} = 5V$** **Figure 4. Peaking at closed loop gain = -10****Figure 5. Peaking at closed loop gain = -3 at  $V_{CC} = 1.5V$** **Figure 6. Peaking at closed loop gain = -3 at  $V_{CC} = 5V$** 

**Figure 7. Positive slew rate vs. supply voltage****Figure 8. Negative slew rate vs. supply voltage****Figure 9. Distortion + noise vs. output voltage at  $V_{CC} = 1.8\text{ V}$** **Figure 10. Distortion + noise vs. output voltage at  $V_{CC} = 5\text{ V}$** **Figure 11. Slew rate timing****Figure 12. Noise vs. frequency at  $V_{CC} = 5\text{ V}$** 

## 3 Application information

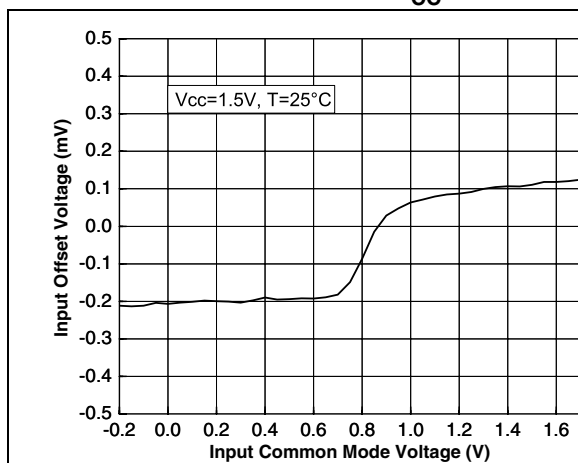
### 3.1 Operating voltages

The TSV6390 and TSV6391 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 TSV639x characteristics at 1.5 V. Additionally, the main specifications are guaranteed in extended temperature ranges from  $-40^{\circ}\text{C}$  to  $+125^{\circ}\text{C}$ .

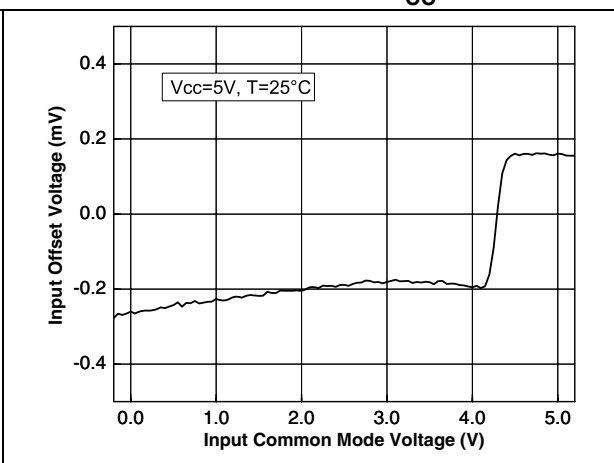
### 3.2 Rail-to-rail input

The TSV6390 and TSV6391 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,  $V_{io}$  and THD is slightly degraded (as shown in [Figure 13](#) and [Figure 14](#) for  $V_{io}$  vs.  $V_{icm}$ ).

**Figure 13. Input offset voltage vs input common mode at  $V_{CC} = 1.5\text{ V}$**



**Figure 14. Input offset voltage vs input common mode at  $V_{CC} = 5\text{ V}$**



The devices are guaranteed without phase reversal.

### 3.3 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 k $\Omega$  resistive load to  $V_{CC}/2$ .

### 3.4 Shutdown function (TSV6390)

The operational amplifier is enabled when the  $\overline{\text{SHDN}}$  pin is pulled high. To disable the amplifier, the  $\overline{\text{SHDN}}$  must be pulled down to  $V_{CC-}$ . When in shutdown mode, the amplifier's 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 15 and Figure 16 show the test configurations).

Figure 15. Test configuration for turn-on time (Vout pulled down)      Figure 16. Test configuration for turn-off time (Vout pulled down)

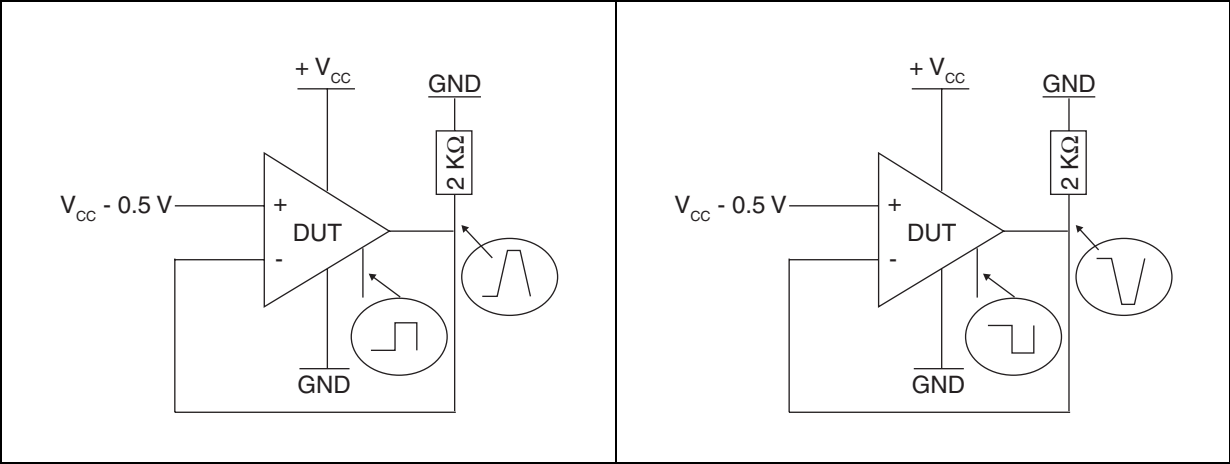
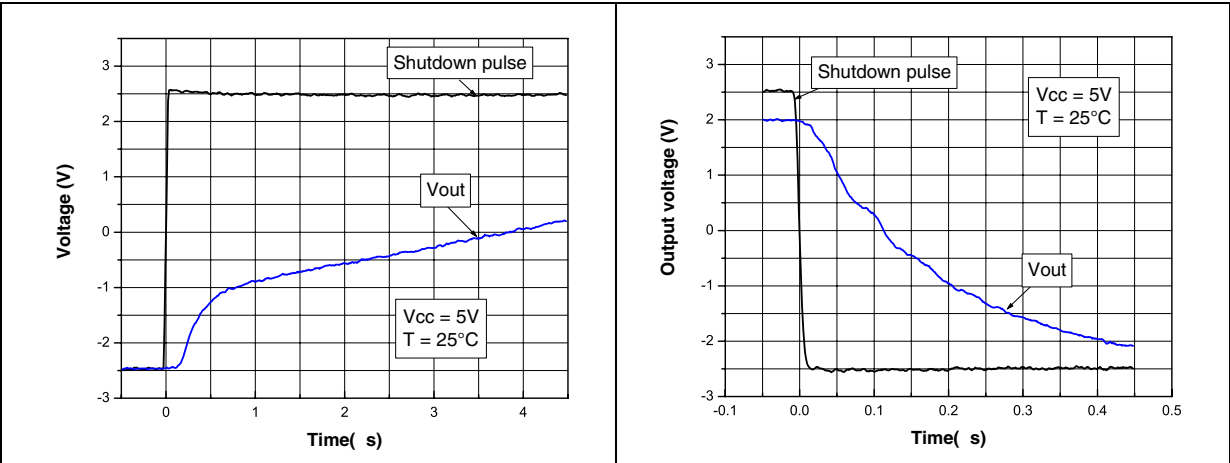


Figure 17. Turn-on time,  $V_{CC} = 5$  V,  $V_{out}$  pulled down,  $T = 25^\circ\text{C}$       Figure 18. Turn-off time,  $V_{CC} = 5$  V,  $V_{out}$  pulled down,  $T = 25^\circ\text{C}$



### 3.5 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  $A_{Vd}$ , benefit from this narrow dispersion.

### 3.6 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.

These operational amplifiers have a relatively low internal compensation capacitor, making them very fast while consuming very little. They are ideal when used in a non-inverting configuration or in an inverting configuration in the following conditions.

- $|Gain| \geq 3$  in an inverting configuration ( $C_L = 20$  pF,  $R_L = 100$  k $\Omega$ ) or  $|gain| \geq 10$  ( $C_L = 100$  pF,  $R_L = 100$  k $\Omega$ )
- $Gain \geq +4$  in a non-inverting configuration ( $C_L = 20$  pF,  $R_L = 100$  k $\Omega$ ) or  $gain \geq +11$  ( $C_L = 100$  pF,  $R_L = 100$  k $\Omega$ )

As these operational amplifiers are not unity gain stable, for a low closed-loop gain it is recommended to use the TSV62x (29  $\mu$ A, 420 kHz) or TSV63x (60  $\mu$ A, 880 kHz) which are unity gain stable.

**Table 8. Related products**

| Part #    | I <sub>cc</sub> ( $\mu$ A) at 5 V | GBP (MHz) | SR (V/ $\mu$ s) | Minimum gain for stability<br>(C <sub>Load</sub> = 100 pF) |
|-----------|-----------------------------------|-----------|-----------------|------------------------------------------------------------|
| TSV620-1  | 29                                | 0.42      | 0.14            | 1                                                          |
| TSV6290-1 | 29                                | 1.3       | 0.5             | +11                                                        |
| TSV630-1  | 60                                | 0.88      | 0.34            | 1                                                          |
| TSV6390-1 | 60                                | 2.4       | 1.1             | +11                                                        |

### 3.7 PCB layouts

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

### 3.8 Macromodel

An accurate macromodel of the TSV6390 and TSV6391 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 TSV639x 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*.

## 4 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.

## 4.1 SOT23-5 package mechanical data

Figure 19. SOT23-5L package mechanical drawing

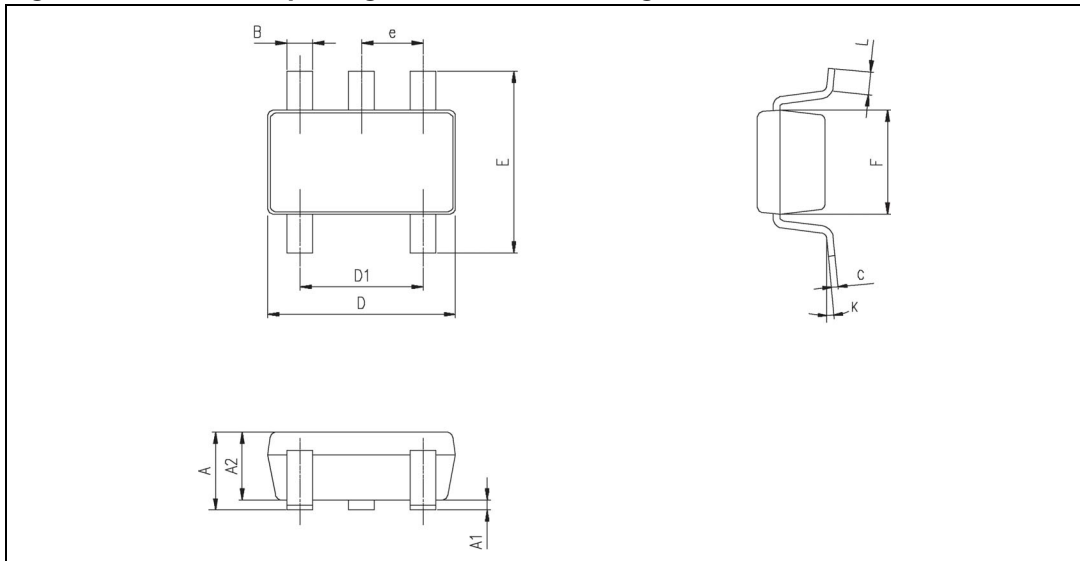


Table 9. SOT23-5L package mechanical data

| Ref. | Dimensions  |      |      |        |       |       |
|------|-------------|------|------|--------|-------|-------|
|      | Millimeters |      |      | Inches |       |       |
|      | Min.        | Typ. | Max. | Min.   | Typ.  | Max.  |
| A    | 0.90        | 1.20 | 1.45 | 0.035  | 0.047 | 0.057 |
| A1   |             |      | 0.15 |        |       | 0.006 |
| A2   | 0.90        | 1.05 | 1.30 | 0.035  | 0.041 | 0.051 |
| B    | 0.35        | 0.40 | 0.50 | 0.013  | 0.015 | 0.019 |
| C    | 0.09        | 0.15 | 0.20 | 0.003  | 0.006 | 0.008 |
| D    | 2.80        | 2.90 | 3.00 | 0.110  | 0.114 | 0.118 |
| D1   |             | 1.90 |      |        | 0.075 |       |
| e    |             | 0.95 |      |        | 0.037 |       |
| E    | 2.60        | 2.80 | 3.00 | 0.102  | 0.110 | 0.118 |
| F    | 1.50        | 1.60 | 1.75 | 0.059  | 0.063 | 0.069 |
| L    | 0.10        | 0.35 | 0.60 | 0.004  | 0.013 | 0.023 |
| K    | 0°          |      | 10°  |        |       |       |

## 4.2 SOT23-6 package mechanical data

Figure 20. SOT23-6L package mechanical drawing

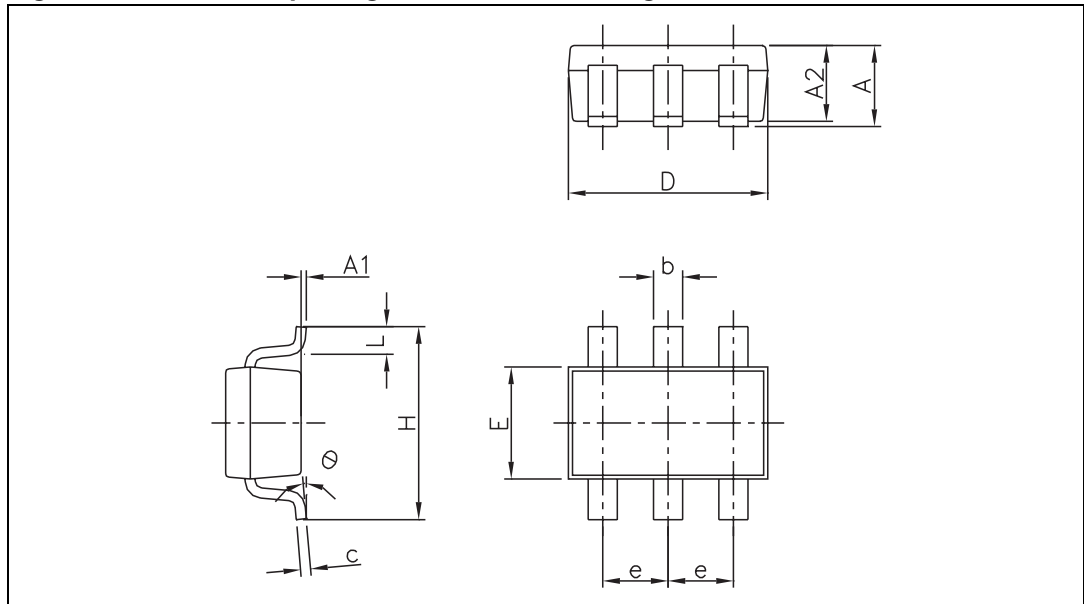


Table 10. SOT23-6L package mechanical data

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



## 4.4 SC70-6 (or SOT323-6) package mechanical data

Figure 22. SC70-6 (or SOT323-6) package mechanical drawing

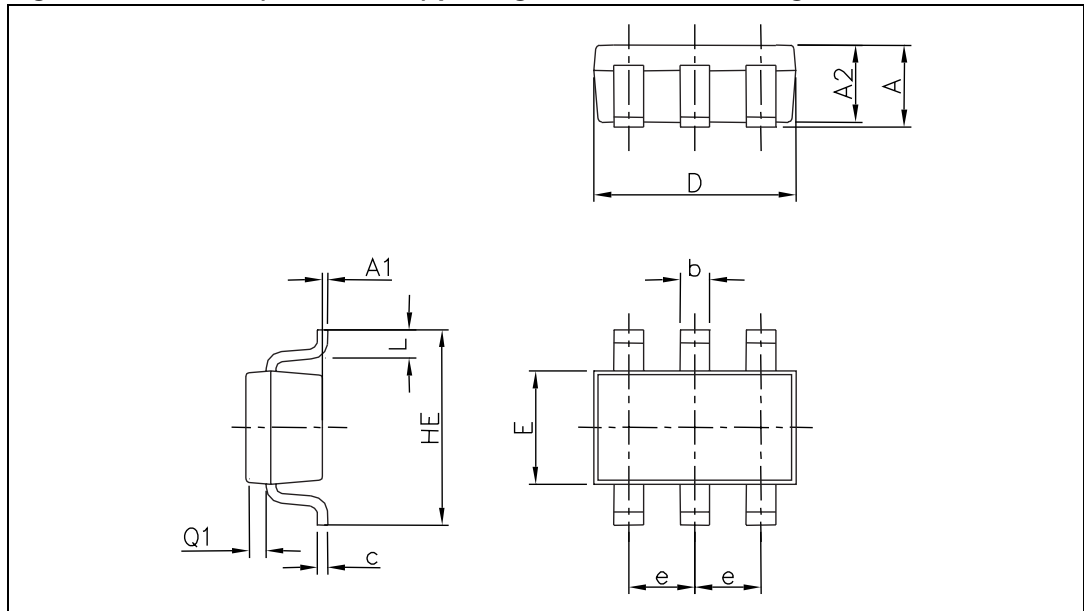
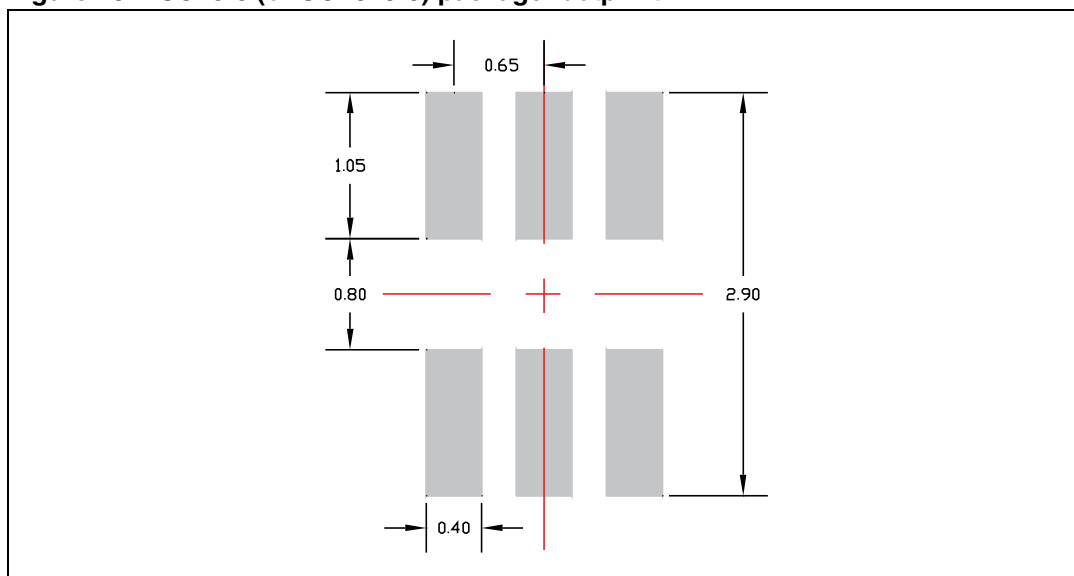


Table 12. SC70-6 (or SOT323-6) package mechanical data

| Ref | Dimensions  |      |      |        |       |       |
|-----|-------------|------|------|--------|-------|-------|
|     | Millimeters |      |      | Inches |       |       |
|     | Min.        | Typ. | Max. | Min.   | Typ.  | Max.  |
| A   | 0.80        |      | 1.10 | 0.031  |       | 0.043 |
| A1  |             |      | 0.10 |        |       | 0.004 |
| A2  | 0.80        |      | 1.00 | 0.031  |       | 0.039 |
| b   | 0.15        |      | 0.30 | 0.006  |       | 0.012 |
| c   | 0.10        |      | 0.18 | 0.004  |       | 0.007 |
| D   | 1.80        |      | 2.20 | 0.071  |       | 0.086 |
| E   | 1.15        |      | 1.35 | 0.045  |       | 0.053 |
| e   |             | 0.65 |      |        | 0.026 |       |
| HE  | 1.80        |      | 2.40 | 0.071  |       | 0.094 |
| L   | 0.10        |      | 0.40 | 0.004  |       | 0.016 |
| Q1  | 0.10        |      | 0.40 | 0.004  |       | 0.016 |

**Figure 23. SC70-6 (or SOT323-6) package footprint**

## 5 Ordering information

**Table 13. Order codes**

| Part number | Temperature range | Package | Packing     | Marking |
|-------------|-------------------|---------|-------------|---------|
| TSV6390ILT  | -40°C to +125°C   | SOT23-6 | Tape & reel | K109    |
| TSV6390ICT  |                   | SC70-6  |             | K19     |
| TSV6390AILT |                   | SOT23-6 |             | K142    |
| TSV6390AICT |                   | SC70-6  |             | K42     |
| TSV6391ILT  |                   | SOT23-5 |             | K108    |
| TSV6391ICT  |                   | SC70-5  |             | K20     |
| TSV6391AILT |                   | SOT23-5 |             | K141    |
| TSV6391AICT |                   | SC70-5  |             | K41     |

## 6 Revision history

**Table 14. Document revision history**

| Date        | Revision | Changes          |
|-------------|----------|------------------|
| 09-Mar-2010 | 1        | Initial release. |

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