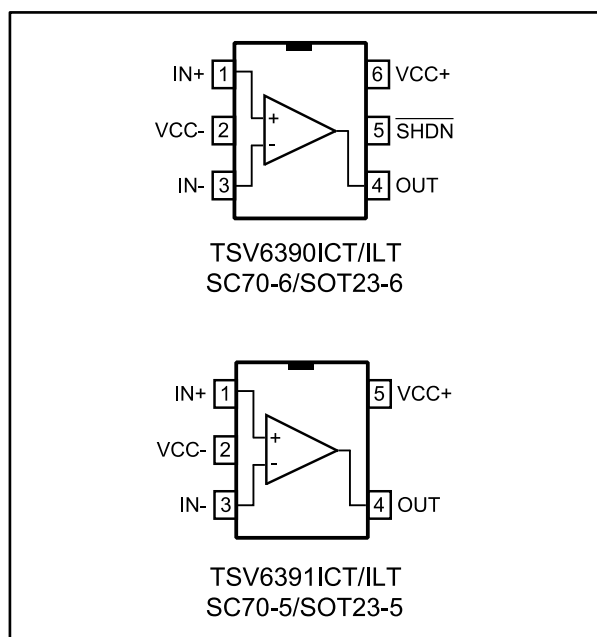


## Micropower (60 $\mu$ A), wide bandwidth (2.4 MHz) CMOS operational amplifiers

Datasheet - production data



- Signal conditioning
- Active filtering
- Medical instrumentation

### Description

The TSV6390, TSV6391, and their "A" versions are single operational amplifiers (op amps) 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.

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.

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  $^{\circ}$ C to 125  $^{\circ}$ C.

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

### 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  $^{\circ}$ C to 125  $^{\circ}$ C
- 4 kV human body model

### Applications

- Battery-powered applications
- Portable devices

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# 1 Absolute maximum ratings and operating conditions

Table 1: Absolute maximum ratings (AMR)

| Symbol                   | Parameter                                                |         | Value                                                  | Unit |
|--------------------------|----------------------------------------------------------|---------|--------------------------------------------------------|------|
| V <sub>CC</sub>          | Supply voltage <sup>(1)</sup>                            |         | 6                                                      | V    |
| V <sub>id</sub>          | Differential input voltage <sup>(2)</sup>                |         | ±V <sub>CC</sub>                                       |      |
| V <sub>in</sub>          | Input voltage <sup>(3)</sup>                             |         | (V <sub>CC-</sub> ) - 0.2 to (V <sub>CC+</sub> ) + 0.2 |      |
| I <sub>in</sub>          | Input current <sup>(4)</sup>                             |         | 10                                                     | mA   |
| $\overline{\text{SHDN}}$ | Shutdown voltage <sup>(3)</sup>                          |         | (V <sub>CC-</sub> ) - 0.2 to (V <sub>CC+</sub> ) + 0.2 | V    |
| T <sub>stg</sub>         | Storage temperature                                      |         | -65 to 150                                             | °C   |
| T <sub>j</sub>           | Maximum junction temperature                             |         | 150                                                    |      |
| R <sub>thja</sub>        | Thermal resistance junction to ambient <sup>(5)(6)</sup> | SC70-6  | 232                                                    | °C/W |
|                          |                                                          | SOT23-6 | 240                                                    |      |
|                          |                                                          | SC70-5  | 205                                                    |      |
|                          |                                                          | SOT23-5 | 250                                                    |      |
| 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   |

**Notes:**

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

<sup>(2)</sup>The differential voltage is the non-inverting input terminal with respect to the inverting input terminal.

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

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

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

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

<sup>(7)</sup>Human body model: 100 pF discharged through a 1.5 kΩ resistor between two pins of the device, done for all couples of pin combinations with other pins floating.

<sup>(8)</sup>Machine model: a 200 pF capacitor is charged to the specified voltage, then discharged directly between two pins of the device with no external series resistor (internal resistor < 5 Ω), done for all couples of pin combinations with other pins floating.

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

Table 2: Operating conditions

| Symbol            | Parameter                            | Value                                                  | Unit |
|-------------------|--------------------------------------|--------------------------------------------------------|------|
| V <sub>CC</sub>   | Supply voltage                       | 1.5 to 5.5                                             | V    |
| V <sub>icm</sub>  | Common mode input voltage range      | (V <sub>CC-</sub> ) - 0.1 to (V <sub>CC+</sub> ) + 0.1 |      |
| T <sub>oper</sub> | Operating free air temperature range | -40 to 125                                             | °C   |

## 2 Electrical characteristics

Table 3: Electrical characteristics at  $V_{CC+} = 1.8\text{ V}$  with  $V_{CC-} = 0\text{ V}$ ,  $V_{icm} = V_{CC}/2$ ,  $T_{amb} = 25\text{ }^{\circ}\text{C}$  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 and TSV6391                                                                           |      |      | 3    | mV     |
|                      |                                                                             | TSV6390A and TSV6391A                                                                         |      |      | 0.5  |        |
|                      |                                                                             | T <sub>min</sub> < T <sub>op</sub> < T <sub>max</sub> ,<br>TSV6390 and TSV6391                |      |      | 4.5  |        |
|                      |                                                                             | T <sub>min</sub> < T <sub>op</sub> < T <sub>max</sub> ,<br>TSV6390A and TSV6391A              |      |      | 2    |        |
| ΔV <sub>io</sub> /ΔT | Input offset voltage drift                                                  |                                                                                               |      | 2    |      | μV/°C  |
| I <sub>io</sub>      | Input offset current, V <sub>out</sub> = V <sub>CC</sub> /2 <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, (V <sub>out</sub> = V <sub>CC</sub> /2) <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<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                                                                        |      | 5    | 35   | mV     |
|                      |                                                                             | T <sub>min</sub> < T <sub>op</sub> < T <sub>max</sub>                                         |      |      | 50   |        |
| V <sub>OL</sub>      | Low-level output voltage                                                    | R <sub>L</sub> = 10 kΩ                                                                        |      | 4    | 35   | 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   |      |        |
|                      |                                                                             | T <sub>min</sub> < T <sub>op</sub> < T <sub>max</sub>                                         | 4    |      |      |        |
| I <sub>CC</sub>      | Supply current, $\overline{\text{SHDN}}$ = 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    |      | V/V    |
|                      |                                                                             |                                                                                               |      | -3   |      |        |
| 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                                                                                     |      | 60   |      | nV/√Hz |
|                      |                                                                             | f = 10 kHz                                                                                    |      | 33   |      |        |

### Notes:

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

Table 4: Shutdown characteristics VCC = 1.8 V (TSV6390)

| Symbol                | Parameter                                       | Conditions                                                                                    | Min. | Typ. | Max. | Unit          |
|-----------------------|-------------------------------------------------|-----------------------------------------------------------------------------------------------|------|------|------|---------------|
| <b>DC performance</b> |                                                 |                                                                                               |      |      |      |               |
| $I_{CC}$              | Supply current in shutdown mode (all operators) | $\overline{SHDN} = V_{CC-}$                                                                   |      | 2.5  | 50   | nA            |
|                       |                                                 | $T_{min} < T_{op} < 85\text{ }^{\circ}\text{C}$                                               |      |      | 200  |               |
|                       |                                                 | $T_{min} < T_{op} < 125\text{ }^{\circ}\text{C}$                                              |      |      | 1.5  | $\mu\text{A}$ |
| $t_{on}$              | Amplifier turn-on time                          | $R_L = 2\text{ k}\Omega$ , $V_{out} = (V_{CC-}) \text{ to } (V_{CC-}) + 0.2\text{ V}$         |      | 300  |      | ns            |
| $t_{off}$             | Amplifier turn-off time                         | $R_L = 2\text{ k}\Omega$ , $V_{out} = (V_{CC+}) - 0.5\text{ V}$ to $(V_{CC+}) - 0.7\text{ V}$ |      | 20   |      |               |
| $V_{IH}$              | $\overline{SHDN}$ logic high                    |                                                                                               | 1.3  |      |      | V             |
| $V_{IL}$              | $\overline{SHDN}$ logic low                     |                                                                                               |      |      | 0.5  |               |
| $I_{IH}$              | $\overline{SHDN}$ current high                  | $\overline{SHDN} = V_{CC+}$                                                                   |      | 10   |      | pA            |
| $I_{IL}$              | $\overline{SHDN}$ current low                   | $\overline{SHDN} = V_{CC-}$                                                                   |      | 10   |      |               |
| $I_{OLeak}$           | Output leakage in shutdown mode                 | $\overline{SHDN} = V_{CC-}$                                                                   |      | 50   |      | nA            |
|                       |                                                 | $T_{min} < T_{op} < T_{max}$                                                                  |      | 1    |      |               |

Table 5:  $V_{CC+} = 3.3\text{ V}$ ,  $V_{CC-} = 0\text{ V}$ ,  $V_{icm} = V_{CC}/2$ ,  $T_{amb} = 25\text{ }^{\circ}\text{C}$ ,  $R_L$  connected to  $V_{CC}/2$  (unless otherwise specified)

| Symbol               | Parameter                                                                   | Conditions                                                                                     | Min. | Typ. | Max. | Unit   |  |
|----------------------|-----------------------------------------------------------------------------|------------------------------------------------------------------------------------------------|------|------|------|--------|--|
| DC performance       |                                                                             |                                                                                                |      |      |      |        |  |
| V <sub>io</sub>      | Offset voltage                                                              | TSV6390 and TSV6391                                                                            |      |      | 3    | mV     |  |
|                      |                                                                             | TSV6390A and TSV6391A                                                                          |      |      | 0.5  |        |  |
|                      |                                                                             | T <sub>min</sub> < T <sub>op</sub> < T <sub>max</sub> ,<br>TSV6390 and TSV6391                 |      |      | 4.5  |        |  |
|                      |                                                                             | T <sub>min</sub> < T <sub>op</sub> < T <sub>max</sub> ,<br>TSV6390A and TSV6391A               |      |      | 2    |        |  |
| ΔV <sub>io</sub> /ΔT | 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   |        |  |
|                      |                                                                             | 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 3.3 V, V <sub>out</sub> = 1.65 V                                                        | 57   | 79   |      | dB     |  |
|                      |                                                                             | T <sub>min</sub> < T <sub>op</sub> < T <sub>max</sub>                                          | 53   |      |      |        |  |
| A <sub>vd</sub>      | Large signal voltage gain                                                   | R <sub>L</sub> = 10 kΩ, V <sub>out</sub> = 0.5 V to 2.8 V                                      | 88   | 98   |      |        |  |
|                      |                                                                             | T <sub>min</sub> < T <sub>op</sub> < T <sub>max</sub>                                          | 83   |      |      |        |  |
| V <sub>OH</sub>      | High-level output voltage                                                   | R <sub>L</sub> = 10 kΩ                                                                         |      | 6    | 35   | mV     |  |
|                      |                                                                             | T <sub>min.</sub> < T <sub>op</sub> < T <sub>max</sub>                                         |      |      | 50   |        |  |
| V <sub>OL</sub>      | Low-level output voltage                                                    | R <sub>L</sub> = 10 kΩ                                                                         |      | 7    | 35   |        |  |
|                      |                                                                             | 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   |      |        |  |
|                      |                                                                             | T <sub>min</sub> < T <sub>op</sub> < T <sub>max</sub>                                          | 20   |      |      |        |  |
| I <sub>CC</sub>      | Supply current, $\overline{\text{SHDN}}$ = 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   |        |  |
| 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    |      | V/V    |  |
|                      |                                                                             |                                                                                                |      | -3   |      |        |  |
| 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   |      | nV/√Hz |  |

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

Table 6: Electrical characteristics at VCC+ = 5 V with VCC- = 0 V, Vicm = VCC/2, Tamb = 25 °C and RL connected to VCC/2 (unless otherwise specified)

| Symbol               | Parameter                                                                      | Conditions                                                                                                                     | Min. | Typ. | Max. | Unit   |  |
|----------------------|--------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------|------|------|------|--------|--|
| DC performance       |                                                                                |                                                                                                                                |      |      |      |        |  |
| V <sub>io</sub>      | Offset voltage                                                                 | TSV6390 and TSV6391                                                                                                            |      |      | 3    | mV     |  |
|                      |                                                                                | TSV6390A and TSV6391A                                                                                                          |      |      | 0.5  |        |  |
|                      |                                                                                | T <sub>min</sub> < T <sub>op</sub> < T <sub>max</sub> ,<br>TSV6390 and TSV6391                                                 |      |      | 4.5  |        |  |
|                      |                                                                                | T <sub>min</sub> < T <sub>op</sub> < T <sub>max</sub> ,<br>TSV6390A and TSV6391A                                               |      |      | 2    |        |  |
| ΔV <sub>io</sub> /ΔT | Input offset voltage drift                                                     |                                                                                                                                |      | 2    |      | μV/°C  |  |
| I <sub>io</sub>      | Input offset current, V <sub>out</sub> = V <sub>CC</sub> /2 <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, V <sub>out</sub> = V <sub>CC</sub> /2 <sup>(1)</sup>       |                                                                                                                                |      | 1    | 10   |        |  |
|                      |                                                                                | 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 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   |      |        |  |
|                      |                                                                                | T <sub>min</sub> < T <sub>op</sub> < T <sub>max</sub>                                                                          | 73   |      |      |        |  |
| A <sub>vd</sub>      | Large signal voltage gain                                                      | R <sub>L</sub> = 10 kΩ, V <sub>out</sub> = 0.5 V to 4.5 V                                                                      | 89   | 98   |      |        |  |
|                      |                                                                                | T <sub>min</sub> < T <sub>op</sub> < T <sub>max</sub>                                                                          | 84   |      |      |        |  |
| V <sub>OH</sub>      | High-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   |        |  |
| V <sub>OL</sub>      | Low-level output voltage                                                       | R <sub>L</sub> = 10 kΩ                                                                                                         |      | 6    | 35   |        |  |
|                      |                                                                                | T <sub>min</sub> < T <sub>op</sub> < T <sub>max</sub>                                                                          |      |      | 50   |        |  |
| I <sub>out</sub>     | I <sub>sink</sub>                                                              | V <sub>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   |      |        |  |
|                      |                                                                                | T <sub>min</sub> < T <sub>op</sub> < T <sub>max</sub>                                                                          | 35   |      |      |        |  |
| I <sub>CC</sub>      | Supply current, $\overline{\text{SHDN}}$ = 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    |      | V/V    |  |
|                      |                                                                                |                                                                                                                                |      | -3   |      |        |  |
| SR                   | Slew rate                                                                      | R <sub>L</sub> = 10 kΩ, C <sub>L</sub> = 100 pF                                                                                |      | 1.1  |      | V/μs   |  |
| e <sub>n</sub>       | Equivalent input noise voltage                                                 | f = 1 kHz                                                                                                                      |      | 60   |      | nV/√Hz |  |
|                      |                                                                                | f = 10 kHz                                                                                                                     |      | 33   |      |        |  |
| THD+N                | Total harmonic distortion + noise                                              | A <sub>v</sub> = -10, f <sub>in</sub> = 1 kHz, R = 100 kΩ,<br>V <sub>icm</sub> = V <sub>CC</sub> /2, V <sub>in</sub> = 40 mVpp |      | 0.11 |      | %      |  |

**Notes:**<sup>(1)</sup>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            |
|                       |                                                 | $T_{\min} < T_{op} < 85\text{ }^{\circ}\text{C}$                                              |      |      | 200  |               |
|                       |                                                 | $T_{\min} < T_{op} < 125\text{ }^{\circ}\text{C}$                                             |      |      | 1.5  | $\mu\text{A}$ |
| $t_{on}$              | Amplifier turn-on time                          | $R_L = 2\text{ k}\Omega$ , $V_{out} = (V_{CC-}) \text{ to } (V_{CC-}) + 0.2\text{ V}$         |      | 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   |      |               |
| $V_{IH}$              | $\overline{\text{SHDN}}$ logic high             |                                                                                               | 4.5  |      |      | V             |
| $V_{IL}$              | $\overline{\text{SHDN}}$ logic low              |                                                                                               |      |      | 0.5  |               |
| $I_{IH}$              | $\overline{\text{SHDN}}$ current high           | $\overline{\text{SHDN}} = V_{CC+}$                                                            |      | 10   |      | pA            |
| $I_{IL}$              | $\overline{\text{SHDN}}$ current low            | $\overline{\text{SHDN}} = V_{CC-}$                                                            |      | 10   |      |               |
| $I_{OLeak}$           | Output leakage in shutdown mode                 | $\overline{\text{SHDN}} = V_{CC-}$                                                            |      | 50   |      | nA            |
|                       |                                                 | $T_{\min} < T_{op} < T_{\max}$                                                                |      | 1    |      |               |



### 3 Electrical characteristics curves

Figure 1: Supply current vs. supply voltage at  $V_{icm} = V_{CC}/2$

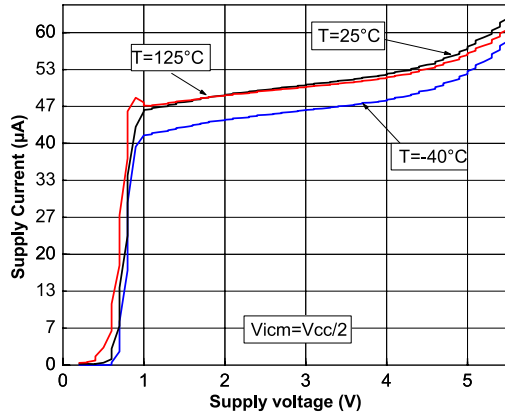


Figure 2: Output current vs. output voltage at  $V_{CC} = 1.5\text{ V}$

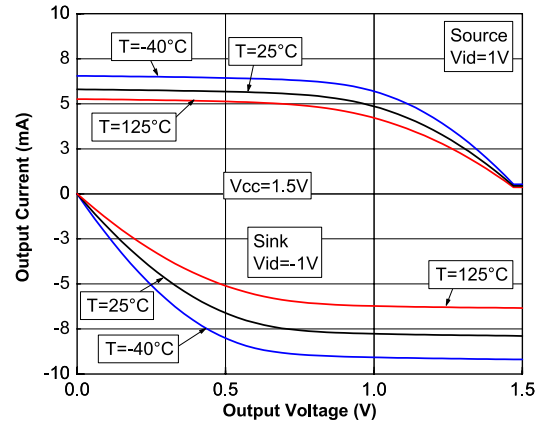


Figure 3: Output current vs. output voltage at  $V_{CC} = 5\text{ V}$

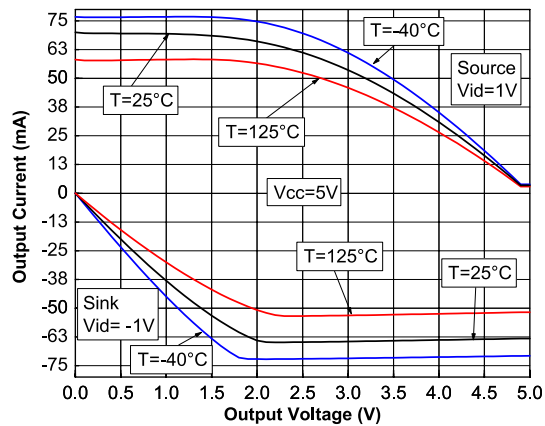


Figure 4: Peaking at closed loop gain = -10

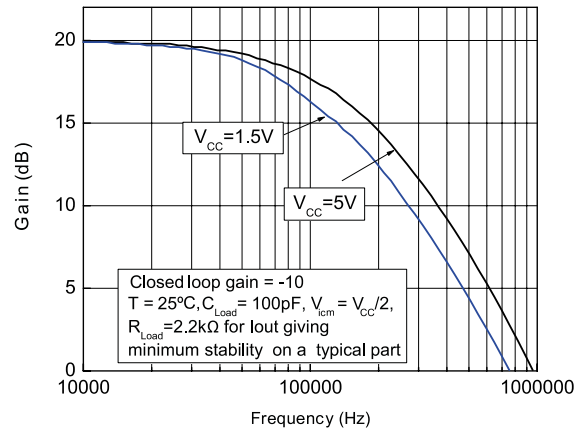


Figure 5: Peaking at closed loop gain = -3 at  $V_{CC} = 1.5\text{ V}$

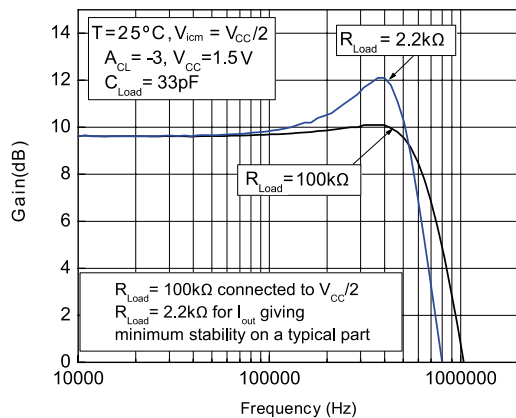


Figure 6: Peaking at closed loop gain = -3 at  $V_{CC} = 5\text{ V}$

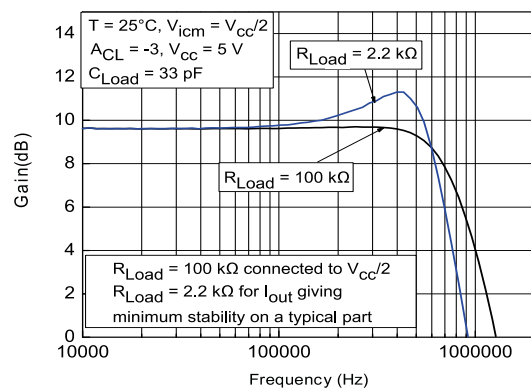


Figure 7: Positive slew rate vs. supply voltage

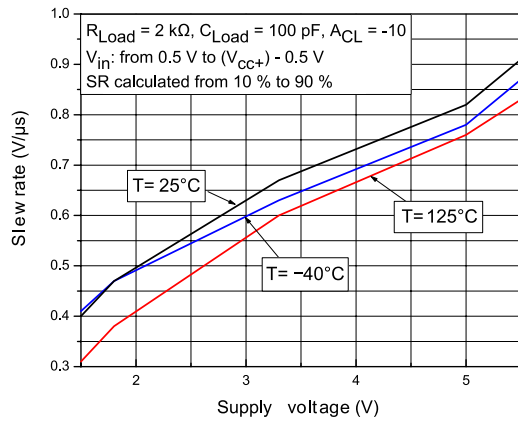


Figure 8: Negative slew rate vs. supply voltage

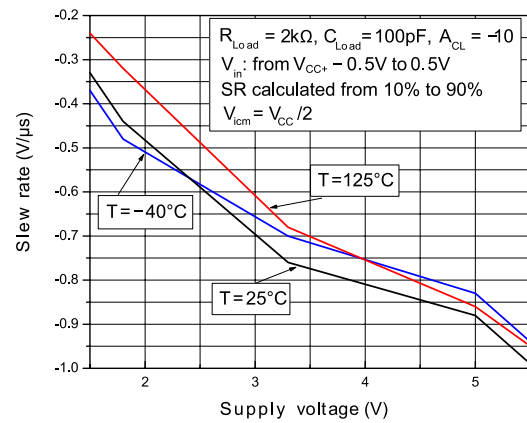


Figure 9: Distortion + noise vs. output voltage at VCC = 1.8 V

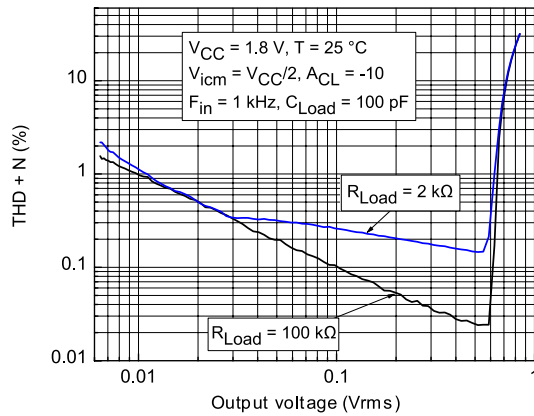


Figure 10: Distortion + noise vs. output voltage at VCC = 5 V

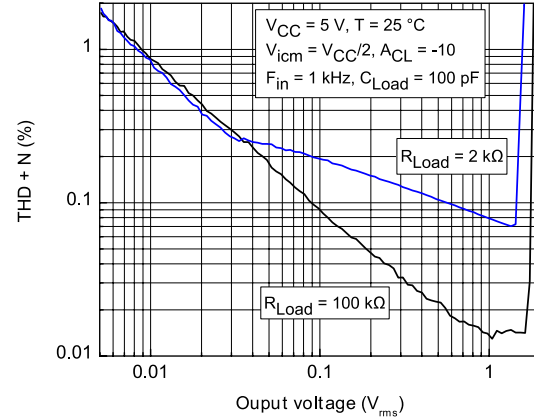


Figure 11: Slew rate timing

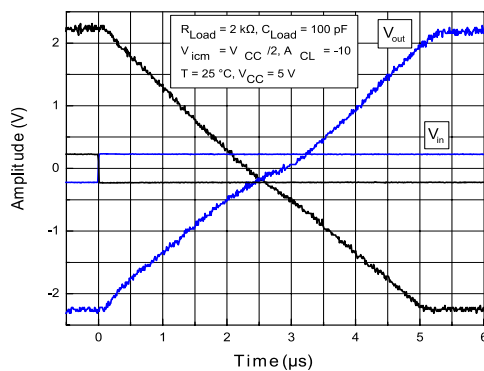
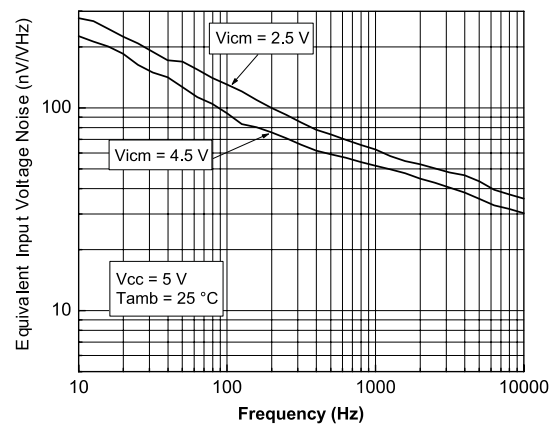


Figure 12: Noise vs. frequency at VCC = 5 V



## 4 Application information

### 4.1 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 °C to 125 °C.

### 4.2 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  $(V_{CC-}) - 0.1$  V to  $(V_{CC+}) + 0.1$  V. The transition between the two pairs appears at  $(V_{CC+}) - 0.7$  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  $V_{CC} = 1.5$  V

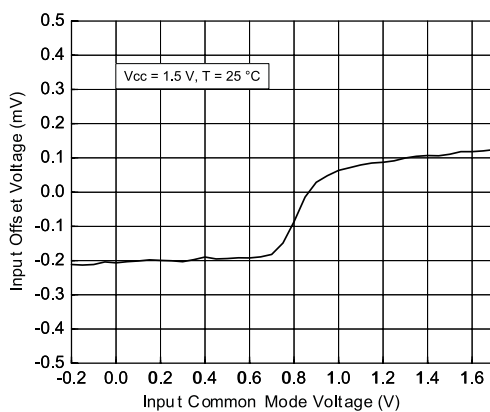
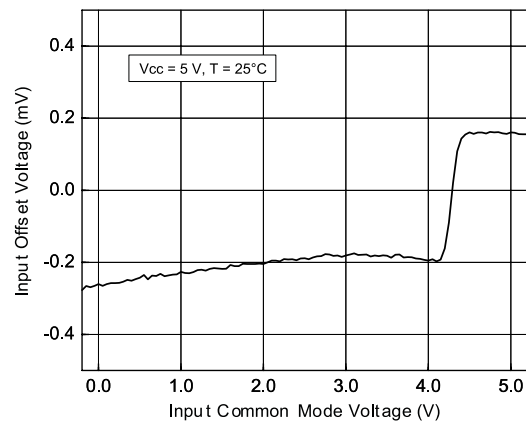


Figure 14: Input offset voltage vs input common-mode at  $V_{CC} = 5$  V



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

## 4.4 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  $V_{\text{CC-}}$ . 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 kept tied to  $V_{\text{CC+}}$  or  $V_{\text{CC-}}$ .

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 ( $V_{\text{out}}$  pulled down)

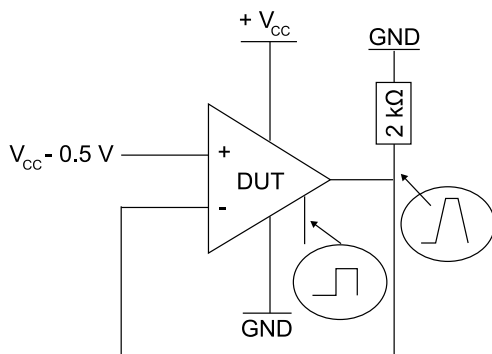


Figure 16: Test configuration for turn-off time ( $V_{\text{out}}$  pulled down)

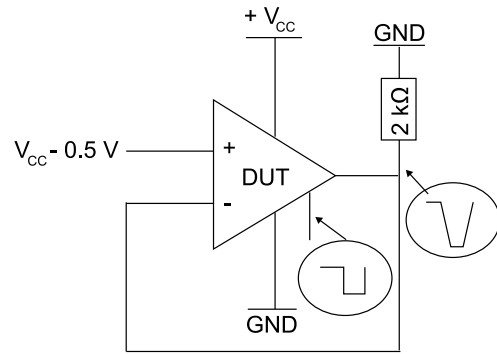


Figure 17: Turn-on time,  $V_{\text{CC}} = 5$  V,  $V_{\text{out}}$  pulled down,  $T = 25$  °C

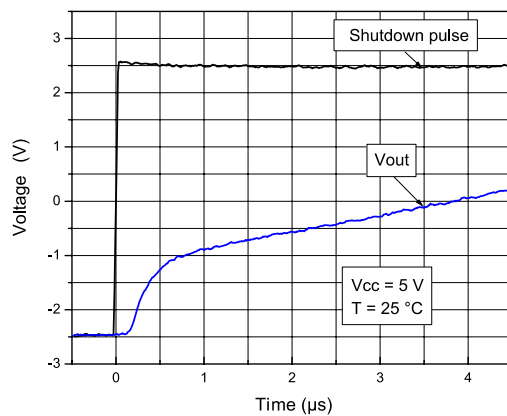
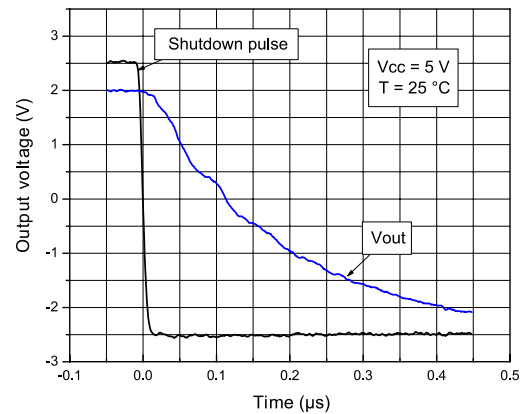


Figure 18: Turn-off time,  $V_{\text{CC}} = 5$  V,  $V_{\text{out}}$  pulled down,  $T = 25$  °C



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

## 4.6 Driving resistive and capacitive loads

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

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>( $C_{Load} = 100$ 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                                                   |

## 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

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*.

## 5 Package information

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

## 5.1 SC70-6 (or SOT323-6) package information

Figure 19: SC70-6 (or SOT323-6) package outline

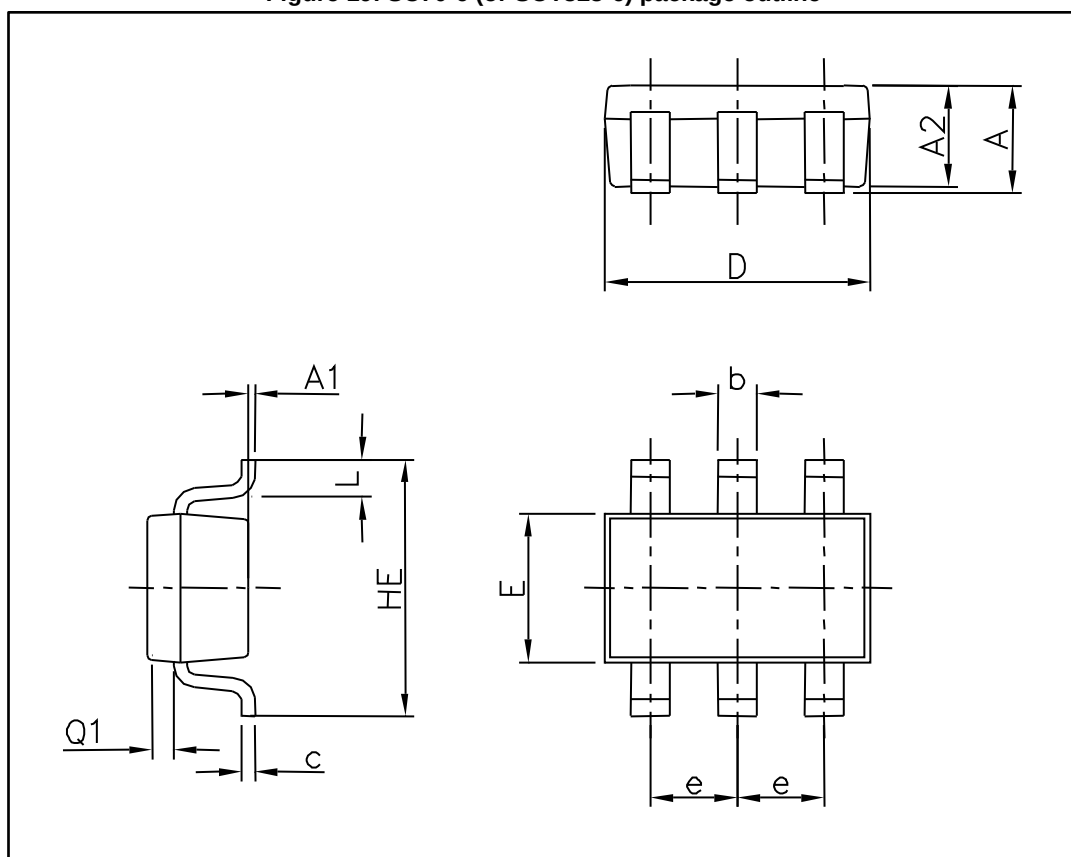
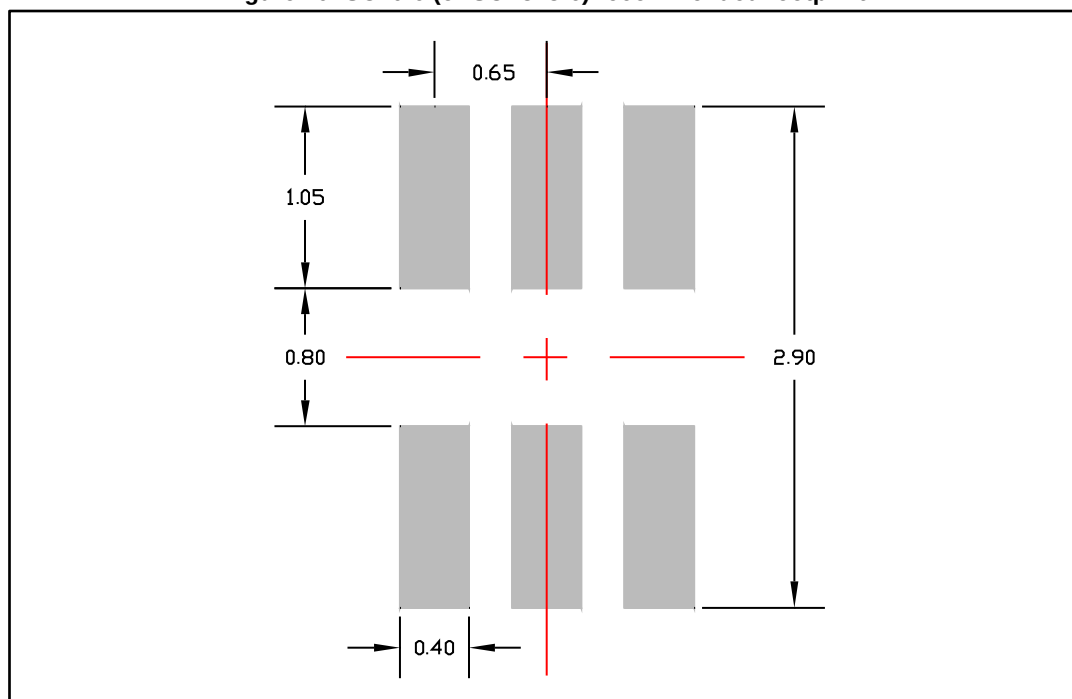


Table 9: SC70-6 (or SOT323-6) mechanical data

| 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 20: SC70-6 (or SOT323-6) recommended footprint





## 5.2 SOT23-6 package information

Figure 21: SOT23-6 package outline

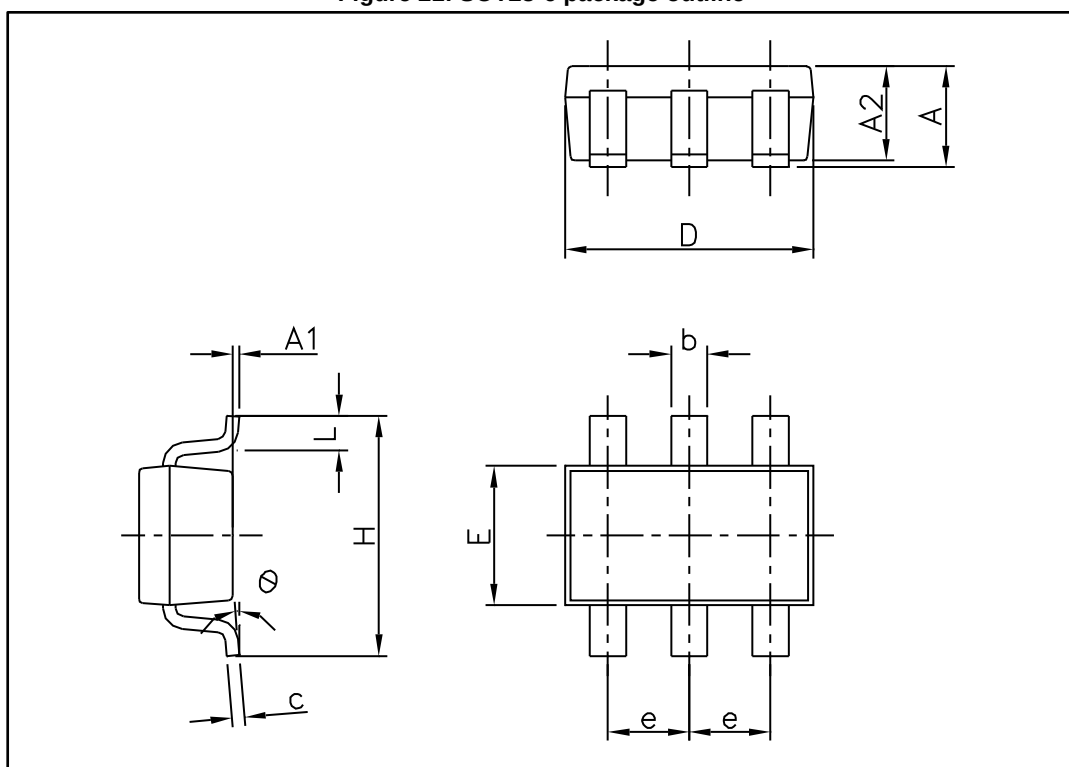


Table 10: SOT23-6 mechanical data

| 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 |
| θ    | 0 °         |      | 10 ° | 0 °    |       | 10 °  |

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

Figure 22: SC70-5 (or SOT323-5) package outline

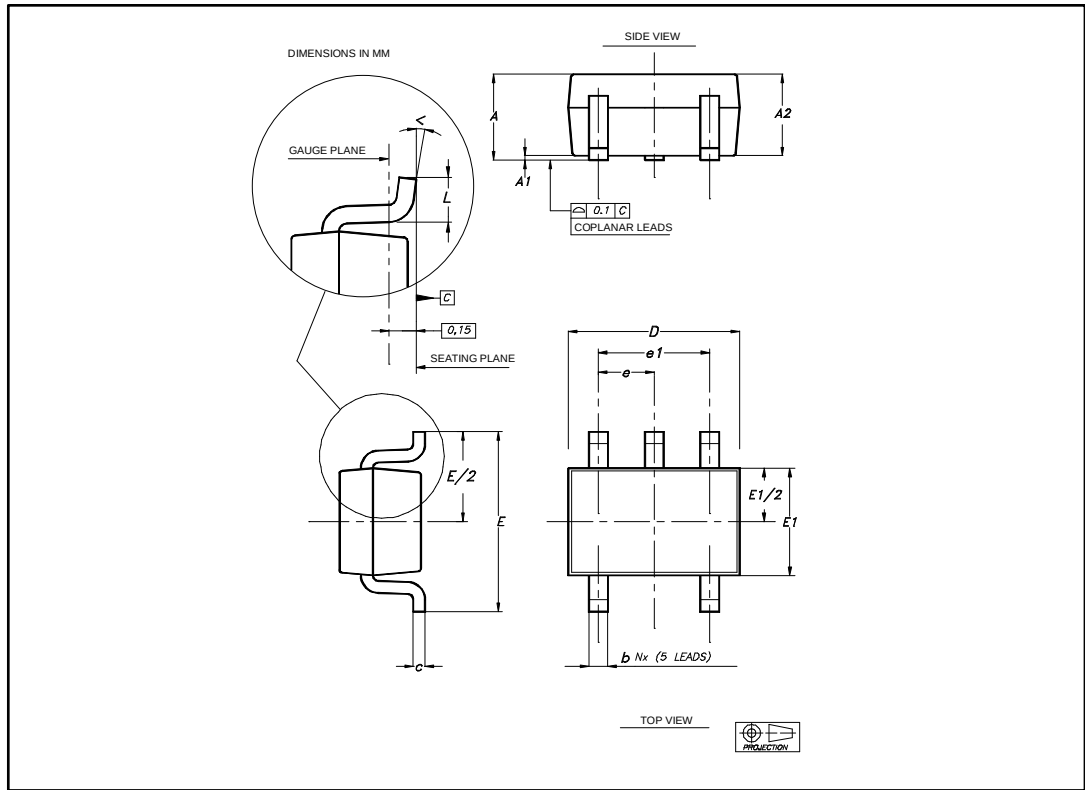


Table 11: SC70-5 (or SOT323-5) mechanical data

| Ref. | Dimensions  |      |      |        |       |       |
|------|-------------|------|------|--------|-------|-------|
|      | Millimeters |      |      | Inches |       |       |
|      | Min.        | Typ. | Max. | Min.   | Typ.  | Max.  |
| A    | 0.80        |      | 1.10 | 0.315  |       | 0.043 |
| A1   |             |      | 0.10 |        |       | 0.004 |
| A2   | 0.80        | 0.90 | 1.00 | 0.315  | 0.035 | 0.039 |
| b    | 0.15        |      | 0.30 | 0.006  |       | 0.012 |
| c    | 0.10        |      | 0.22 | 0.004  |       | 0.009 |
| D    | 1.80        | 2.00 | 2.20 | 0.071  | 0.079 | 0.087 |
| E    | 1.80        | 2.10 | 2.40 | 0.071  | 0.083 | 0.094 |
| E1   | 1.15        | 1.25 | 1.35 | 0.045  | 0.049 | 0.053 |
| e    |             | 0.65 |      |        | 0.025 |       |
| e1   |             | 1.30 |      |        | 0.051 |       |
| L    | 0.26        | 0.36 | 0.46 | 0.010  | 0.014 | 0.018 |
| <    | 0°          |      | 8°   | 0°     |       | 8°    |

## 5.4 SOT23-5 package information

Figure 23: SOT23-5 package outline

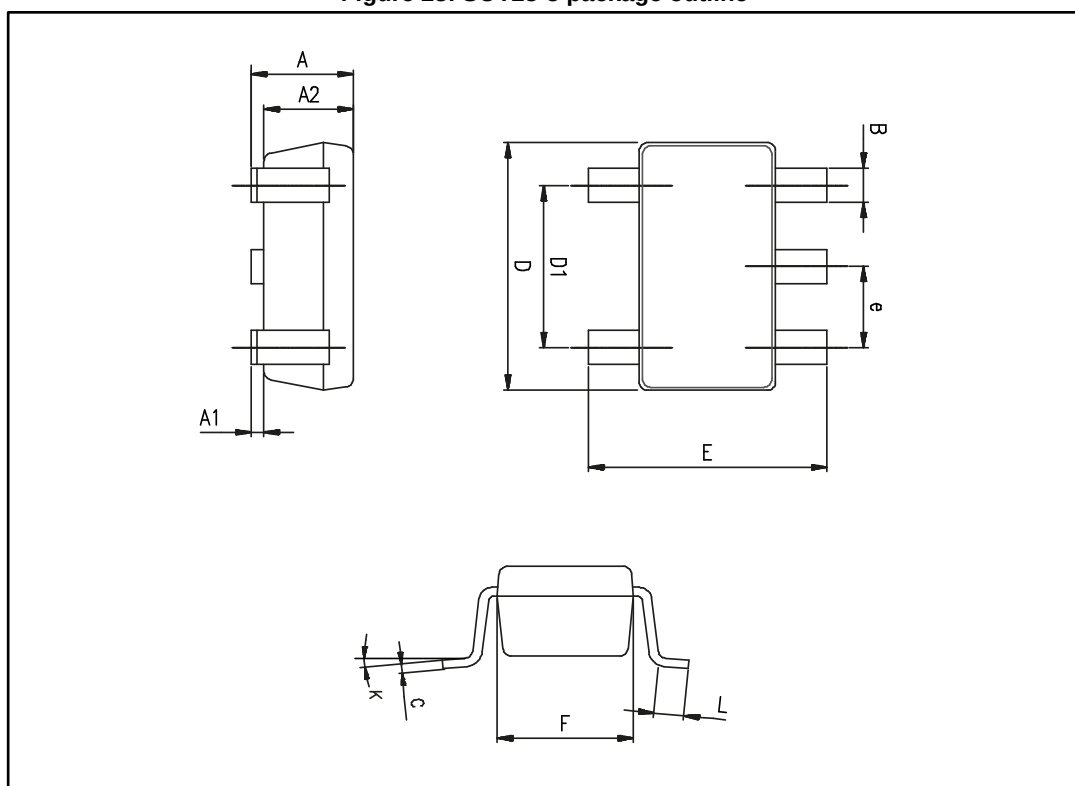


Table 12: SOT23-5 mechanical data

| Ref. | Dimensions  |      |            |           |       |            |
|------|-------------|------|------------|-----------|-------|------------|
|      | Millimeters |      |            | Inches    |       |            |
|      | Min.        | Typ. | Max.       | Min.      | Typ.  | Max.       |
| A    | 0.90        | 1.20 | 1.45       | 0.035     | 0.047 | 0.057      |
| A1   |             |      | 0.15       |           |       | 0.006      |
| A2   | 0.90        | 1.05 | 1.30       | 0.035     | 0.041 | 0.051      |
| B    | 0.35        | 0.40 | 0.50       | 0.014     | 0.016 | 0.020      |
| C    | 0.09        | 0.15 | 0.20       | 0.004     | 0.006 | 0.008      |
| D    | 2.80        | 2.90 | 3.00       | 0.110     | 0.114 | 0.118      |
| D1   |             | 1.90 |            |           | 0.075 |            |
| e    |             | 0.95 |            |           | 0.037 |            |
| E    | 2.60        | 2.80 | 3.00       | 0.102     | 0.110 | 0.118      |
| F    | 1.50        | 1.60 | 1.75       | 0.059     | 0.063 | 0.069      |
| L    | 0.10        | 0.35 | 0.60       | 0.004     | 0.014 | 0.024      |
| K    | 0 degrees   |      | 10 degrees | 0 degrees |       | 10 degrees |

## 6 Ordering information

Table 13: Order codes

| Part number | Temperature range | Package | Packing       | Marking |
|-------------|-------------------|---------|---------------|---------|
| TSV6390ILT  | -40 °C to 125 °C  | SOT23-6 | Tape and 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     |

## 7 Revision history

Table 14: Document revision history

| Date        | Revision | Changes                                                                                                                                                                                                                                                                                                                                                                                                                                               |
|-------------|----------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 09-Mar-2010 | 1        | Initial release.                                                                                                                                                                                                                                                                                                                                                                                                                                      |
| 04-Dec-2015 | 2        | Updated layout<br><i>Section 2: "Electrical characteristics"</i> : replaced $DV_{IO}$ by $\Delta V_{IO}/\Delta T$ and updated $V_{OH}$ values. In <i>Table 7</i> , updated $t_{off}$ conditions.<br><i>Electrical characteristic curves</i> : updated Y-axes of <i>Figure 7</i> and <i>Figure 8</i> .<br><i>Shutdown function (TSV6390)</i> : updated X-axes of <i>Figure 17</i> and <i>Figure 18</i> .<br><i>Table 10</i> : replaced ° with $\theta$ |

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