

General purpose input/output rail-to-rail low-power operational amplifiers

Datasheet - production data



Features

- Operating range $V_{CC} = 2.5\text{ V to }6\text{ V}$
- Rail-to-rail input and output
- Extended V_{icm} ($V_{DD} - 0.2\text{ V to }V_{CC} + 0.2\text{ V}$)
- Capable of driving a $32\ \Omega$ load resistor
- High stability: 500 pF
- Operating temperature range: $-40\text{ to }125\text{ }^\circ\text{C}$

Related products

- See LMV321L, LMV358L, LMV324L for newer technology version
- See TSV851, TSV852, TSV854 for enhanced performances

Applications

- Battery powered applications
- Audio driver (headphone driver)
- Sensor signal conditioning
- Laptop/notebook computers

Description

The TSV358, TSV358A, TSV324, and TSV324A (dual and quad) devices are low voltage versions of the LM358 and LM324 commodity operational amplifiers. The TSV321 and TSV321A are the single version. All devices operate with voltages as low as 2.5 V and feature both I/O rail-to-rail.

The common mode input voltage extends 200 mV beyond the supply voltages at $25\text{ }^\circ\text{C}$ while the output voltage swing is within 100 mV of each rail with a $600\ \Omega$ load resistor. At $V_{CC} = 3\text{ V}$, these devices offer 1.3 MHz of gain bandwidth product and provide high output current capability with a typical value of 80 mA .

These features make the TSV3xx and TSV3xxA family ideal for active filters, general purpose low voltage applications, and general purpose portable devices.

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1 Absolute maximum ratings and operating conditions

Table 1: Absolute maximum ratings

| Symbol | Parameter | Value | Unit | |
|------------|--|----------------------------------|------|------|
| V_{CC} | Supply voltage ⁽¹⁾ | 7 | V | |
| V_{id} | Differential input voltage ⁽²⁾ | ±1 | | |
| V_{in} | Input voltage | $V_{DD} - 0.3$ to $V_{CC} + 0.3$ | | |
| T_{stg} | Storage temperature | -65 to +150 | °C | |
| T_j | Maximum junction temperature | 150 | | |
| R_{thja} | Thermal resistance junction-to-ambient ⁽³⁾ | SOT23-5 | 250 | °C/W |
| | | SO8 | 125 | |
| | | MiniSO8 | 190 | |
| | | TSSOP8 | 120 | |
| | | SO14 | 105 | |
| | | TSSOP14 | 100 | |
| R_{thjc} | Thermal resistance junction-to-case ⁽³⁾ | SOT23-5 | 81 | |
| | | SO8 | 40 | |
| | | MiniSO8 | 39 | |
| | | TSSOP8 | 37 | |
| | | SO14 | 31 | |
| | | TSSOP14 | 32 | |
| ESD | HBM: human body model ⁽⁴⁾ | 2 | kV | |
| | MM: machine model ⁽⁵⁾ | 200 | V | |
| | CDM: charged device model ⁽⁶⁾ | 1.5 | kV | |
| | Latch-up immunity | 200 | mA | |
| | Lead temperature (soldering, 10 s) | 250 | °C | |
| | Output short-circuit duration | See ⁽⁷⁾ | | |

Notes:

- ⁽¹⁾All voltage values, except the differential voltage are with respect to the network terminal.
- ⁽²⁾The differential voltage is the non-inverting input terminal with respect to the inverting input terminal. If $V_{id} > \pm 1$ V, the maximum input current must not exceed ± 1 mA. When $V_{id} > \pm 1$ V, an input series resistor must be added to limit input current.
- ⁽³⁾Short-circuits can cause excessive heating and destructive dissipation. R_{th} are typical values.
- ⁽⁴⁾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.
- ⁽⁵⁾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.
- ⁽⁶⁾Charged device model: all pins plus package are charged together to the specified voltage and then discharged directly to ground.
- ⁽⁷⁾Short-circuits from the output to V_{CC} can cause excessive heating. The maximum output current is approximately 80 mA, independent of the magnitude of V_{CC} . Destructive dissipation can result from simultaneous short-circuits on all amplifiers.

Table 2: Operating conditions

| Symbol | Parameter | Value | Unit |
|------------|--------------------------------------|---|----------------------------------|
| V_{CC} | Supply voltage | 2.5 to 6 | V |
| V_{icm} | Common mode input voltage range | $T_{amb} = 25\text{ }^{\circ}\text{C}, 2.5 \leq V_{CC} \leq 6\text{ V}$ | $V_{DD} - 0.2$ to $V_{CC} + 0.2$ |
| | | $T_{min} < T_{amb} < T_{max}, 2.5 \leq V_{CC} \leq 5.5\text{ V}$ | V_{DD} to V_{CC} |
| T_{oper} | Operating free air temperature range | -40 to + 125 | $^{\circ}\text{C}$ |

2 Electrical characteristics

Table 3: Electrical characteristics at VCC = +3 V, VDD = 0 V, RL, CL connected to VCC/2, and Tamb = 25 °C (unless otherwise specified)

| Symbol | Parameter | Test conditions | Min. | Typ. | Max. | Unit |
|----------------------|--|--|------|------|------|---------|
| V _{io} | Input offset voltage | V _{icm} = V _{out} = V _{CC} /2 | | | | mV |
| | | TSV321/358/324 | | 0.2 | 3 | |
| | | T _{min} ≤ T _{amb} ≤ T _{max} | | | 6 | |
| | | TSV321A/358A/324A | | 0.1 | 1 | |
| | | T _{min} ≤ T _{amb} ≤ T _{max} | | | 3 | |
| ΔV _{io} /ΔT | Input offset voltage drift | | | 2 | | μV/°C |
| I _{io} | Input offset current | V _{icm} = V _{out} = V _{CC} /2 ⁽¹⁾ | | 3 | 30 | nA |
| | | T _{min} ≤ T _{amb} ≤ T _{max} | | | 60 | |
| I _{ib} | Input bias current | V _{icm} = V _{out} = V _{CC} /2 ⁽¹⁾ | | 40 | 125 | |
| | | T _{min} ≤ T _{amb} ≤ T _{max} | | | 150 | |
| CMR | Common mode rejection ratio 20 log (ΔV _{ic} /ΔV _{io}) | 0 ≤ V _{icm} ≤ V _{CC} , V _{out} = V _{CC} /2 | 60 | 80 | | dB |
| A _{vd} | Large signal voltage gain | V _{out} = 0.5 V to 2.5 V, R _L = 2 kΩ | 80 | 92 | | |
| | | V _{out} = 0.5 V to 2.5 V, R _L = 600 Ω | 74 | 95 | | |
| V _{OH} | High level output voltage, V _{OH} = V _{out} | V _{id} = 100 mV, R _L = 2 kΩ | 2.82 | 2.95 | | V |
| | | V _{id} = 100 mV, R _L = 600 Ω | 2.80 | 2.95 | | |
| | | V _{id} = 100 mV, T _{min} ≤ T _{amb} ≤ T _{max} , R _L = 2 kΩ | 2.82 | | | |
| | | V _{id} = 100 mV, T _{min} ≤ T _{amb} ≤ T _{max} , R _L = 600 Ω | 2.80 | | | |
| V _{OL} | Low level output voltage | V _{id} = -100 mV, R _L = 2 kΩ | | 88 | 120 | mV |
| | | V _{id} = -100 mV, R _L = 600 Ω | | 115 | 160 | |
| | | V _{id} = -100 mV, T _{min} ≤ T _{amb} ≤ T _{max} , R _L = 2 kΩ | | | 120 | |
| | | V _{id} = -100 mV, T _{min} ≤ T _{amb} ≤ T _{max} , R _L = 600 Ω | | | 160 | |
| I _o | Output source current | V _{id} = 100 mV, V _O = V _{DD} | 20 | 80 | | mA |
| | Output sink current | V _{id} = -100 mV, V _O = V _{CC} | 20 | 80 | | |
| I _{CC} | Supply current (per amplifier) | A _{VCL} = 1, no load | | 420 | 650 | μA |
| | | T _{min} ≤ T _{amb} ≤ T _{max} | | | 690 | |
| GBP | Gain bandwidth product | R _L = 10 kΩ, C _L = 100 pF, f = 100 kHz | 1 | 1.3 | | MHz |
| SR | Slew rate | R _L = 10 kΩ, C _L = 100 pF | 0.42 | 0.6 | | V/μs |
| φ _m | Phase margin | C _L = 100 pF | | 53 | | Degrees |
| e _n | Input voltage noise | | | 27 | | nV/√Hz |
| THD | Total harmonic distortion | | | 0.01 | | % |

Notes:

⁽¹⁾Maximum values include unavoidable inaccuracies of the industrial tests.

Table 4: Electrical characteristics at VCC = +5 V, VDD = 0 V, RL, CL connected to VCC/2, and Tamb = 25 °C (unless otherwise specified)

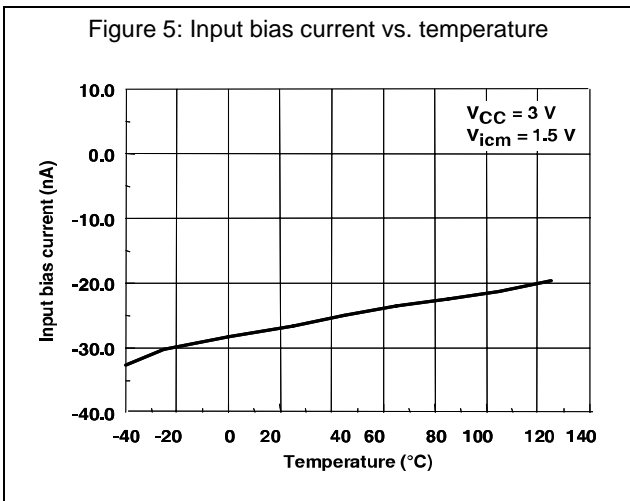
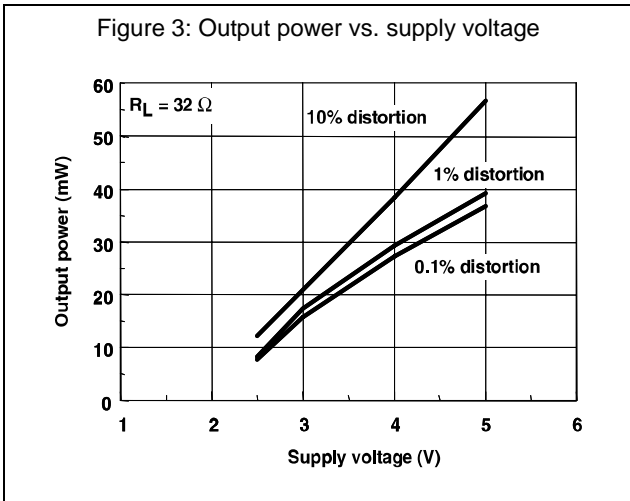
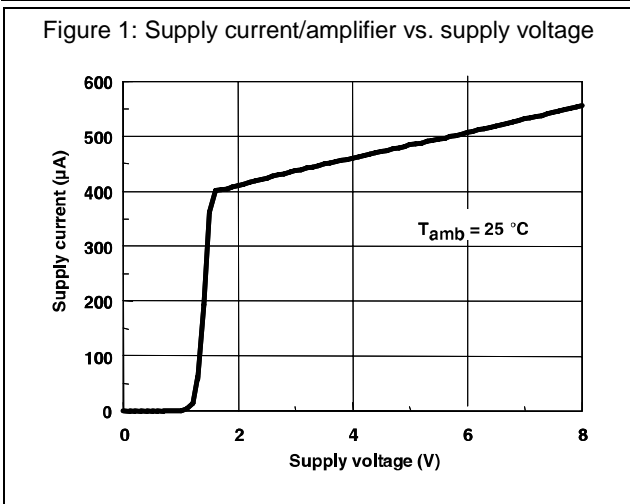
| Symbol | Parameter | Conditions | Min. | Typ. | Max. | Unit |
|----------------------|---|--|------|------|------|-------|
| V _{io} | Input offset voltage | V _{icm} = V _{out} = V _{CC} /2 | | | | mV |
| | | TSV321/358/324 | | 0.2 | 3 | |
| | | T _{min} ≤ T _{amb} ≤ T _{max} | | | 6 | |
| | | TSV321A/358A/324A | | 0.1 | 1 | |
| | | T _{min} ≤ T _{amb} ≤ T _{max} | | | 3 | |
| ΔV _{io} /ΔT | Input offset voltage drift | | | 2 | | μV/°C |
| I _{io} | Input offset current | V _{icm} = V _{out} = V _{CC} /2 ⁽¹⁾ | | 3 | 30 | nA |
| | | T _{min} ≤ T _{amb} ≤ T _{max} | | | 60 | |
| I _{ib} | Input bias current | V _{icm} = V _{out} = V _{CC} /2 ⁽¹⁾ | | 70 | 130 | |
| | | T _{min} ≤ T _{amb} ≤ T _{max} | | | 150 | |
| CMR | Common mode rejection ratio 20 log (ΔV _{ic} /ΔV _{io}) | 0 ≤ V _{icm} ≤ V _{CC} , V _{out} = V _{CC} /2 | 65 | 85 | | dB |
| SVR | Supply voltage rejection ratio 20 log (ΔV _{CC} /ΔV _{io}) | V _{CC} = 2.5 V to 5 V | 70 | 90 | | |
| A _{vd} | Large signal voltage gain | V _{out} = 0.5 V to 4.5 V, R _L = 2 kΩ | 83 | 92 | | |
| | | V _{out} = 0.5 V to 4.5 V, R _L = 600 Ω | 77 | 85 | | |
| V _{OH} | High level output voltage, V _{OH} = V _{out} | V _{id} = 100 mV, R _L = 2 kΩ | 4.80 | 4.95 | | V |
| | | V _{id} = 100 mV, R _L = 600 Ω | 4.75 | 4.90 | | |
| | | V _{id} = 100 mV, T _{min} ≤ T _{amb} ≤ T _{max} , R _L = 2 kΩ | 4.80 | | | |
| | | V _{id} = 100 mV, T _{min} ≤ T _{amb} ≤ T _{max} , R _L = 600 Ω | 4.75 | | | |
| V _{OL} | Low level output voltage | V _{id} = -100 mV, R _L = 2 kΩ | | 88 | 130 | mV |
| | | V _{id} = -100 mV, R _L = 600 Ω | | 115 | 188 | |
| | | V _{id} = -100 mV, T _{min} ≤ T _{amb} ≤ T _{max} , R _L = 2 kΩ | | | 130 | |
| | | V _{id} = -100 mV, T _{min} ≤ T _{amb} ≤ T _{max} , R _L = 600 Ω | | | 188 | |
| I _o | Output source current | V _{id} = 100 mV, V _O = V _{DD} | 20 | 80 | | mA |
| | Output sink current | V _{id} = -100 mV, V _O = V _{CC} | 20 | 80 | | |
| I _{CC} | Supply current (per amplifier) | A _{VCL} = 1, no load | | 500 | 835 | μA |
| | | T _{min} ≤ T _{amb} ≤ T _{max} | | | 875 | |
| GBP | Gain bandwidth product | R _L = 10 kΩ, C _L = 100 pF, f = 100 kHz | 1 | 1.4 | | MHz |
| SR | Slew rate | R _L = 10 kΩ, C _L = 100 pF | 0.42 | 0.6 | | V/μs |

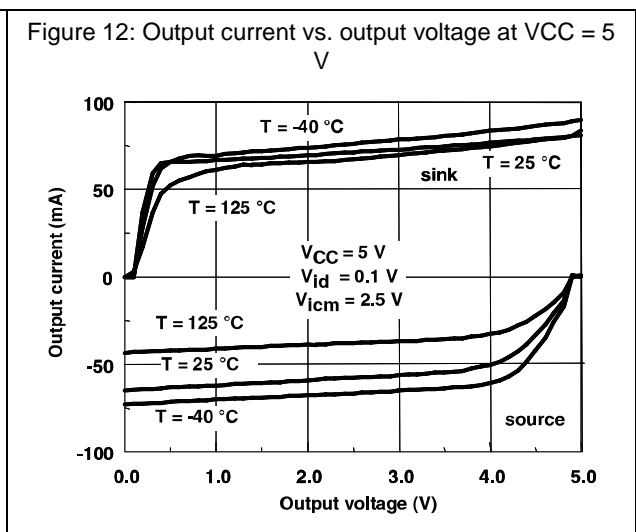
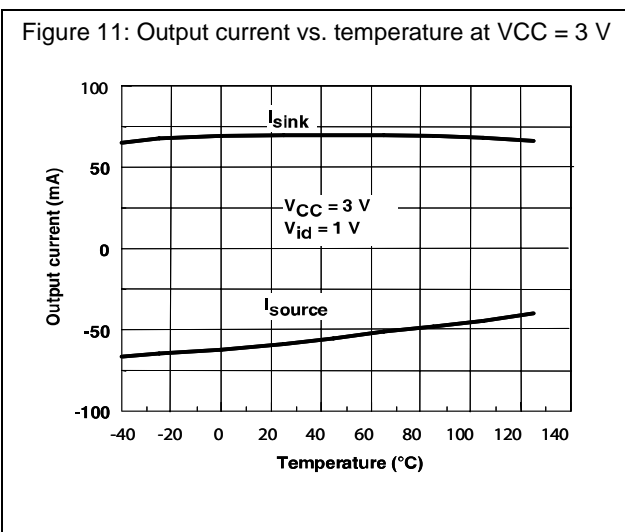
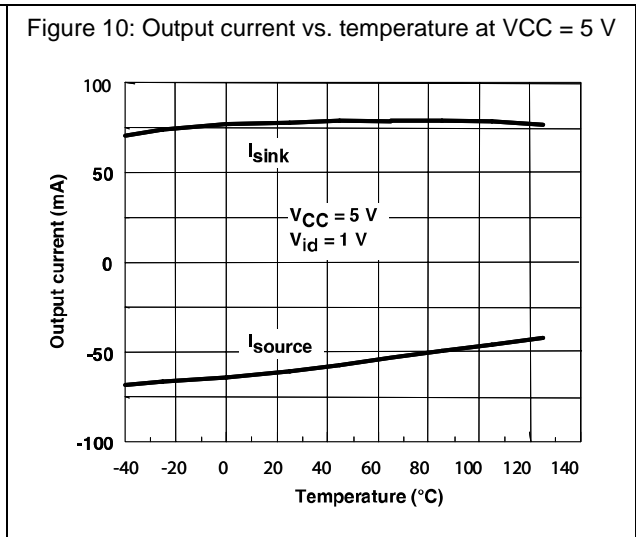
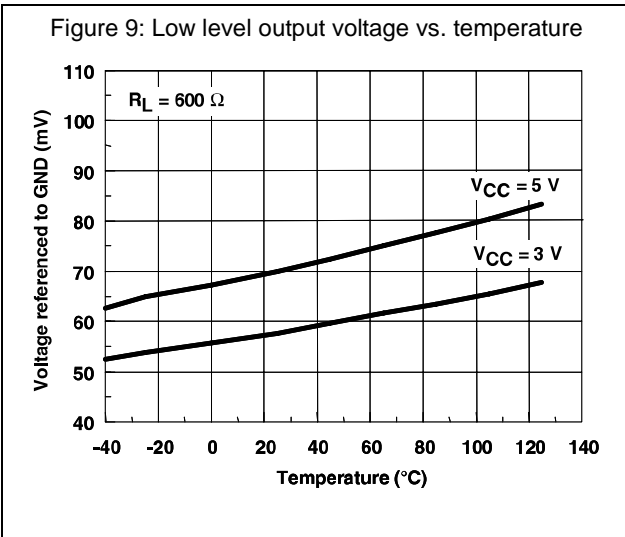
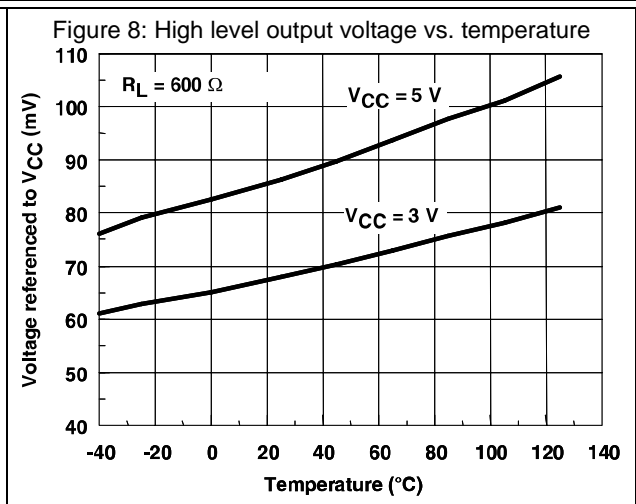
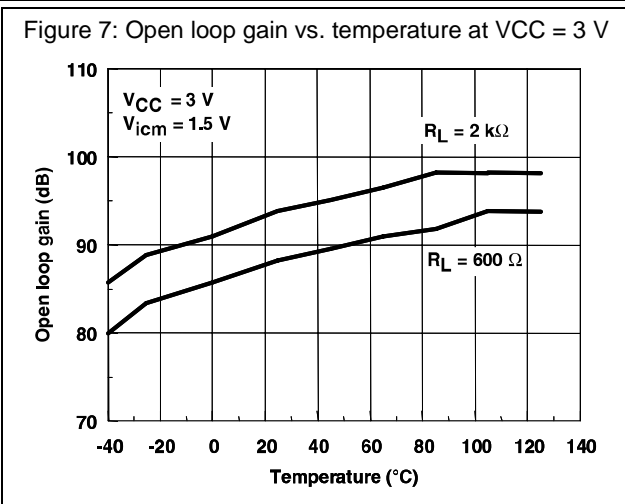


| Symbol | Parameter | Conditions | Min. | Typ. | Max. | Unit |
|----------|---------------------------|------------------------|------|------|------|------------------------------|
| ϕ_m | Phase margin | $C_L = 100 \text{ pF}$ | | 55 | | Degrees |
| e_n | Input voltage noise | | | 27 | | $\text{nV}/\sqrt{\text{Hz}}$ |
| THD | Total harmonic distortion | | | 0.01 | | % |

Notes:

⁽¹⁾Maximum values include unavoidable inaccuracies of the industrial tests.







3 Package information

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

3.1 SOT23-5 package information

Figure 19: SOT23-5 package outline

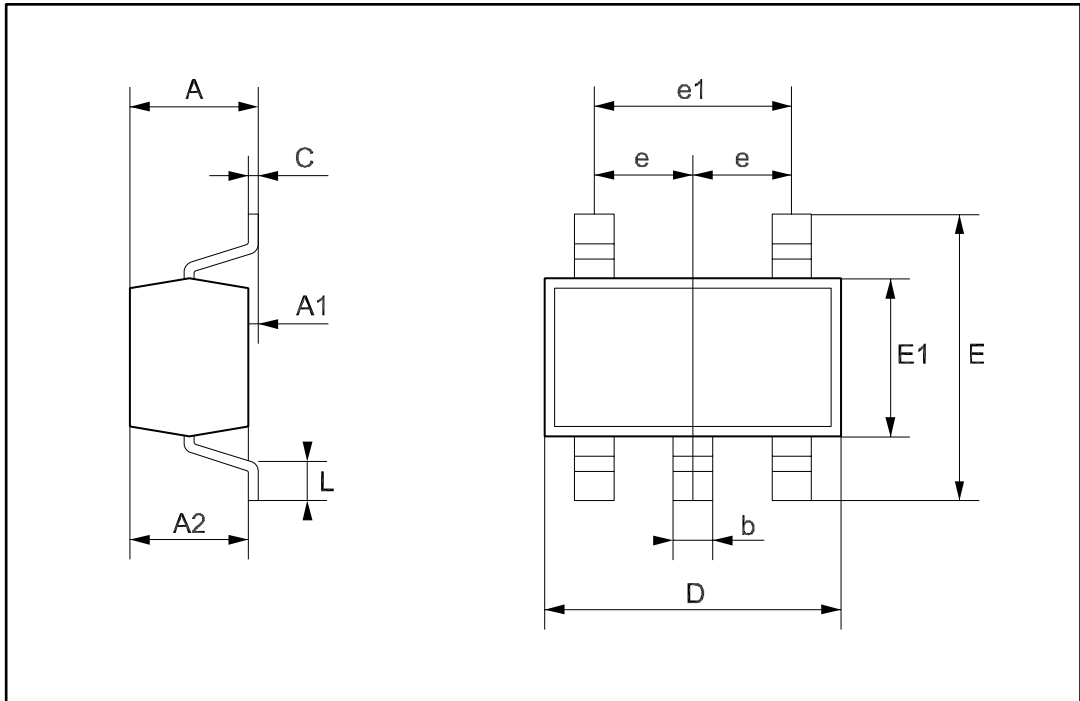


Table 5: SOT23-5 package mechanical data

| Symbol | Dimensions | | | | | |
|--------|-------------|------|------|-------|------|-------|
| | Millimeters | | | Mils | | |
| | Min. | Typ. | Max. | Min. | Typ. | Max. |
| A | 0.90 | | 1.45 | 35.4 | | 57.1 |
| A1 | 0.00 | | 0.15 | 0.00 | | 5.9 |
| A2 | 0.90 | | 1.30 | 35.4 | | 51.2 |
| b | 0.35 | | 0.50 | 13.7 | | 19.7 |
| C | 0.09 | | 0.20 | 3.5 | | 7.8 |
| D | 2.80 | | 3.00 | 110.2 | | 118.1 |
| E | 2.60 | | 3.00 | 102.3 | | 118.1 |
| E1 | 1.50 | | 1.75 | 59.0 | | 68.8 |
| e | | 0.95 | | | 37.4 | |
| e1 | | 1.9 | | | 74.8 | |
| L | 0.35 | | 0.55 | 13.7 | | 21.6 |

3.3 MiniSO8 package information

Figure 21: MiniSO8 package outline



Table 7: MiniSO8 package mechanical data

| Symbol | Dimensions | | | | | |
|--------|-------------|------|------|--------|-------|-------|
| | Millimeters | | | Inches | | |
| | Min. | Typ. | Max. | Min. | Typ. | Max. |
| A | | | 1.1 | | | 0.043 |
| A1 | 0 | | 0.15 | 0 | | 0.006 |
| A2 | 0.75 | 0.85 | 0.95 | 0.030 | 0.033 | 0.037 |
| b | 0.22 | | 0.40 | 0.009 | | 0.016 |
| c | 0.08 | | 0.23 | 0.003 | | 0.009 |
| D | 2.80 | 3.00 | 3.20 | 0.11 | 0.118 | 0.126 |
| E | 4.65 | 4.90 | 5.15 | 0.183 | 0.193 | 0.203 |
| E1 | 2.80 | 3.00 | 3.10 | 0.11 | 0.118 | 0.122 |
| e | | 0.65 | | | 0.026 | |
| L | 0.40 | 0.60 | 0.80 | 0.016 | 0.024 | 0.031 |
| L1 | | 0.95 | | | 0.037 | |
| L2 | | 0.25 | | | 0.010 | |
| k | 0° | | 8° | 0° | | 8° |
| ccc | | | 0.10 | | | 0.004 |

3.4 TSSOP8 package information

Figure 22: TSSOP8 package outline

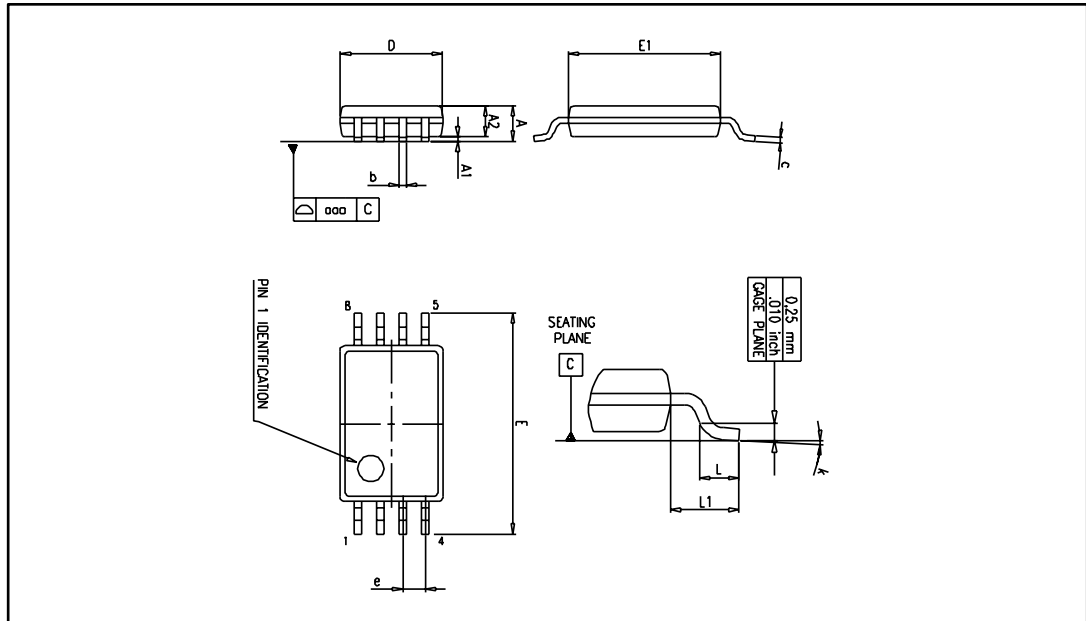


Table 8: TSSOP8 package mechanical data

| Symbol | Dimensions | | | | | |
|--------|-------------|------|------|--------|--------|-------|
| | Millimeters | | | Inches | | |
| | Min. | Typ. | Max. | Min. | Typ. | Max. |
| A | | | 1.2 | | | 0.047 |
| A1 | 0.05 | | 0.15 | 0.002 | | 0.006 |
| A2 | 0.80 | 1.00 | 1.05 | 0.031 | 0.039 | 0.041 |
| b | 0.19 | | 0.30 | 0.007 | | 0.012 |
| c | 0.09 | | 0.20 | 0.004 | | 0.008 |
| D | 2.90 | 3.00 | 3.10 | 0.114 | 0.118 | 0.122 |
| E | 6.20 | 6.40 | 6.60 | 0.244 | 0.252 | 0.260 |
| E1 | 4.30 | 4.40 | 4.50 | 0.169 | 0.173 | 0.177 |
| e | | 0.65 | | | 0.0256 | |
| k | 0° | | 8° | 0° | | 8° |
| L | 0.45 | 0.60 | 0.75 | 0.018 | 0.024 | 0.030 |
| L1 | | 1 | | | 0.039 | |
| aaa | | 0.1 | | | 0.004 | |

3.5 SO14 package information

Figure 23: SO14 package outline



Table 9: SO14 package mechanical data

| Symbol | Dimensions | | | | | |
|--------|-------------|------|------|--------|-------|-------|
| | Millimeters | | | Inches | | |
| | Min. | Typ. | Max. | Min. | Typ. | Max. |
| A | | | 1.75 | | | 0.068 |
| a1 | 0.1 | | 0.2 | 0.003 | | 0.007 |
| a2 | | | 1.65 | | | 0.064 |
| b | 0.35 | | 0.46 | 0.013 | | 0.018 |
| b1 | 0.19 | | 0.25 | 0.007 | | 0.010 |
| C | | 0.5 | | | 0.019 | |
| c1 | 45° (typ.) | | | | | |
| D | 8.55 | | 8.75 | 0.336 | | 0.344 |
| E | 5.8 | | 6.2 | 0.228 | | 0.244 |
| e | | 1.27 | | | 0.050 | |
| e3 | | 7.62 | | | 0.300 | |
| F | 3.8 | | 4.0 | 0.149 | | 0.157 |
| G | 4.6 | | 5.3 | 0.181 | | 0.208 |
| L | 0.5 | | 1.27 | 0.019 | | 0.050 |
| M | | | 0.68 | | | 0.026 |
| S | 8° (max.) | | | | | |

3.6 TSSOP14 package information

Figure 24: TSSOP14 package outline

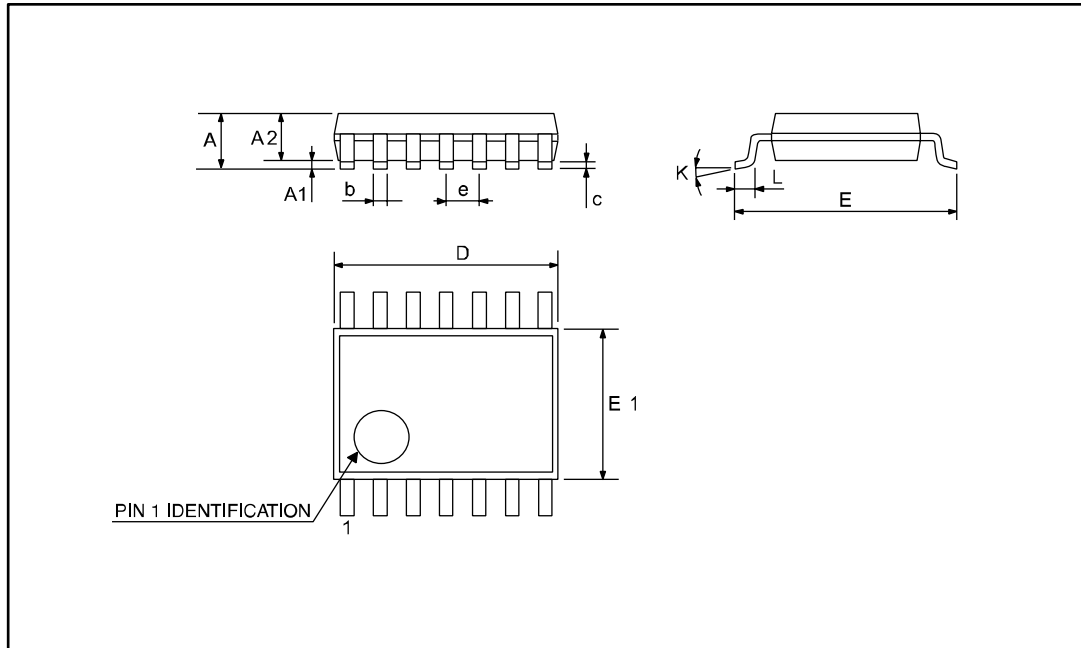


Table 10: TSSOP14 package mechanical data

| Symbol | Dimensions | | | | | |
|--------|-------------|----------|------|--------|------------|--------|
| | Millimeters | | | Inches | | |
| | Min. | Typ. | Max. | Min. | Typ. | Max. |
| A | | | 1.2 | | | 0.047 |
| A1 | 0.05 | | 0.15 | 0.002 | 0.004 | 0.006 |
| A2 | 0.8 | 1 | 1.05 | 0.031 | 0.039 | 0.041 |
| b | 0.19 | | 0.30 | 0.007 | | 0.012 |
| c | 0.09 | | 0.20 | 0.004 | | 0.0089 |
| D | 4.9 | 5 | 5.1 | 0.193 | 0.197 | 0.201 |
| E | 6.2 | 6.4 | 6.6 | 0.244 | 0.252 | 0.260 |
| E1 | 4.3 | 4.4 | 4.48 | 0.169 | 0.173 | 0.176 |
| e | | 0.65 BSC | | | 0.0256 BSC | |
| K | 0° | | 8° | 0° | | 8° |
| L1 | 0.45 | 0.60 | 0.75 | 0.018 | 0.024 | 0.030 |

4 Ordering information

Table 11: Order codes

| Order code | Temperature range | Package | Packaging | Marking | |
|-----------------------------|--|------------------------------------|---------------|---|--------|
| TSV321RILT | -40 °C to +125 °C | SOT23-5 | Tape and reel | K174 | |
| TSV321RAILT | | | | K178 | |
| TSV321RIYLT ⁽¹⁾ | | | | SOT23-5 (automotive grade level) | K179 |
| TSV321RAIYLT ⁽¹⁾ | | | | | K187 |
| TSV321IDT | | SO8 | | V321ID | |
| TSV321AIDT | | | | V321AI | |
| TSV358IDT | | | | V358ID | |
| TSV358AIDT | | | | V358AID | |
| TSV358IYDT ⁽¹⁾ | | | | SO8 (automotive grade level) | V358YD |
| TSV358AIYDT ⁽¹⁾ | | | | | V358AY |
| TSV358IPT | | | | TSSOP8 (thin shrink outline package) | V358I |
| TSV358AIPT | | | | | V358A |
| TSV358IYPT ⁽¹⁾ | | TSSOP8 (automotive grade level) | | V358Y | |
| TSV358AIYPT ⁽¹⁾ | | | | V58AY | |
| TSV358IST | | MiniSO8 | | K175 | |
| TSV358AIST | | | | K184 | |
| TSV324IDT | | SO14 | | V324ID | |
| TSV324AIDT | | | | V324AI | |
| TSV324IYDT ⁽¹⁾ | | SO14 (automotive grade level) | | V324YD | |
| TSV324AIYDT ⁽¹⁾ | | | | V324AY | |
| TSV324IPT | TSSOP14 (thin shrink outline package) | V324IP | | | |
| TSV324AIPT | | V324A | | | |
| TSV324AIYPT ⁽¹⁾ | TSSOP14 (automotive grade level) | V324AY | | | |
| TSV324IYPT ⁽¹⁾ | | V324Y | | | |

Notes:

⁽¹⁾ Qualified and characterized according to AEC Q100 and Q003 or equivalent, advanced screening according to AEC Q001 and Q 002 or equivalent.

5 Revision history

Table 12: Document revision history

| Date | Revision | Changes |
|-------------|----------|--|
| 2-Aug-2005 | 1 | First release - Products in full production. |
| 20-Sep-2005 | 2 | Addition of TS321A/TS324A/TS358A data in tables in Section 2: "Electrical characteristics" . Minor formatting and grammatical changes. |
| 7-Dec-2005 | 3 | Missing PPAP references inserted see Section 4: "Ordering information" . |
| 28-Jun-2007 | 4 | Correction made on output drive capability, 80mA in description on cover page. SVR measurement conditions inserted in electrical characteristics tables. Offset voltage limit in temperature added in Section 2: "Electrical characteristics" . Correction made on Input Bias Current typical value in Section 2: "Electrical characteristics" . Captions of electrical characteristics figures updated. Automotive grade order codes added to Section 4: "Ordering information" . |
| 21-Feb-2008 | 5 | Corrected SO-14 R_{thja} value to 105 °C/W. Updated presentation of package information. Corrected footnote for automotive grade order codes in order code table. |
| 13-Sep-2012 | 6 | Updated Features (added SO-8, SO-14, TSSOP8, TSSOP14, and MiniSO-8 package). Updated "Pin connection" figure on page 1 (removed part numbers). Removed TSV321ID, TSV321AID, TSV321IYDT, TSV358ID, TSV358AID, TSV324ID, TSV324AID, TSV321IYD, TSV358IYD, TSV358AIYD, TSV321IYD, TSV324IYD, and TSV324AIYD order code from Table 11: "Order codes" . Qualified status of TSV324AIYPT, TSV324IYPT, TSV324IYDT, TSV324AIYDT, TSV358IYDT, TSV321RIYLT, TSV321RAIYLT, and TSV358AIYDT order code in Table 11: "Order codes" . Updated ECOPACK text in Section 3: "Package information" . Minor corrections throughout document. |
| 16-Aug-2013 | 7 | Updated Features Added Related products Table 3 and Table 4 : replaced ΔV_{io} with $\Delta V_{io}/\Delta T$ Table 11: "Order codes" : order code TSV321IDT renamed TSV321AIDT, added order code TSV358AIDT, updated footnote associated with order codes TSV358IYPT and TSV358AIYPT. |

Revision history

TSV321, TSV358, TSV324, TSV321A, TSV358A,
TSV324A,

| Date | Revision | Changes |
|-------------|----------|--|
| 27-Jun-2014 | 8 | Added part numbers TSV321A, TSV358A, and TSV324A. <i>Table 6: "SO8 package mechanical data"</i> : added L1 dimensions <i>Table 11: "Order codes"</i> : removed "tube" from all packaging Updated disclaimer |



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