



Input/Output Rail-to-Rail Low Power Operational Amplifier

- Rail-to-rail input common-mode voltage range
- Rail-to-rail output voltage swing
- Operating from 2.7V to 12V
- High-speed (3MHz, 1V/μs)
- Low consumption (0.9mA @ 3V)
- Supply voltage rejection ratio: 80dB
- Latch-up immunity
- Available in SOT23-5 micropackage

Description

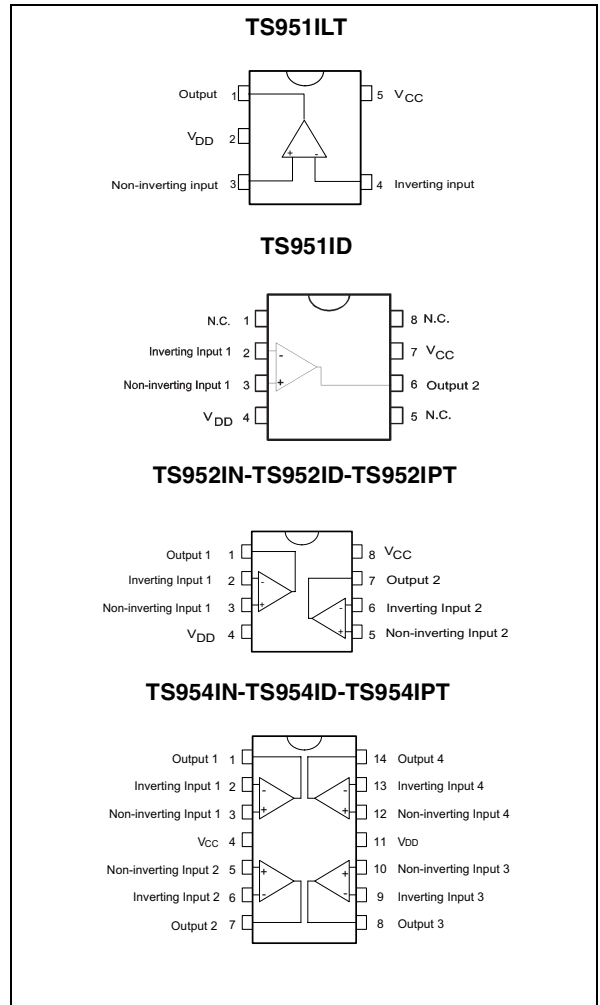
The TS95x family are rail-to-rail BiCMOS operational amplifiers optimized and fully specified for 3V and 5V operation.

The TS951 is housed in the space-saving 5 pins SOT23 package that makes it well suited for battery-powered systems. This micropackage simplifies the PC board design because of its ability to be placed in tight spaces (outside dimensions are: 2.8mm x 2.9mm)

Applications

- Set-top boxes
- Laptop/notebook computers
- Transformer/line drivers
- Personal entertainments (CD players)
- Portable communication (cell phones, pagers)
- Instrumentation & sensing
- Digital to analog converter buffers
- Portable headphone speaker drivers

Pin Connections (top view)



Order Codes

| Part Number | Temperature Range | Package | Packaging | Marking |
|-------------|-------------------|--|---------------------|---------|
| TS951IN | -40°C, +125°C | DIP | Tube | |
| TS951ILT | | SOT23-5L | Tape & Reel | K101 |
| TS952IN | | DIP | Tube | |
| TS952ID/IDT | | SO | Tube or Tape & Reel | |
| TS952IPT | | TSSOP (Thin Shrink Outline Package) | Tape & Reel | |
| TS954IN | | DIP | Tube | |
| TS954ID/IDT | | SO | Tube or Tape & Reel | |
| TS954IPT | | TSSOP (Thin Shrink Outline Package) | Tape & Reel | |

1 Absolute Maximum Ratings

Table 1: Key parameters and their absolute maximum ratings

| Symbol | Parameter | Value | Unit |
|----------|---|------------------------------|------|
| V_{CC} | Supply voltage ¹ | 14 | V |
| V_{id} | Differential Input Voltage ² | ± 1 | V |
| V_{in} | Input Voltage | $V_{DD}-0.3$ to $V_{CC}+0.3$ | V |
| Tstg | Storage Temperature Range | -65 to +150 | |
| T_j | Maximum Junction Temperature | 150 | °C |
| Rthja | Thermal Resistance Junction to Ambient ³ | | °C/W |
| | SOT23-5 | 250 | |
| | SO8 | 125 | |
| | SO14 | 103 | |
| | TSSOP8 TSSOP14 | 120 100 | |
| ESD | Human Body Model | 2 | kV |
| ESD | HBM: Human Body Model ⁴ | | |
| | TS951 | 1 | kV |
| | TS952 | 2 | |
| | TS954 | 3 | |
| | MM: Machine Model ⁵ | 100 | V |
| | CDM: Charged Device Model | 1.5 | kV |
| | Latch-up Immunity | 200 | mA |
| | Lead Temperature (soldering, 10sec) | 260 | °C |

1) All voltage values, except differential voltage are with respect to network ground terminal.

2) Differential voltages are the non-inverting input terminal with respect to the inverting input terminal. If $V_{id} > \pm 1V$, the maximum input current must not exceed $\pm 1mA$. In this case ($V_{id} > \pm 1V$) an input serie resistor must be added to limit input current.

3) Short-circuits can cause excessive heating and destructive dissipation.

4) Human body model, 100pF discharged through a 1.5k Ω resistor into pin of device.

5) Machine model ESD, a 200pF cap is charged to the specified voltage, then discharged directly into the IC with no external series resistor (internal resistor < 5 Ω), into pin to pin of device.

Table 2: Operating Conditions

| Symbol | Parameter | Value | Unit |
|------------|--------------------------------------|------------------------------|------|
| V_{CC} | Supply voltage | 2.7 to 12 | V |
| V_{icm} | Common Mode Input Voltage Range | $V_{DD}-0.2$ to $V_{CC}+0.1$ | V |
| T_{oper} | Operating Free Air Temperature Range | -40 to +125 | °C |

2 Electrical Characteristics

Table 3: $V_{CC} = +3V$, $V_{DD} = 0V$, R_L connected to $V_{CC}/2$, $T_{amb} = 25^\circ C$ (unless otherwise specified)

| Symbol | Parameter | Min. | Typ. | Max. | Unit |
|-----------|---|-----------------------------------|------|------------|------------------------|
| V_{io} | Input Offset Voltage $T_{min} \leq T_{amb} \leq T_{max}$ | | | 6 8 | mV |
| DV_{io} | Input Offset Voltage Drift | | 2 | | $\mu V/^\circ C$ |
| I_{io} | Input Offset Current $T_{min} \leq T_{amb} \leq T_{max}$ | | 1 | 30 80 | nA |
| I_{ib} | Input Bias Current $V_{icm} = V_{CC}/2$ $T_{min} \leq T_{amb} \leq T_{max}$ | | 35 | 100 200 | nA |
| V_{icm} | Common Mode Input Voltage Range | $V_{DD} - 0.2$ to $V_{CC} + 0.2V$ | | | V |
| CMR | Common Mode Rejection Ratio | 50 | 80 | | dB |
| SVR | Supply Voltage Rejection Ratio $V_{CC} = 2.7V$ to $3.3V$ | 60 | 80 | | dB |
| A_{Vd} | Large Signal Voltage Gain $V_o = 2V_{pk-pk}$ $R_L = 600\Omega$ | | 80 | | dB |
| V_{OH} | High Level Output Voltage $R_L = 600\Omega$ | 2.8 | 2.9 | | V |
| V_{OL} | Low Level Output Voltage $R_L = 600\Omega$ | | 80 | 250 | mV |
| I_{sc} | Output Short Circuit Current | 10 | | | mA |
| I_{cc} | Supply Current (per Amplifier) No load, $V_{icm} = V_{CC}/2$ | | 0.9 | 1.3 | mA |
| GBP | Gain Bandwidth Product $R_L = 2k\Omega$ | | 3 | | MHz |
| SR | Slew Rate | | 1 | | $V/\mu s$ |
| ϕ_m | Phase Margin at Unit Gain $R_L = 600\Omega$, $C_L = 100pF$ | | 60 | | Degrees |
| Gm | Gain Margin $R_L = 600\Omega$, $C_L = 100pF$ | | 10 | | dB |
| e_n | Equivalent Input Noise Voltage $f = 1kHz$ | | 25 | | $\frac{nV}{\sqrt{Hz}}$ |
| THD | Total Harmonic Distortion $V_{out} = 4V_{pk-pk}$, $F = 10kHz$, $A_v = 2$, $R_L = 10k\Omega$ | | 0.01 | | % |

Table 4: $V_{CC} = +5V$, $V_{DD} = 0V$, R_L connected to $V_{CC}/2$, $T_{amb} = 25^\circ C$ (unless otherwise specified)

| Symbol | Parameter | Min. | Typ. | Max. | Unit |
|-----------|---|---------------------------------------|------|------------|------------------------|
| V_{io} | Input Offset Voltage $T_{min} \leq T_{amb} \leq T_{max}$ | | | 6 8 | mV |
| DV_{io} | Input Offset Voltage Drift | | 2 | | $\mu V/^\circ C$ |
| I_{io} | Input Offset Current $V_{icm} = V_{cc}/2$ $T_{min} \leq T_{amb} \leq T_{max}$ | | 1 | 30 80 | nA |
| I_{ib} | Input Bias Current $V_{icm} = V_{cc}/2$ $T_{min} \leq T_{amb} \leq T_{max}$ | | 35 | 100 200 | nA |
| V_{icm} | Common Mode Input Voltage Range | $V_{DD}^- - 0.2$ to $V_{CC}^+ + 0.2V$ | | | V |
| CMR | Common Mode Rejection Ratio | 50 | 80 | | dB |
| SVR | Supply Voltage Rejection Ratio $V_{cc} = 2.7V$ to $3.3V$ | 60 | 80 | | dB |
| A_{vd} | Large Signal Voltage Gain $V_o = 2V_{pk-pk}$ $R_L = 600\Omega$ | | 86 | | dB |
| V_{OH} | High Level Output Voltage $R_L = 600\Omega$ | 4.7 | 4.8 | | V |
| V_{OL} | Low Level Output Voltage $R_L = 600\Omega$ | | 80 | 300 | mV |
| I_{sc} | Output Short Circuit Current | 10 | | | mA |
| I_{cc} | Supply Current (per Amplifier) No load, $V_{icm} = V_{cc}/2$ | | 0.95 | 1.4 | mA |
| GBP | Gain Bandwidth Product $R_L = 2k\Omega$ | | 3 | | MHz |
| SR | Slew Rate | | 1 | | $V/\mu s$ |
| ϕ_m | Phase Margin at Unit Gain $R_L = 600\Omega$, $C_L = 100pF$ | | 60 | | Degrees |
| Gm | Gain Margin $R_L = 600\Omega$, $C_L = 100pF$ | | 10 | | dB |
| e_n | Equivalent Input Noise Voltage $f = 1kHz$ | | 25 | | $\frac{nV}{\sqrt{Hz}}$ |
| THD | Total Harmonic Distortion $V_{out} = 4V_{pk-pk}$, $F = 10kHz$, $A_v = 2$, $R_L = 10k\Omega$ | | 0.01 | | % |

Figure 1: Supply current vs. supply voltage

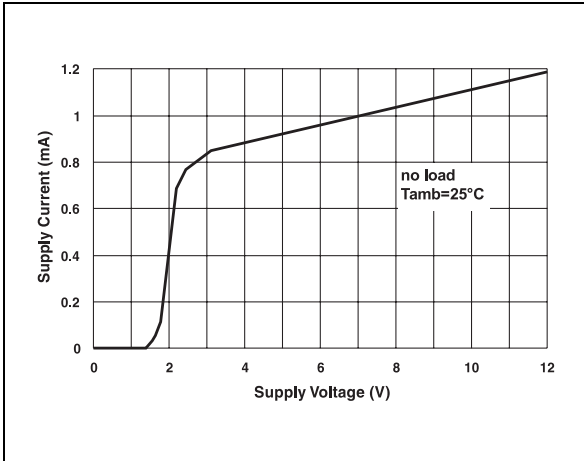


Figure 4: Supply current vs. temperature

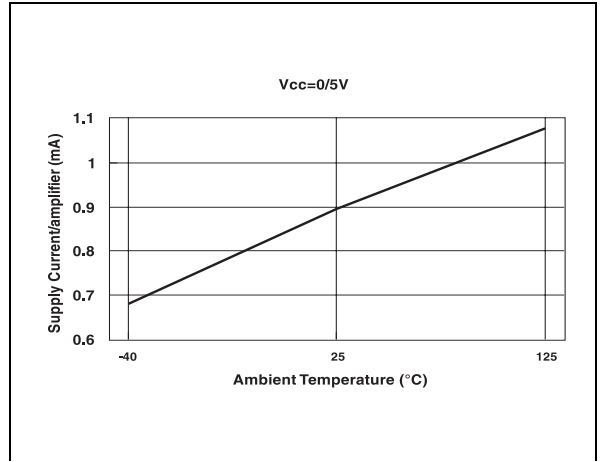


Figure 2: Output short circuit current vs. output voltage

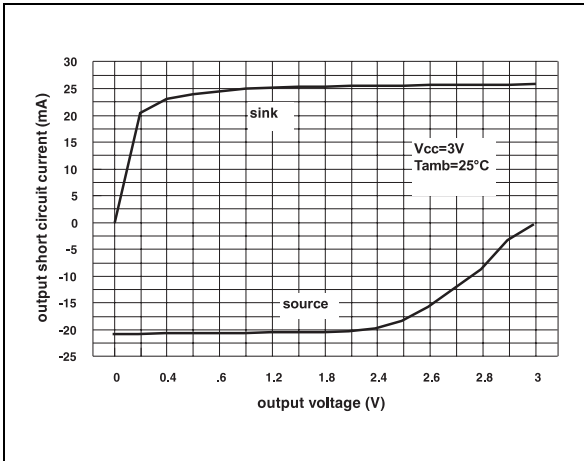


Figure 5: Output short circuit current vs. temperature

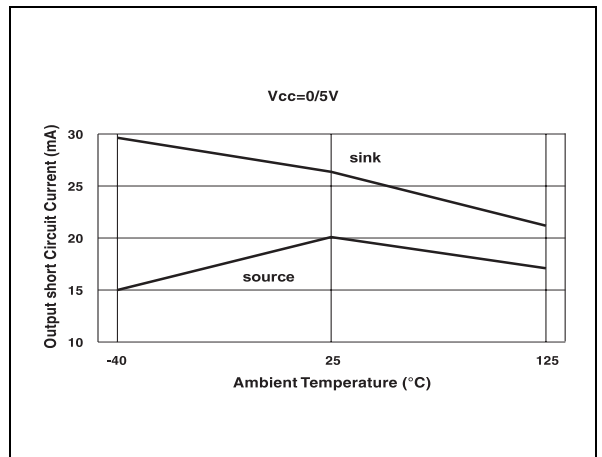


Figure 3: Voltage gain and phase vs. frequency

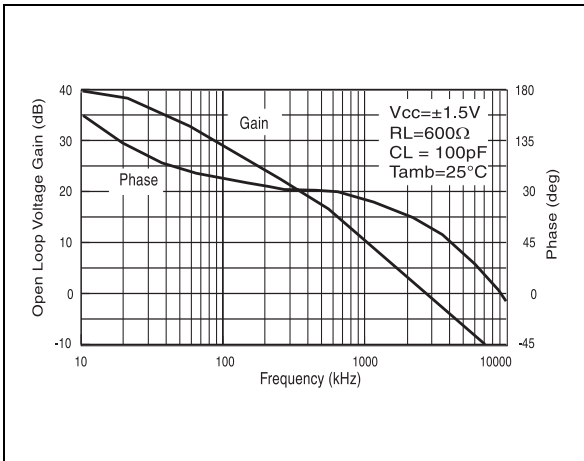


Figure 6: Slew rate vs. temperature

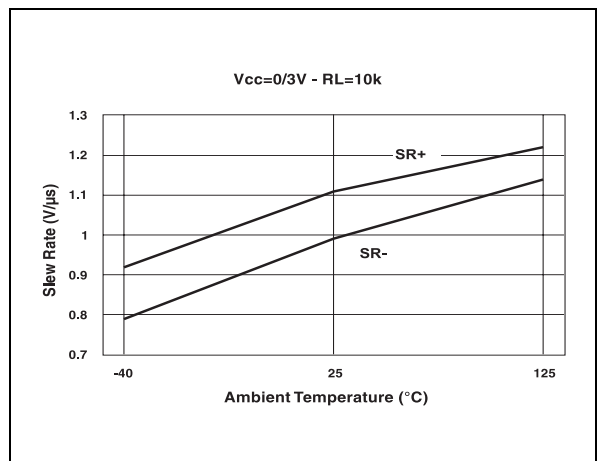


Figure 7: THD + noise vs. Vout

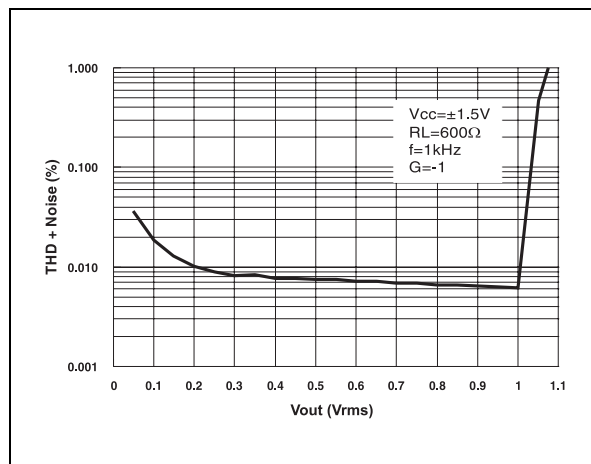


Figure 9: THD + noise vs. Vout

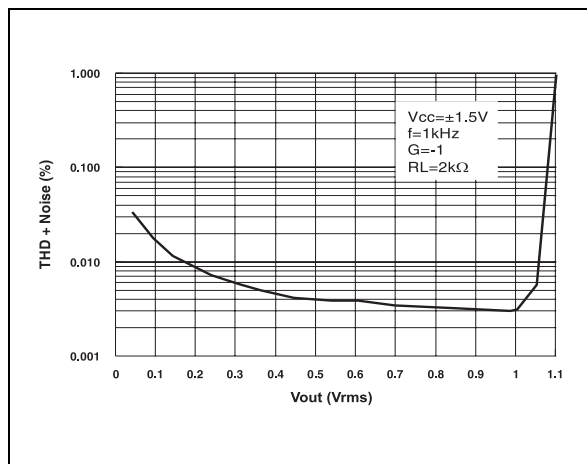


Figure 8: THD + noise vs. frequency

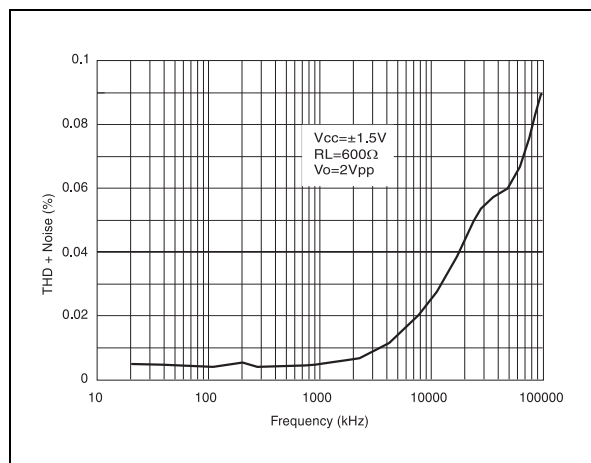
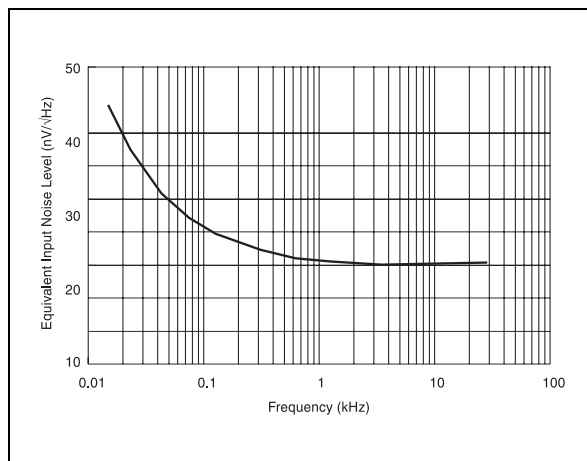


Figure 10: Equivalent input noise voltage vs. frequency

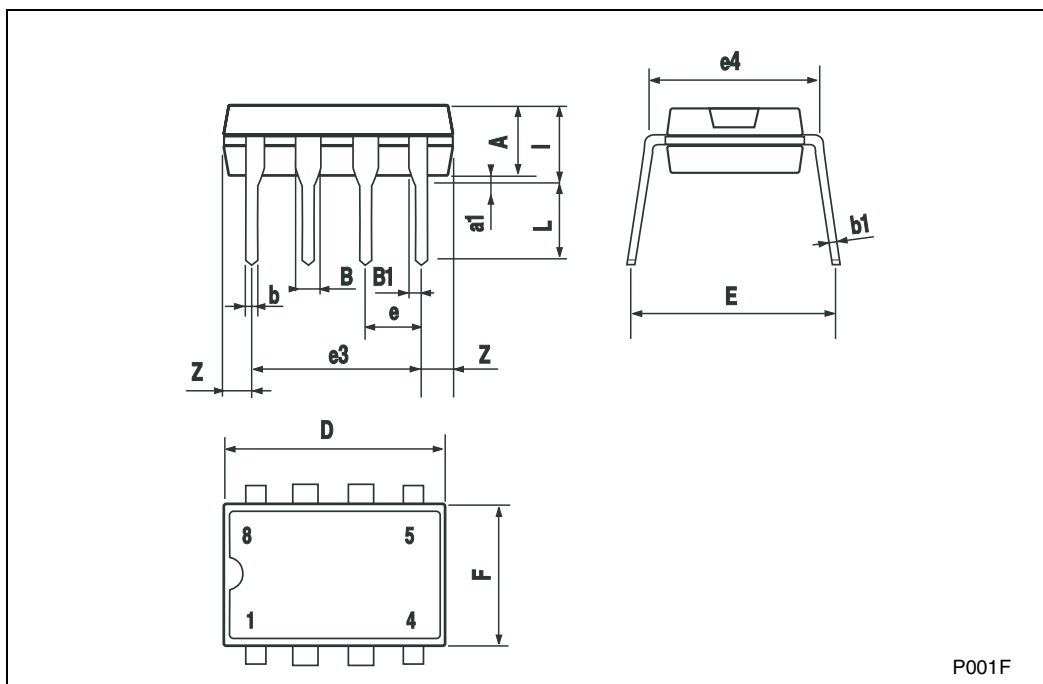


3 Package Mechanical Data

3.1 DIP8 package

Plastic DIP-8 MECHANICAL DATA

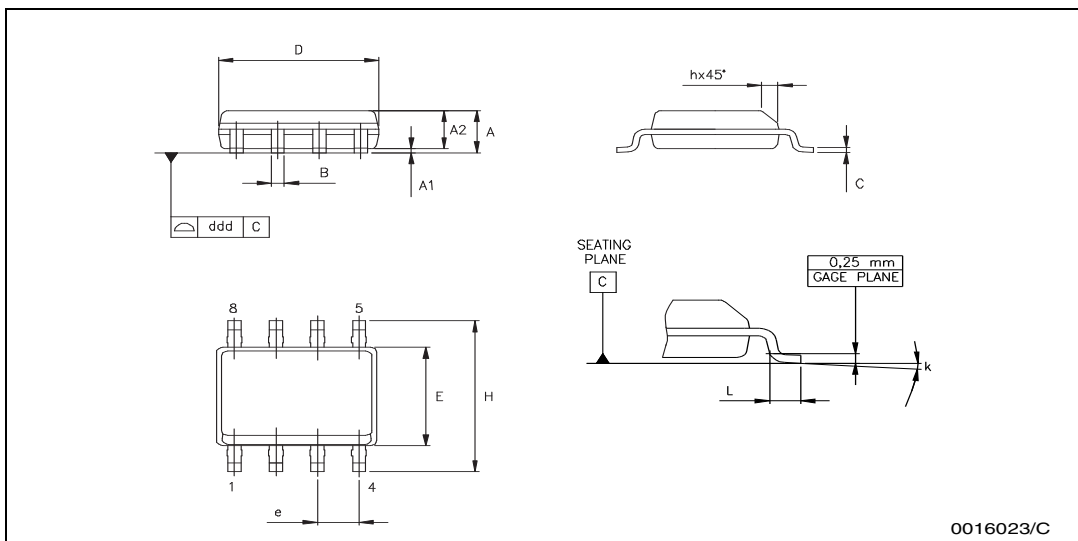
| DIM. | mm. | | | inch | | |
|------|------|------|------|-------|-------|-------|
| | MIN. | TYP | MAX. | MIN. | TYP. | MAX. |
| A | | 3.3 | | | 0.130 | |
| a1 | 0.7 | | | 0.028 | | |
| B | 1.39 | | 1.65 | 0.055 | | 0.065 |
| B1 | 0.91 | | 1.04 | 0.036 | | 0.041 |
| b | | 0.5 | | | 0.020 | |
| b1 | 0.38 | | 0.5 | 0.015 | | 0.020 |
| D | | | 9.8 | | | 0.386 |
| E | | 8.8 | | | 0.346 | |
| e | | 2.54 | | | 0.100 | |
| e3 | | 7.62 | | | 0.300 | |
| e4 | | 7.62 | | | 0.300 | |
| F | | | 7.1 | | | 0.280 |
| I | | | 4.8 | | | 0.189 |
| L | | 3.3 | | | 0.130 | |
| Z | 0.44 | | 1.6 | 0.017 | | 0.063 |



3.2 SO8 package

SO-8 MECHANICAL DATA

| DIM. | mm. | | | inch | | |
|------|-----------|------|------|-------|-------|-------|
| | MIN. | TYP. | MAX. | MIN. | TYP. | MAX. |
| A | 1.35 | | 1.75 | 0.053 | | 0.069 |
| A1 | 0.10 | | 0.25 | 0.04 | | 0.010 |
| A2 | 1.10 | | 1.65 | 0.043 | | 0.065 |
| B | 0.33 | | 0.51 | 0.013 | | 0.020 |
| C | 0.19 | | 0.25 | 0.007 | | 0.010 |
| D | 4.80 | | 5.00 | 0.189 | | 0.197 |
| E | 3.80 | | 4.00 | 0.150 | | 0.157 |
| e | | 1.27 | | | 0.050 | |
| H | 5.80 | | 6.20 | 0.228 | | 0.244 |
| h | 0.25 | | 0.50 | 0.010 | | 0.020 |
| L | 0.40 | | 1.27 | 0.016 | | 0.050 |
| k | 8° (max.) | | | | | |
| ddd | | | 0.1 | | | 0.04 |

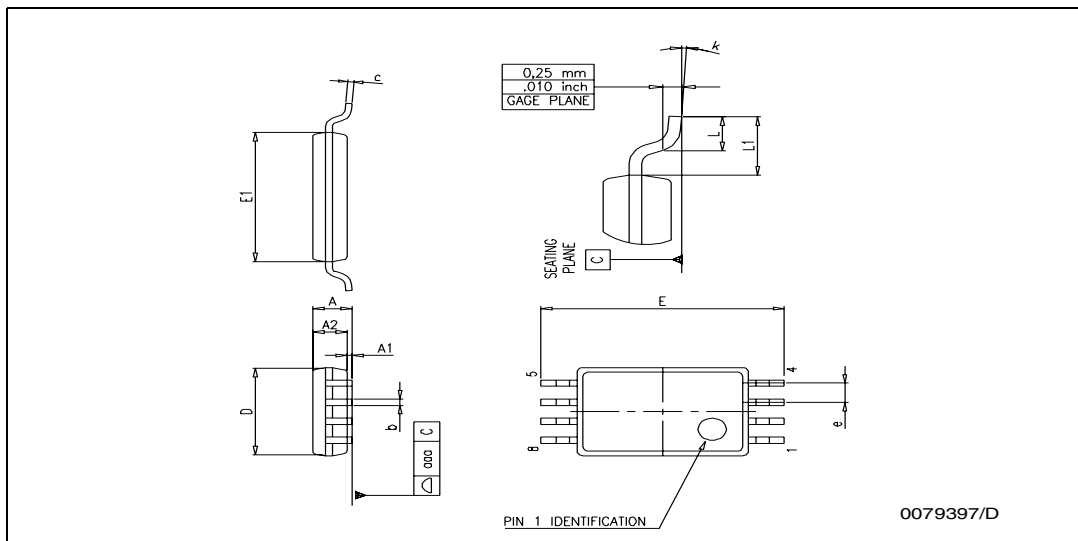


0016023/C

3.3 TSSOP8 package

TSSOP8 MECHANICAL DATA

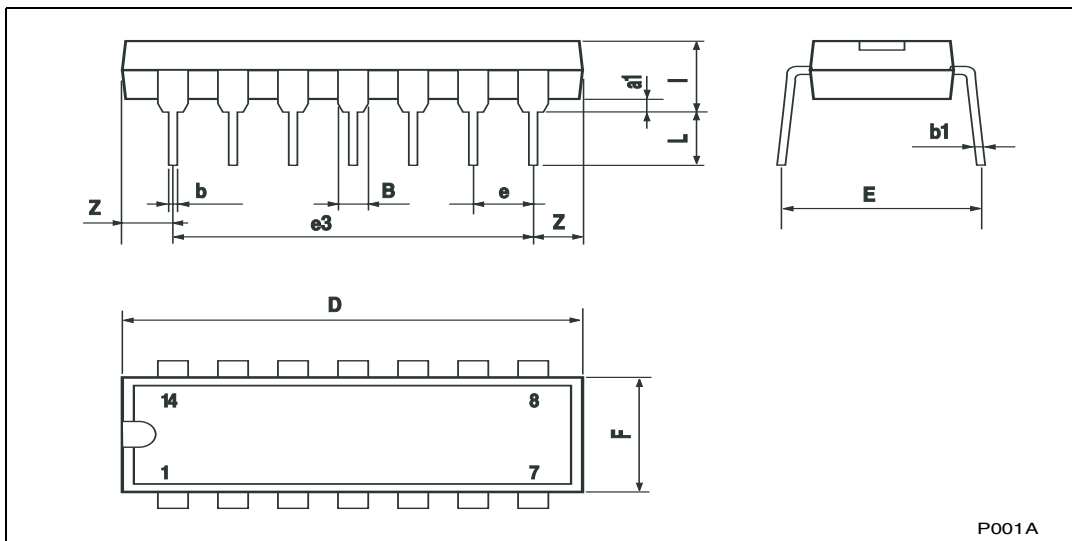
| DIM. | mm. | | | inch | | |
|------|------|------|------|-------|--------|-------|
| | MIN. | TYP | MAX. | MIN. | TYP. | MAX. |
| A | | | 1.2 | | | 0.047 |
| A1 | 0.05 | | 0.15 | 0.002 | | 0.006 |
| A2 | 0.80 | 1.00 | 1.05 | 0.031 | 0.039 | 0.041 |
| b | 0.19 | | 0.30 | 0.007 | | 0.012 |
| c | 0.09 | | 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 | |



3.4 DIP14 package

Plastic DIP-14 MECHANICAL DATA

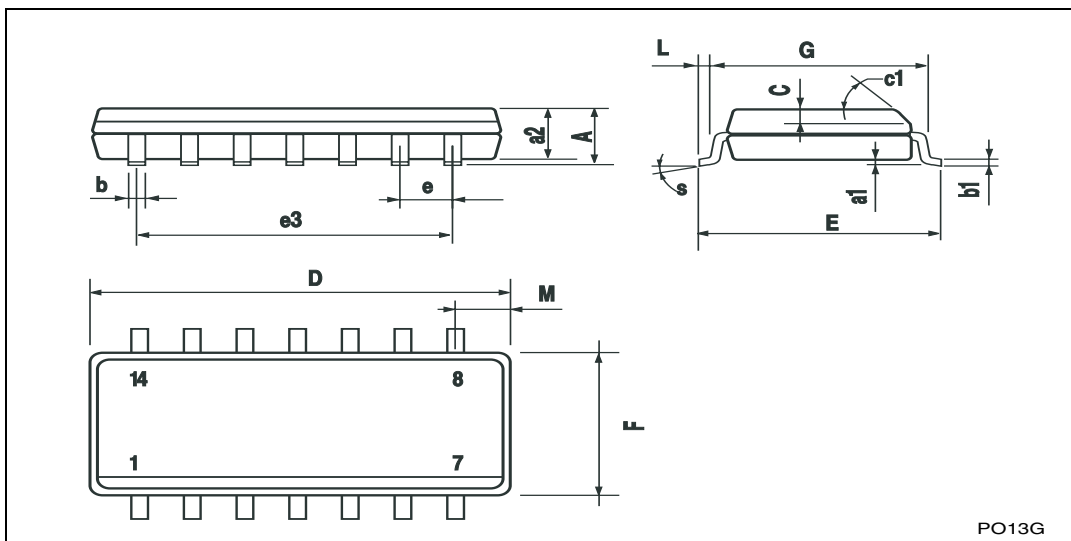
| DIM. | mm. | | | inch | | |
|------|------|-------|------|-------|-------|-------|
| | MIN. | TYP | MAX. | MIN. | TYP. | MAX. |
| a1 | 0.51 | | | 0.020 | | |
| B | 1.39 | | 1.65 | 0.055 | | 0.065 |
| b | | 0.5 | | | 0.020 | |
| b1 | | 0.25 | | | 0.010 | |
| D | | | 20 | | | 0.787 |
| E | | 8.5 | | | 0.335 | |
| e | | 2.54 | | | 0.100 | |
| e3 | | 15.24 | | | 0.600 | |
| F | | | 7.1 | | | 0.280 |
| I | | | 5.1 | | | 0.201 |
| L | | 3.3 | | | 0.130 | |
| Z | 1.27 | | 2.54 | 0.050 | | 0.100 |



3.5 SO14 package

SO-14 MECHANICAL DATA

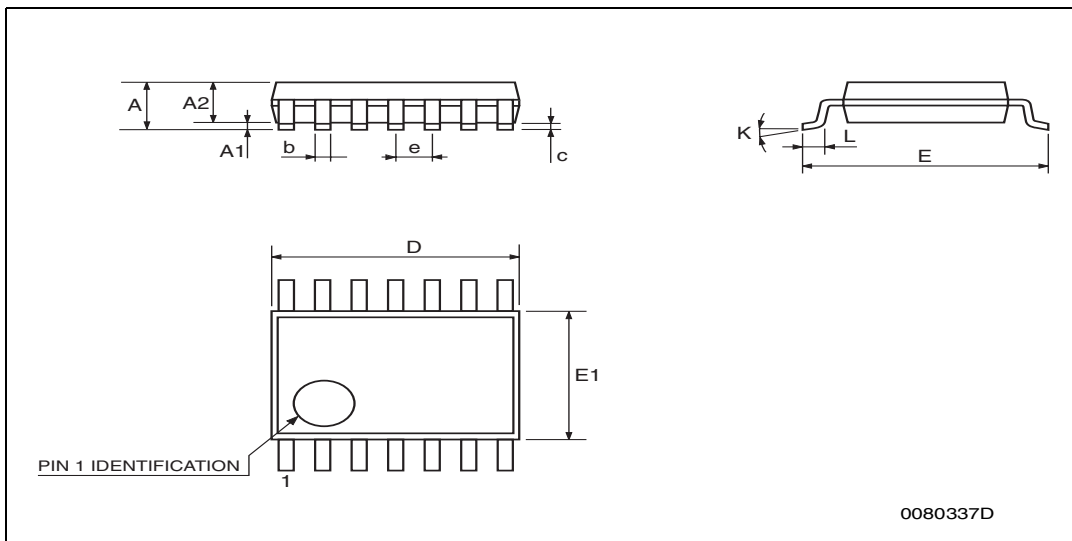
| DIM. | mm. | | | inch | | |
|------|------------|------|------|-------|-------|-------|
| | MIN. | TYP | MAX. | MIN. | TYP. | MAX. |
| A | | | 1.75 | | | 0.068 |
| a1 | 0.1 | | 0.2 | 0.003 | | 0.007 |
| a2 | | | 1.65 | | | 0.064 |
| b | 0.35 | | 0.46 | 0.013 | | 0.018 |
| b1 | 0.19 | | 0.25 | 0.007 | | 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

TSSOP14 MECHANICAL DATA

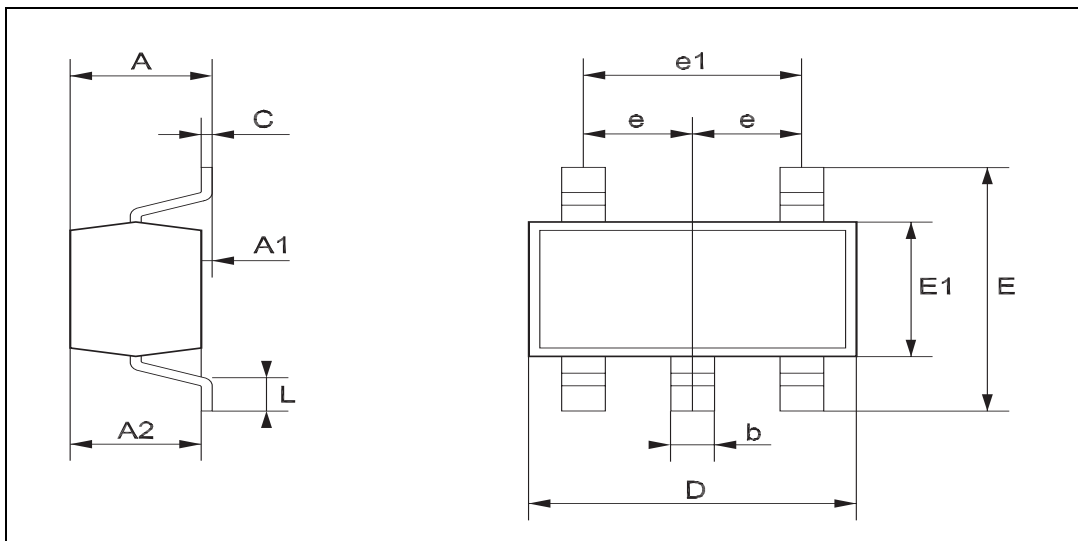
| DIM. | mm. | | | inch | | |
|------|------|----------|------|-------|------------|--------|
| | MIN. | TYP | MAX. | MIN. | TYP. | MAX. |
| A | | | 1.2 | | | 0.047 |
| A1 | 0.05 | | 0.15 | 0.002 | 0.004 | 0.006 |
| A2 | 0.8 | 1 | 1.05 | 0.031 | 0.039 | 0.041 |
| b | 0.19 | | 0.30 | 0.007 | | 0.012 |
| 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° |
| L | 0.45 | 0.60 | 0.75 | 0.018 | 0.024 | 0.030 |



3.7 SOT23-5 package

SOT23-5L MECHANICAL DATA

| DIM. | mm. | | | mils | | |
|------|------|------|------|-------|------|-------|
| | MIN. | TYP | MAX. | MIN. | TYP. | MAX. |
| A | 0.90 | | 1.45 | 35.4 | | 57.1 |
| A1 | 0.00 | | 0.15 | 0.0 | | 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 |



4 Summary of Changes

| Date | Revision | Description of Changes |
|--------------|----------|---|
| 01 May 2001 | 1 | First Release |
| 01 Jan. 2005 | 2 | Modifications on AMR Table 1 on page 2 (explanation of Vid and Vi limits, ESD MM and CDM values added, Rthja added) |

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