# TS931-TS932-TS934

## Output Rail-to-Rail Micropower Operational Amplifiers

- **Rail-to-rail output voltage swing**
- **Micropower consumption (20µA)**
- **Single supply operation (2.7V to 10V**
- **Low offset (2mV max for TS93xB)**
- **CMOS inputs**
- **Ultra low input bias current (1pA)**
- **ESD protection (2kV)**
- **Latch-up immunity (class A)**
- **Available in SOT23-5 micropackage**

### Description

The TS93x (single, dual & quad) series are operational amplifiers able to operate with voltage as low as 2.7V and to reach 2.9Vpp of output swing with $R_L$ = 100kΩ when supplied @ 3V.

Offering a typical consumption of only 20µA, they are particularly well-suited for battery-powered applications.

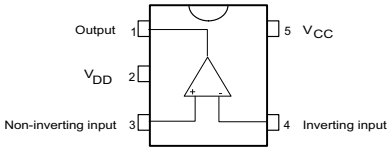
Fitting the TS93x onto your board design is very easy because of its space-saving 5-pin SOT23-5 package with outer dimensions of 2.8mm x 2.9mm.

### Applications

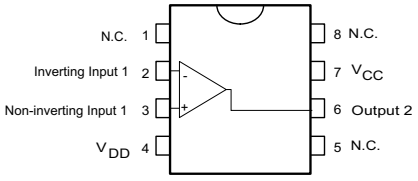
- **Battery-powered systems**
- **Portable communication systems**
- **Alarm, smoke detectors**
- **Instrumentation & sensoring**
- **PH Meter**
- **Digital scales**

### Pin Connections (top view)

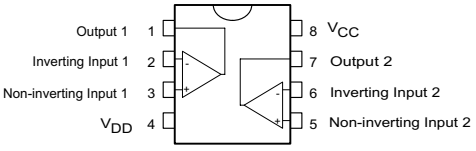
**TS931ILT**



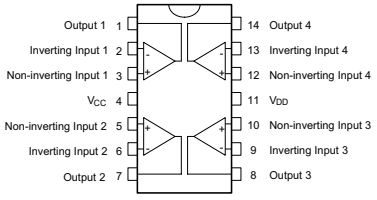

**TS931ID-TS931IDT**




**TS932IN-TS932ID-TS932IDT**




**TS934IN-TS934ID-TS934IDT-TS934IPT**




### Order Codes

| Part Number | Temperature Range | Package | Packaging | Marking |
|---|---|---|---|---|
| TS931ID/IDT/AID/AIDT/BID/BIDT | -40°C, +85°C | SO | Tube or Tape & Reel | |
| TS931ILT/AILT/BILT | | SOT23-5L | Tape & Reel | K205<br>K206<br>K207 |
| TS932IN/AIN/BIN | | DIP | Tube | |
| TS932ID/IDT/AID/AIDT/BID/BIDT | | SO | Tube or Tape & Reel | |
| TS934IN/AIN/BIN | | DIP | Tube | |
| TS934ID/IDT/AID/AIDT/BIDT/BIDT | | SO | Tube or Tape & Reel | |
| TS934IPT/AIPT/BIPT | | TSSOP<br>(Thin Shrink Outline Package) | Tape & Reel | |

# 1 Absolute Maximum Ratings

### Table 1: Key parameters and their absolute maximum ratings

| Symbol | Parameter | Value | Unit |
|---|---|---|---|
| VCC | Supply voltage [1] | 12 | V |
| Vid | Differential Input Voltage [2] | ±12 | V |
| $V_{in}$ | Input Voltage Range [3] | Vdd-0.3 to Vcc+0.3 | V |
| $T_{oper}$ | Operating Free Air Temperature Range | -40 to + 85 | °C |
| $T_{std}$ | Storage Temperature Range | -65 to +150 | °C |
| $T_j$ | Maximum Junction Temperature | 150 | °C |
| $R_{thja}$ | Thermal Resistance Junction to Ambient [4]<br>SOT23-5<br>DIP8<br>DIP14<br>SO8<br>SO14<br>TSSOP8<br>TSSOP14 | <br>250<br>85<br>66<br>125<br>103<br>120<br>100 | °C/W |
| ESD | HBM: Human Body Model[5] | 2 | kV |
| | MM: Machine Model[6] | 200 | V |
| | CDM: Charged Device Model | 2 | kV |
| | Latch-up Immunity | 200 | mA |
| | Soldering Temperature (10sec), leaded version | 250 | °C |

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

2) Differential voltages are non-inverting input terminal with respect to the inverting input terminal.

3) The magnitude of input and output voltages must never exceed $V_{CC}$ +0.3V.

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

5) Human body model, 100pF discharged through a 1.5kΩ resistor into pin of device.

6) 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 < 5Ω), into pin to pin of device.

### Table 2: Operating Conditions

| Symbol | Parameter | Value | Unit |
|---|---|---|---|
| VCC | Supply Voltage | 2.7 to 10 | V |
| Vicm | Common Mode Input Voltage Range | $V_{dd}$ - 0.2 to $V_{CC}$ - 1.5 | V |
| $T_{oper}$ | Operating Free Air Temperature Range | -40 to + 85 | °C |

## 2 Electrical Characteristics

*Tables 3* and *4* give the electrical characteristics at each $V_{cc}$ value.

**Table 3: $V_{CC}$ = +3V, $V_{dd}$ = 0V, $T_{amb}$ = 25°C (unless otherwise specified)**

| Symbol | Parameter | | Min. | Typ. | Max. | Unit |
|---|---|---|---|---|---|---|
| $V_{io}$ | Input Offset Voltage | TS931/2/4<br>TS931/2/4A<br>TS931/2/4B | | | 10<br>5<br>2 | mV |
| $\Delta V_{io}$ | Input Offset Voltage Drift | | | 3 | | µV/°C |
| $I_{io}$ | Input Offset Current [1] | | | 1 | 100 | pA |
| $I_{ib}$ | Input Bias Current [1)] | | | 1 | 150 | pA |
| CMR | Common Mode Rejection Ratio<br>$0 \le V_{icm} \le V_{CC}$ - 1.7 | | | 85 | | dB |
| SVR | Supply Voltage Rejection Ratio [2] | | | 85 | | dB |
| $A_{vd}$ | Large Signal Voltage Gain<br>$V_O$ = 2Vpp | $R_L$ = 1MΩ<br>$R_L$ = 100kΩ | | 120<br>106 | | dB |
| $V_{OH}$ | High Level Output Voltage<br>$V_{ID}$ = 100mV | $R_L$ = 100kΩ | 2.95 | | | V |
| $V_{OL}$ | Low Level Output Voltage<br>$V_{ID}$ = -100mV | $R_L$ = 100kΩ | | | 50 | mV |
| $I_o$ | Output Source Current<br>$V_{ID}$ = 100mV, $V_O$ = $V_{DD}$<br>Output Sink Current<br>$V_{ID}$ = -100mV, $V_O$ = $V_{CC}$ | | | 1.5<br><br>1.5 | | mA |
| $I_{CC}$ | Supply Current (per amplifier)<br>$A_{VCL}$ = 1, no load | | | 20 | 31 | µA |
| GBP | Gain Bandwidth Product | $R_L$ = 100kΩ, $C_L$ = 50pF | | 100 | | kHz |
| SR | Slew Rate | $R_L$ = 100kΩ, $C_L$ = 50pF | | 50 | | V/ms |
| ϕm | Phase Margin | $C_L$ = 50pF | | 65 | | Degrees |
| en | Input Voltage Noise | | | 75 | | nV/√Hz |

1) Maximum values including unavoidable inaccurates of the industrial test.

2) $V_{CC}$ has a 0.2V variation.

**Table 4: $V_{CC}$ = +5V, $V_{dd}$ = 0V, $T_{amb}$ = 25°C (unless otherwise specified)**

| Symbol | Parameter | | Min. | Typ. | Max. | Unit |
|---|---|---|---|---|---|---|
| $V_{io}$ | Input Offset Voltage<br>TS931/2/4<br>TS931/2/4A<br>TS931/2/4B | | | | 10<br>5<br>2 | mV |
| $\Delta V_{io}$ | Input Offset Voltage Drift | | | 3 | | µV/°C |
| $I_{io}$ | Input Offset Current [1] | | | 1 | 100 | pA |
| $I_{ib}$ | Input Bias Current [1)] | | | 1 | 150 | pA |
| CMR | Common Mode Rejection Ratio<br>$0 \le V_{icm} \le V_{CC}$ - 1.7 | | | 85 | | dB |
| SVR | Supply Voltage Rejection Ratio [2] | | | 85 | | dB |
| $A_{vd}$ | Large Signal Voltage Gain<br>$V_O$ = 4Vpp | $R_L$ = 1MΩ<br>$R_L$ = 100kΩ | | 120<br>112 | | dB |
| $V_{OH}$ | High Level Output Voltage<br>$V_{ID}$ = 100mV | $R_L$ = 100kΩ | 4.95 | | | V |
| $V_{OL}$ | Low Level Output Voltage<br>$V_{ID}$ = -100mV | $R_L$ = 100kΩ | | | 50 | mV |
| $I_o$ | Output Source Current<br>$V_{ID}$ = 100mV, $V_O$ = $V_{DD}$<br>Output Sink Current<br>$V_{ID}$ = -100mV, $V_O$ = $V_{CC}$ | | | 5<br><br>5 | | mA |
| $I_{CC}$ | Supply Current (per amplifier)<br>$A_{VCL}$ = 1, no load | | | 20 | 33 | µA |
| GBP | Gain Bandwidth Product | $R_L$ = 100KΩ, $C_L$ = 50pF | | 100 | | kHz |
| SR | Slew Rate | $R_L$ = 100KΩ, $C_L$ = 50pF | | 50 | | V/ms |
| $\phi m$ | Phase Margin | $C_L$ = 50pF | | 65 | | Degrees |
| en | Input Voltage Noise | | | 76 | | nV/√Hz |

1) Maximum values including unavoidable inaccurates of the industrial test.

2) $V_{CC}$ has a 0.2V variation.

**Figure 1:**

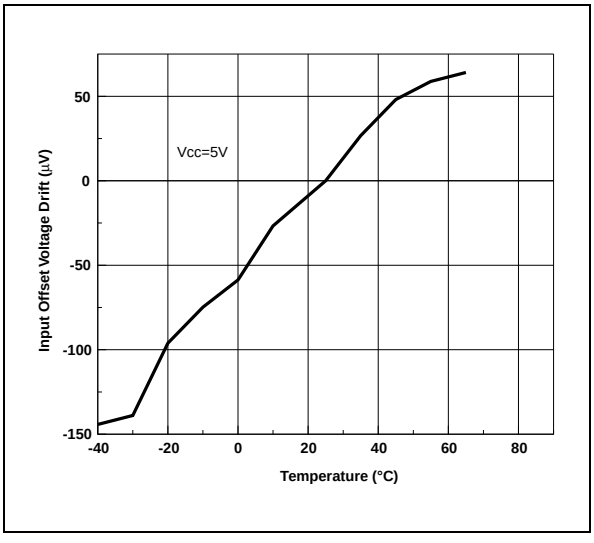



**Figure 2:**

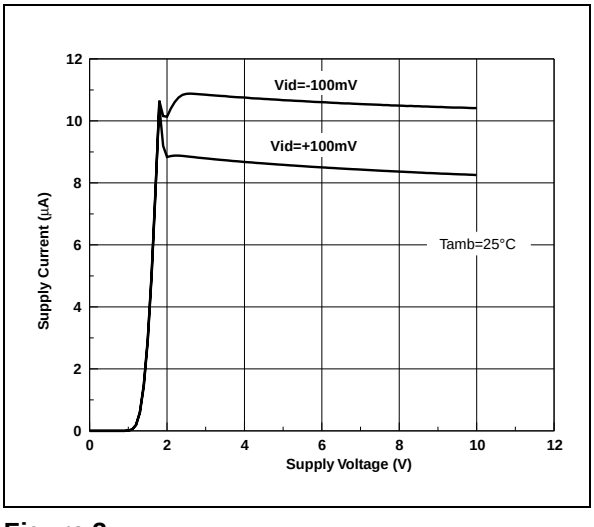



**Figure 3:**

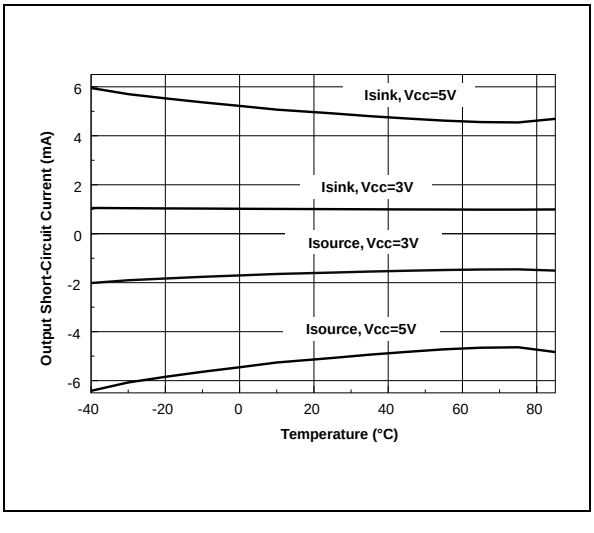



**Figure 4:**

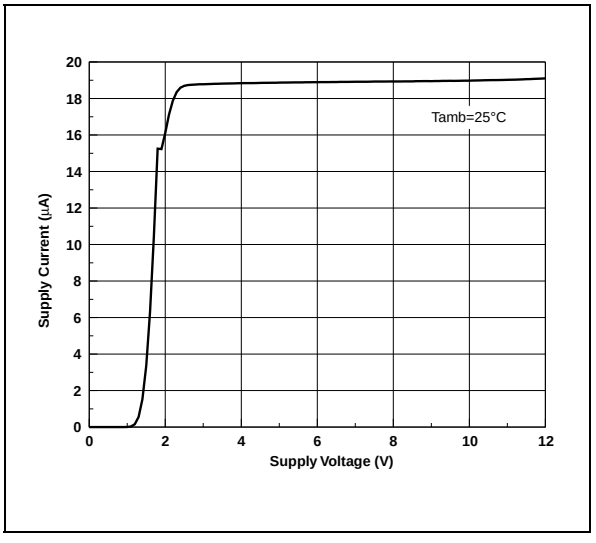
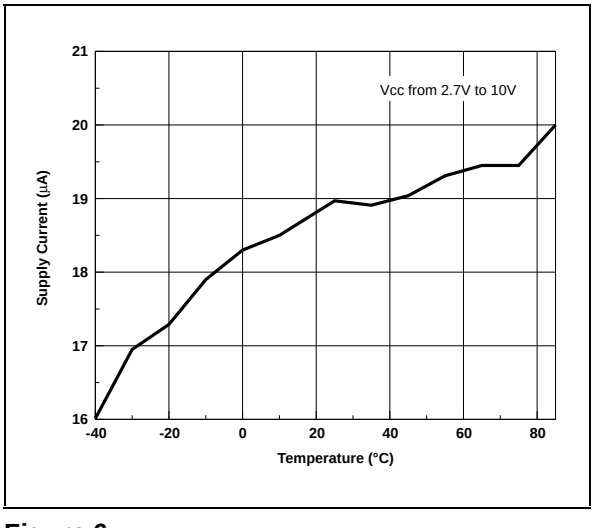



**Figure 5:**

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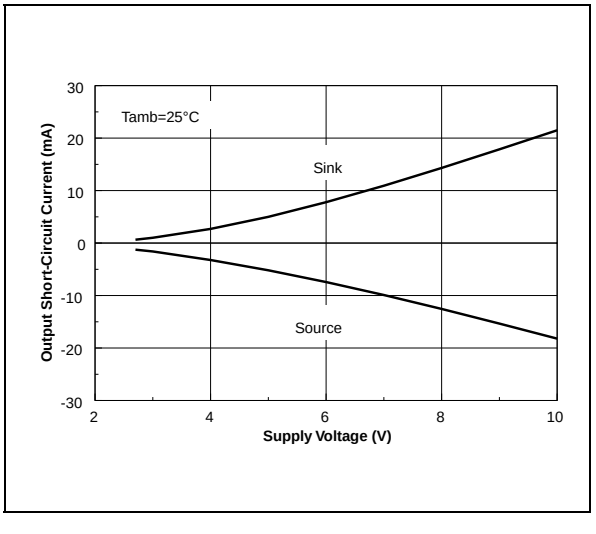

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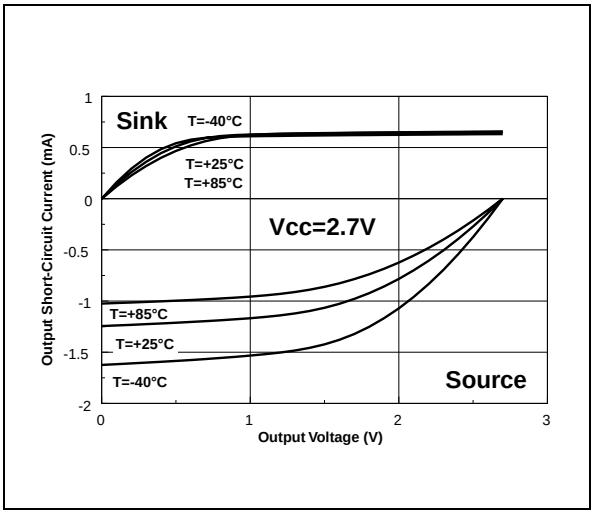


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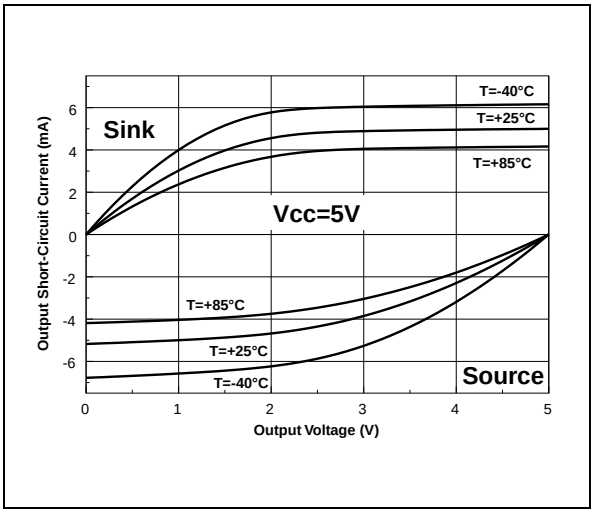


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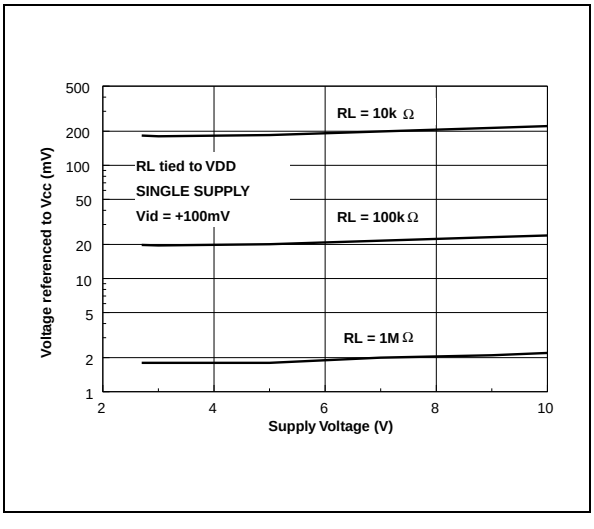


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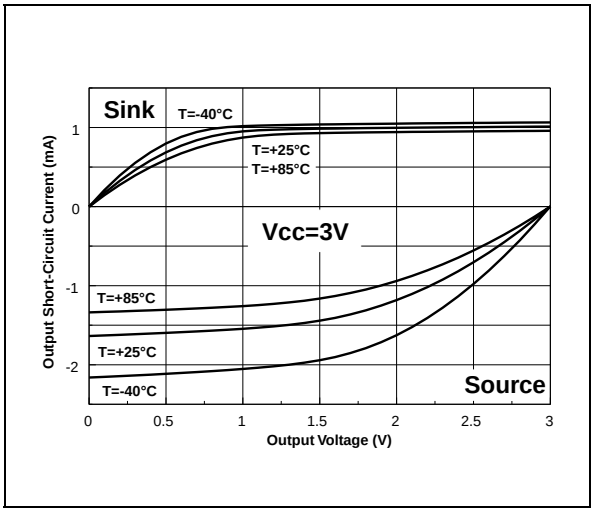


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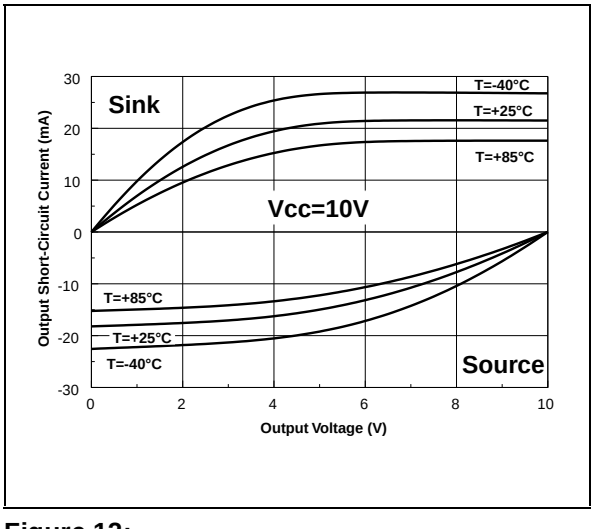
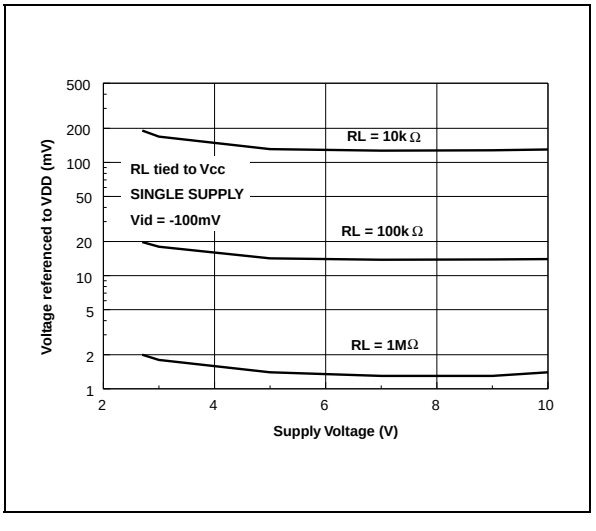



**Figure 12:**



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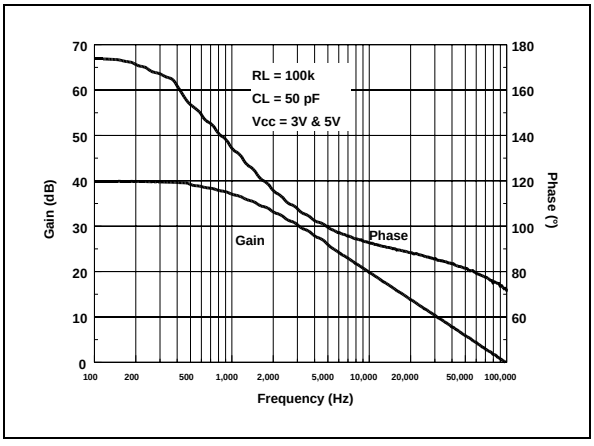


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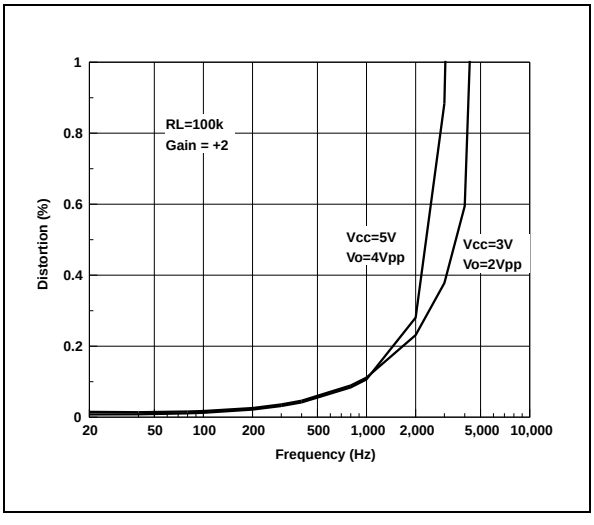


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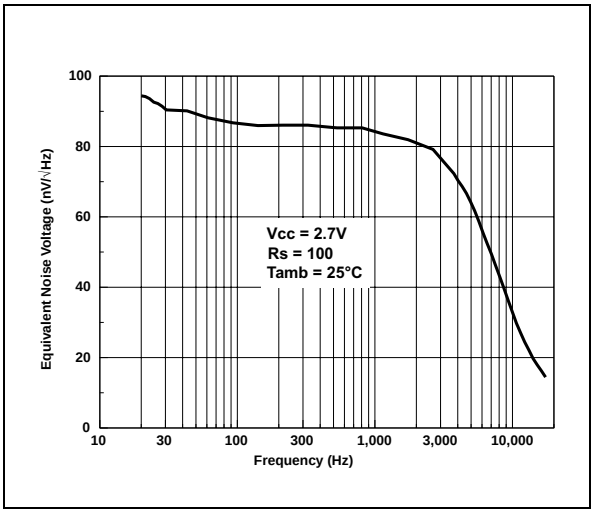


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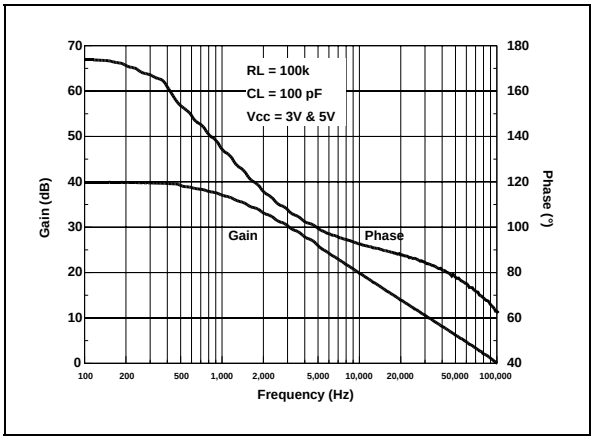


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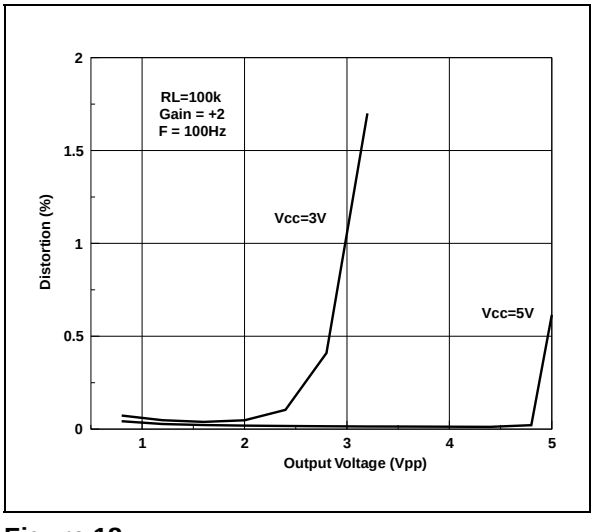


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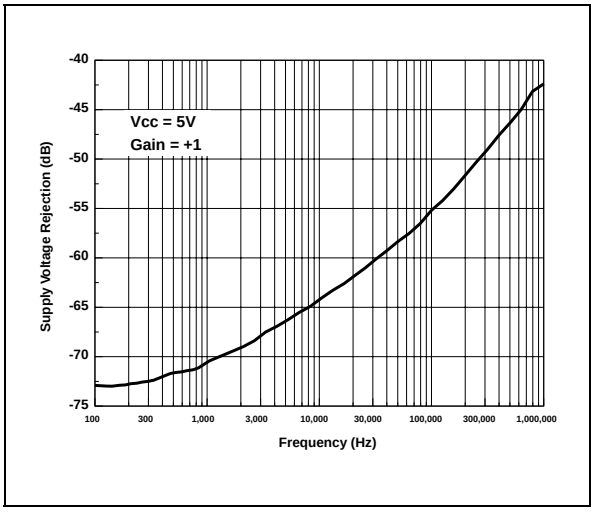

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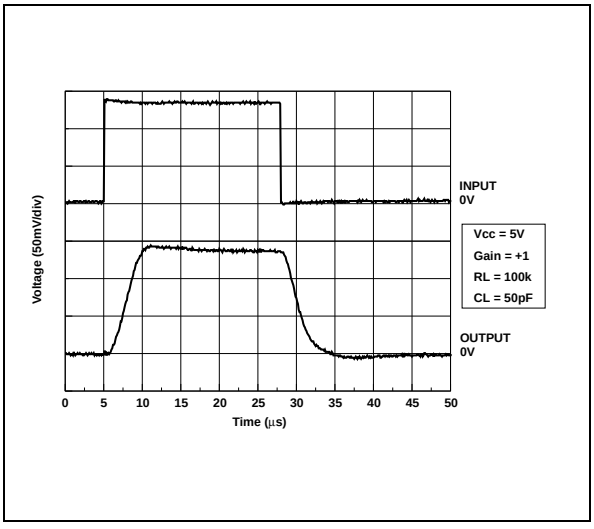


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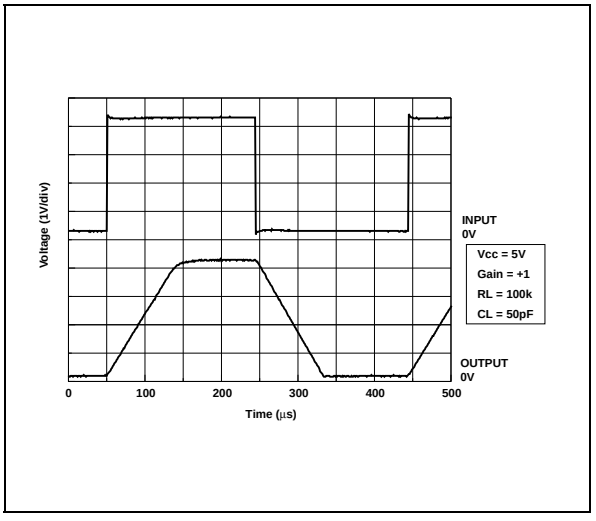
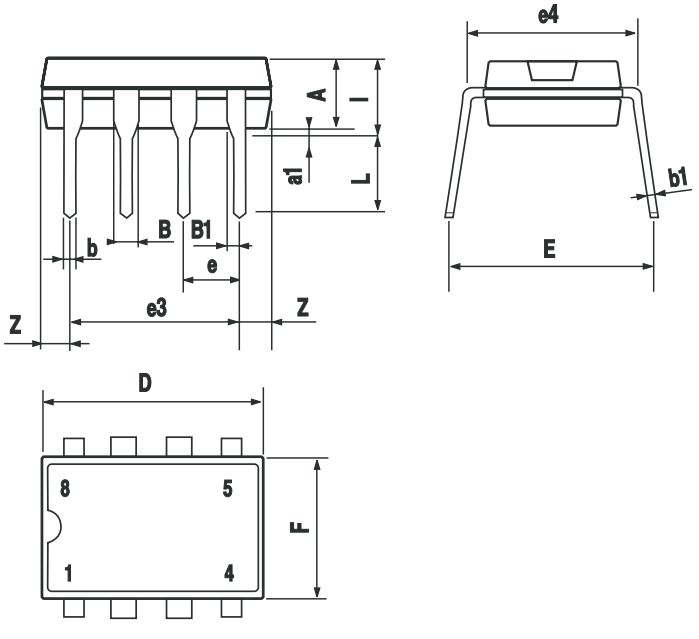


# 3 Package Mechanical Data

## 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 |

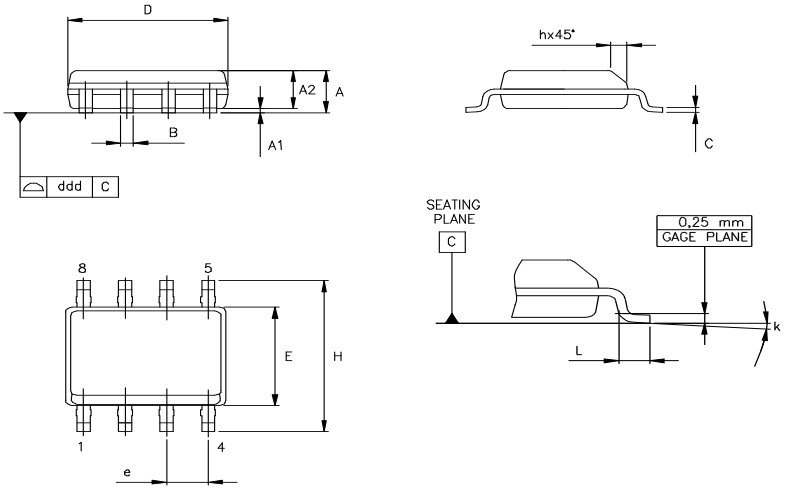



P001F

## 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 |

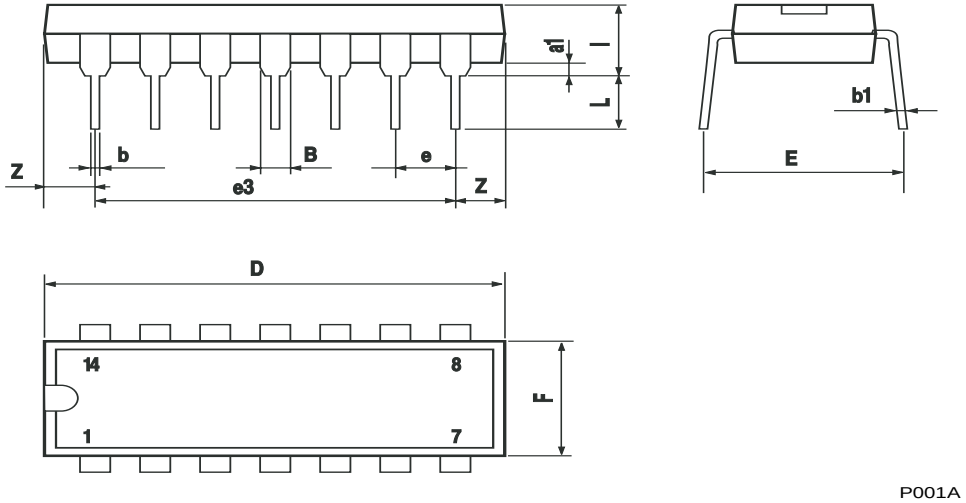



0016023/C

## 3.3 DIP14 package

**Plastic DIP-14 MECHANICAL DATA**

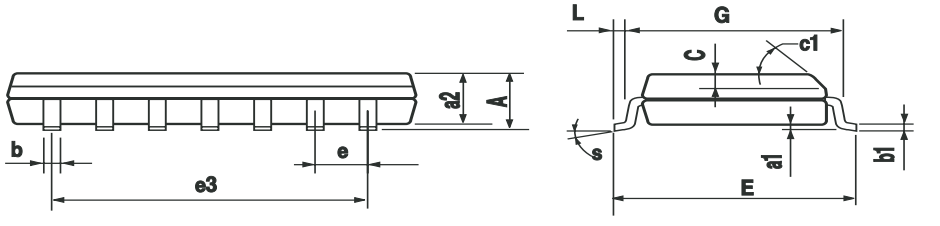
| DIM. | mm. | | | inch | | |
|---|---|---|---|---|---|---|
| | MIN. | TYP | MAX. | MIN. | TYP. | MAX. |
| a1 | 0.51 | | | 0.020 | | |
| B | 1.39 | | 1.65 | 0.055 | | 0.065 |
| b | | 0.5 | | | 0.020 | |
| b1 | | 0.25 | | | 0.010 | |
| D | | | 20 | | | 0.787 |
| E | | 8.5 | | | 0.335 | |
| e | | 2.54 | | | 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 |



## 3.4 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.) | | | | | |

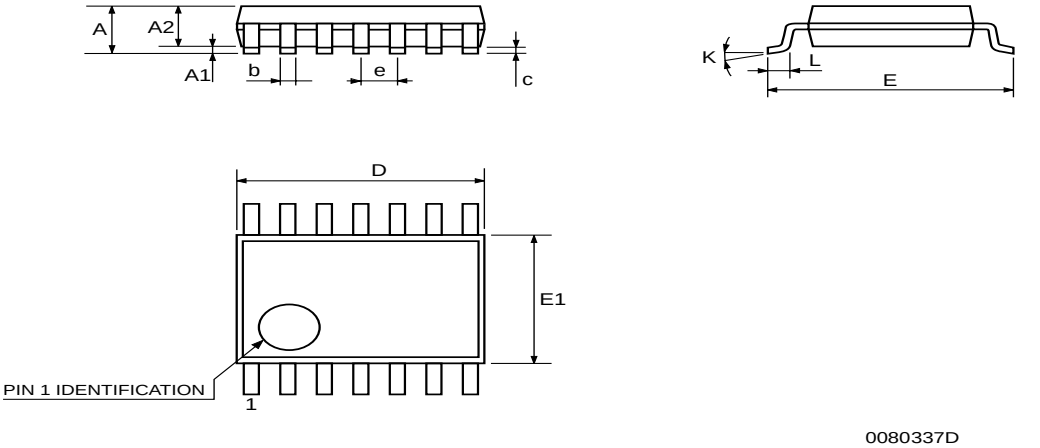



PO13G

## 3.5 TSSOP14 package

**TSSOP14 MECHANICAL DATA**

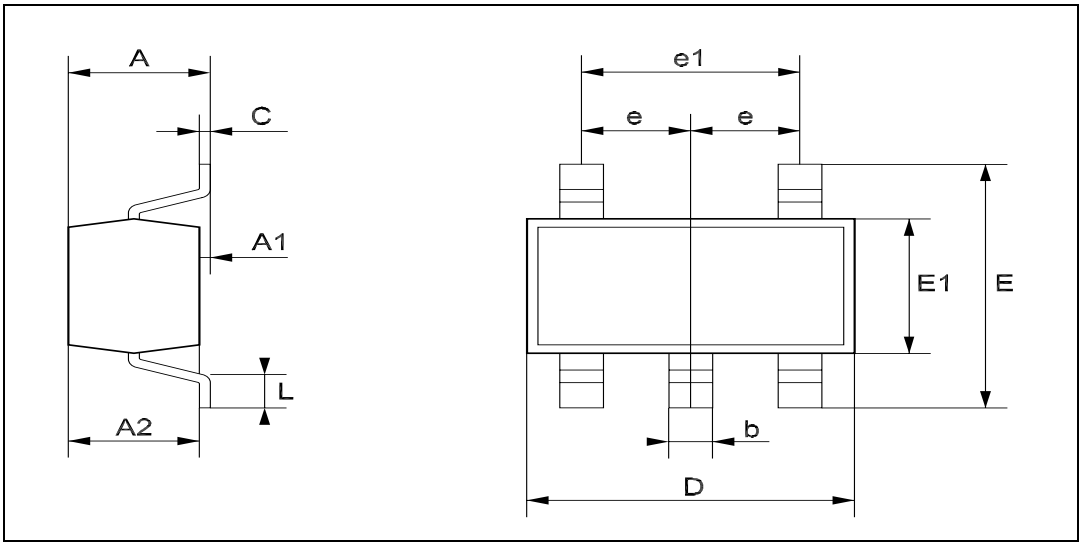
| DIM. | mm. | | | inch | | |
|---|---|---|---|---|---|---|
| | MIN. | TYP | MAX. | MIN. | TYP. | MAX. |
| A | | | 1.2 | | | 0.047 |
| A1 | 0.05 | | 0.15 | 0.002 | 0.004 | 0.006 |
| A2 | 0.8 | 1 | 1.05 | 0.031 | 0.039 | 0.041 |
| b | 0.19 | | 0.30 | 0.007 | | 0.012 |
| c | 0.09 | | 0.20 | 0.004 | | 0.0089 |
| 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 |



## 3.6 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 Nov 2001 | 1 | First Release |
| 01 Dec 2004 | 2 | Modifications on AMR table page 2 (explanation of Vid and Vi limits) |