



**TS941**  
**TS942**  
**TS944**

## OUTPUT RAIL TO RAIL MICROPOWER OPERATIONAL AMPLIFIERS

- RAIL TO RAIL **OUTPUT** VOLTAGE SWING
- **MICROPOWER** CONSUMPTION (**1.2μA**)
- SINGLE SUPPLY OPERATION (**2.5V to 10V**)
- **CMOS INPUTS**
- ULTRA LOW INPUT BIAS CURRENT (**1pA**)
- ESD PROTECTION (**2kV**)
- LATCH-UP IMMUNITY (**Class A**)
- AVAILABLE IN **SOT23-5 MICROPACKAGE**

### DESCRIPTION

The TS94x (Single, Dual & Quad) is Operational Amplifier characterized for 2.5V to 10V operation over -40°C to +85°C temperature range.

It is exhibiting an excellent consumption - 1.2μA, while featuring 10kHz gain bandwidth product, 1.5mA output capability and output Rail to Rail operation - 2.85V typ @ 3V with RL=10kΩ.

The TS94x Op-Amp is ideal for battery-powered systems, where very low supply current and output Rail to Rail are required. Its very low - 1pA typ input bias current and constant supply current over supply voltage enhance TS94x's performance near the end of the life battery charge.

### APPLICATION

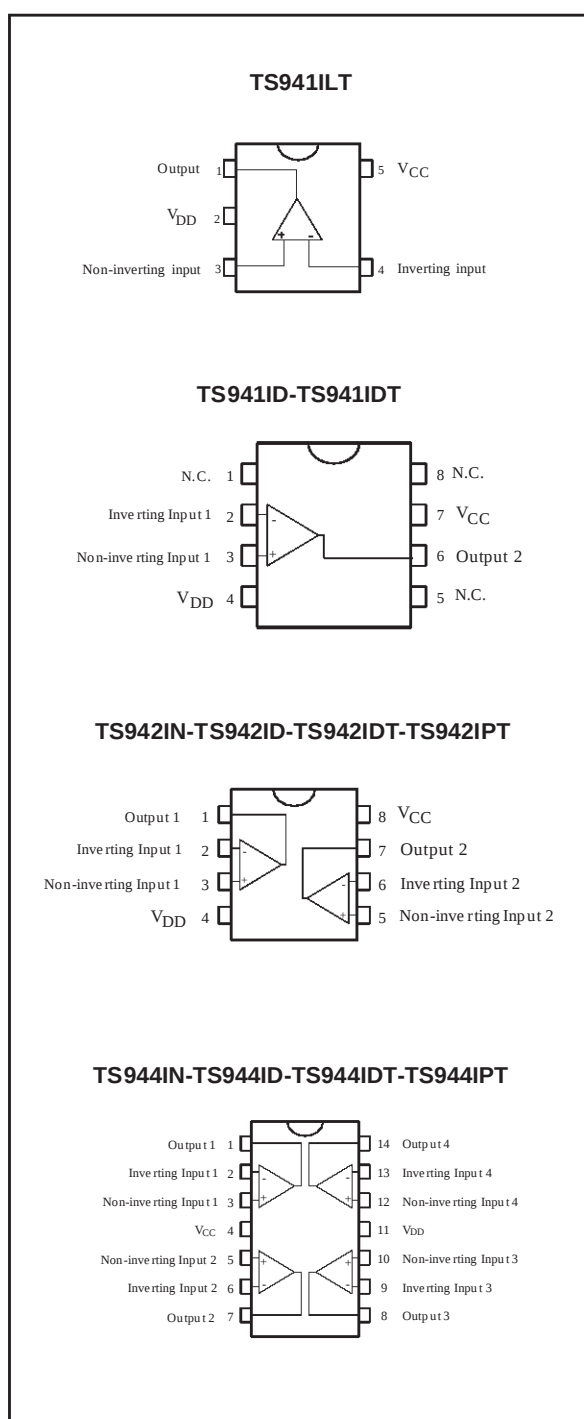
- Battery-powered systems (Alarm)
- Portable communication systems (Paggers)
- Smoke/gas/fire detectors
- Instrumentation & sensing
- PH Meter

### ORDER CODE

| Part Number                  | Temperature Range | Package |   |   |   | SOT23 Marking        |
|------------------------------|-------------------|---------|---|---|---|----------------------|
|                              |                   | N       | D | P | L |                      |
| TS941I<br>TS941AI<br>TS941BI | -40, +85°C        |         | • |   | • | K201<br>K202<br>K203 |
| TS942I<br>TS942AI<br>TS942BI | -40, +85°C        | •       | • | • |   |                      |
| TS944I<br>TS944AI<br>TS944BI | -40, +85°C        | •       | • | • |   |                      |

N = Dual in Line Package (DIP)  
D = Small Outline Package (SO) - also available in Tape & Reel (DT)  
P = Thin Shrink Small Outline Package (TSSOP) - only available in Tape & Reel (PT)  
L = Tiny Package (SOT23-5) - only available in Tape & Reel (LT)

### PIN CONNECTIONS (top view)



## ABSOLUTE MAXIMUM RATINGS

| Symbol     | Parameter                                         | Value        | Unit |
|------------|---------------------------------------------------|--------------|------|
| $V_{CC}$   | Supply voltage <sup>1)</sup>                      | 12           | V    |
| $V_{id}$   | Differential Input Voltage <sup>2)</sup>          | $\pm 12$     | V    |
| $V_{in}$   | Input Voltage Range <sup>3)</sup>                 | -0.3 to 12.3 | 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   |
| $R_{thjc}$ | Thermal Resistance Junction to Case <sup>4)</sup> |              | °C/W |
|            | SOT23-5                                           | 81           |      |
|            | DIP8                                              | 42           |      |
|            | DIP14                                             | 32           |      |
|            | SO8                                               | 28           |      |
|            | SO14                                              | 22           |      |
|            | TSSOP8                                            | 26           |      |
|            | TSSOP14                                           | 21           |      |
| $R_{thja}$ | Thermal Resistance Junction to Ambient - SOT23-5  | 256          | °C/W |
| ESD        | Human Body Model                                  | 2            | kV   |
|            | Latch-up Immunity                                 | Class A      |      |
|            | Lead Temperature (soldering, 10sec)               | 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.

## OPERATING CONDITIONS

| Symbol    | Parameter                       | Value                                | Unit |
|-----------|---------------------------------|--------------------------------------|------|
| $V_{CC}$  | Supply Voltage                  | 2.5 to 10                            | V    |
| $V_{icm}$ | Common Mode Input Voltage Range | $V_{CC}^- - 0.2$ to $V_{CC}^+ - 1.3$ | V    |

## TS941-TS942-TS944

### ELECTRICAL CHARACTERISTICS

$V_{CC} = +2.5V$ ,  $V_{DD} = 0V$ ,  $R_L$  connected to  $V_{CC/2}$ ,  
 $T_{amb} = 25^{\circ}C$  (unless otherwise specified)

| Symbol          | Parameter                                                                                                               | Min.        | Typ.        | Max.         | Unit              |
|-----------------|-------------------------------------------------------------------------------------------------------------------------|-------------|-------------|--------------|-------------------|
| $V_{io}$        | Input Offset Voltage<br>TS941/2/4<br>TS941/2/4A<br>TS941/2/4B                                                           |             |             | 10<br>5<br>2 | mV                |
| $\Delta V_{io}$ | Input Offset Voltage Drift                                                                                              |             | 7           |              | $\mu V/^{\circ}C$ |
| $I_{io}$        | Input Offset Current <sup>1)</sup>                                                                                      |             | 1           | 100          | pA                |
| $I_{ib}$        | Input Bias Current <sup>1)</sup>                                                                                        |             | 1           | 150          | pA                |
| CMR             | Common Mode Rejection Ratio                                                                                             | 60          | 85          |              | dB                |
| SVR             | Supply Voltage Rejection Ratio                                                                                          | 50          | 78          |              | dB                |
| $A_{vd}$        | Large Signal Voltage Gain<br>$V_O = 2V_{pp}$ $R_L = 1M\Omega$                                                           |             | 100         |              | dB                |
| $V_{OH}$        | High Level Output Voltage<br>$V_{ID} = 100mV$ $R_L = 1M\Omega$<br>$R_L = 10k\Omega$                                     | 2.45<br>2.3 | 2.49<br>2.4 |              | V                 |
| $V_{OL}$        | Low Level Output Voltage<br>$V_{ID} = -100mV$ $R_L = 1M\Omega$<br>$R_L = 10k\Omega$                                     |             | 1<br>100    | 5<br>200     | mV                |
| $I_o$           | Output Source Current<br>$V_{ID} = 100mV$ , $V_O = V_{DD}$<br>Output Sink Current<br>$V_{ID} = -100mV$ , $V_O = V_{CC}$ | 350<br>280  | 650<br>500  |              | $\mu A$           |
| $I_{CC}$        | Supply Current (per amplifier)<br>$A_{VCL} = 1$ , no load                                                               |             | 1.2         | 1.8          | $\mu A$           |
| GBP             | Gain Bandwidth Product $R_L = 1M\Omega$ , $C_L = 50pF$                                                                  |             | 10          |              | kHz               |
| SR              | Slew Rate $R_L = 1M\Omega$ , $C_L = 50pF$                                                                               | 3           | 4.5         |              | V/ms              |
| $\phi_m$        | Phase Margin $C_L = 50pF$                                                                                               |             | 65          |              | Degrees           |

1. Maximum values including unavoidable inaccuracies of the industrial test.

**ELECTRICAL CHARACTERISTICS**

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

| Symbol          | Parameter                                                                                                               | Min.       | Typ.         | Max.         | Unit              |
|-----------------|-------------------------------------------------------------------------------------------------------------------------|------------|--------------|--------------|-------------------|
| $V_{io}$        | Input Offset Voltage<br>TS941/2/4<br>TS941/2/4A<br>TS941/2/4B                                                           |            |              | 10<br>5<br>2 | mV                |
| $\Delta V_{io}$ | Input Offset Voltage Drift                                                                                              |            | 7            |              | $\mu V/^{\circ}C$ |
| $I_{io}$        | Input Offset Current <sup>1)</sup>                                                                                      |            | 1            | 100          | pA                |
| $I_{ib}$        | Input Bias Current <sup>1)</sup>                                                                                        |            | 1            | 150          | pA                |
| CMR             | Common Mode Rejection Ratio                                                                                             | 60         | 85           |              | dB                |
| SVR             | Supply Voltage Rejection Ratio                                                                                          | 50         | 85           |              | dB                |
| $A_{vd}$        | Large Signal Voltage Gain<br>$V_O = 2V_{pp}$ $R_L = 1M\Omega$                                                           |            | 100          |              | dB                |
| $V_{OH}$        | High Level Output Voltage<br>$V_{ID} = 100mV$ $R_L = 1M\Omega$<br>$R_L = 10k\Omega$                                     | 2.9<br>2.8 | 2.99<br>2.85 |              | V                 |
| $V_{OL}$        | Low Level Output Voltage<br>$V_{ID} = -100mV$ $R_L = 1M\Omega$<br>$R_L = 10k\Omega$                                     |            | 1<br>100     | 5<br>200     | mV                |
| $I_o$           | Output Source Current<br>$V_{ID} = 100mV$ , $V_O = V_{DD}$<br>Output Sink Current<br>$V_{ID} = -100mV$ , $V_O = V_{CC}$ | 680<br>650 | 1500<br>1300 |              | $\mu A$           |
| $I_{CC}$        | Supply Current (per amplifier)<br>$A_{VCL} = 1$ , no load                                                               |            | 1.2          | 1.8          | $\mu A$           |
| GBP             | Gain Bandwidth Product $R_L = 1M\Omega$ , $C_L = 50pF$                                                                  |            | 10           |              | kHz               |
| SR              | Slew Rate $R_L = 1M\Omega$ , $C_L = 50pF$                                                                               | 3          | 4.5          |              | V/ms              |
| $\phi_m$        | Phase Margin $C_L = 50pF$                                                                                               |            | 65           |              | Degrees           |

1. Maximum values including unavoidable inaccuracies of the industrial test.

2. All electrical values are guaranteed with correlation measurements at 2.5V and 5V

## TS941-TS942-TS944

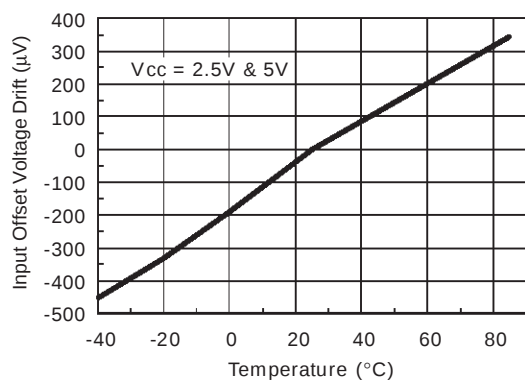
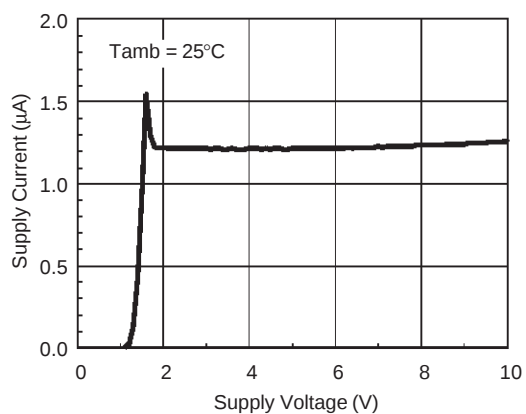
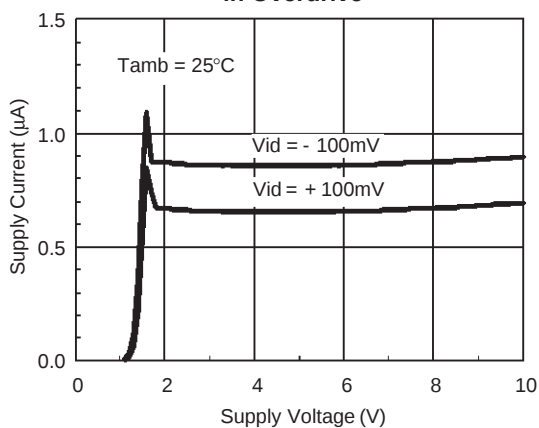
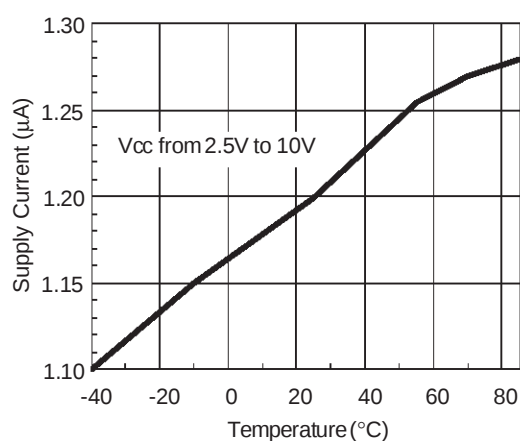
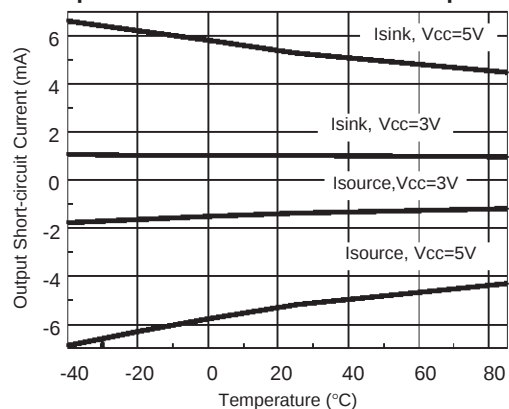
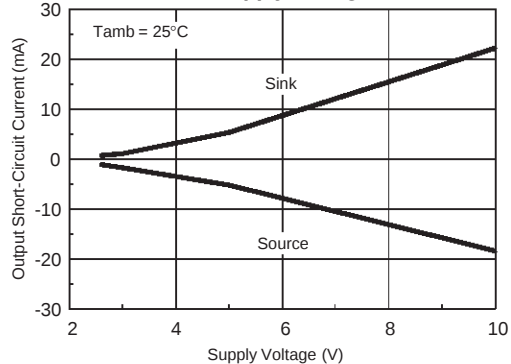
### ELECTRICAL CHARACTERISTICS

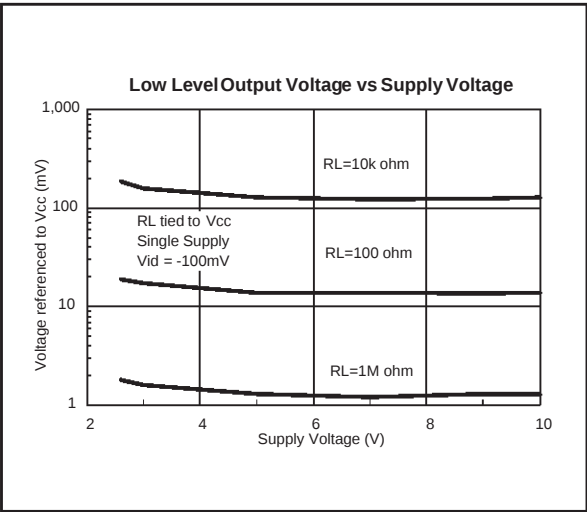
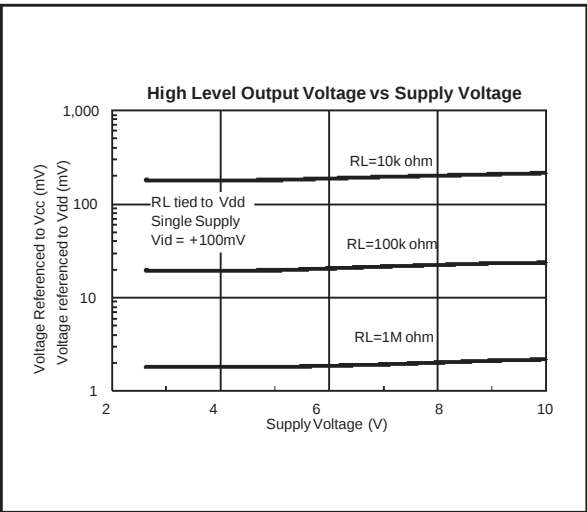
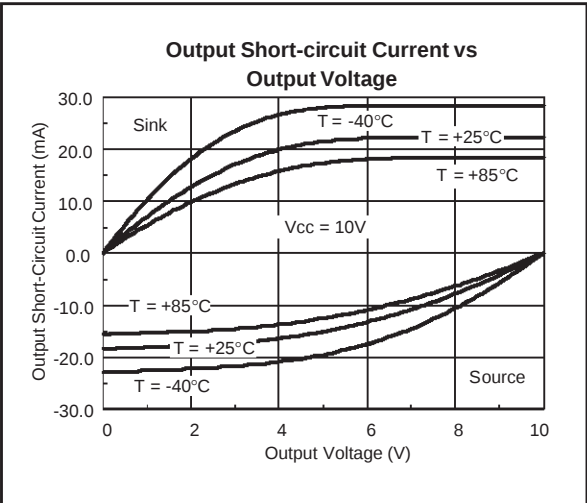
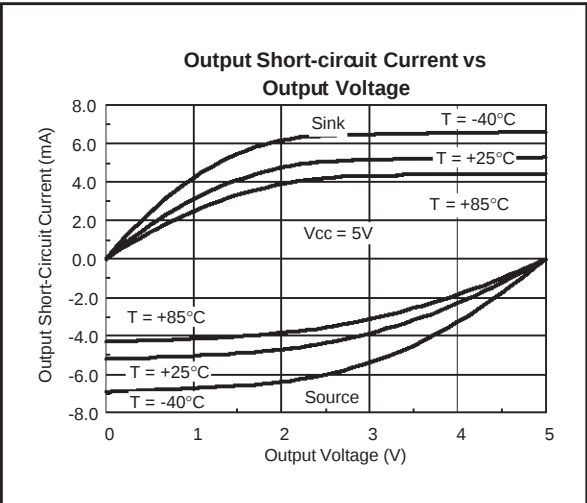
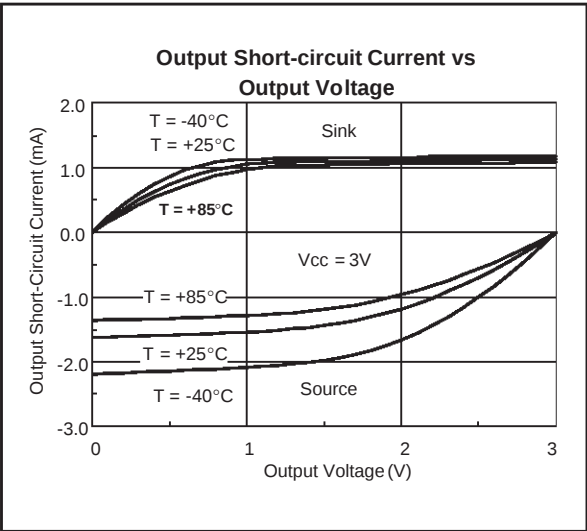
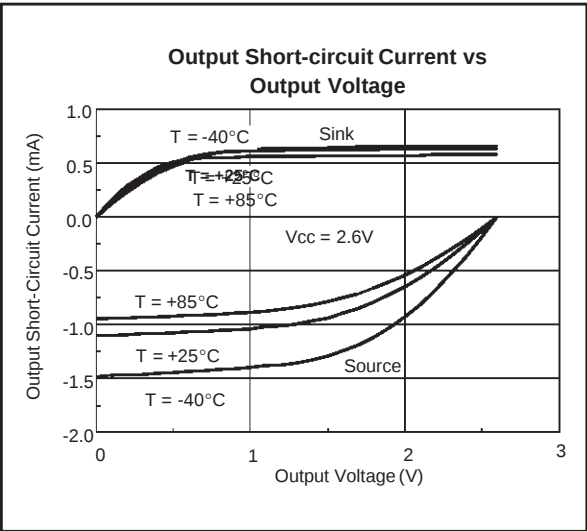
$V_{CC} = +5V$ ,  $V_{DD} = 0V$ ,  $R_L$  connected to  $V_{CC/2}$ ,

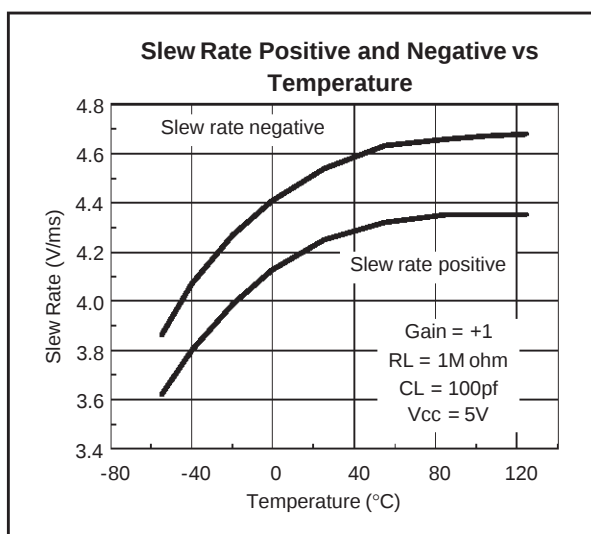
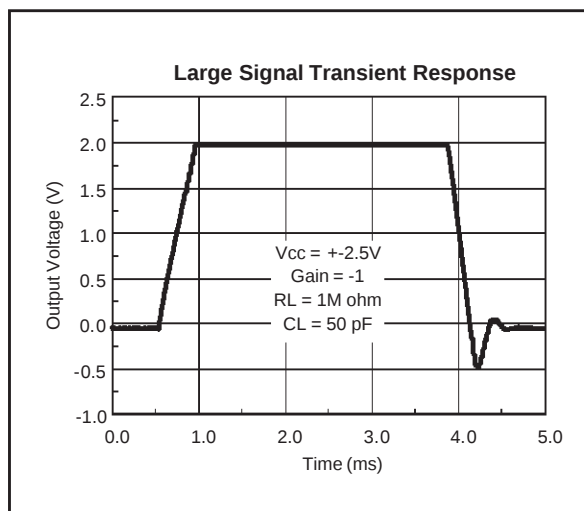
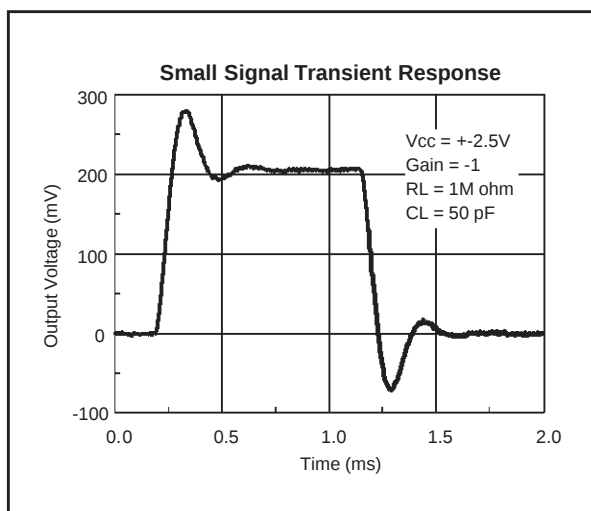
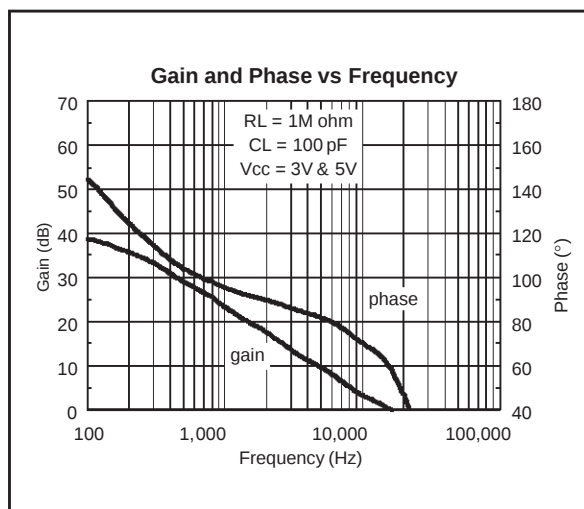
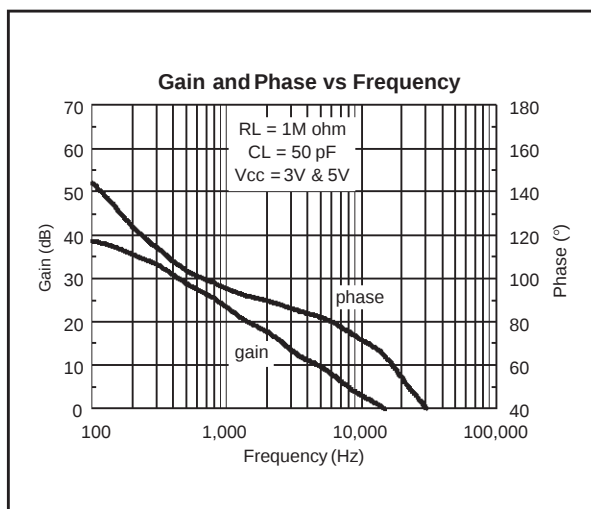
$T_{amb} = 25^{\circ}C$  (unless otherwise specified)

| Symbol          | Parameter                                                                                                               | Min.       | Typ.         | Max.         | Unit              |
|-----------------|-------------------------------------------------------------------------------------------------------------------------|------------|--------------|--------------|-------------------|
| $V_{io}$        | Input Offset Voltage<br>TS941/2/4<br>TS941/2/4A<br>TS941/2/4B                                                           |            |              | 10<br>5<br>2 | mV                |
| $\Delta V_{io}$ | Input Offset Voltage Drift                                                                                              |            | 7            |              | $\mu V/^{\circ}C$ |
| $I_{io}$        | Input Offset Current <sup>1)</sup>                                                                                      |            | 1            | 100          | pA                |
| $I_{ib}$        | Input Bias Current <sup>1)</sup>                                                                                        |            | 1            | 150          | pA                |
| CMR             | Common Mode Rejection Ratio                                                                                             | 60         | 85           |              | dB                |
| SVR             | Supply Voltage Rejection Ratio                                                                                          | 50         | 85           |              | dB                |
| $A_{vd}$        | Large Signal Voltage Gain<br>$V_O = 2V_{pp}$ $R_L = 1M\Omega$                                                           |            | 100          |              | dB                |
| $V_{OH}$        | High Level Output Voltage<br>$V_{ID} = 100mV$ $R_L = 1M\Omega$<br>$R_L = 10k\Omega$                                     | 4.9<br>4.8 | 4.99<br>4.85 |              | V                 |
| $V_{OL}$        | Low Level Output Voltage<br>$V_{ID} = -100mV$ $R_L = 1M\Omega$<br>$R_L = 10k\Omega$                                     |            | 1<br>100     | 5<br>150     | mV                |
| $I_o$           | Output Source Current<br>$V_{ID} = 100mV$ , $V_O = V_{DD}$<br>Output Sink Current<br>$V_{ID} = -100mV$ , $V_O = V_{CC}$ | 3<br>3.7   | 4.5<br>5     |              | mA                |
| $I_{CC}$        | Supply Current (per amplifier)<br>$A_{VCL} = 1$ , no load                                                               |            | 1.2          | 1.85         | $\mu A$           |
| GBP             | Gain Bandwidth Product $R_L = 1M\Omega$ , $C_L = 50pF$                                                                  |            | 10           |              | kHz               |
| SR              | Slew Rate $R_L = 1M\Omega$ , $C_L = 50pF$                                                                               | 3          | 4.5          |              | V/ms              |
| $\phi_m$        | Phase Margin $C_L = 50pF$                                                                                               |            | 65           |              | Degrees           |

1. Maximum values including unavoidable inaccuracies of the industrial test.

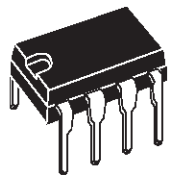
**Input Offset Voltage Drift vs Temperature****Supply Current/Amplifier vs Supply Voltage****Supply Current/Amplifier vs Supply Voltage in Overdrive****Supply Current/Amplifier vs Temperature****Output Short-Circuit Current vs Temperature****Output Short-Circuit Current vs Supply Voltage**



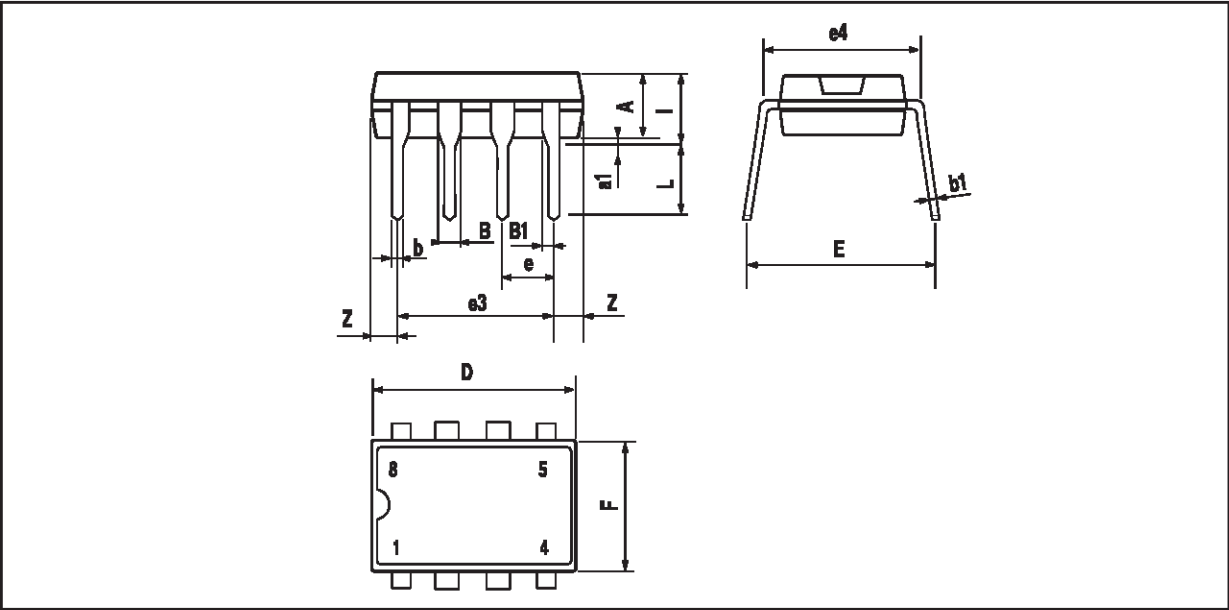


TS941-TS942-TS944

TS942IN

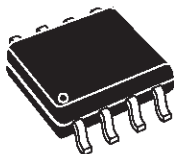


PACKAGE MECHANICAL DATA  
8 PINS - PLASTIC PACKAGE



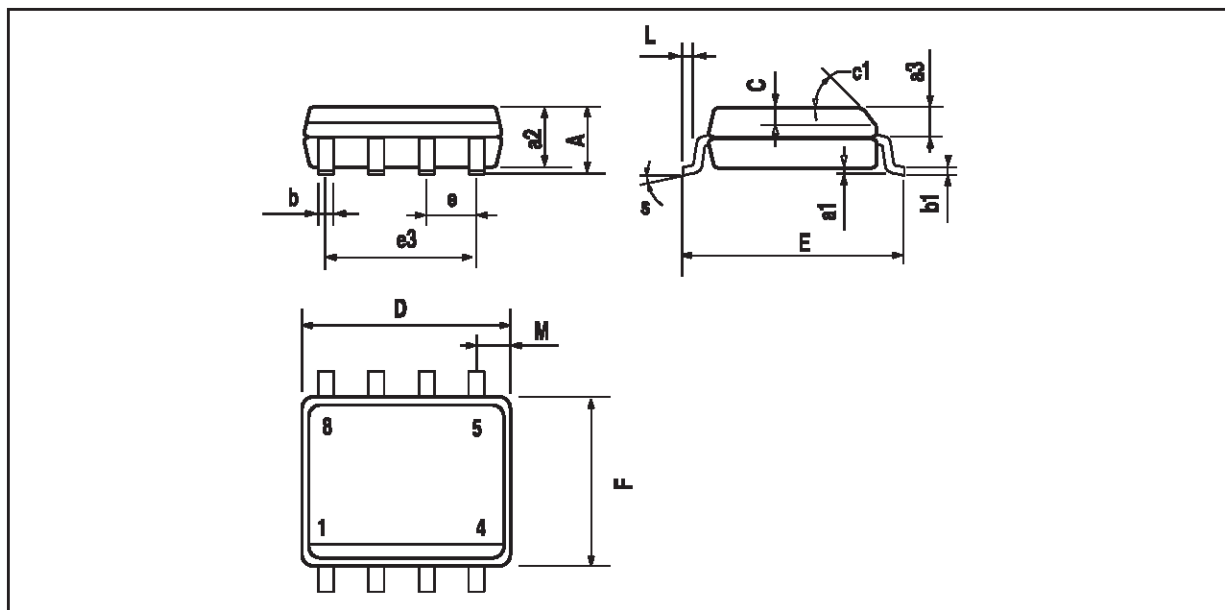
| Dim. | Millimeters |      |       | Inches |       |       |
|------|-------------|------|-------|--------|-------|-------|
|      | Min.        | Typ. | Max.  | Min.   | Typ.  | Max.  |
| A    |             | 3.32 |       |        | 0.131 |       |
| a1   | 0.51        |      |       | 0.020  |       |       |
| B    | 1.15        |      | 1.65  | 0.045  |       | 0.065 |
| b    | 0.356       |      | 0.55  | 0.014  |       | 0.022 |
| b1   | 0.204       |      | 0.304 | 0.008  |       | 0.012 |
| D    |             |      | 10.92 |        |       | 0.430 |
| E    | 7.95        |      | 9.75  | 0.313  |       | 0.384 |
| e    |             | 2.54 |       |        | 0.100 |       |
| e3   |             | 7.62 |       |        | 0.300 |       |
| e4   |             | 7.62 |       |        | 0.300 |       |
| F    |             |      | 6.6   |        |       | 0.260 |
| i    |             |      | 5.08  |        |       | 0.200 |
| L    | 3.18        |      | 3.81  | 0.125  |       | 0.150 |
| Z    |             |      | 1.52  |        |       | 0.060 |

## TS941ID - TS942ID



## PACKAGE MECHANICAL DATA

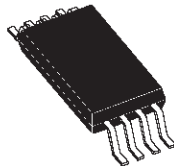
8 PINS - PLASTIC MICROPACKAGE (SO)



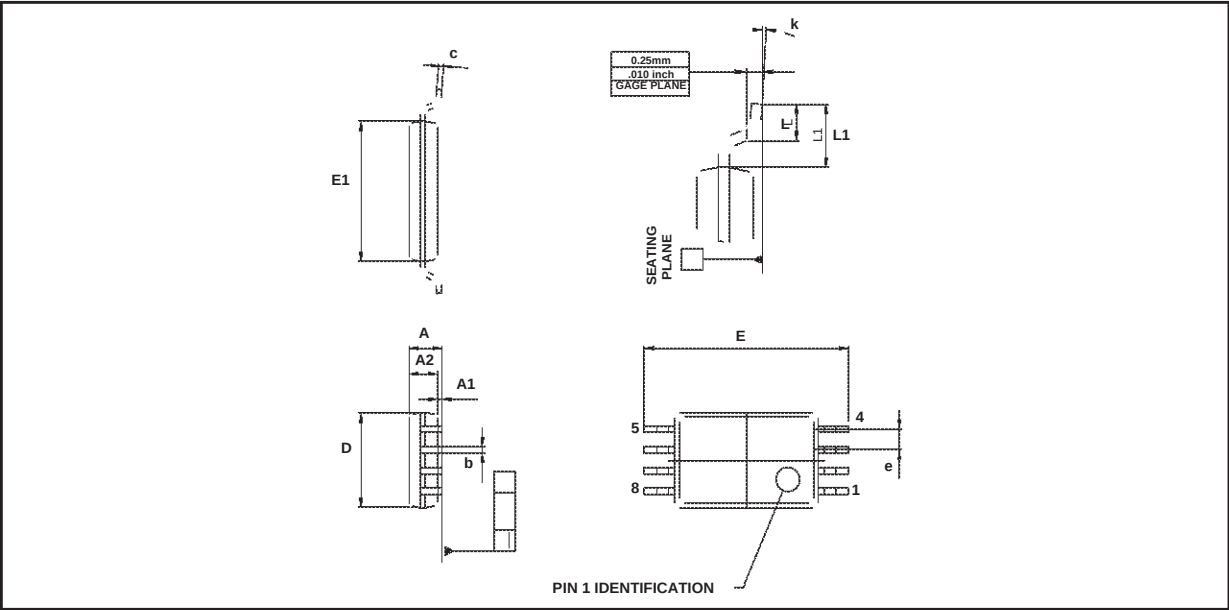
| Dim. | Millimeters |      |      | Inches |       |       |
|------|-------------|------|------|--------|-------|-------|
|      | Min.        | Typ. | Max. | Min.   | Typ.  | Max.  |
| A    |             |      | 1.75 |        |       | 0.069 |
| a1   | 0.1         |      | 0.25 | 0.004  |       | 0.010 |
| a2   |             |      | 1.65 |        |       | 0.065 |
| a3   | 0.65        |      | 0.85 | 0.026  |       | 0.033 |
| b    | 0.35        |      | 0.48 | 0.014  |       | 0.019 |
| b1   | 0.19        |      | 0.25 | 0.007  |       | 0.010 |
| C    | 0.25        |      | 0.5  | 0.010  |       | 0.020 |
| c1   | 45° (typ.)  |      |      |        |       |       |
| D    | 4.8         |      | 5.0  | 0.189  |       | 0.197 |
| E    | 5.8         |      | 6.2  | 0.228  |       | 0.244 |
| e    |             | 1.27 |      |        | 0.050 |       |
| e3   |             | 3.81 |      |        | 0.150 |       |
| F    | 3.8         |      | 4.0  | 0.150  |       | 0.157 |
| L    | 0.4         |      | 1.27 | 0.016  |       | 0.050 |
| M    |             |      | 0.6  |        |       | 0.024 |
| S    | 8° (max.)   |      |      |        |       |       |

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TS942IPT

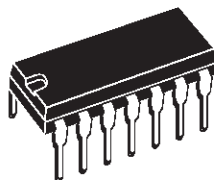


PACKAGE MECHANICAL DATA  
8 PINS - THIN SHRINK SMALL OUTLINE PACKAGE



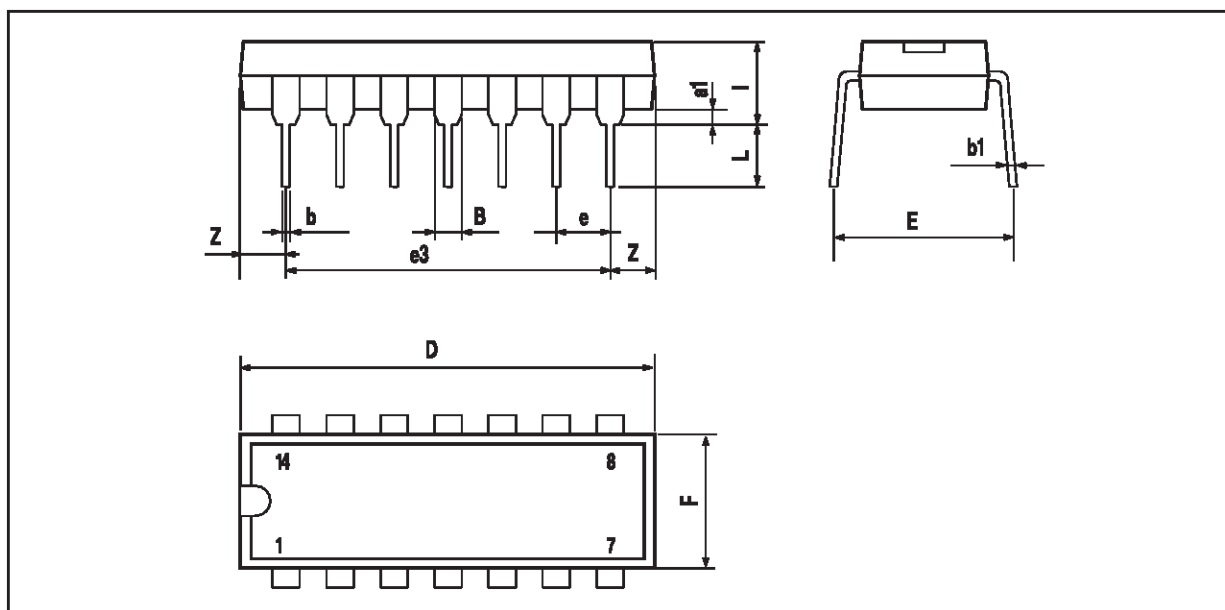
| Dim. | Millimeters |      |      | Inches |        |       |
|------|-------------|------|------|--------|--------|-------|
|      | Min.        | Typ. | Max. | Min.   | Typ.   | Max.  |
| A    |             |      | 1.20 |        |        | 0.05  |
| A1   | 0.05        |      | 0.15 | 0.01   |        | 0.006 |
| A2   | 0.80        | 1.00 | 1.05 | 0.031  | 0.039  | 0.041 |
| b    | 0.19        |      | 0.30 | 0.007  |        | 0.15  |
| c    | 0.09        |      | 0.20 | 0.003  |        | 0.012 |
| D    | 2.90        | 3.00 | 3.10 | 0.114  | 0.118  | 0.122 |
| E    |             | 6.40 |      |        | 0.252  |       |
| E1   | 4.30        | 4.40 | 4.50 | 0.169  | 0.173  | 0.177 |
| e    |             | 0.65 |      |        | 0.025  |       |
| k    | 0°          |      | 8°   | 0°     |        | 8°    |
| l    | 0.50        | 0.60 | 0.75 | 0.09   | 0.0236 | 0.030 |

## TS944IN



## PACKAGE MECHANICAL DATA

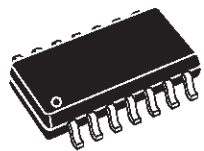
14 PINS - PLASTIC PACKAGE



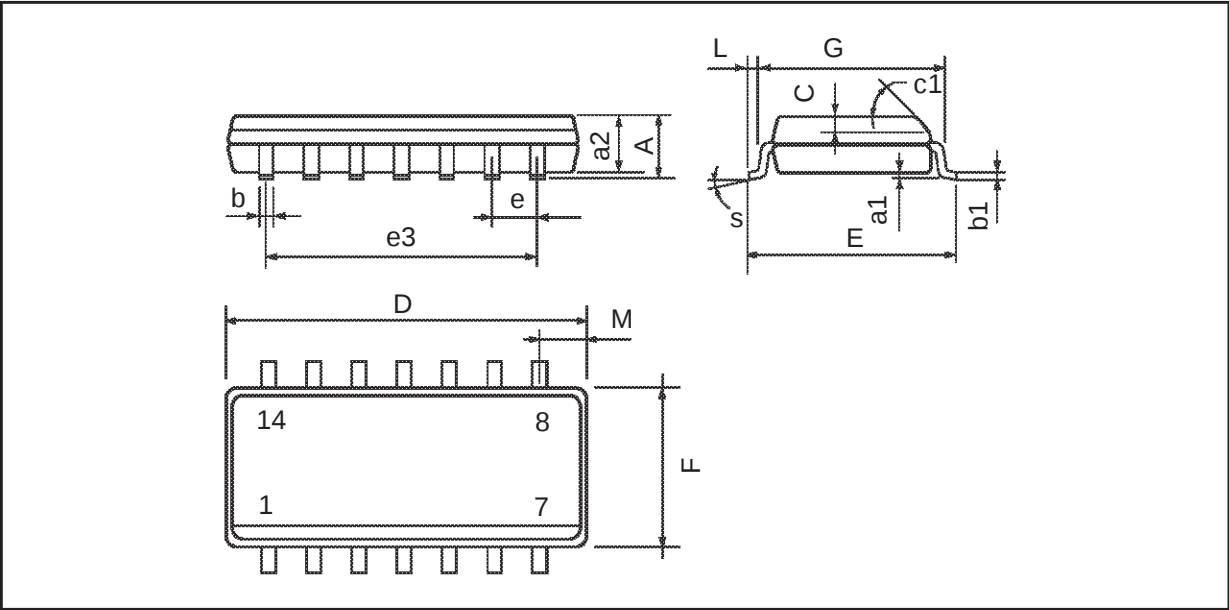
| Dim. | Millimeters |       |      | Inches |       |       |
|------|-------------|-------|------|--------|-------|-------|
|      | Min.        | Typ.  | Max. | Min.   | Typ.  | Max.  |
| a1   | 0.51        |       |      | 0.020  |       |       |
| B    | 1.39        |       | 1.65 | 0.055  |       | 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 |

TS941-TS942-TS944

TS944ID



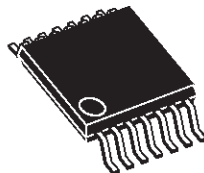
PACKAGE MECHANICAL DATA  
14 PINS - PLASTIC MICROPACKAGE (SO)



| Dim.  | Millimeters |      |      | Inches |       |       |
|-------|-------------|------|------|--------|-------|-------|
|       | Min.        | Typ. | Max. | Min.   | Typ.  | Max.  |
| A     |             |      | 1.75 |        |       | 0.069 |
| a1    | 0.1         |      | 0.2  | 0.004  |       | 0.008 |
| a2    |             |      | 1.6  |        |       | 0.063 |
| b     | 0.35        |      | 0.46 | 0.014  |       | 0.018 |
| b1    | 0.19        |      | 0.25 | 0.007  |       | 0.010 |
| C     |             | 0.5  |      |        | 0.020 |       |
| c1    | 45° (typ.)  |      |      |        |       |       |
| D (1) | 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 (1) | 3.8         |      | 4.0  | 0.150  |       | 0.157 |
| G     | 4.6         |      | 5.3  | 0.181  |       | 0.208 |
| L     | 0.5         |      | 1.27 | 0.020  |       | 0.050 |
| M     |             |      | 0.68 |        |       | 0.027 |
| S     | 8° (max.)   |      |      |        |       |       |

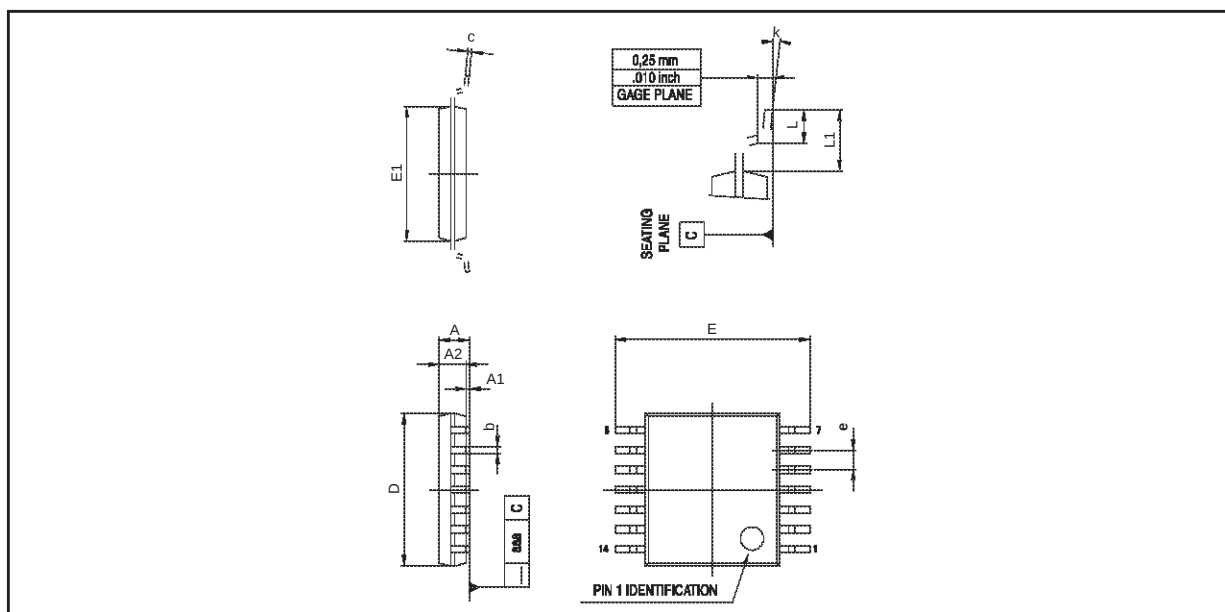
Note : (1) D and F do not include mold flash or protrusions - Mold flash or protrusions shall not exceed 0.15mm (.066 inc) ONLY FOR DATA BOOK.

## TS944IPT



## PACKAGE MECHANICAL DATA

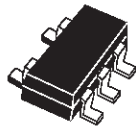
14 PINS - THIN SHRINK SMALL OUTLINE PACKAGE



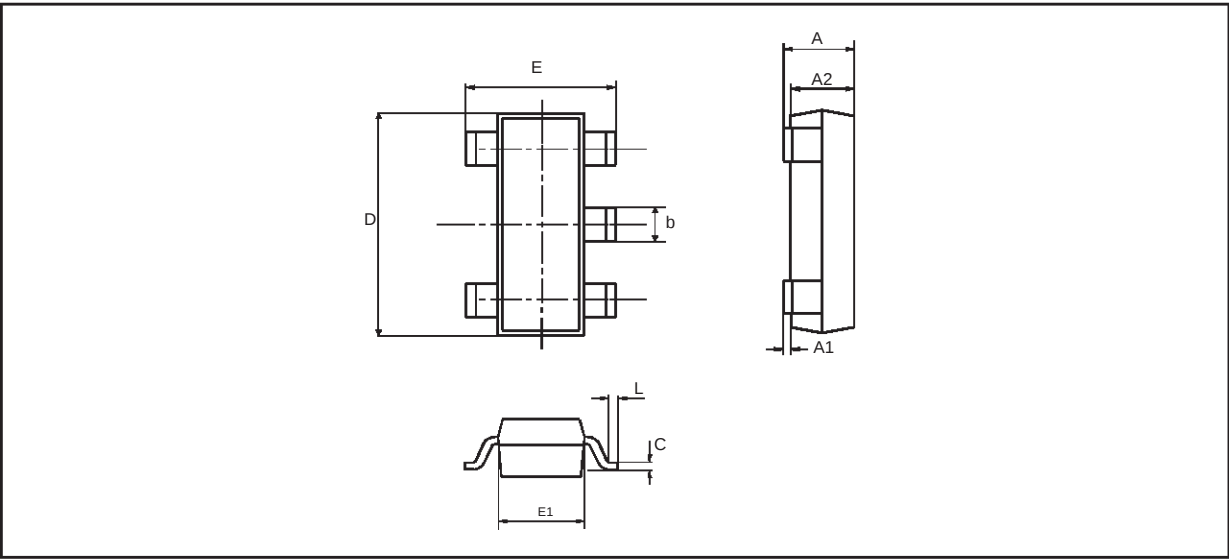
| Dim. | Millimeters |      |      | Inches |        |       |
|------|-------------|------|------|--------|--------|-------|
|      | Min.        | Typ. | Max. | Min.   | Typ.   | Max.  |
| A    |             |      | 1.20 |        |        | 0.05  |
| A1   | 0.05        |      | 0.15 | 0.01   |        | 0.006 |
| A2   | 0.80        | 1.00 | 1.05 | 0.031  | 0.039  | 0.041 |
| b    | 0.19        |      | 0.30 | 0.007  |        | 0.15  |
| c    | 0.09        |      | 0.20 | 0.003  |        | 0.012 |
| D    | 4.90        | 5.00 | 5.10 | 0.192  | 0.196  | 0.20  |
| E    |             | 6.40 |      |        | 0.252  |       |
| E1   | 4.30        | 4.40 | 4.50 | 0.169  | 0.173  | 0.177 |
| e    |             | 0.65 |      |        | 0.025  |       |
| k    | 0°          |      | 8°   | 0°     |        | 8°    |
| l    | 0.50        | 0.60 | 0.75 | 0.09   | 0.0236 | 0.030 |

TS941-TS942-TS944

TS941ILT



PACKAGE MECHANICAL DATA  
5 PINS - TINY PACKAGE (SOT23)



| Dim. | Millimeters |      |      | Inches |       |        |
|------|-------------|------|------|--------|-------|--------|
|      | Min.        | Typ. | Max. | Min.   | Typ.  | Max.   |
| A    | 0.90        | 1.20 | 1.45 | 0.035  | 0.047 | 0.057  |
| A1   | 0           |      | 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 | 0.0118 |
| F    | 1.50        | 1.60 | 1.75 | 0.059  | 0.063 | 0.069  |
| L    | 0.10        | 0.5  | 0.60 | 0.004  | 0.014 | 0.024  |
| K    | 0d          |      | 10d  | 0d     |       | 10d    |

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