# 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) series are operational amplifiers characterized for 2.5V to 10V operation over -40°C to +85°C temperature range.

They exhibit 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.

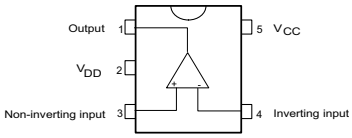
The TS94x op-amps are ideal for battery-powered systems, where very low supply current and output rail-to-rail are required. Their very low - 1pA typ input bias current and constant supply current over supply voltage enhance TS94x's performance near the end of the life battery charge.

### Applications

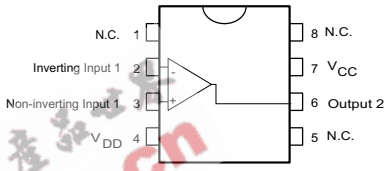
- **Battery-powered systems (alarm)**
- **Portable communication systems (pagers)**
- **Smoke/gas/fire detectors**
- **Instrumentation & sensoring**
- **PH meter**

### Pin Connections (top view)

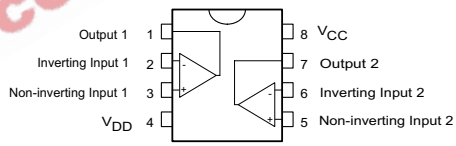
**TS941ILT**



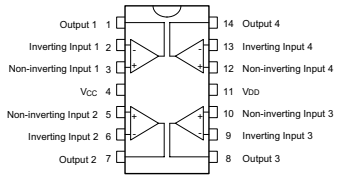

**TS941ID-TS941IDT**




**TS942IN-TS942ID-TS942IDT-TS942IPT**




**TS944IN-TS944ID-TS944IDT-TS944IPT**



## Order Codes

| Part Number | Temperature Range | Package | Packaging | Marking |
|---|---|---|---|---|
| TS941ID/IDT/AID/AIDT/BID/BIDT | -40°C, +85°C | SO | Tube or Tape & Reel | |
| TS941ILT/AILT/BILT | | SOT23-5L | Tape & Reel | K201<br>K202<br>K203 |
| TS942IN/AIN/BIN | | DIP | Tube | |
| TS942ID/IDT/AID/AIDT/BID/BIDT | | SO | Tube or Tape & Reel | |
| TS942IPT/AIPT/BIPT | | TSSOP<br>(Thin Shrink Outline Package) | Tape & Reel | |
| TS944IN/AIN/BIN | | DIP | Tube | |
| TS944ID/IDT/AID/AIDT/BIDT/BIDT | | SO | Tube or Tape & Reel | |
| TS944IPT/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 |
| $T_{std}$ | 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] (TS941, TS942) | 200 | V |
| | CDM: Charged Device Model TS941 | 1.5 | kV |
| | TS942 | 1 | kV |
| | Latch-up Immunity | 200 | mA |
| | 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.

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 | 2.5 to 10 | V |
| Vicm | Common Mode Input Voltage Range | $V_{DD}$ -0.2 to $V_{CC}$ -1.3 | V |
| $T_{oper}$ | Operating Free Air Temperature Range | -40 to + 85 | °C |

## 2 Electrical Characteristics

**Table 3: $V_{CC}$ = +2.5V, $V_{DD}$ = 0V, $R_L$ connected to $V_{CC/2}$, $T_{amb}$ = 25°C (unless otherwise specified)**

| Symbol | Parameter | | Min. | Typ. | Max. | Unit |
|---|---|---|---|---|---|---|
| $V_{io}$ | Input Offset Voltage | 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 | | 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 | | 60 | 85 | | dB |
| SVR | Supply Voltage Rejection Ratio | | 50 | 78 | | dB |
| $A_{vd}$ | Large Signal Voltage Gain<br>$V_O$ = 2Vpp | $R_L$ = 1MΩ | | 100 | | dB |
| $V_{OH}$ | High Level Output Voltage<br>$V_{ID}$ = 100mV | $R_L$ = 1MΩ<br>$R_L$ = 10kΩ | 2.45<br>2.3 | 2.49<br>2.4 | | V |
| $V_{OL}$ | Low Level Output Voltage<br>$V_{ID}$ = -100mV | $R_L$ = 1MΩ<br>$R_L$ = 10kΩ | | 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><br>280 | 650<br><br>500 | | µA |
| $I_{CC}$ | Supply Current (per amplifier)<br>$A_{VCL}$ = 1, no load | | | 1.2 | 1.8 | µA |
| GBP | Gain Bandwidth Product | $R_L$ = 1MΩ, $C_L$ = 50pF | | 10 | | kHz |
| SR | Slew Rate | $R_L$ = 1MΩ, $C_L$ = 50pF | 3 | 4.5 | | V/ms |
| ϕm | Phase Margin | $C_L$ = 50pF | | 65 | | Degrees |

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

**Table 4: $V_{CC}$ = +3V, $V_{DD}$ = 0V, $R_L$ connected to $V_{CC/2}$, $T_{amb}$ = 25°C (unless otherwise specified) 2)**

| Symbol | Parameter | | Min. | Typ. | Max. | Unit |
|---|---|---|---|---|---|---|
| $V_{io}$ | Input Offset Voltage | 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 | | 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 | | 60 | 85 | | dB |
| SVR | Supply Voltage Rejection Ratio | | 50 | 85 | | dB |
| $A_{vd}$ | Large Signal Voltage Gain | $V_O$ = 2VppR$_L$ = 1MΩ | | 100 | | dB |
| $V_{OH}$ | High Level Output Voltage<br>$V_{ID}$ = 100mV | $R_L$ = 1MΩ<br>$R_L$ = 10kΩ | 2.9<br>2.8 | 2.99<br>2.85 | | V |
| $V_{OL}$ | Low Level Output Voltage<br>$V_{ID}$ = -100mV | $R_L$ = 1MΩ<br>$R_L$ = 10kΩ | | 1<br>100 | 5<br>200 | mV |
| $I_o$ | Output Source Current<br>Output Sink Current | $V_{ID}$ = 100mV, $V_O$ = $V_{DD}$<br>$V_{ID}$ = -100mV, $V_O$ = $V_{CC}$ | 680<br>650 | 1500<br>1300 | | µA |
| $I_{CC}$ | Supply Current (per amplifier) | $A_{VCL}$ = 1, no load | | 1.2 | 1.8 | µA |
| GBP | Gain Bandwidth Product | $R_L$ = 1MΩ, $C_L$ = 50pF | | 10 | | kHz |
| SR | Slew Rate | $R_L$ = 1MΩ, $C_L$ = 50pF | 3 | 4.5 | | V/ms |
| ϕm | Phase Margin | $C_L$ = 50pF | | 65 | | Degrees |

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

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

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

| Symbol | Parameter | | Min. | Typ. | Max. | Unit |
|---|---|---|---|---|---|---|
| $V_{io}$ | Input Offset Voltage | 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 | | 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 | | 60 | 85 | | dB |
| SVR | Supply Voltage Rejection Ratio | | 50 | 85 | | dB |
| $A_{vd}$ | Large Signal Voltage Gain<br>$V_O$ = 2Vpp | $R_L$ = 1MΩ | | 100 | | dB |
| $V_{OH}$ | High Level Output Voltage<br>$V_{ID}$ = 100mV | $R_L$ = 1MΩ<br>$R_L$ = 10kΩ | 4.9<br>4.8 | 4.99<br>4.85 | | V |
| $V_{OL}$ | Low Level Output Voltage<br>$V_{ID}$ = -100mV | $R_L$ = 1MΩ<br>$R_L$ = 10kΩ | | 1<br>100 | 5<br>150 | mV |
| $I_o$ | Output Source Current<br>Output Sink Current | $V_{ID}$ = 100mV, $V_O$ = $V_{DD}$<br>$V_{ID}$ = -100mV, $V_O$ = $V_{CC}$ | 3<br>3.7 | 4.5<br>5 | | mA |
| $I_{CC}$ | Supply Current (per amplifier) | $A_{VCL}$ = 1, no load | | 1.2 | 1.85 | µA |
| GBP | Gain Bandwidth Product | $R_L$ = 1MΩ, $C_L$ = 50pF | | 10 | | kHz |
| SR | Slew Rate | $R_L$ = 1MΩ, $C_L$ = 50pF | 3 | 4.5 | | V/ms |
| ϕm | Phase Margin | $C_L$ = 50pF | | 65 | | Degrees |

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

**Figure 1:**

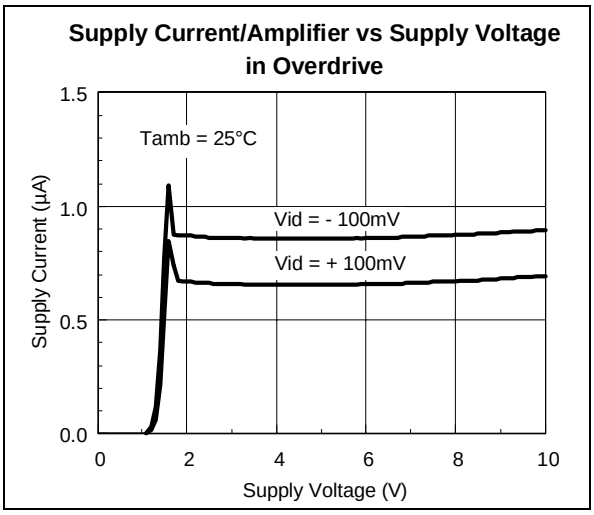



**Figure 2:**

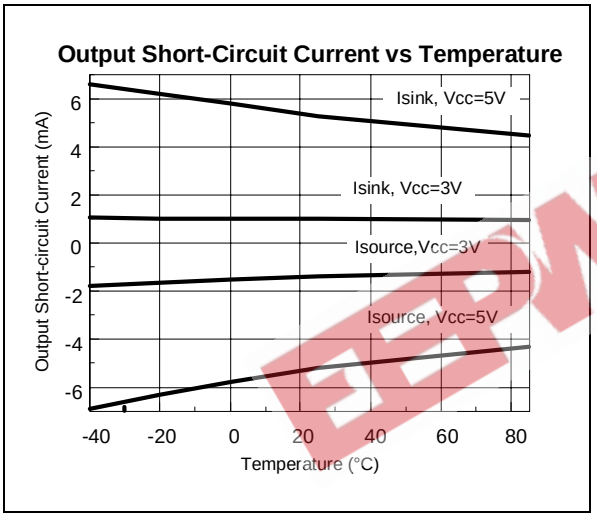



**Figure 3:**

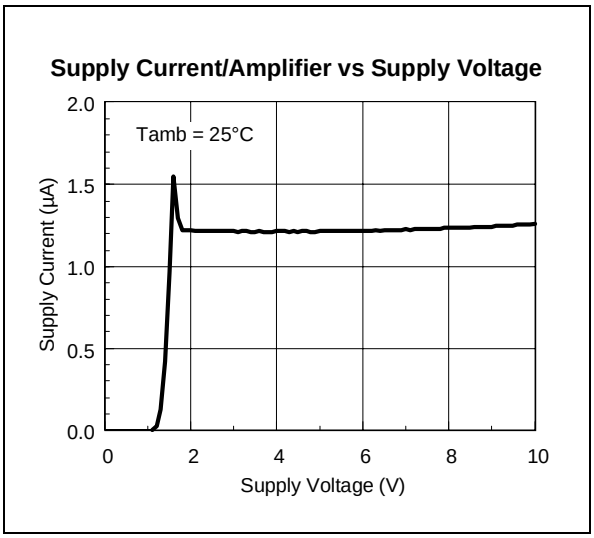



**Figure 4:**

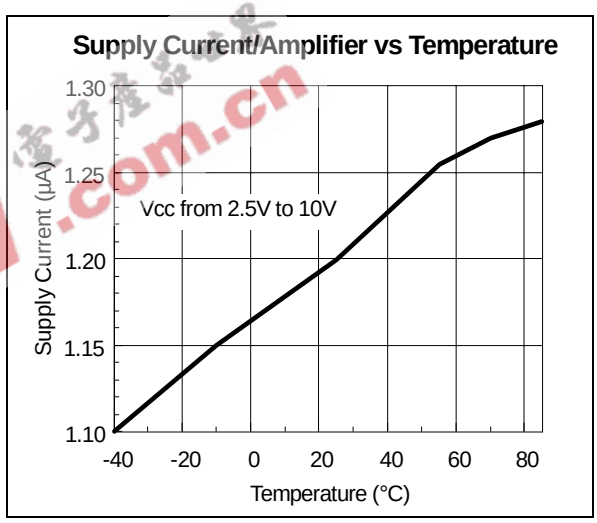
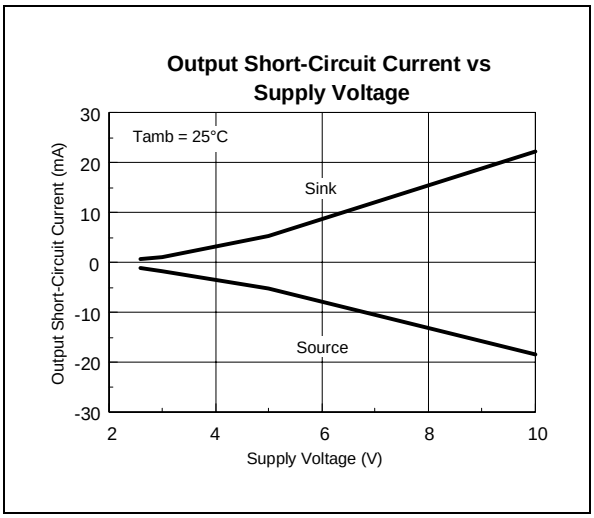


**Figure 5:**

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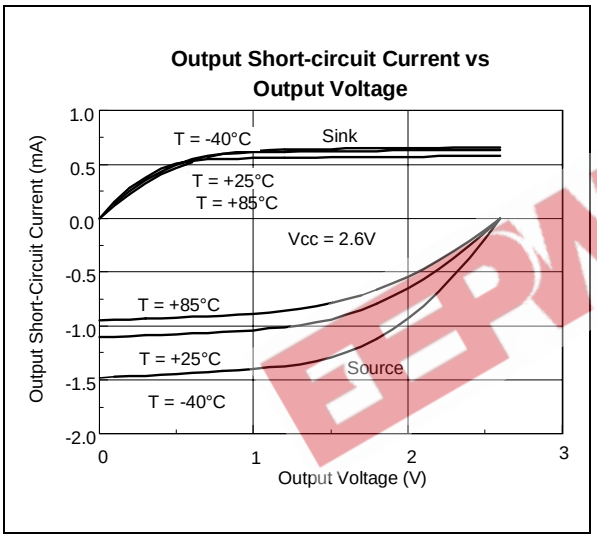


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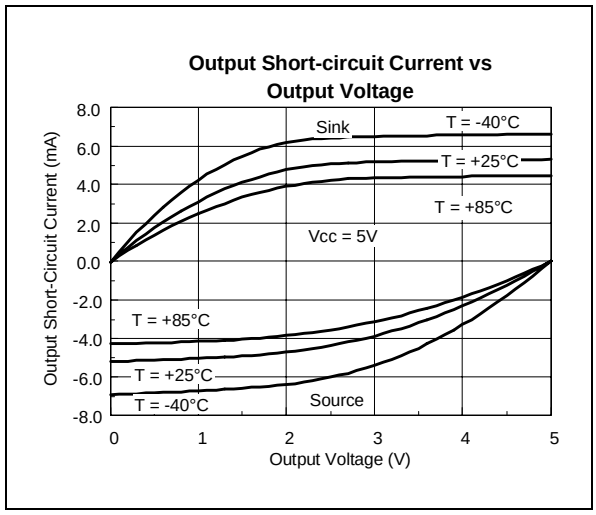
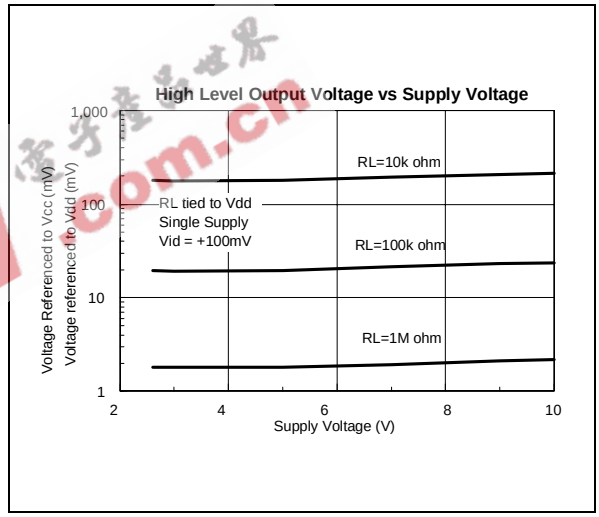



**Figure 8:**



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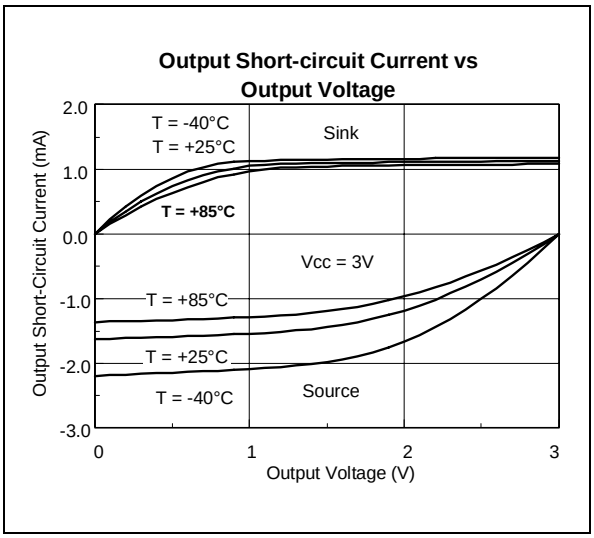
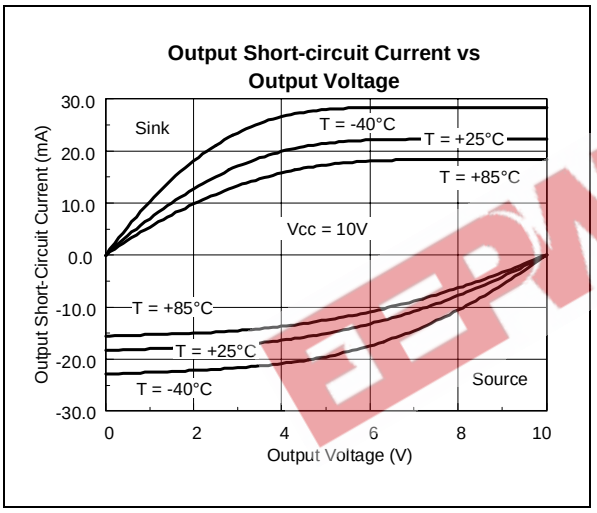



**Figure 10:**

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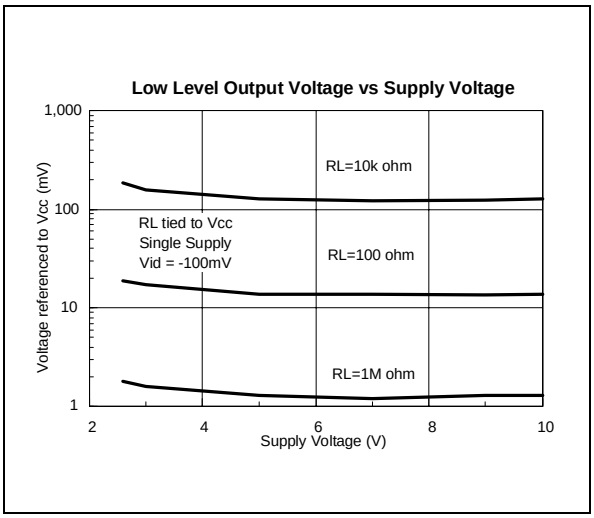


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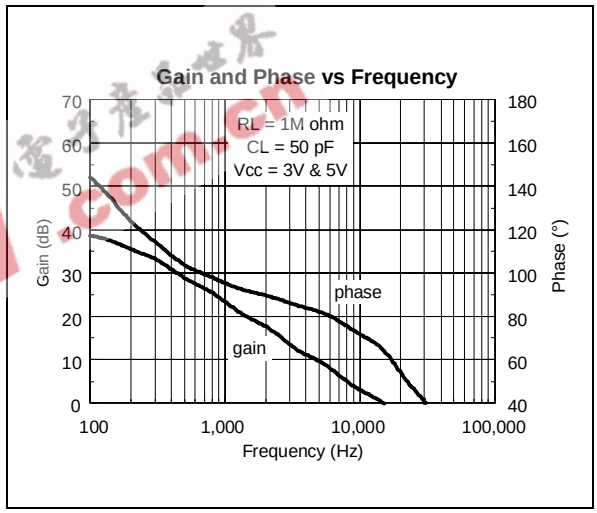

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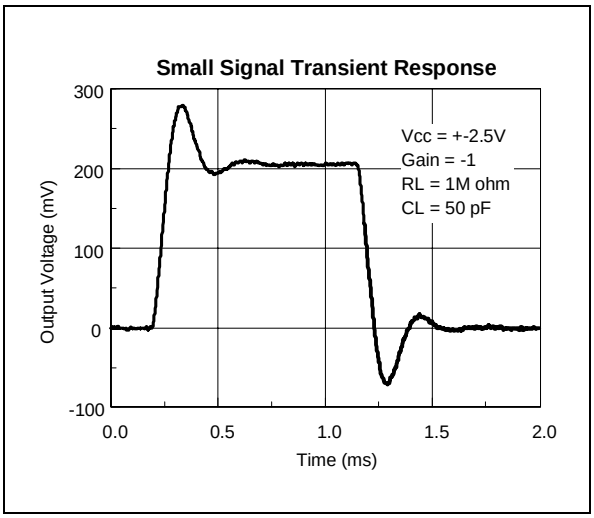
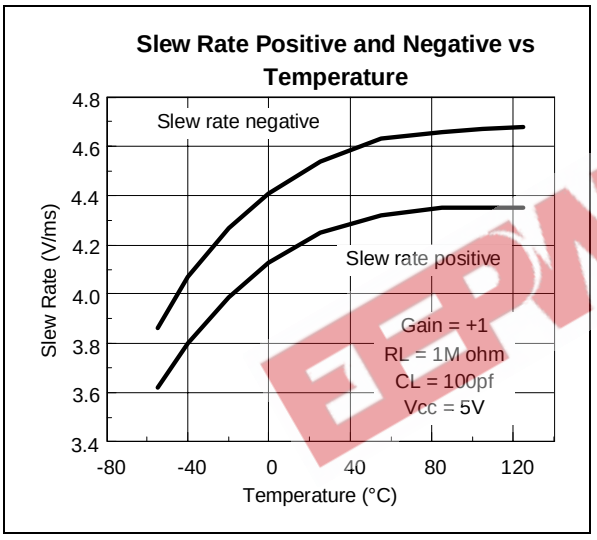



**Figure 14:**

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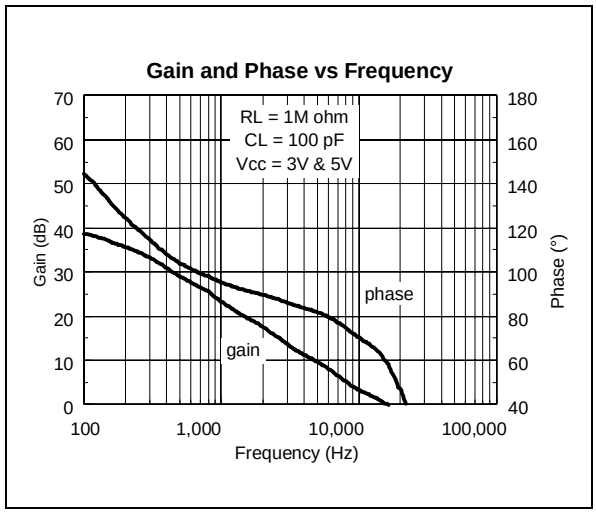
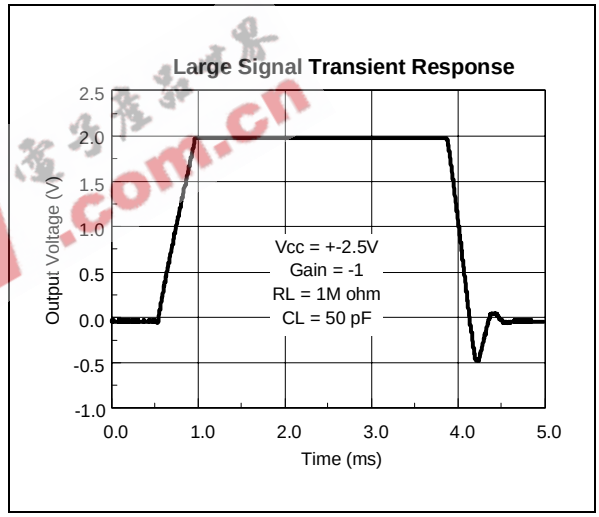



**Figure 16:**

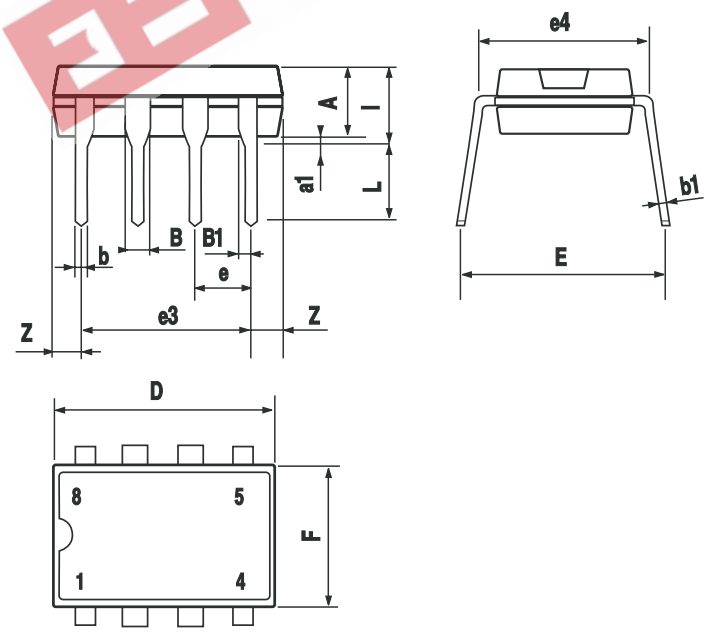


# 3 Package Mechanical Data

## 3.1 DIP8 package

**Plastic DIP-8 MECHANICAL DATA**

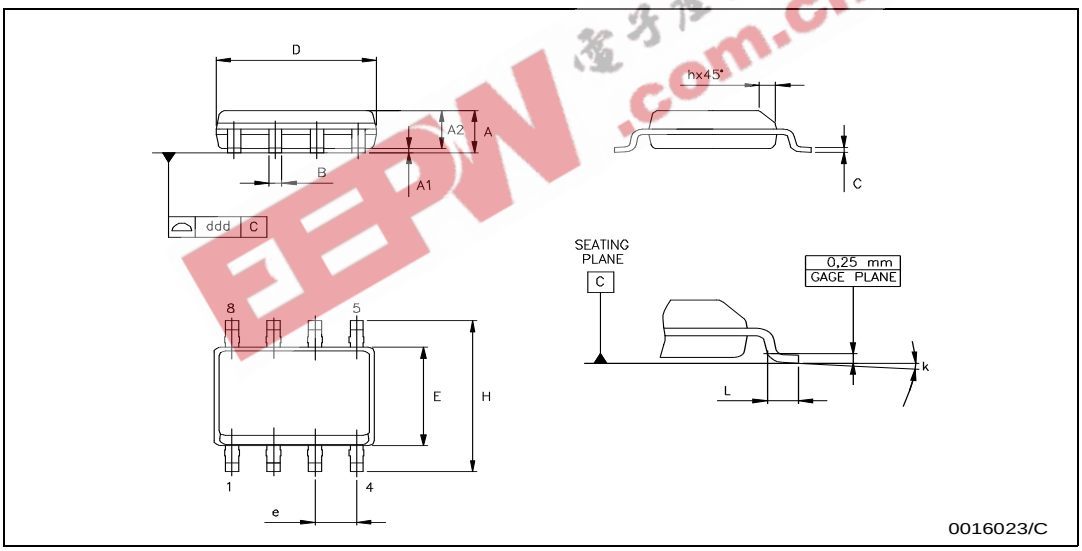
| DIM. | mm. | | | inch | | |
|---|---|---|---|---|---|---|
| | MIN. | TYP | MAX. | MIN. | TYP. | MAX. |
| A | | 3.3 | | | 0.130 | |
| a1 | 0.7 | | | 0.028 | | |
| B | 1.39 | | 1.65 | 0.055 | | 0.065 |
| B1 | 0.91 | | 1.04 | 0.036 | | 0.041 |
| b | | 0.5 | | | 0.020 | |
| b1 | 0.38 | | 0.5 | 0.015 | | 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

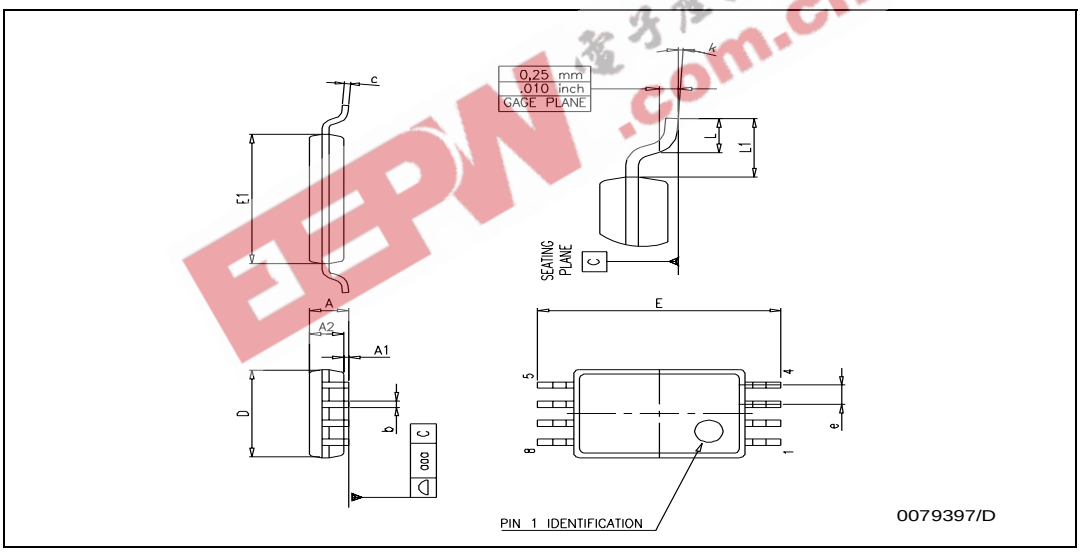
| SO-8 MECHANICAL DATA | | | | | | |
|---|---|---|---|---|---|---|
| DIM. | mm. | | | inch | | |
| | MIN. | TYP | MAX. | MIN. | TYP. | MAX. |
| A | 1.35 | | 1.75 | 0.053 | | 0.069 |
| A1 | 0.10 | | 0.25 | 0.04 | | 0.010 |
| A2 | 1.10 | | 1.65 | 0.043 | | 0.065 |
| B | 0.33 | | 0.51 | 0.013 | | 0.020 |
| 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 |



## 3.3 TSSOP8 package

**TSSOP8 MECHANICAL DATA**

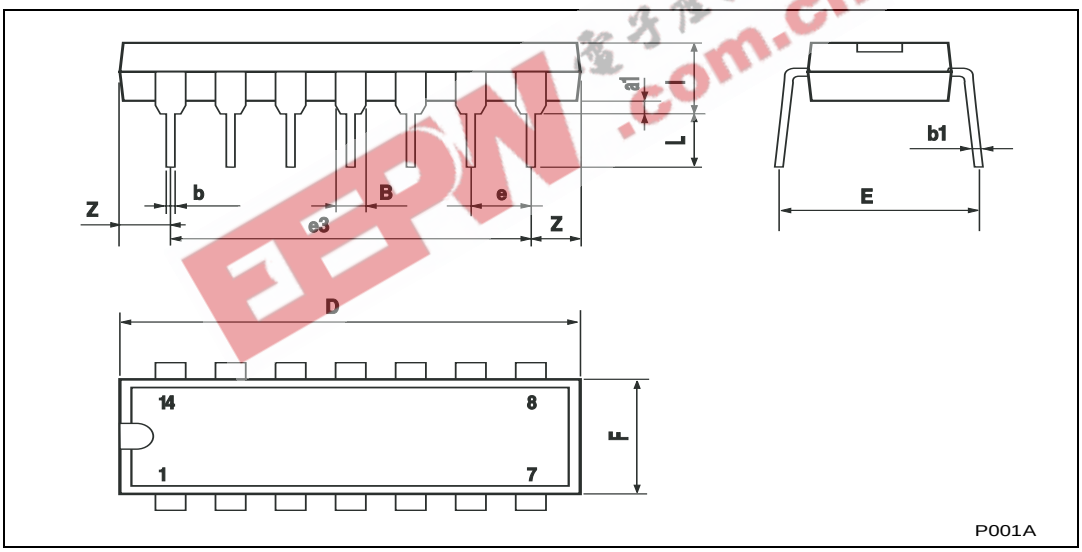
| DIM. | mm. | | | inch | | |
|---|---|---|---|---|---|---|
| | MIN. | TYP | MAX. | MIN. | TYP. | MAX. |
| A | | | 1.2 | | | 0.047 |
| A1 | 0.05 | | 0.15 | 0.002 | | 0.006 |
| A2 | 0.80 | 1.00 | 1.05 | 0.031 | 0.039 | 0.041 |
| b | 0.19 | | 0.30 | 0.007 | | 0.012 |
| c | 0.09 | | 0.20 | 0.004 | | 0.008 |
| 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**

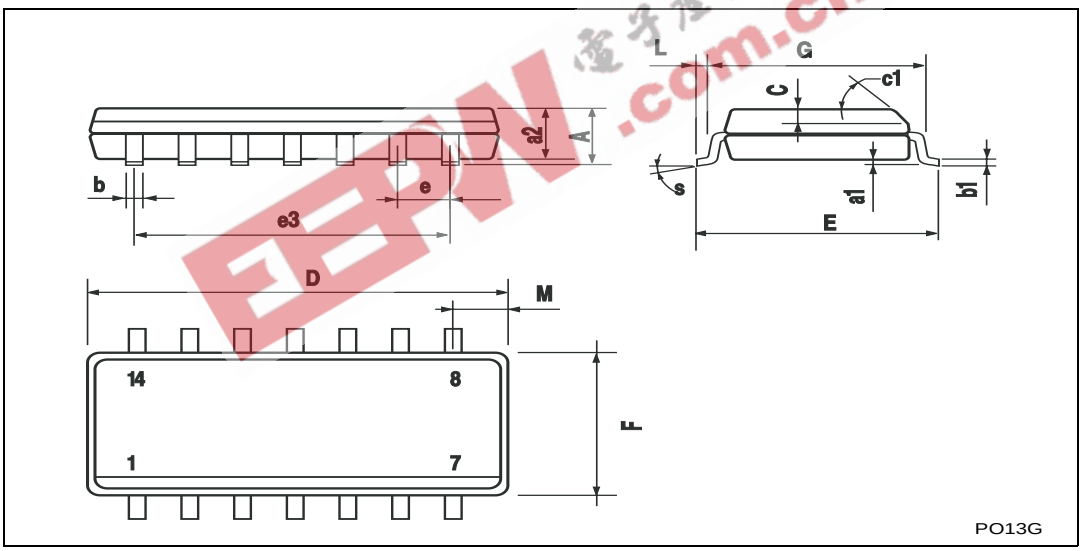
| DIM. | mm. | | | inch | | |
|---|---|---|---|---|---|---|
| | MIN. | TYP | MAX. | MIN. | TYP. | MAX. |
| a1 | 0.51 | | | 0.020 | | |
| B | 1.39 | | 1.65 | 0.055 | | 0.065 |
| b | | 0.5 | | | 0.020 | |
| b1 | | 0.25 | | | 0.010 | |
| D | | | 20 | | | 0.787 |
| E | | 8.5 | | | 0.335 | |
| e | | 2.54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

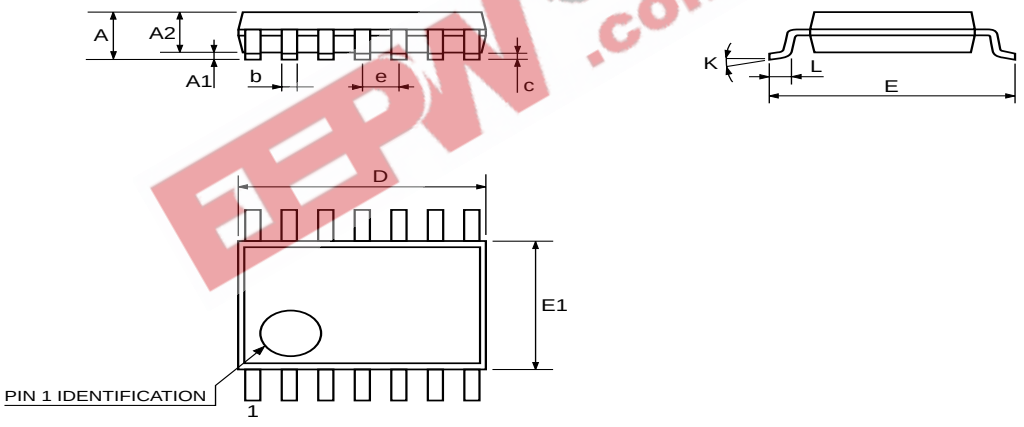
| DIM. | mm. | | | inch | | |
|---|---|---|---|---|---|---|
| | MIN. | TYP | MAX. | MIN. | TYP. | MAX. |
| A | | | 1.75 | | | 0.068 |
| a1 | 0.1 | | 0.2 | 0.003 | | 0.007 |
| a2 | | | 1.65 | | | 0.064 |
| b | 0.35 | | 0.46 | 0.013 | | 0.018 |
| b1 | 0.19 | | 0.25 | 0.007 | | 0.010 |
| C | | 0.5 | | | 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

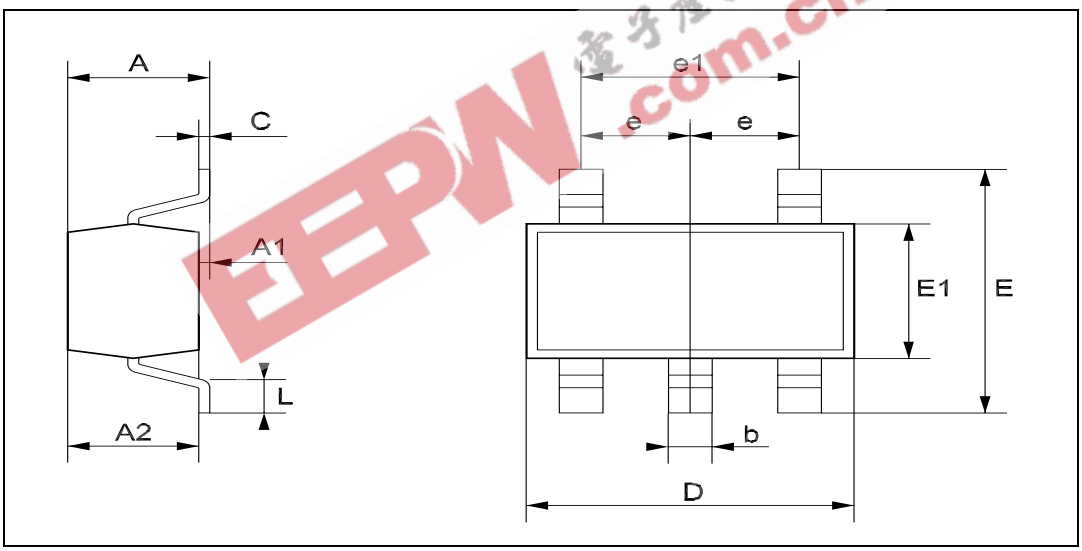
**TSSOP14 MECHANICAL DATA**

| 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 OU

| Date | Revision | Description of Changes |
|---|---|---|
| 01 Dec 2001 | 1 | First Release |
| 01 Dec 2004 | 2 | Modifications on AMR table page 2 (explanation of Vid and Vi limits) |