



**TS941  
TS942  
TS944**

## OUTPUT RAIL TO RAIL MICROPOWER OPERATIONAL AMPLIFIERS

- RAIL TO RAIL **OUTPUT** VOLTAGE SWING
- **MICROPOWER** CONSUMPTION (1.2 $\mu$ A)
- 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 - 1.2 $\mu$ A, while featuring 10kHz gain bandwidth product, 1.5mA output capability and output Rail to Rail operation - 2.85V typ @ 3V with RL=10k $\Omega$ .

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

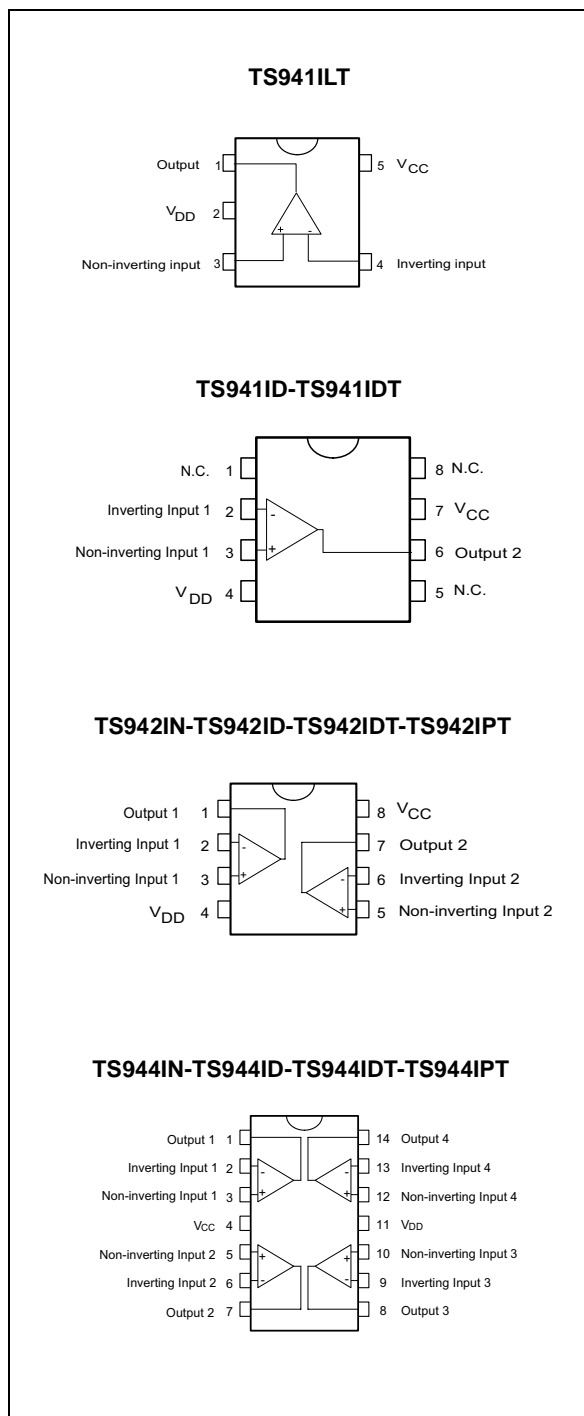
- Battery-powered systems (Alarm)
- Portable communication systems (Paggers)
- Smoke/gas/fire detectors
- Instrumentation & sensing
- PH Meter

### ORDER CODE

Part Number	Temperature Range	Package				SOT23 Marking
		N	D	P	L	
TS941I TS941AI TS941BI	-40, +85°C		•		•	K201 K202 K203
TS942I TS942AI TS942BI	-40, +85°C	•	•	•		
TS944I TS944AI 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> SOT23-5 DIP8 DIP14 SO8 SO14 TSSOP8 TSSOP14	81 42 32 28 22 26 21	°C/W
$R_{thja}$	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

**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 TS941/2/4 TS941/2/4A TS941/2/4B			10 5 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 $V_O = 2V_{pp}$ $R_L = 1M\Omega$		100		dB
$V_{OH}$	High Level Output Voltage $V_{ID} = 100mV$ $R_L = 1M\Omega$ $R_L = 10k\Omega$	2.45 2.3	2.49 2.4		V
$V_{OL}$	Low Level Output Voltage $V_{ID} = -100mV$ $R_L = 1M\Omega$ $R_L = 10k\Omega$		1 100	5 200	mV
$I_o$	Output Source Current $V_{ID} = 100mV, V_O = V_{DD}$ Output Sink Current $V_{ID} = -100mV, V_O = V_{CC}$	350 280	650 500		$\mu A$
$I_{CC}$	Supply Current (per amplifier) $A_{VCL} = 1$ , 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 TS941/2/4 TS941/2/4A TS941/2/4B			10 5 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 $V_O = 2V_{pp}$ $R_L = 1M\Omega$		100		dB
$V_{OH}$	High Level Output Voltage $V_{ID} = 100mV$ $R_L = 1M\Omega$ $R_L = 10k\Omega$	2.9 2.8	2.99 2.85		V
$V_{OL}$	Low Level Output Voltage $V_{ID} = -100mV$ $R_L = 1M\Omega$ $R_L = 10k\Omega$		1 100	5 200	mV
$I_o$	Output Source Current $V_{ID} = 100mV$ , $V_O = V_{DD}$ Output Sink Current $V_{ID} = -100mV$ , $V_O = V_{CC}$	680 650	1500 1300		$\mu A$
$I_{CC}$	Supply Current (per amplifier) $A_{VCL} = 1$ , 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

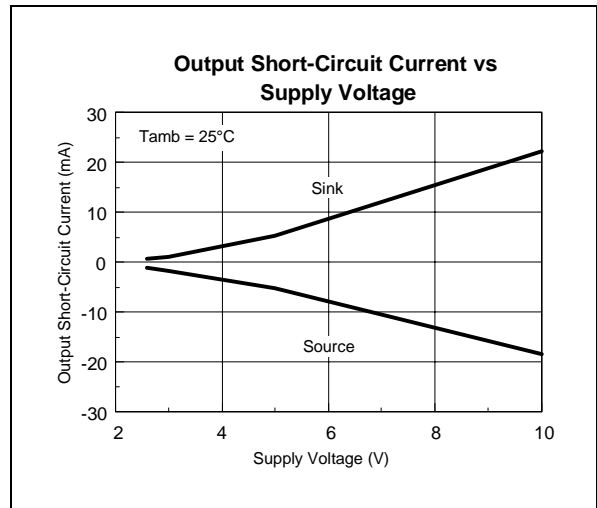
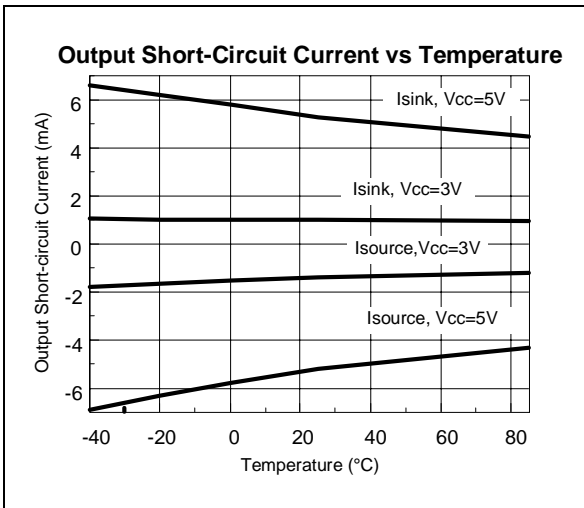
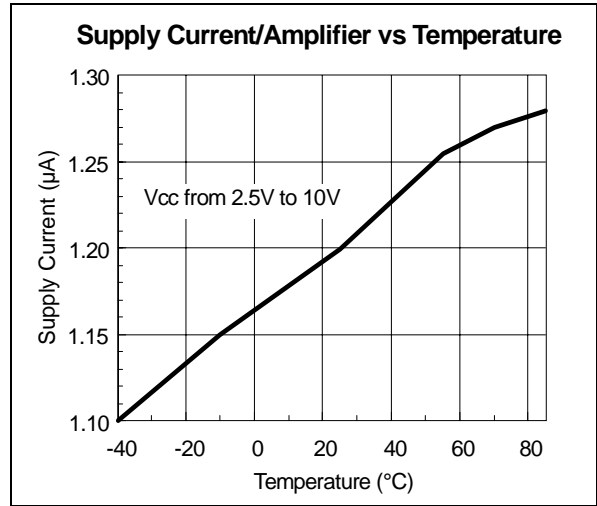
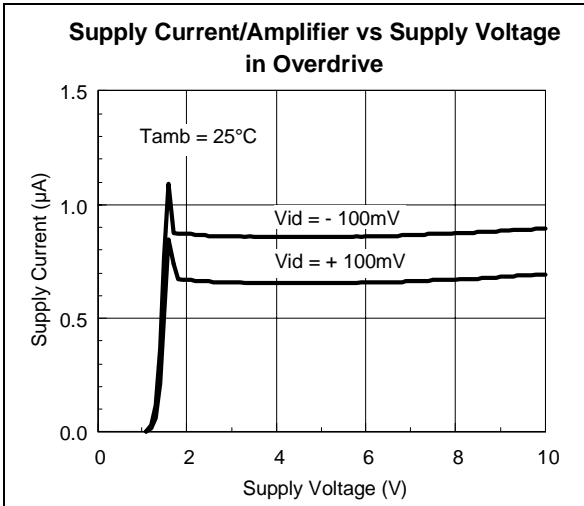
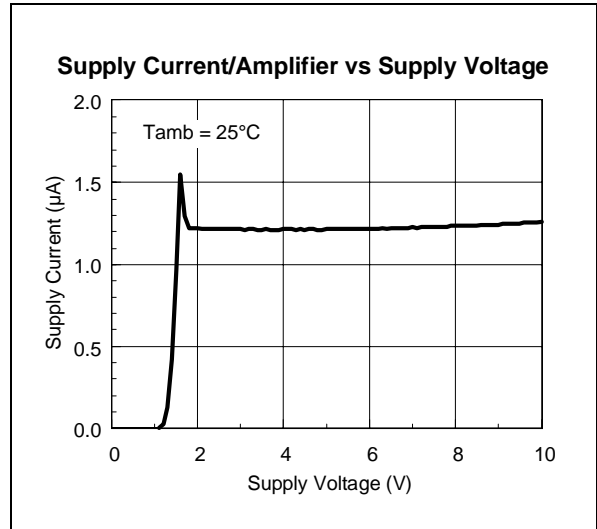
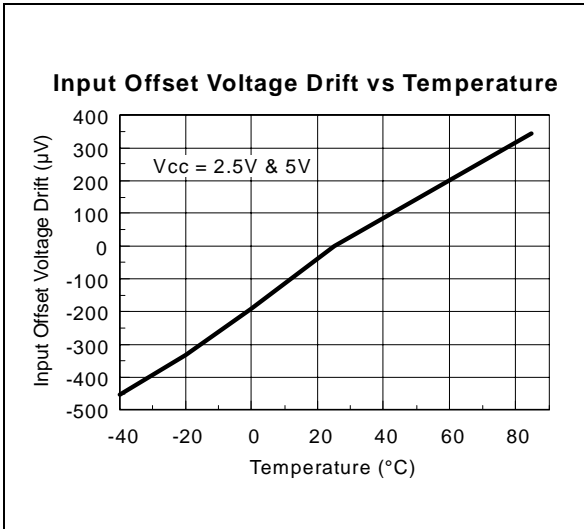
**ELECTRICAL CHARACTERISTICS**

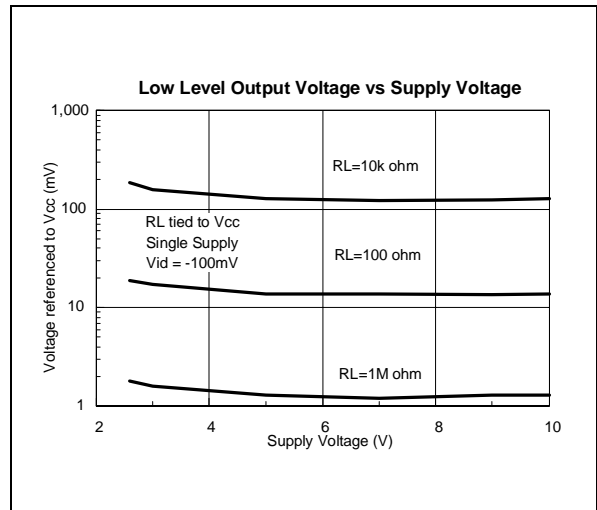
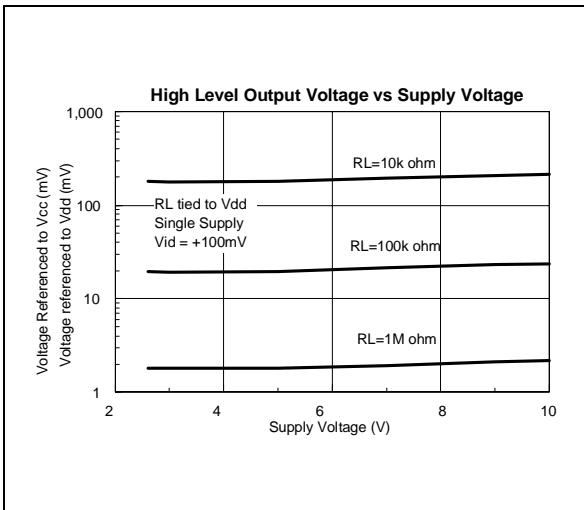
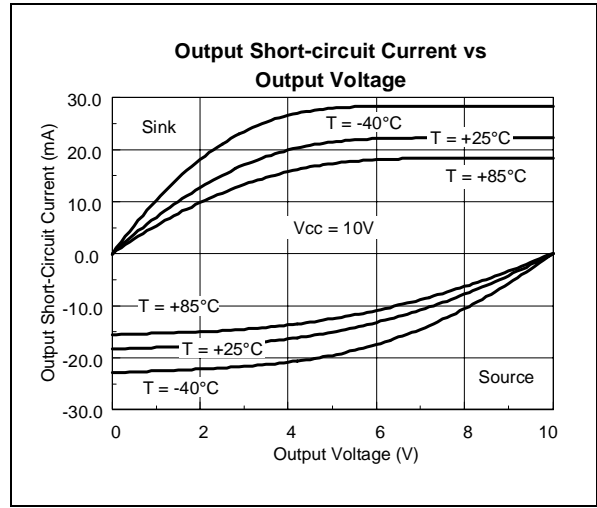
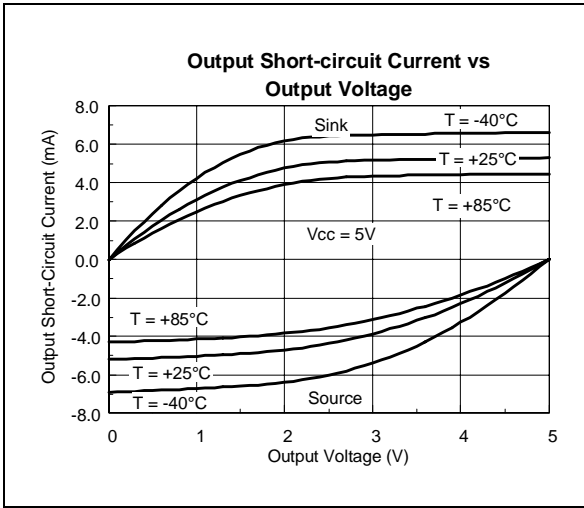
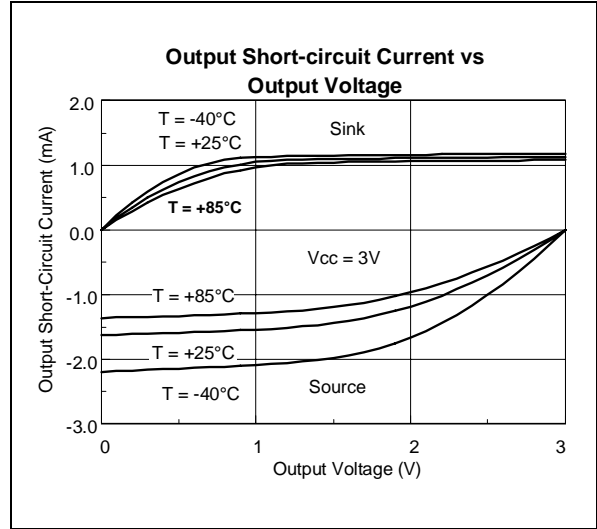
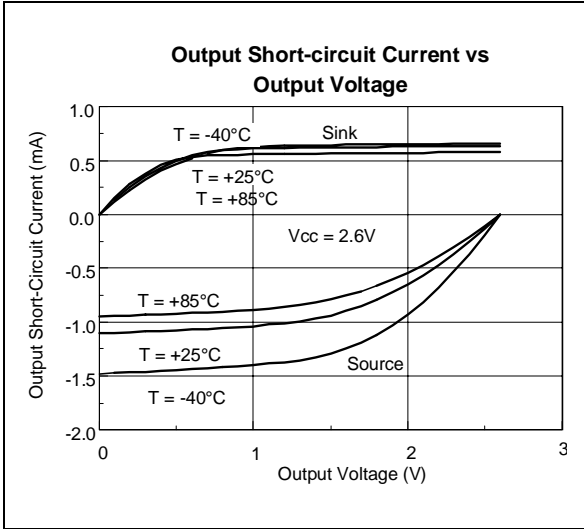
$V_{CC} = +5V$ ,  $V_{DD} = 0V$ ,  $R_L$  connected to  $V_{CC/2}$ ,

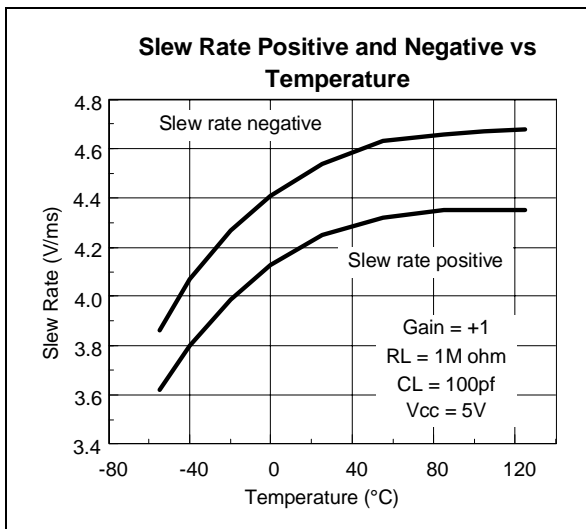
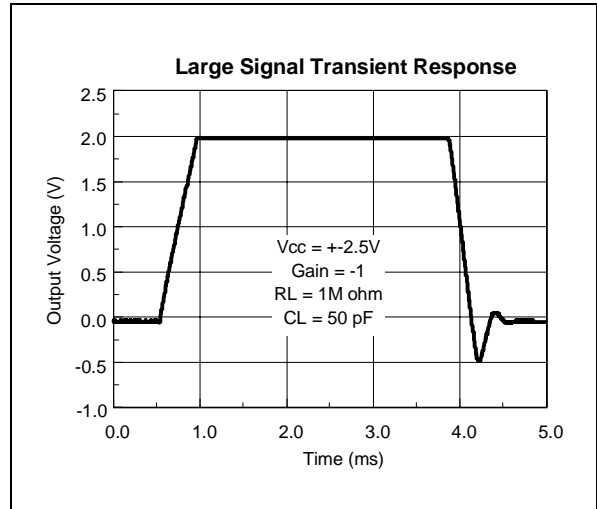
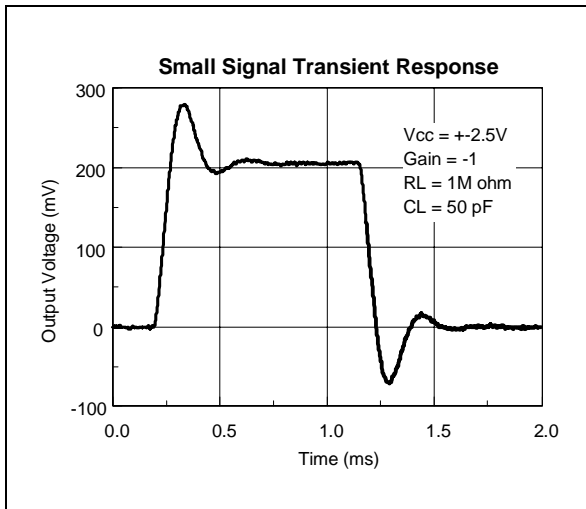
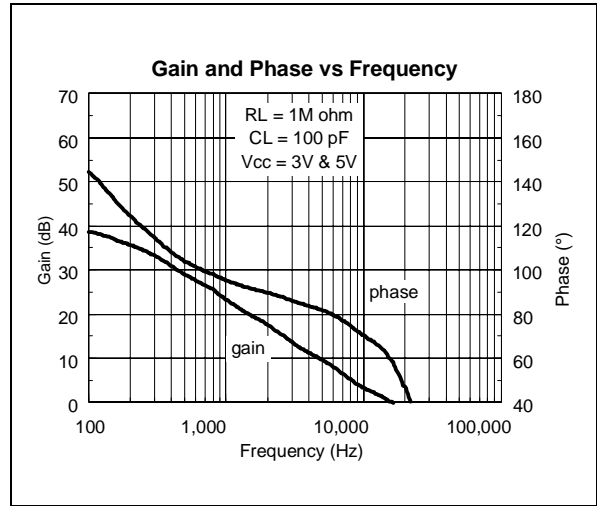
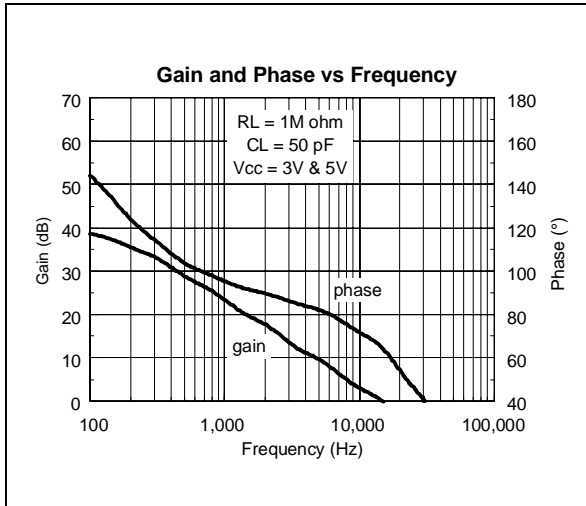
$T_{amb} = 25^\circ C$  (unless otherwise specified)

Symbol	Parameter	Min.	Typ.	Max.	Unit
$V_{io}$	Input Offset Voltage TS941/2/4 TS941/2/4A TS941/2/4B			10 5 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 $V_O = 2V_{pp}$ $R_L = 1M\Omega$		100		dB
$V_{OH}$	High Level Output Voltage $V_{ID} = 100mV$ $R_L = 1M\Omega$ $R_L = 10k\Omega$	4.9 4.8	4.99 4.85		V
$V_{OL}$	Low Level Output Voltage $V_{ID} = -100mV$ $R_L = 1M\Omega$ $R_L = 10k\Omega$		1 100	5 150	mV
$I_o$	Output Source Current $V_{ID} = 100mV$ , $V_O = V_{DD}$	3	4.5		mA
	Output Sink Current $V_{ID} = -100mV$ , $V_O = V_{CC}$	3.7	5		
$I_{CC}$	Supply Current (per amplifier) $A_{VCL} = 1$ , no load		1.2	1.85	$\mu A$
GBP	Gain Bandwith 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.

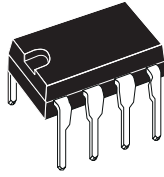




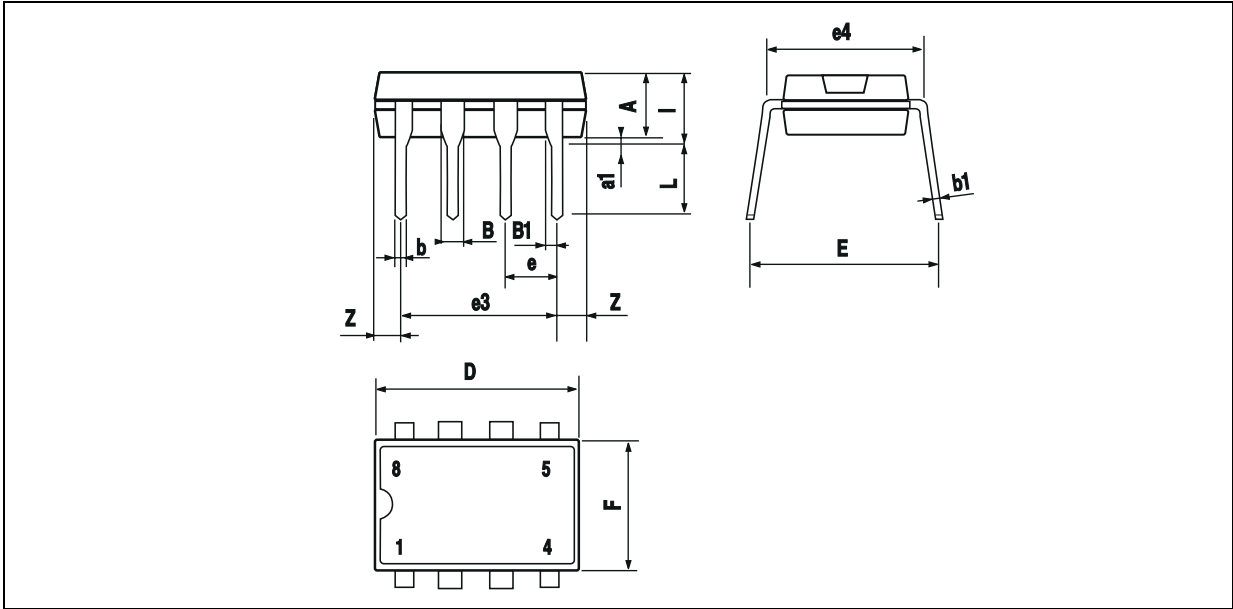




TS942IN

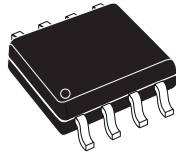


**PACKAGE MECHANICAL DATA**  
8 PINS - PLASTIC PACKAGE

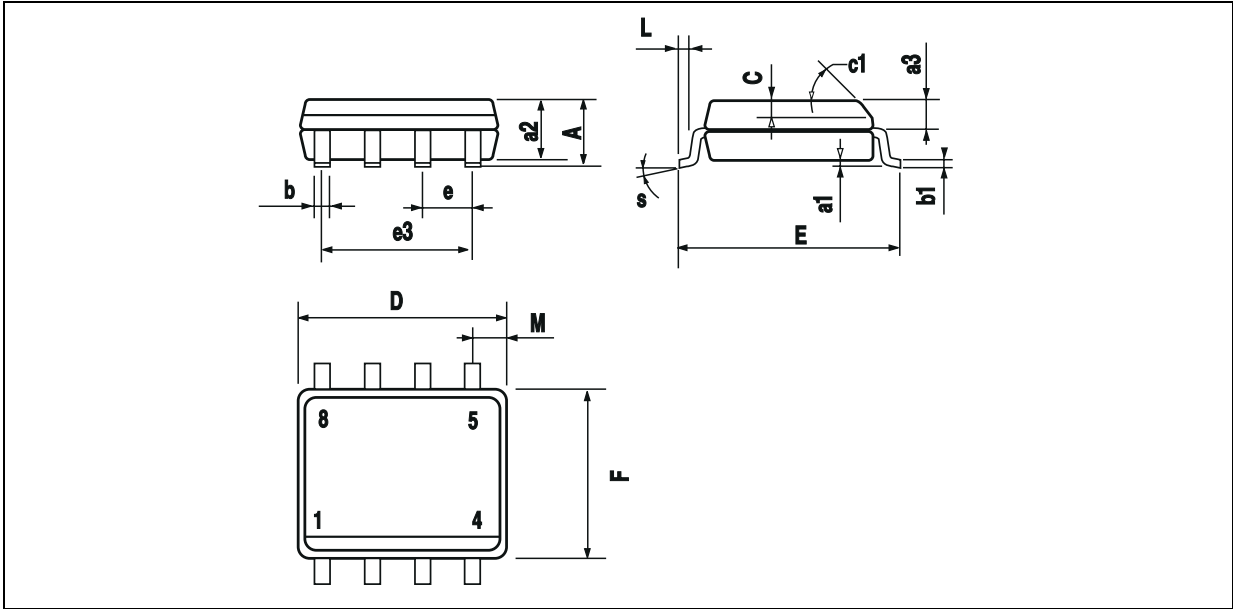


Dim.	Millimeters			Inches		
	Min.	Typ.	Max.	Min.	Typ.	Max.
A		3.32			0.131	
a1	0.51			0.020		
B	1.15		1.65	0.045		0.065
b	0.356		0.55	0.014		0.022
b1	0.204		0.304	0.008		0.012
D			10.92			0.430
E	7.95		9.75	0.313		0.384
e		2.54			0.100	
e3		7.62			0.300	
e4		7.62			0.300	
F			6.6			0.260
i			5.08			0.200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

TS941ID - TS942ID

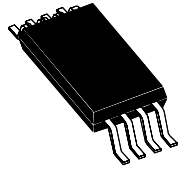


**PACKAGE MECHANICAL DATA**  
8 PINS - PLASTIC MICROPACKAGE (SO)



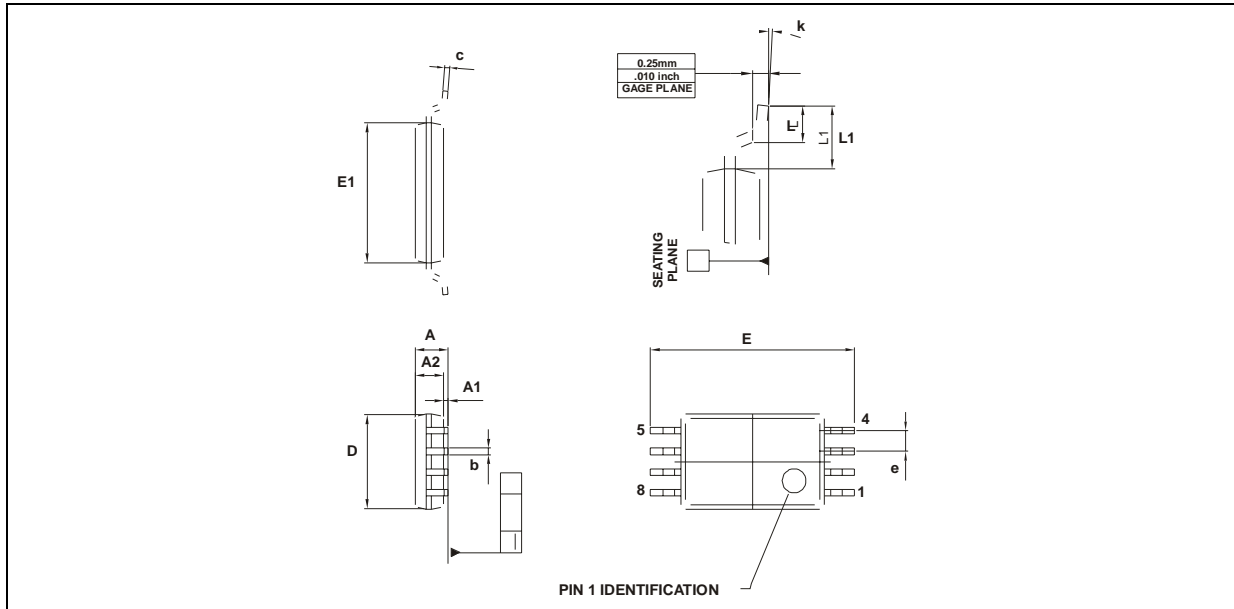
Dim.	Millimeters			Inches		
	Min.	Typ.	Max.	Min.	Typ.	Max.
A			1.75			0.069
a1	0.1		0.25	0.004		0.010
a2			1.65			0.065
a3	0.65		0.85	0.026		0.033
b	0.35		0.48	0.014		0.019
b1	0.19		0.25	0.007		0.010
C	0.25		0.5	0.010		0.020
c1	45° (typ.)					
D	4.8		5.0	0.189		0.197
E	5.8		6.2	0.228		0.244
e		1.27			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.)					

TS942IPT



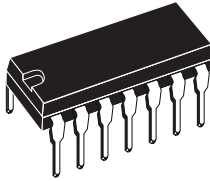
**PACKAGE MECHANICAL DATA**

8 PINS - THIN SHRINK SMALL OUTLINE PACKAGE

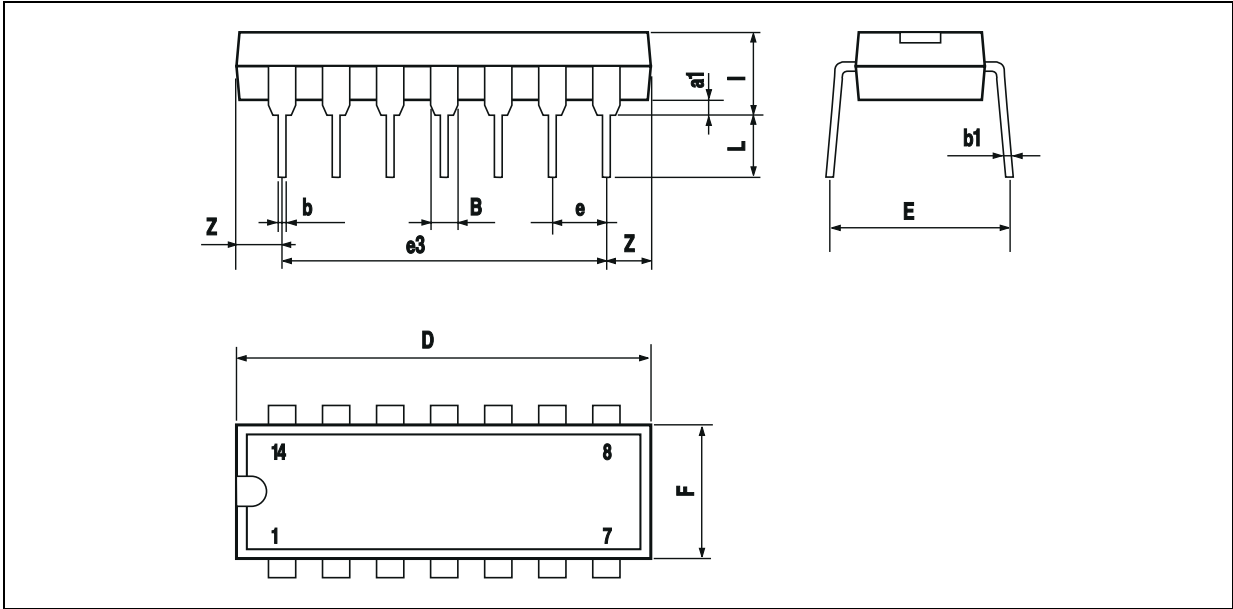


Dim.	Millimeters			Inches		
	Min.	Typ.	Max.	Min.	Typ.	Max.
A			1.20			0.05
A1	0.05		0.15	0.01		0.006
A2	0.80	1.00	1.05	0.031	0.039	0.041
b	0.19		0.30	0.007		0.15
c	0.09		0.20	0.003		0.012
D	2.90	3.00	3.10	0.114	0.118	0.122
E		6.40			0.252	
E1	4.30	4.40	4.50	0.169	0.173	0.177
e		0.65			0.025	
k	0°		8°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

TS944IN

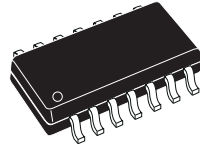


**PACKAGE MECHANICAL DATA**  
14 PINS - PLASTIC PACKAGE

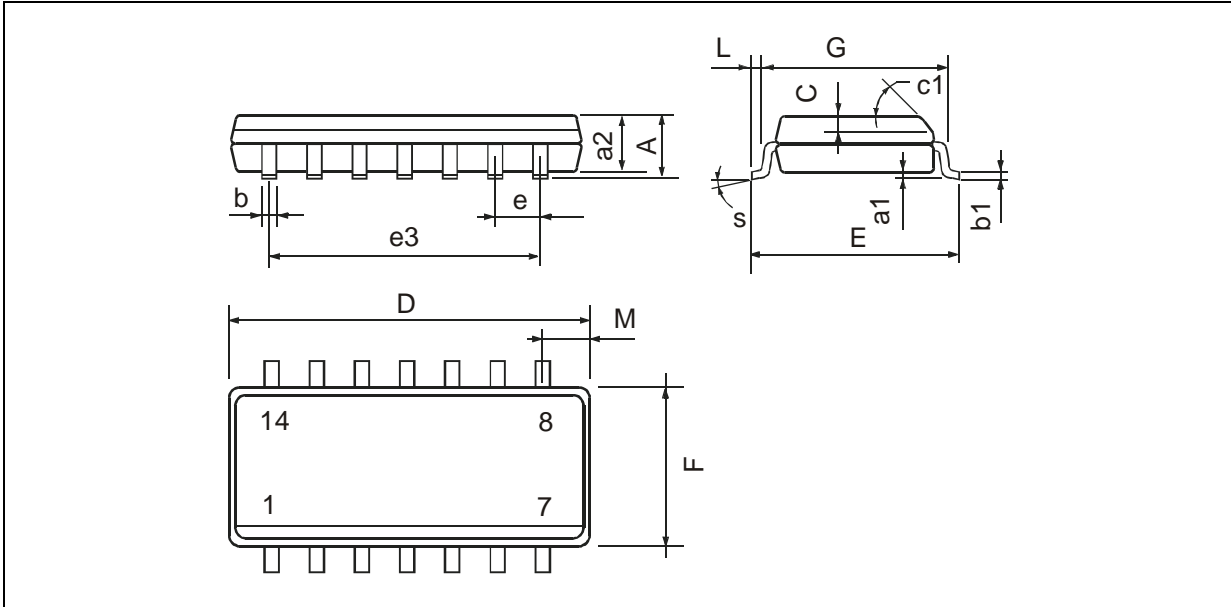


Dim.	Millimeters			Inches		
	Min.	Typ.	Max.	Min.	Typ.	Max.
a1	0.51			0.020		
B	1.39		1.65	0.055		0.065
b		0.5			0.020	
b1		0.25			0.010	
D			20			0.787
E		8.5			0.335	
e		2.54			0.100	
e3		15.24			0.600	
F			7.1			0.280
i			5.1			0.201
L		3.3			0.130	
Z	1.27		2.54	0.050		0.100

TS944ID



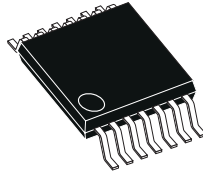
**PACKAGE MECHANICAL DATA**  
14 PINS - PLASTIC MICROPACKAGE (SO)



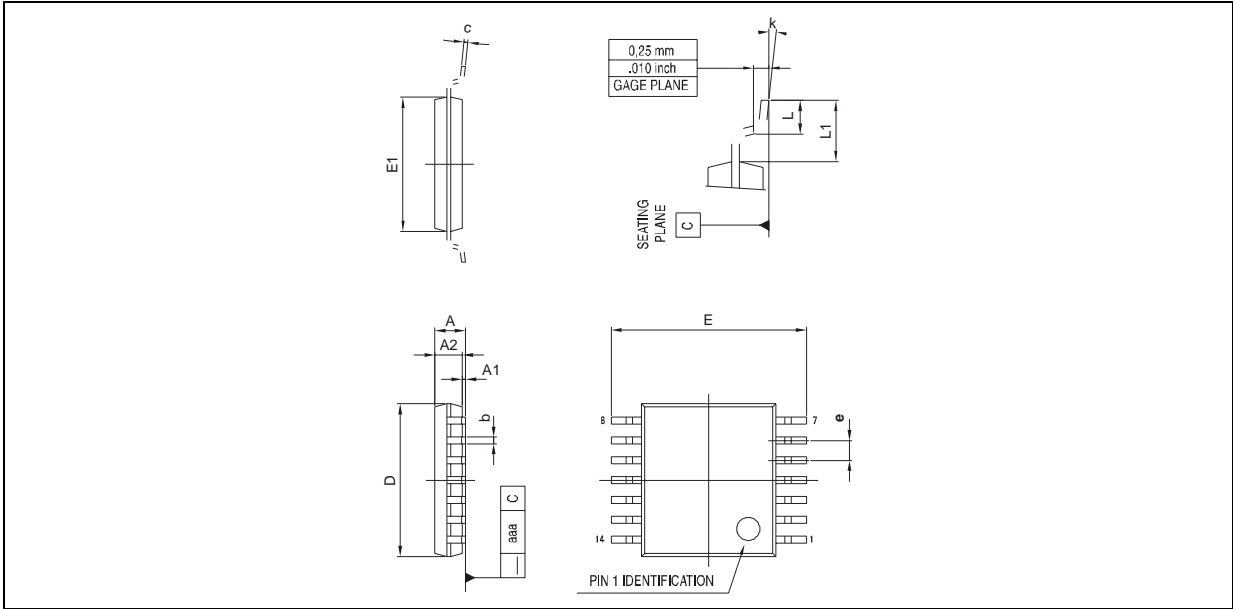
Dim.	Millimeters			Inches		
	Min.	Typ.	Max.	Min.	Typ.	Max.
A			1.75			0.069
a1	0.1		0.2	0.004		0.008
a2			1.6			0.063
b	0.35		0.46	0.014		0.018
b1	0.19		0.25	0.007		0.010
C		0.5			0.020	
c1	45° (typ.)					
D (1)	8.55		8.75	0.336		0.344
E	5.8		6.2	0.228		0.244
e		1.27			0.050	
e3		7.62			0.300	
F (1)	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

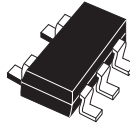


**PACKAGE MECHANICAL DATA**  
14 PINS - THIN SHRINK SMALL OUTLINE PACKAGE

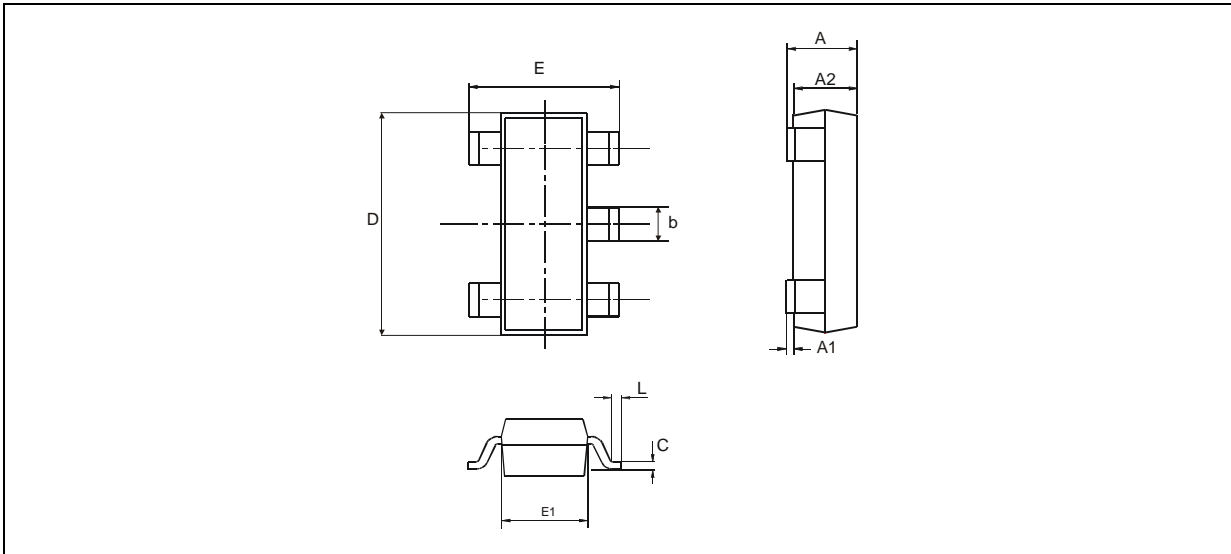


Dim.	Millimeters			Inches		
	Min.	Typ.	Max.	Min.	Typ.	Max.
A			1.20			0.05
A1	0.05		0.15	0.01		0.006
A2	0.80	1.00	1.05	0.031	0.039	0.041
b	0.19		0.30	0.007		0.15
c	0.09		0.20	0.003		0.012
D	4.90	5.00	5.10	0.192	0.196	0.20
E		6.40			0.252	
E1	4.30	4.40	4.50	0.169	0.173	0.177
e		0.65			0.025	
k	0°		8°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

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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