

# OUTPUT RAIL TO RAIL VERY LOW NOISE OPERATIONAL AMPLIFIERS

- RAIL TO RAIL **OUTPUT** VOLTAGE SWING ( $\pm 2.4V$  @  $V_{CC} = \pm 2.5V$ )
- VERY LOW NOISE LEVEL :  $4nV/\sqrt{Hz}$
- ULTRA LOW DISTORTION : **0.003%**
- HIGH DYNAMIC FEATURES (**12MHz,  $4V/\mu s$** )
- OPERATING RANGE : **2.7V to 10V**
- ESD PROTECTION (**2kV**)
- LATCH-UP IMMUNITY (**Class A**)
- **AVAILABLE IN SOT23-5 & 3X3 QFN8 MICROPACKAGE**

## DESCRIPTION

The TS97x family operational amplifiers is able to operate with voltages as low as  $\pm 1.35V$  and featuring output Rail to Rail signal swing. The TS97x boasts characteristics that make them particularly well suited for portable and battery-supplied equipment. Very low noise and low distortion characteristics make them ideal for audio pre-amplification.

The TS971 is housed in the space-saving 5 pins SOT23 package which simplifies the board design because of the ability to be placed everywhere (outside dimensions are 2.8mm x 2.9mm)

## APPLICATIONS

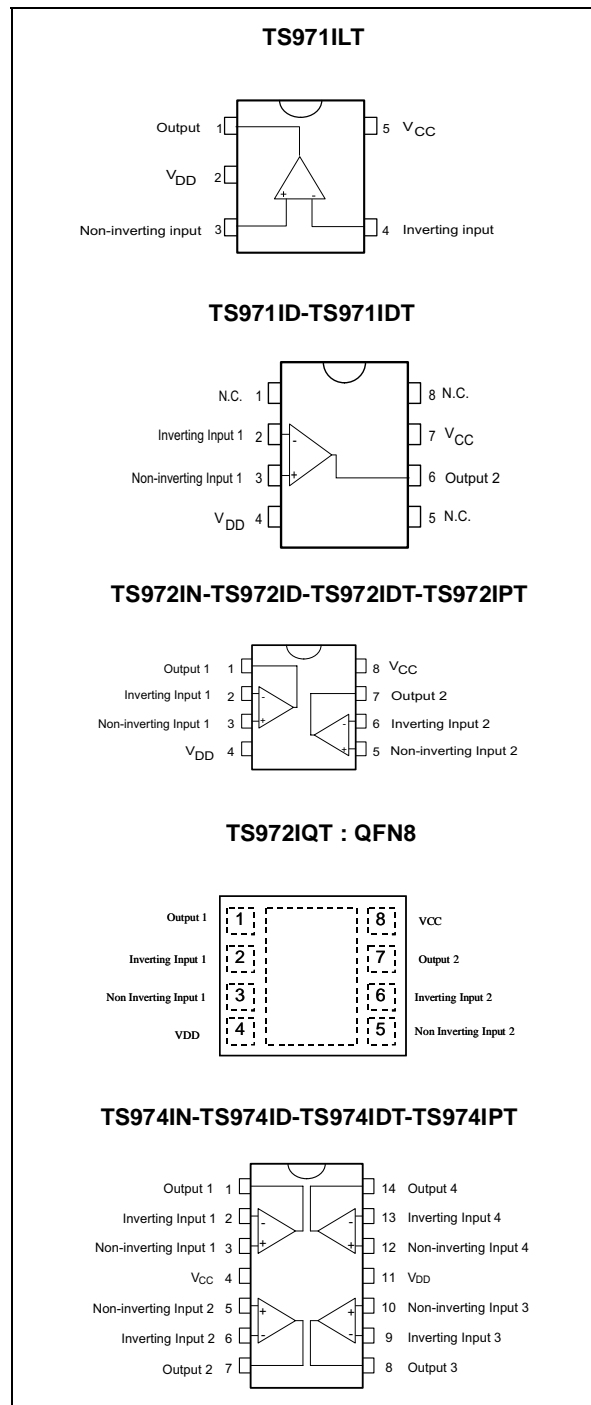
- Portable equipments (CD players, PDA)
- Portable communications (cell phones, pagers)
- Instrumentation & sensing
- Professional audio circuits

## ORDER CODE

Part Number	Temperature Range	Package					SOT23 Marking
		N	D	P	L	Q	
TS971I	-40°C, +125°C		•		•		K120
TS972I	-40°C, +125°C	•	•	•		•	
TS974I	-40°C, +125°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)  
**Q** = QFN only available in Tape & Reel with T suffix,

## PIN CONNECTIONS (top view)



**ABSOLUTE MAXIMUM RATINGS**

Symbol	Parameter	Value	Unit
$V_{CC}$	Supply voltage <sup>1)</sup>	2.7V to 12	V
$V_{id}$	Differential Input Voltage <sup>2)</sup>	$\pm V_{CC}$	V
$V_{in}$	Input Voltage <sup>3)</sup>	-0.3 to 12.3	V
$T_{oper}$	Operating Free Air Temperature Range	-40 to +125	°C
$T_{stg}$	Storage Temperature Range	-65 to +150	
$T_j$	Maximum Junction Temperature	150	°C
Rthjc	Thermal Resistance Junction to Case <sup>4)</sup>		°C/W
	SOT23-5	81	
	QFN8	5	
	SO8	28	
	SO14	22	
	TSSOP8 TSSOP14	26 21	
Rthja	Thermal Resistance Junction to Ambient - SOT23-5	256	°C/W
ESD	Human Body Model	2	kV
	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.
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.

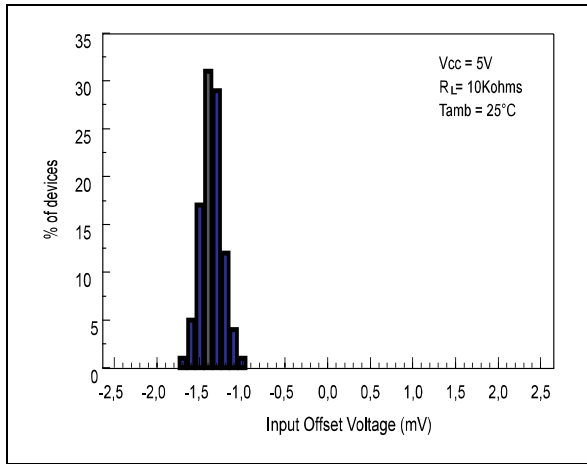
**OPERATING CONDITIONS**

Symbol	Parameter	Value	Unit
$V_{CC}$	Supply voltage	2.7 to 10	V
$V_{icm}$	Common Mode Input Voltage Range	$V_{DD} + 1.15$ to $V_{CC} - 1.15$	V

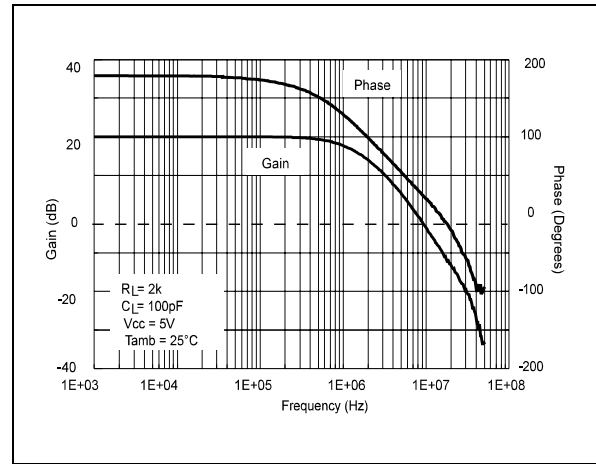
**ELECTRICAL CHARACTERISTICS** $V_{CC} = +2.5V$ ,  $V_{DD} = -2.5V$ ,  $T_{amb} = 25^{\circ}C$  (unless otherwise specified)

Symbol	Parameter	Min.	Typ.	Max.	Unit
$V_{io}$	Input Offset Voltage $T_{min} \leq T_{amb} \leq T_{max}$		1	5 7	mV
$DV_{io}$	Input Offset Voltage Drift $V_{icm} = 0V, V_o = 0V$		5		$\mu V/^{\circ}C$
$I_{io}$	Input Offset Current $V_{icm} = 0V, V_o = 0V$		10	150	nA
$I_{ib}$	Input Bias Current $V_{icm} = 0V, V_o = 0V$ $T_{min} \leq T_{amb} \leq T_{max}$		200 200	750 1000	nA
$V_{icm}$	Common Mode Input Voltage Range	-1.35		1.35	V
CMR	Common Mode Rejection Ratio $V_{icm} = \pm 1.35V$	60	85		dB
SVR	Supply Voltage Rejection Ratio $V_{cc} = \pm 2V$ to $\pm 3V$	60	70		dB
$A_{vd}$	Large Signal Voltage Gain $R_L = 2k\Omega$	70	80		dB
$V_{OH}$	High Level Output Voltage $R_L = 2k\Omega$	2	2.4		V
$V_{OL}$	Low Level Output Voltage $R_L = 2k\Omega$		-2.4	-2	V
$I_{source}$	Output Source Current		1.5		mA
$I_{sink}$	Output Sink Current		100		mA
$I_{cc}$	Supply Current - per amplifier Unity gain - No load		2	2.8	mA
GBP	Gain Bandwidth Product $f = 100kHz$ $R_L = 2k\Omega, C_L = 100pF$	8.5	12		MHz
SR	Slew Rate $A_v = 1, V_{in} = \pm 1V$	2.8	4		$V/\mu s$
$\phi_m$	Phase Margin at Unit Gain $R_L = 2k\Omega, C_L = 100pF$		60		Degrees
Gm	Gain Margin $R_L = 2k\Omega, C_L = 100pF$		10		dB
$e_n$	Equivalent Input Noise Voltage $f = 100kHz$		4		$\frac{nV}{\sqrt{Hz}}$
THD	Total Harmonic Distortion $f = 1KHz, A_v = -1$ $R_L = 10k\Omega$		0.003		%

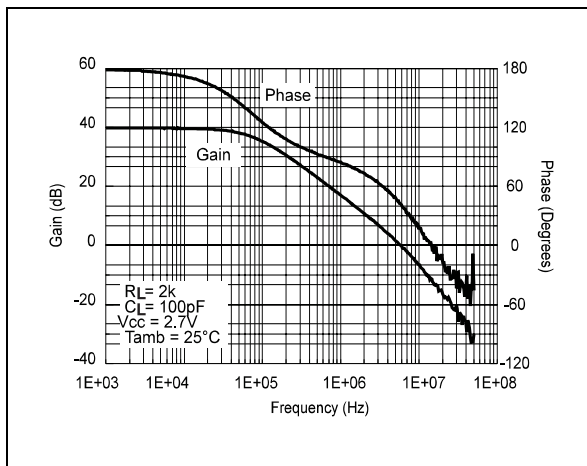
INPUT OFFSET VOLTAGE DISTRIBUTION



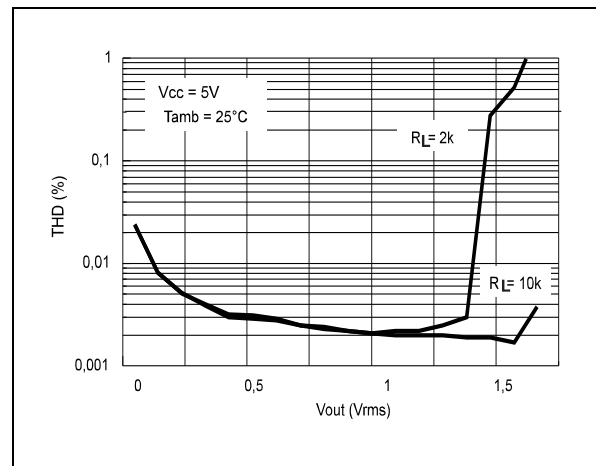
VOLTAGE GAIN & PHASE vs FREQUENCY



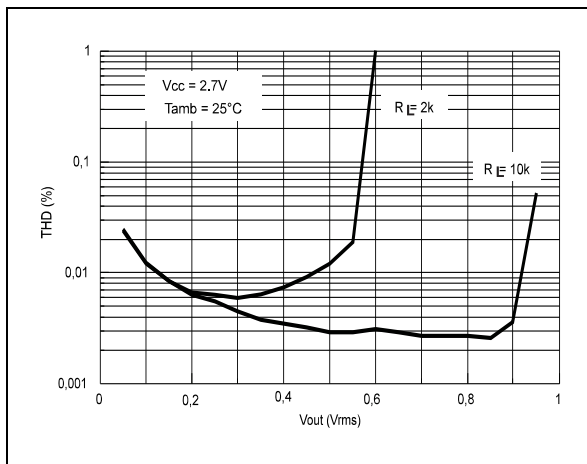
VOLTAGE GAIN & PHASE vs FREQUENCY



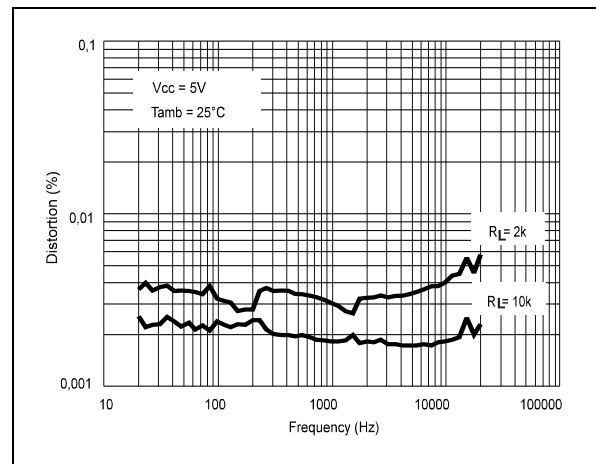
THD vs  $V_{out}$



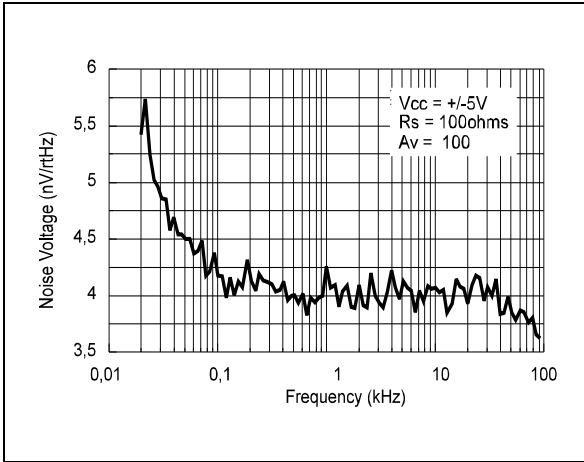
THD vs  $V_{out}$



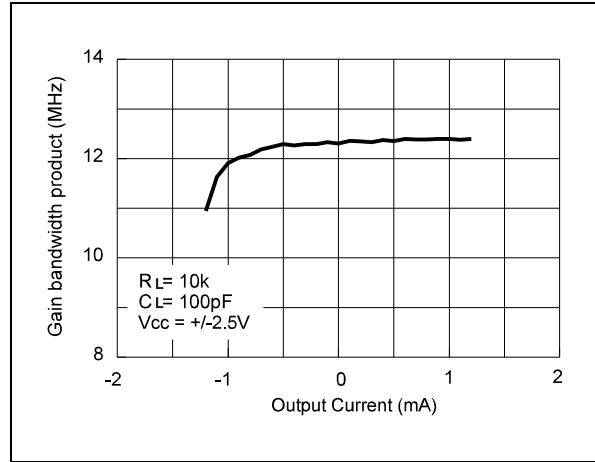
THD vs FREQUENCY



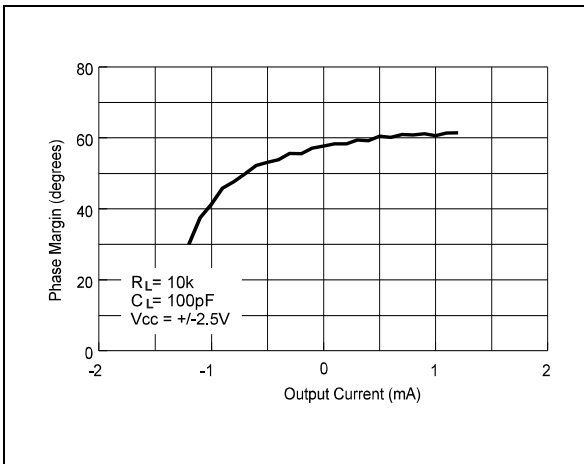
**NOISE VOLTAGE vs FREQUENCY**



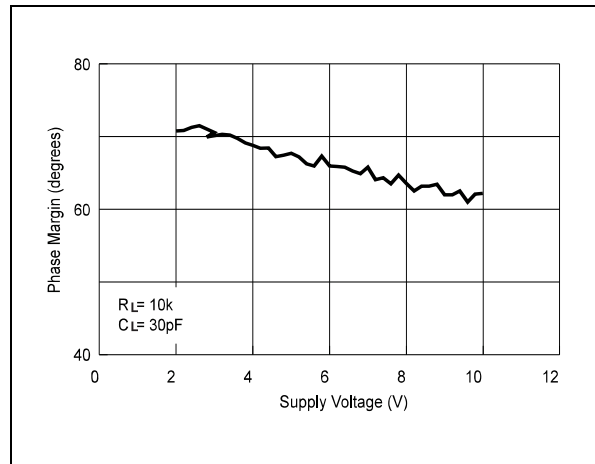
**GAIN BANDWIDTH PRODUCT vs  $I_{out}$**



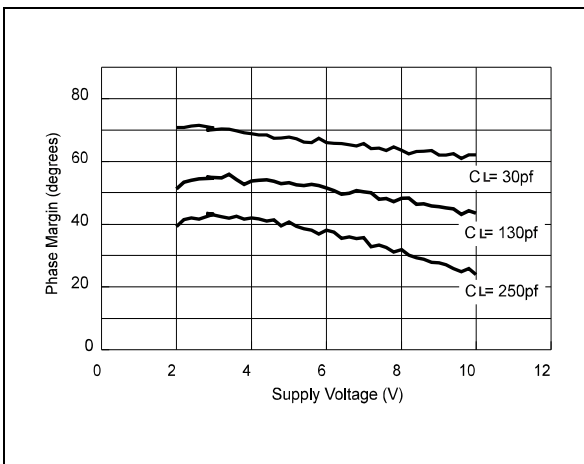
**PHASE MARGIN vs  $I_{out}$**



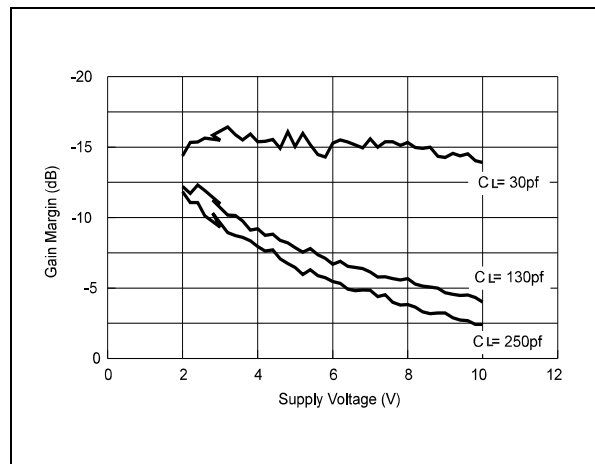
**PHASE MARGIN vs  $V_{cc}$**



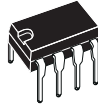
**PHASE MARGIN vs  $V_{cc}$**



**GAIN MARGIN vs  $V_{cc}$**

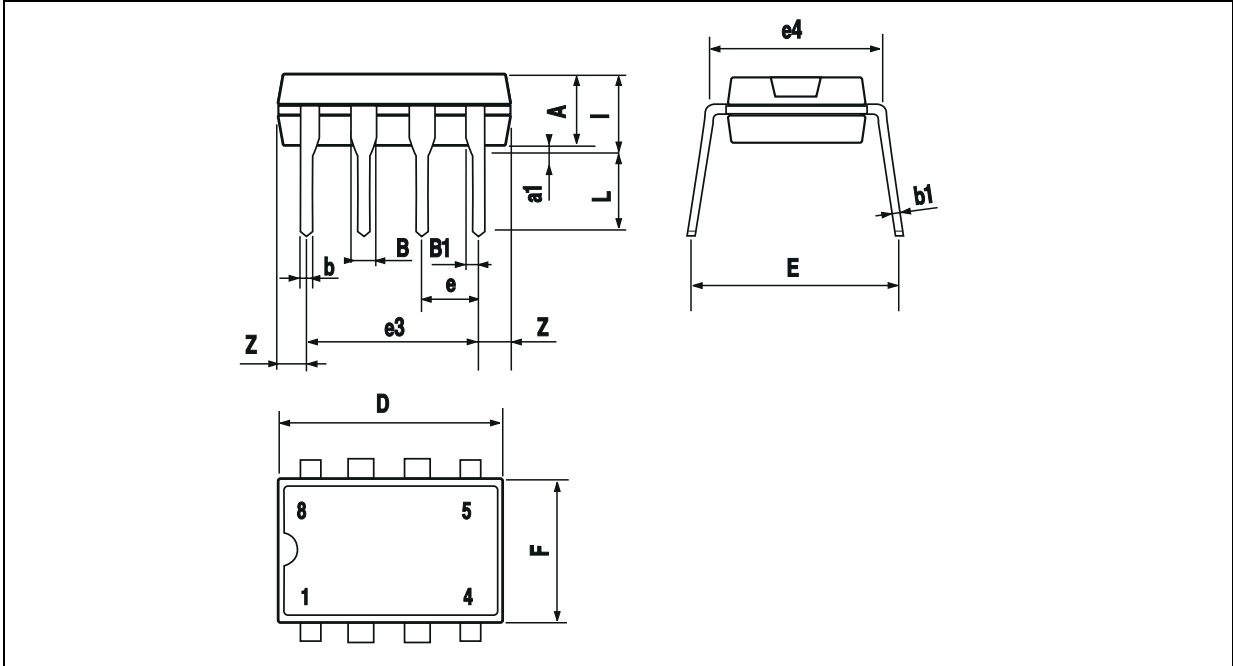


TS972IN



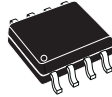
PACKAGE MECHANICAL DATA

8 PINS - PLASTIC PACKAGE

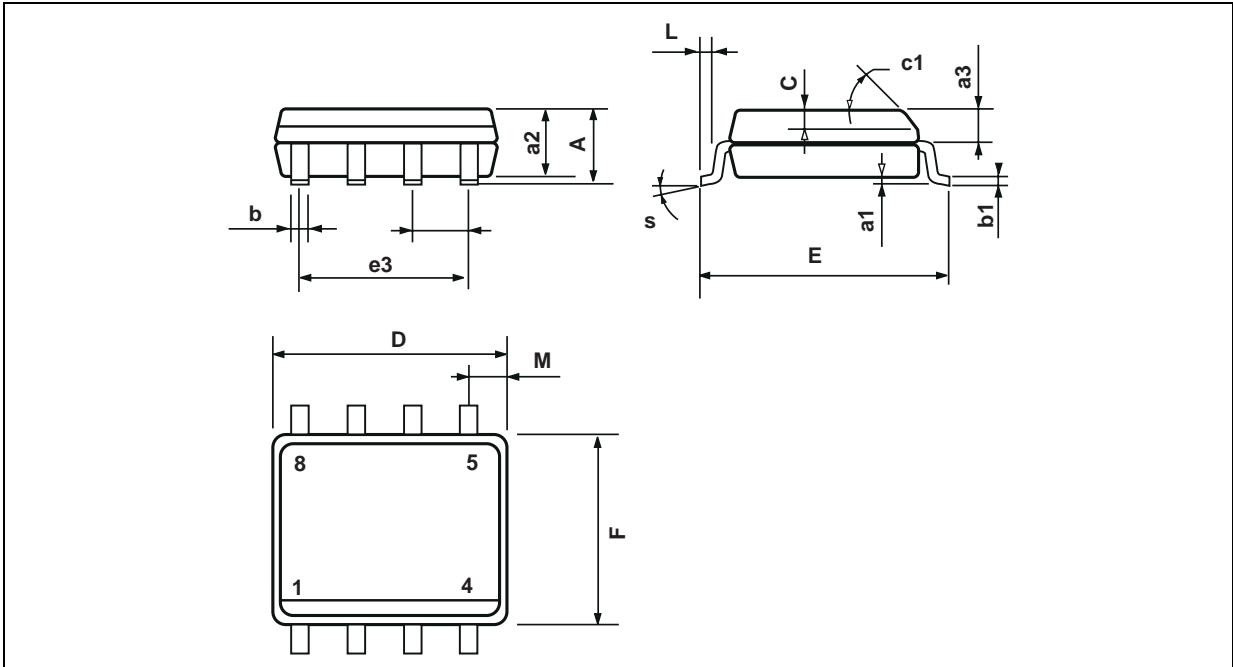


Dim.	Millimeters			Inches		
	Min.	Typ.	Max.	Min.	Typ.	Max.
A		3.32			0.131	
a1	0.51			0.020		
B	1.15		1.65	0.045		0.065
b	0.356		0.55	0.014		0.022
b1	0.204		0.304	0.008		0.012
D			10.92			0.430
E	7.95		9.75	0.313		0.384
e		2.54			0.100	
e3		7.62			0.300	
e4		7.62			0.300	
F			6.6			0.260
i			5.08			0.200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

TS971ID-TS972ID

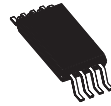


**PACKAGE MECHANICAL DATA**  
8 PINS - PLASTIC MICROPACKAGE (SO)

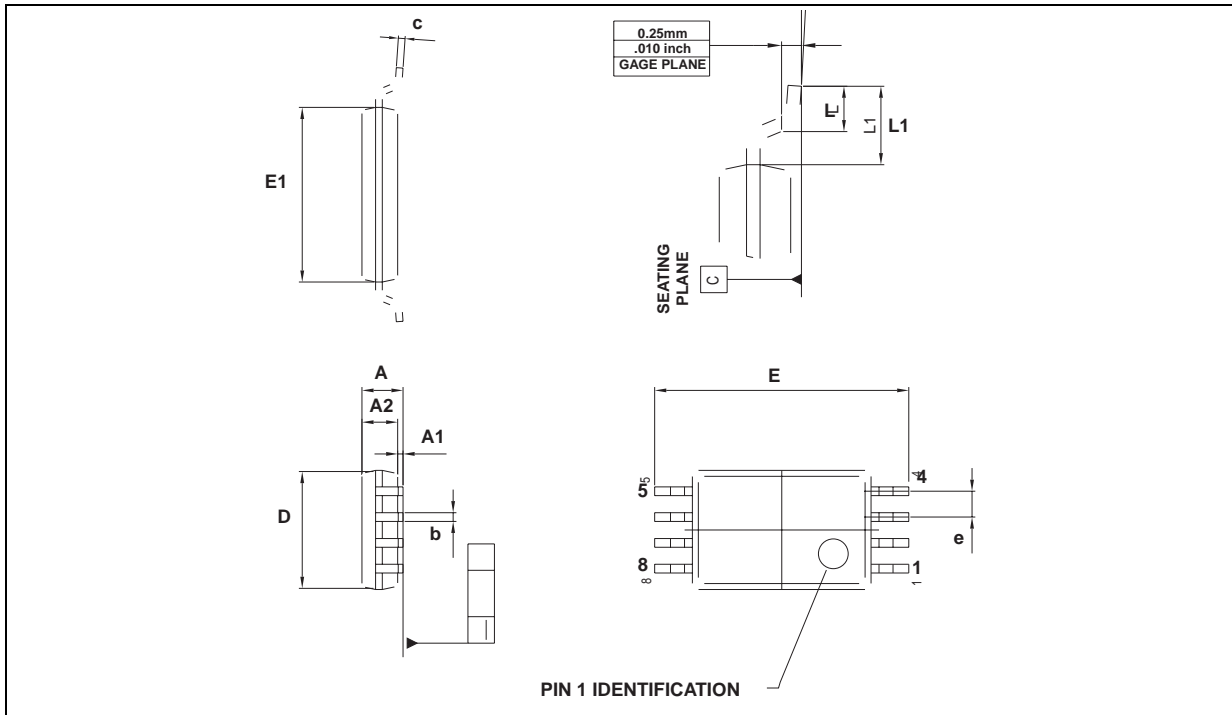


Dim.	Millimeters			Inches		
	Min.	Typ.	Max.	Min.	Typ.	Max.
A			1.75			0.069
a1	0.1		0.25	0.004		0.010
a2			1.65			0.065
a3	0.65		0.85	0.026		0.033
b	0.35		0.48	0.014		0.019
b1	0.19		0.25	0.007		0.010
C	0.25		0.5	0.010		0.020
c1	45° (typ.)					
D	4.8		5.0	0.189		0.197
E	5.8		6.2	0.228		0.244
e		1.27	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

TS972IPT



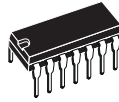
**PACKAGE MECHANICAL DATA**  
8 PINS - THIN SHRINK SMALL OUTLINE PACKAGE



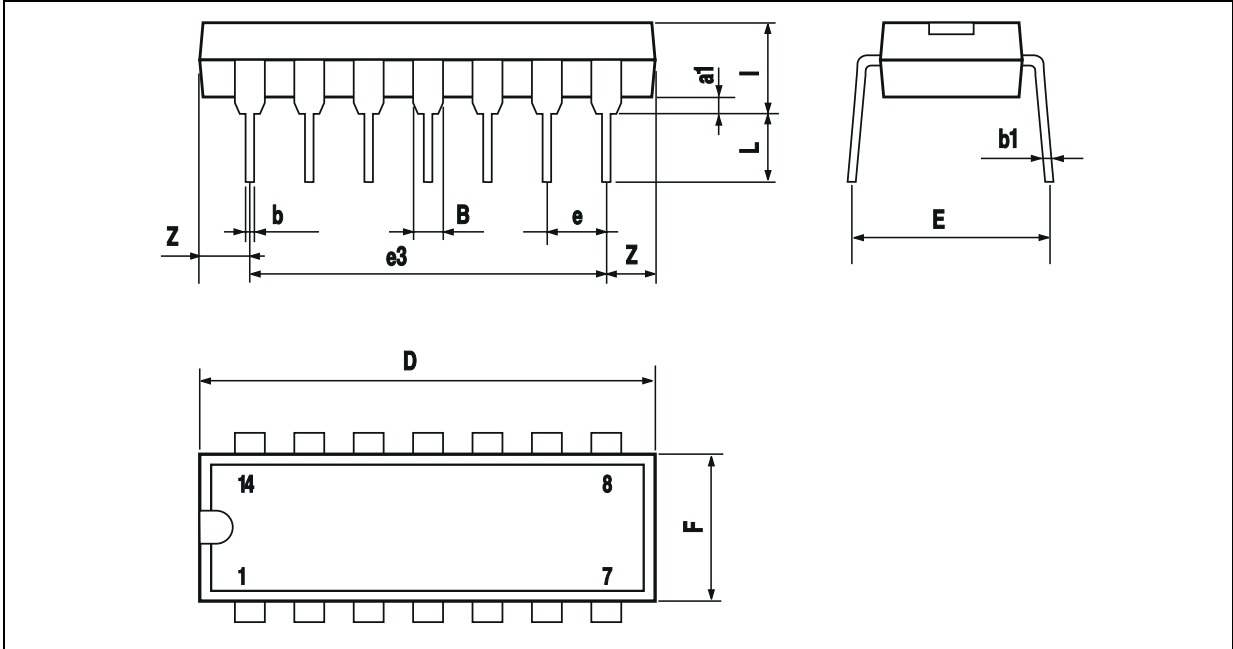
Dim.	Millimeters			Inches		
	Min.	Typ.	Max.	Min.	Typ.	Max.
A			1.20			0.05
A1	0.05		0.15	0.01		0.006
A2	0.80	1.00	1.05	0.031	0.039	0.041
b	0.19		0.30	0.007		0.15
c	0.09		0.20	0.003		0.012
D	2.90	3.00	3.10	0.114	0.118	0.122
E		6.40			0.252	
E1	4.30	4.40	4.50	0.169	0.173	0.177
e		0.65			0.025	
k	0°		8°	0°		8°
l	0.50	0.60	0.75	0.09	0.0236	0.030
L	0.45	0.600	0.75	0.018	0.024	0.030
L1		1.000			0.039	



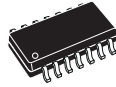
TS974IN



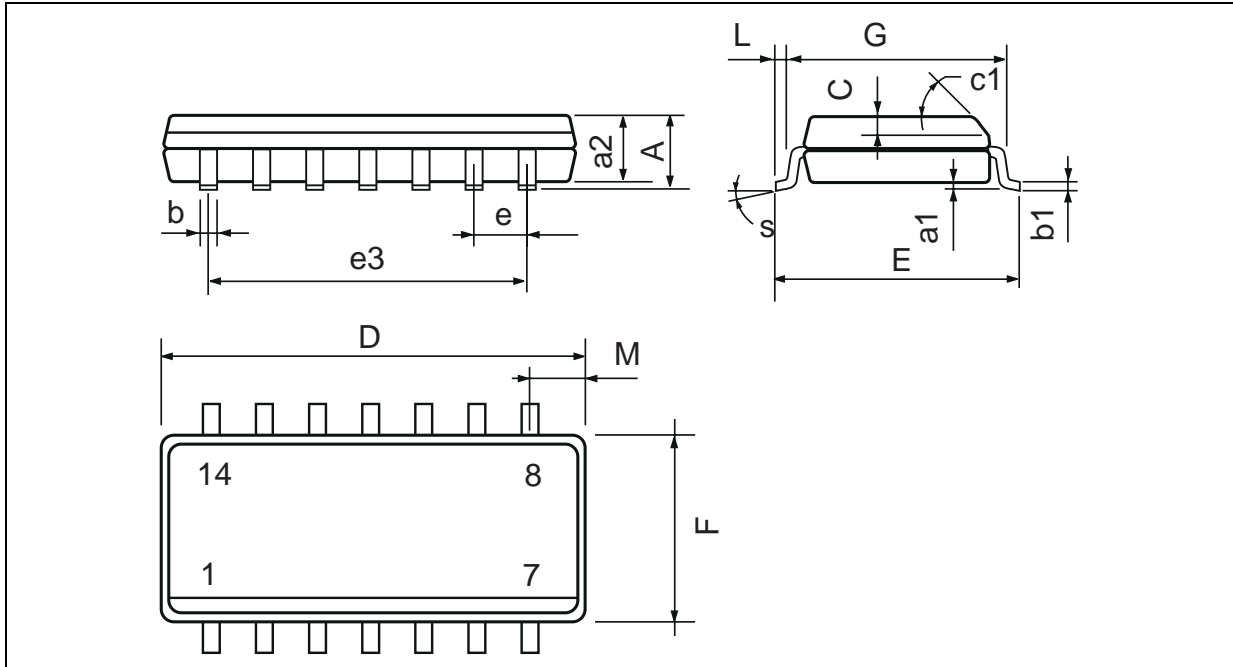
**PACKAGE MECHANICAL DATA**  
14 PINS - PLASTIC PACKAGE



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



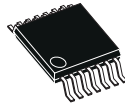
**PACKAGE MECHANICAL DATA**  
14 PINS - PLASTIC MICROPACKAGE (SO)



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.)					

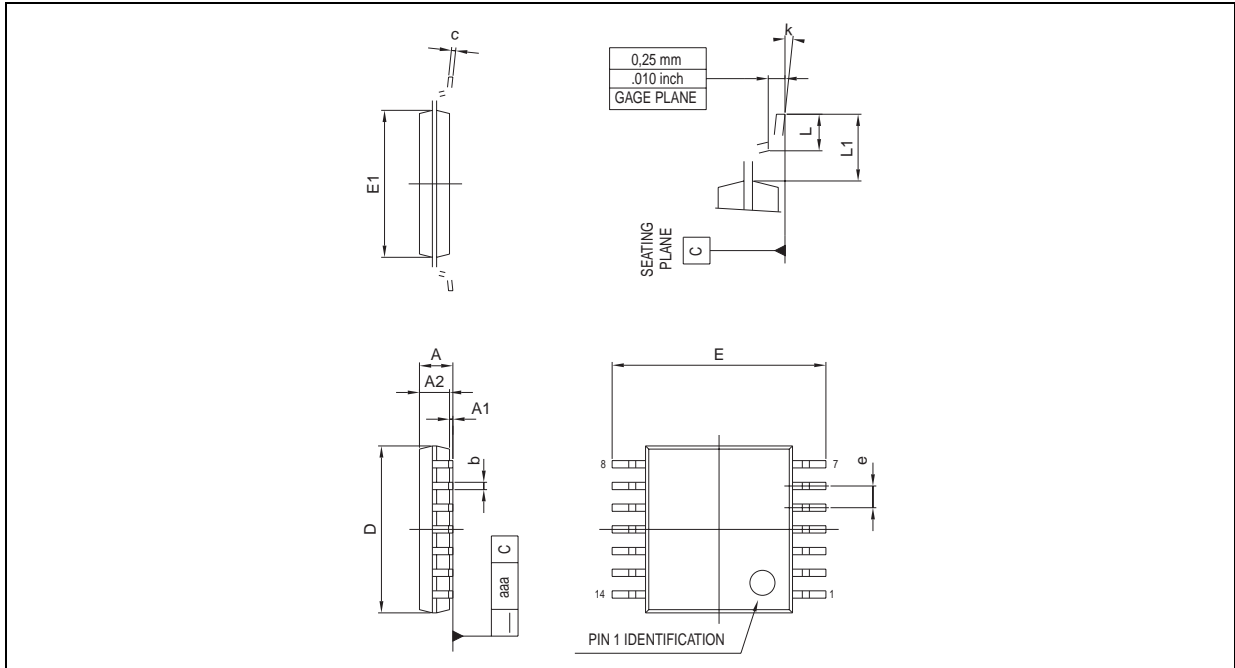
Note : (1) D and F do not include mold flash or protrusions - Mold flash or protrusions shall not exceed 0.15mm (.066 inc) ONLY FOR DATA BOOK.

TS974IPT



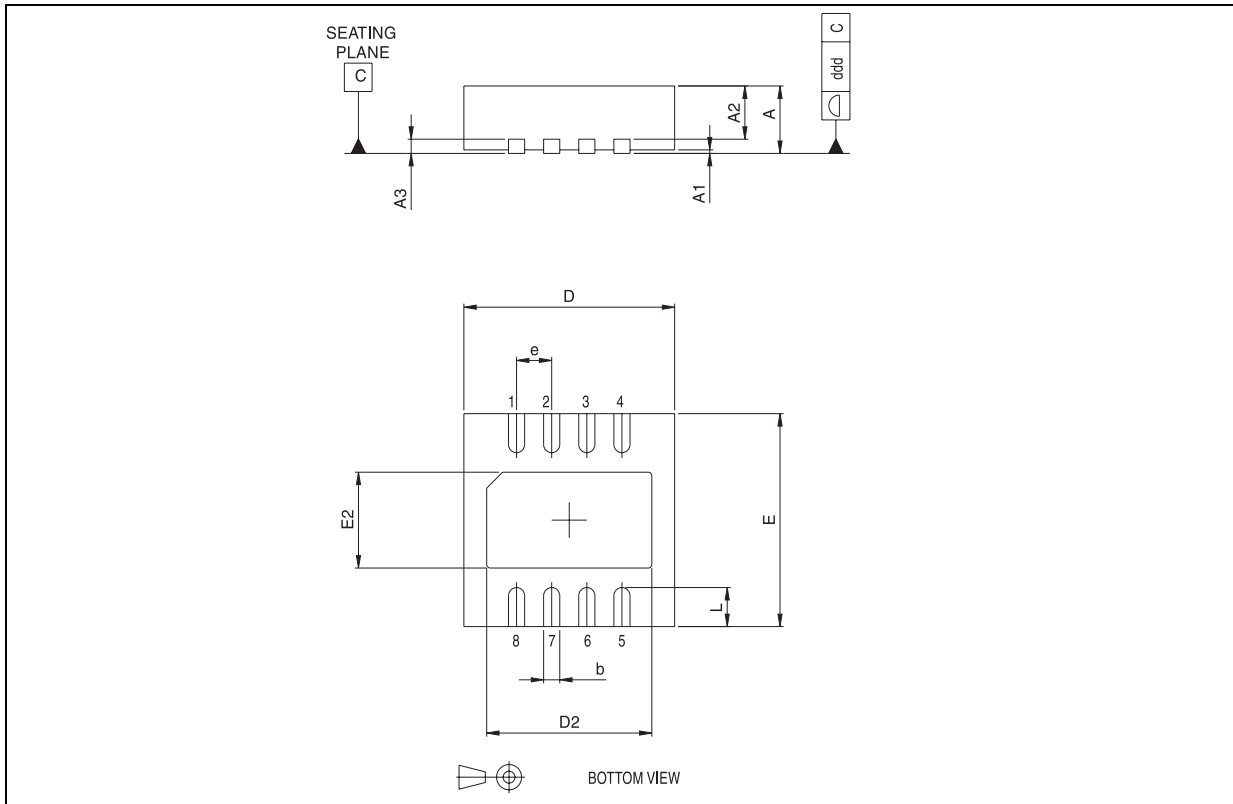
**PACKAGE MECHANICAL DATA**

14 PINS - THIN SHRINK SMALL OUTLINE PACKAGE (TSSOP)



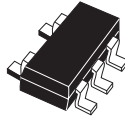
Dim.	Millimeters			Inches		
	Min.	Typ.	Max.	Min.	Typ.	Max.
A			1.20			0.05
A1	0.05		0.15	0.01		0.006
A2	0.80	1.00	1.05	0.031	0.039	0.041
b	0.19		0.30	0.007		0.15
c	0.09		0.20	0.003		0.012
D	4.90	5.00	5.10	0.192	0.196	0.20
E		6.40			0.252	
E1	4.30	4.40	4.50	0.169	0.173	0.177
e		0.65			0.025	
k	0°		8°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

**TS972IQ - PACKAGE MECHANICAL DATA**  
 8 CONNECTIONS - Dual Micro Leadframe Package (QFN)

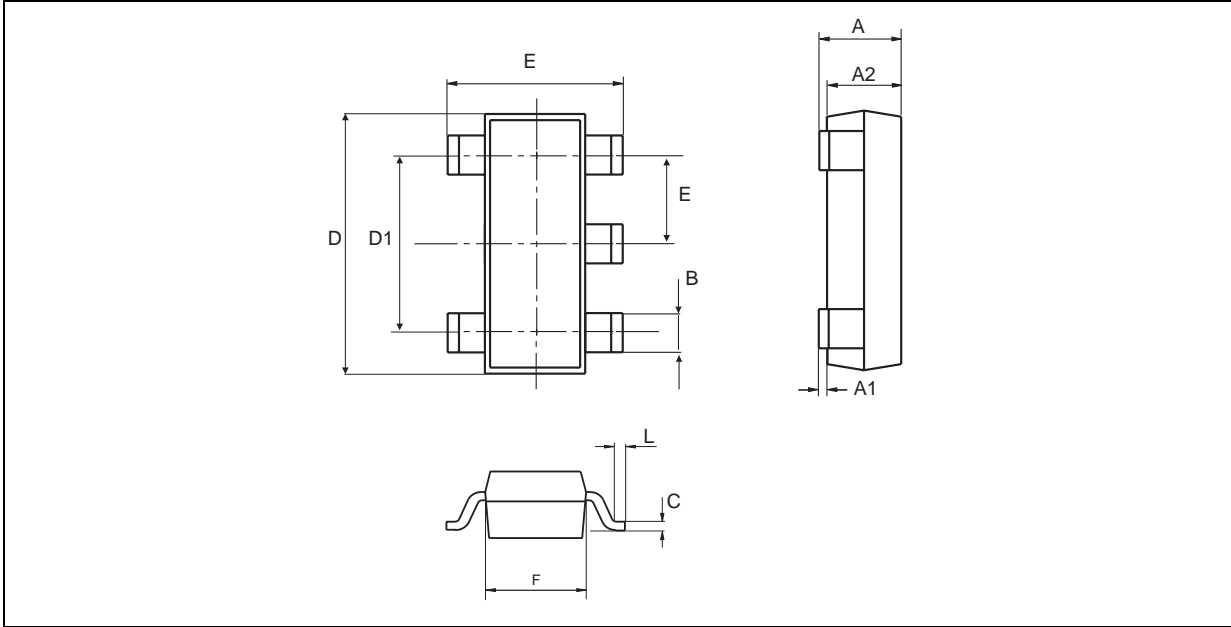


Dimensions	Millimeters		
	Min.	Typ.	Max.
A	0.80	0.90	1.00
A1		0.02	0.05
A2		0.70	
A3		0.20	
b	0.18	0.23	0.30
D		3.00	
D2	2.20	2.35	2.45
E		3.00	
E2	1.20	1.35	1.45
e		0.50	
L	0.45	0.55	0.65
ddd			0.08

TS971ILT



**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	0.118
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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