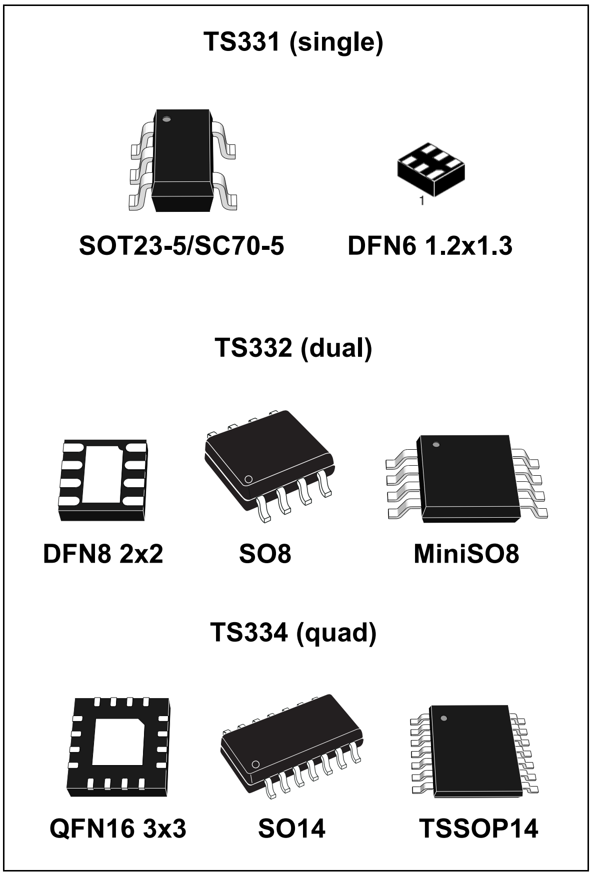
TS331, TS332, TS334

Micropower low-voltage, rail-to-rail comparators

Datasheet - production data



Features

- Supply operation from 1.6 V to 5 V
- Low current consumption: 20 µA
- Rail-to-rail inputs
- Wide temperature range: -40 °C to +125 °C
- Low output saturation voltage
- Low propagation delay: 210 ns
- Open-drain output
- ESD tolerance: 2 kV HBM/200 V MM
- SMD packages
- Automotive qualified

Applications

- Mobile phones
- Notebooks and PDAs
- Battery-supplied electronics
- General-purpose portable devices
- General-purpose low voltage applications

Description

The TS331, TS332 and TS334 are single, dual and quad micropower and low-voltage comparators. They can operate with a supply voltage ranging from 1.6 V to 5 V with a typical current consumption as low as 20 µA. In addition, rail-to-rail inputs make them a perfect choice for low-voltage applications.

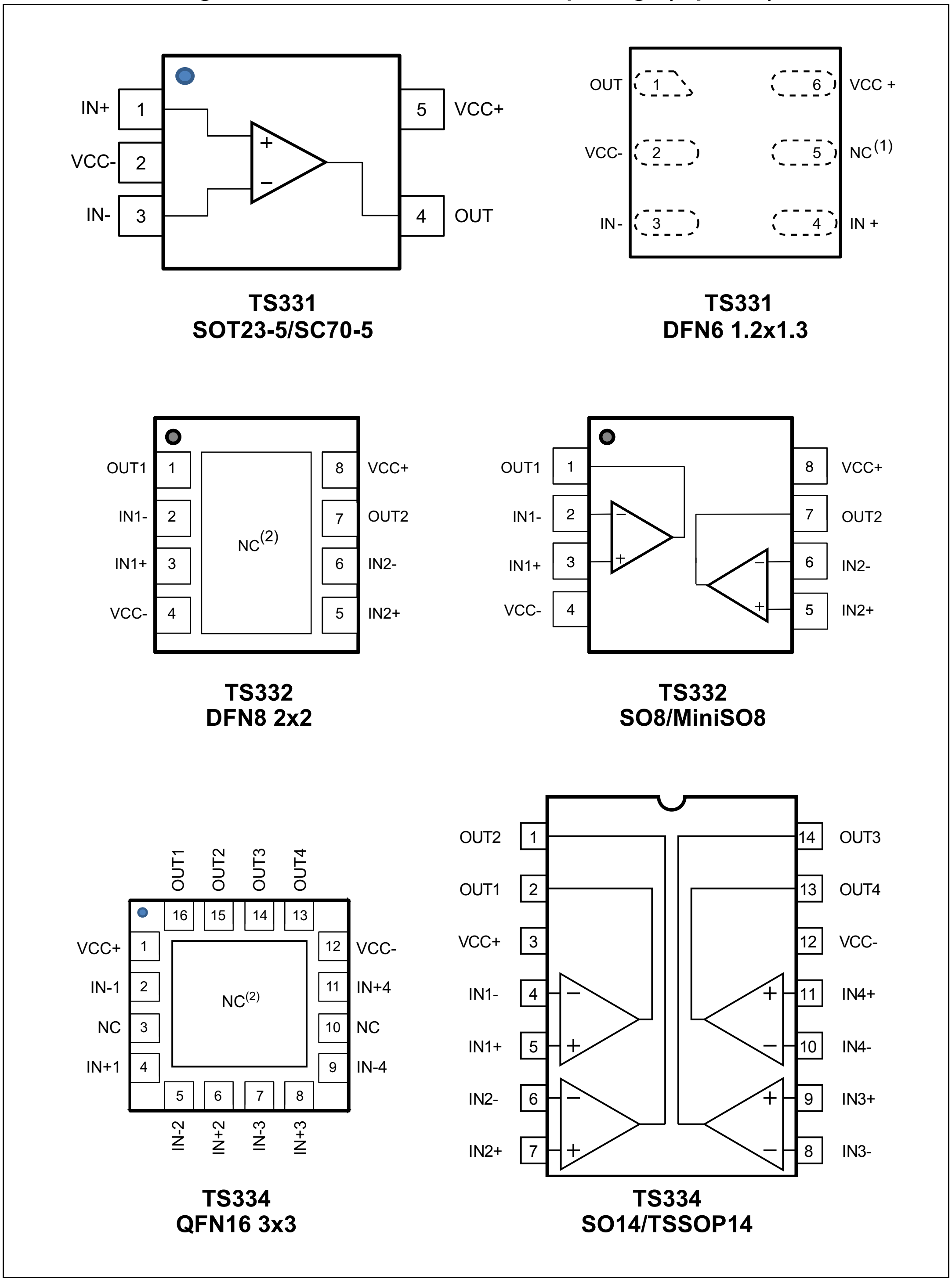
Their availability in tiny packages is a real advantage for overcoming space constraints.

The TS33x are specified for temperatures between -40 °C to +125 °C, making them ideal for a wide range of applications.

Contents

1 Package pin connections

Figure 1. Pin connections for each package (top view)



1. NC = not connected
2. The exposed pads of the DFN8 2x2 and the QFN16 3x3 can be connected to VCC- or left floating.

2 Absolute maximum ratings and operating conditions

Table 1. Absolute maximum ratings

Symbol	Parameter	Value	Unit
V_{CC}	Supply voltage(1)	5.5	V
V_{ID}	Differential input voltage	± 5.5	
V_{IN}	Input voltage range	$(V_{CC}-)$ - 0.3 to $(V_{CC}+)$ + 0.3	
V_{out}	Output voltage(1)	5.5	
R_{thja}	Thermal resistance junction to ambient(2) SOT23-5 SC70-5 DFN6 1.2x1.3 DFN8 2x2 SO8 MiniSO8 QFN16 3x3 SO14 TSSOP14	 250 205 40 57 125 190 39 105 100	°C/W
R_{thjc}	Thermal resistance junction to case (2) SOT23-5 SC70-5 SO8 MiniSO8 QFN16 3x3 SO14 TSSOP14	 81 172 40 39 5 31 32	
T_{stg}	Storage temperature	-65 to +150	°C
T_j	Junction temperature	150	
T_{LEAD}	Lead temperature (soldering 10 seconds)	260	
ESD	Human body model (HBM)(3)	2000	V
	Machine model (MM)(4)	200	
	Charged device model (CDM)(5)	1500	
	Latchup immunity	200	mA

1. All voltage values, except differential voltage, are referenced to V_{cc}-
2. Short-circuits can cause excessive heating. These values are typical
3. According to JEDEC standard JESD22-A114F.
4. According to JEDEC standard JESD22-A115A.
5. According to ANSI/ESD STM5.3.1.

Table 2. Operating conditions

Symbol	Parameter	Value	Unit
T_{oper}	Operating temperature range	-40 to +125	°C
V_{CC}	Supply voltage (V_{CC}+) - (V_{CC}-) -40°C < T_{amb} < +125°C	1.6 to 5.0	V
V_{ICM}	Common mode input voltage range T_{amb} = +25°C -40°C < T_{amb} < +125°C	(V_{CC}-) - 0.2 to (V_{CC}+) + 0.2 (V_{CC}-) to (V_{CC}+)	V

3 Electrical characteristics

Table 3. $V_{CC}+ = +1.8$ V, $V_{CC}- = 0$ V, $T_{amb} = +25$°C (unless otherwise specified)

Symbol	Parameter	Test conditions	Min.	Typ.	Max.	Unit
V_{IO}	Input offset voltage			0.5	5	mV
		-40 °C < T_{amb} < +125 °C			6	
$\Delta V_{io}/\Delta T$	Input offset voltage drift	-40 °C < T_{amb} < +125 °C		4.5		µV/°C
I_{IB}	Input bias current(1)			25	40	nA
		-40°C < T_{amb} < +125 °C			100	
I_{IO}	Input offset current(1)			1	10	
		-40°C < T_{amb} < +125 °C			100	
I_{CC}	Supply current	No load, output low, V_{ICM} = 0 V		20	26	µA
		-40 °C < T_{amb} < +125 °C			30	
		No load, output high, V_{ICM} = 0 V		22	29	
		-40 °C < T_{amb} < +125 °C			33	
I_{OH}	Output current leakage	$V_{OUT} = V_{CC}+$		1	10	nA
		-40 °C < T_{amb} < +125 °C			500	
V_{OL}	Output voltage low	I_{SINK} = 1 mA		24	30	mV
		-40 °C < T_{amb} < +125 °C			50	
I_{SINK}	Output sink current	V_{OUT} = 1.5 V	20	22		mA
		-40°C < T_{amb} < +125°C	15			
CMRR	Common mode rejection ratio	0 < V_{ICM} < 1.8 V	50	68		dB
TP_{HL}	Propagation delay(2) High to low output level	V_{ICM} = 0 V, R_L = 5.1 kΩ, C_L = 50 pF, overdrive = 10 mV		300		ns
		V_{ICM} = 0 V, R_L = 5.1 kΩ, C_L = 50 pF, overdrive = 100 mV		210	310	
TP_{LH}	Propagation delay(3) Low to high output level	V_{ICM} = 0 V, R_L = 5.1 kΩ, C_L = 50 pF, overdrive = 10 mV		540		
		V_{ICM} = 0 V, R_L = 5.1 kΩ, C_L = 50 pF, overdrive = 100 mV		420	620	

1. Maximum values include unavoidable inaccuracies of the industrial tests.
2. TP_{HL} is measured when the output signal crosses a voltage level at 50% of Vcc with the following conditions: inverting input voltage (IN-) = VICM and non-inverting input voltage (IN+) moving from VICM + 100 mV to VICM - overdrive.
3. TP_{LH} is measured when the output signal crosses a voltage level at 50% of Vcc with the following conditions: inverting input voltage (IN-) = VICM and non-inverting input voltage (IN+) moving from VICM - 100 mV to VICM + overdrive.

Table 4. $V_{CC}+ = +2.7$ V, $V_{CC}- = 0$ V, $T_{amb} = +25$°C (unless otherwise specified)

Symbol	Parameter	Test conditions	Min.	Typ.	Max.	Unit
V_{IO}	Input offset voltage			0.5	5	mV
		-40 °C < T_{amb} < +125 °C			6	
$\Delta V_{io}/\Delta T$	Input offset voltage drift	-40 °C < T_{amb} < +125 °C		3.3		µV/°C
I_{IB}	Input bias current(1)			25	40	nA
		-40 °C < T_{amb} < +125 °C			100	
I_{IO}	Input offset current(1)			1	10	
		-40 °C < T_{amb} < +125 °C			100	
I_{CC}	Supply current	No load, output low, V_{ICM} = 0 V		21	27	µA
		-40 °C < T_{amb} < +125 °C			31	
		No load, output high, V_{ICM} = 0 V		23	30	
		-40°C < T_{amb} < +125 °C			34	
I_{OH}	Output current leakage	$V_{OUT} = V_{CC}+$		1	10	nA
		-40 °C < T_{amb} < +125 °C			500	
V_{OL}	Output voltage low	I_{SINK} = 1 mA		17	30	mV
		-40 °C < T_{amb} < +125 °C			50	
I_{SINK}	Output sink current	V_{OUT} = 1.5 V	40	47		mA
		-40 °C < T_{amb} < +125 °C	30			
CMRR	Common mode rejection ratio	0 < V_{ICM} < 2.7 V	54	74		dB
		-40 °C < T_{amb} < +125 °C	53			
TP_{HL}	Propagation delay(2) High to low output level	V_{ICM} = 0 V, R_L = 5.1 kΩ, C_L = 50 pF, overdrive = 10 mV		320		ns
		V_{ICM} = 0 V, R_L = 5.1 kΩ, C_L = 50 pF, overdrive = 100 mV		220	320	
TP_{LH}	Propagation delay(3) Low to high output level	V_{ICM} = 0 V, R_L = 5.1 kΩ, C_L = 50 pF, overdrive = 10 mV		550		
		V_{ICM} = 0 V, R_L = 5.1 kΩ, C_L = 50 pF, overdrive = 100 mV		420	640	

1. Maximum values include unavoidable inaccuracies of the industrial tests.
2. TP_{HL} is measured when the output signal crosses a voltage level at 50% of Vcc with the following conditions: Inverting input voltage (IN-) = VICM and non-inverting input voltage (IN+) moving from VICM + 100 mV to VICM - overdrive.
3. TP_{LH} is measured when the output signal crosses a voltage level at 50% of Vcc with the following conditions: Inverting input voltage (IN-) = VICM and non-inverting input voltage (IN+) moving from VICM - 100 mV to VICM + overdrive.

Table 5. $V_{CC}+ = +5$ V, $V_{CC}- = 0$ V, $T_{amb} = +25°C$ (unless otherwise specified)

Symbol	Parameter	Test conditions	Min.	Typ.	Max.	Unit
V_{IO}	Input offset voltage			0.5	5	mV
		-40 °C < T_{amb} < +125 °C			6	
$\Delta V_{io}/\Delta T$	Input offset voltage drift	-40 °C < T_{amb} < +125 °C		1.3		µV/°C
I_{IB}	Input bias current[1]			30	40	nA
		-40 °C < T_{amb} < +125 °C			100	
I_{IO}	Input offset current[1]			1	10	
		-40 °C < T_{amb} < +125 °C			100	
I_{CC}	Supply current	No load, output low, V_{ICM} = 0 V		23	30	µA
		-40 °C < T_{amb} < +125 °C			34	
		No load, output high, V_{ICM} = 0 V		26	34	
		-40 °C < T_{amb} < +125 °C			38	
I_{OH}	Output current leakage	$V_{OUT} = V_{CC}+$		1	10	nA
		-40 °C < T_{amb} < +125 °C			600	
V_{OL}	Output voltage low	I_{SINK} = 4 mA		48	60	mV
		-40 °C < T_{amb} < +125 °C			80	
I_{SINK}	Output sink current	V_{OUT} = 1.5 V	82	93		mA
		-40 °C < T_{amb} < +125 °C	60			
A_V	Voltage gain		40	100		V/mV
CMRR	Common mode rejection ratio	0 < V_{ICM} < 5 V	60	79		dB
		-40 °C < T_{amb} < +125 °C	58			
SVR	Supply voltage rejection	ΔV_{CC} = 1.8 to 5 V	56	75		
		-40 °C < T_{amb} < +125 °C	56			
TP_{HL}	Propagation delay[2] High to low output level	V_{ICM} = 0 V, R_L = 5.1 kΩ, C_L = 50 pF, overdrive = 10 mV		380		ns
		V_{ICM} = 0 V, R_L = 5.1 kΩ, C_L = 50 pF, overdrive = 100 mV		270	430	
TP_{LH}	Propagation delay[3] Low to high output level	V_{ICM} = 0 V, R_L = 5.1 kΩ, C_L = 50 pF, overdrive = 10 mV		570		
		V_{ICM} = 0 V, R_L = 5.1 kΩ, C_L = 50 pF, overdrive = 100 mV		450	720	

1. Maximum values include unavoidable inaccuracies of the industrial tests.
2. TP_{HL} is measured when the output signal crosses a voltage level at 50% of Vcc with the following conditions: Inverting input voltage (IN-) = VICM and non-inverting input voltage (IN+) moving from VICM + 100 mV to VICM - overdrive.
3. TP_{LH} is measured when the output signal crosses a voltage level at 50% of Vcc with the following conditions: Inverting input voltage (IN-) = VICM and non-inverting input voltage (IN+) moving from VICM - 100 mV to VICM + overdrive.

Figure 2. Supply current versus supply voltage with output high, V_{ICM} = 0 V

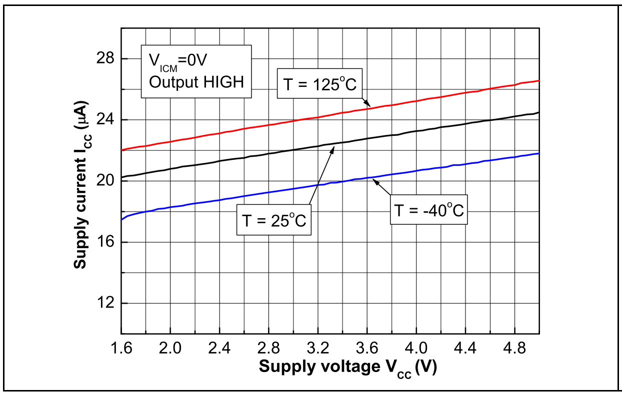


Figure 3. Supply current versus supply voltage with output high, V_{ICM} = V_{CC}

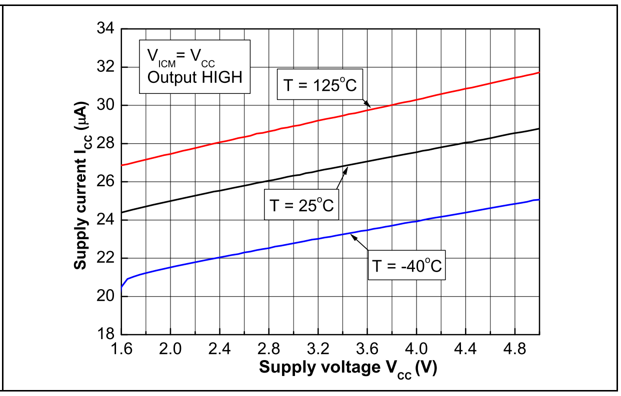


Figure 4. Supply current versus supply voltage with output low, V_{ICM} = 0 V

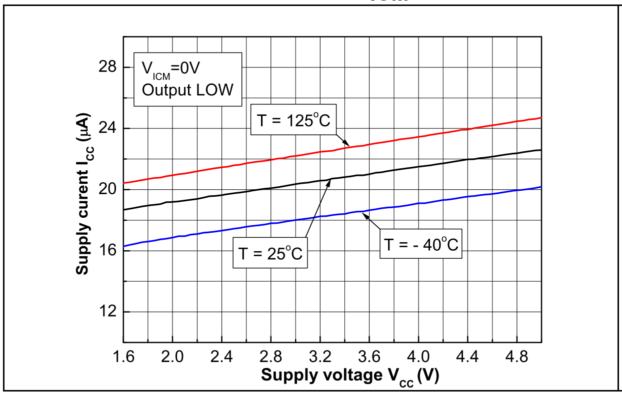


Figure 5. Supply current versus supply voltage with output low, V_{ICM} = V_{CC}

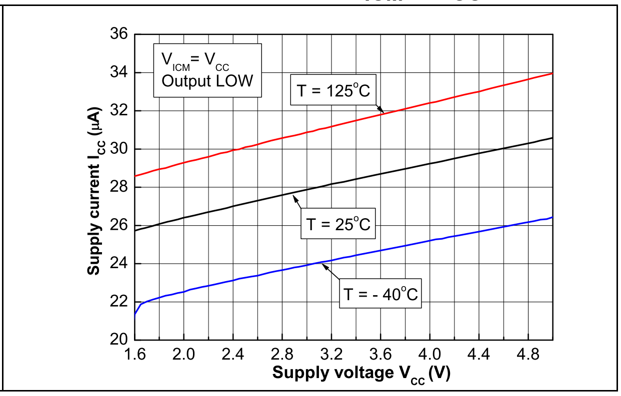


Figure 6. Supply current versus temperature

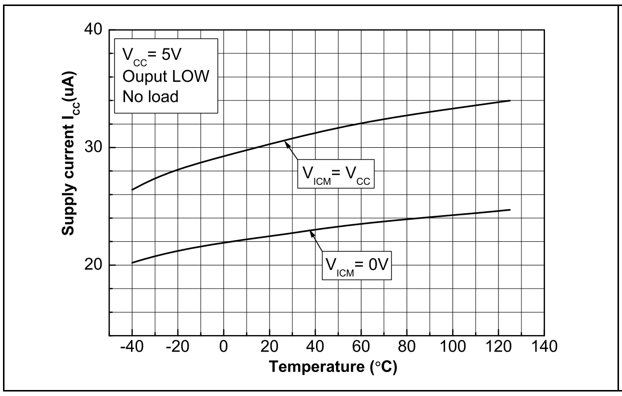


Figure 7. Input bias current versus input common-mode voltage

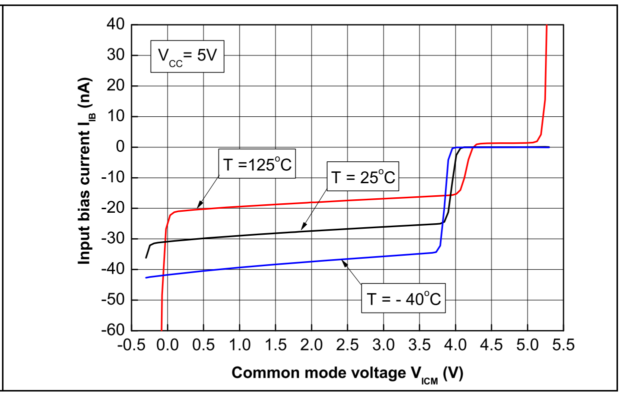


Figure 8. Input current versus differential input voltage

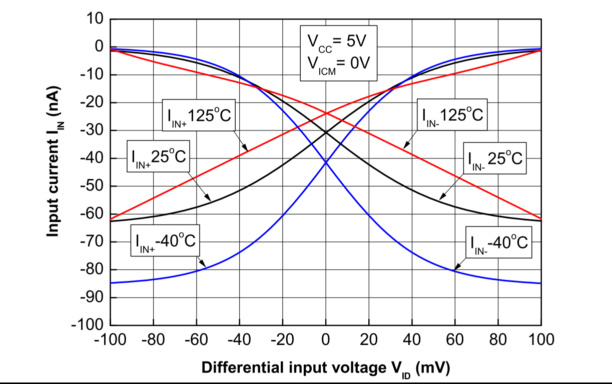


Figure 9. Input offset voltage versus temperature

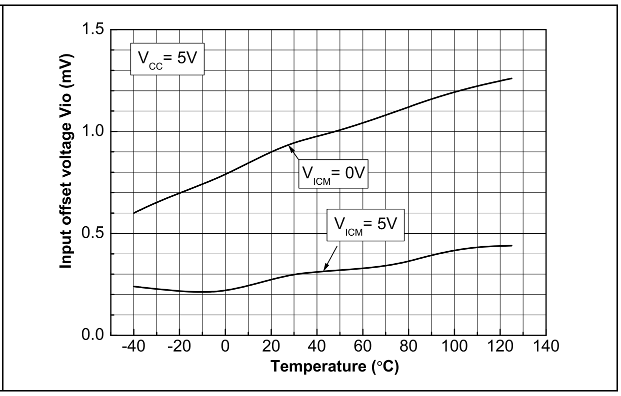


Figure 10. Output voltage versus output sink current, V_{CC} = 1.8 V

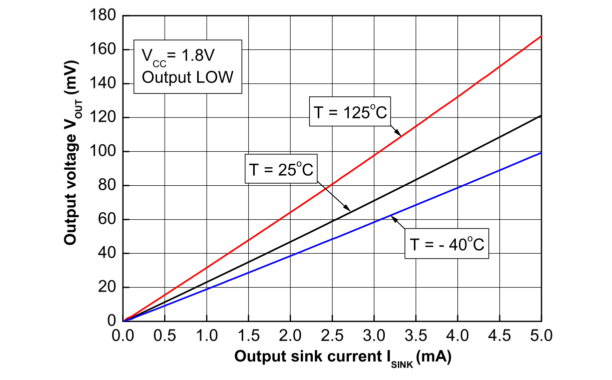


Figure 11. Output voltage versus output sink current, V_{CC} = 2.7 V

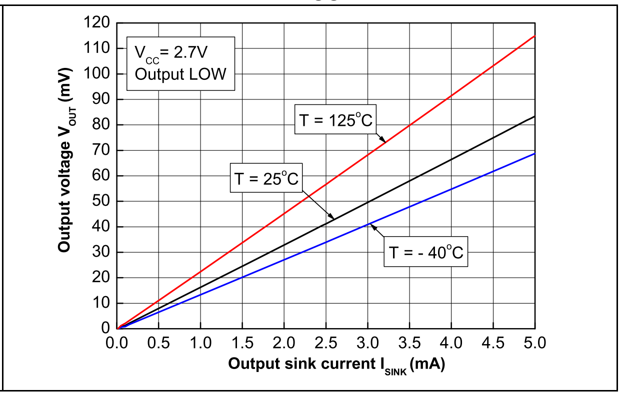


Figure 12. Output voltage versus output sink current, V_{CC} = 5 V

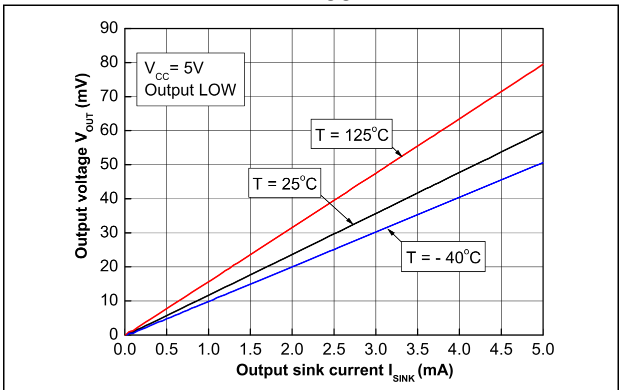


Figure 13. Output sink current versus output voltage

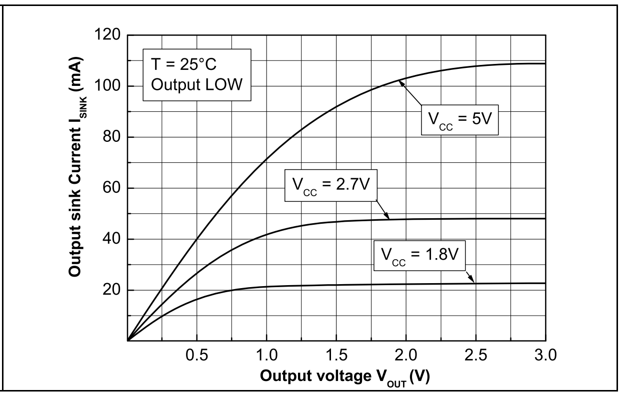


Figure 14. Output voltage versus temperature

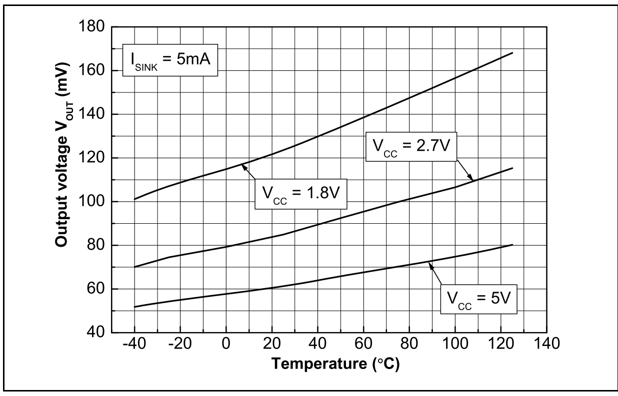


Figure 15. Propagation delay versus overdrive with negative transition, V_{CC} = 1.8 V

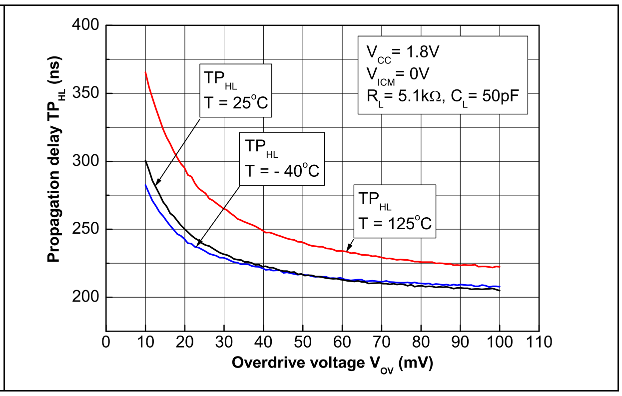


Figure 16. Propagation delay versus overdrive with positive transition, V_{CC} = 1.8 V

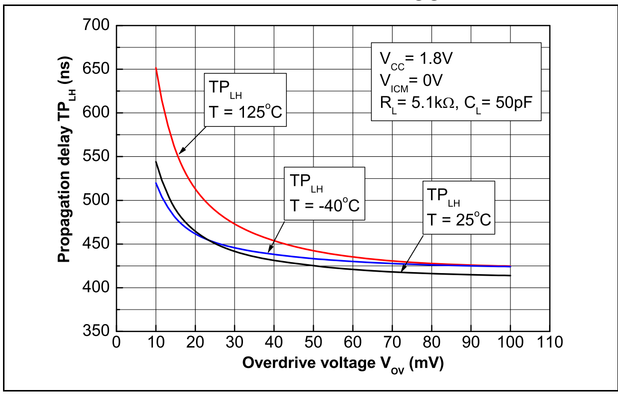


Figure 17. Propagation delay versus common mode voltage, V_{CC} = 1.8 V

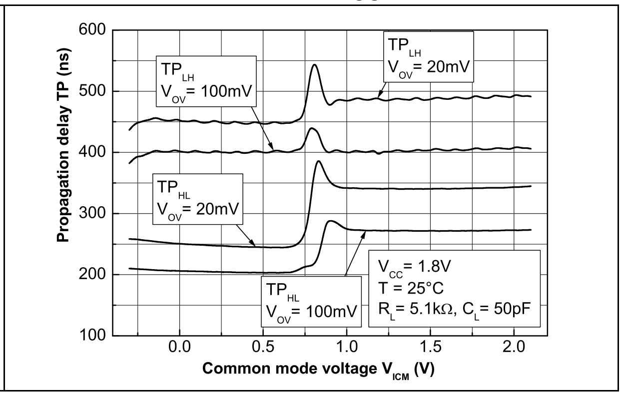


Figure 18. Propagation delay versus overdrive with negative transition, V_{CC} = 2.7 V

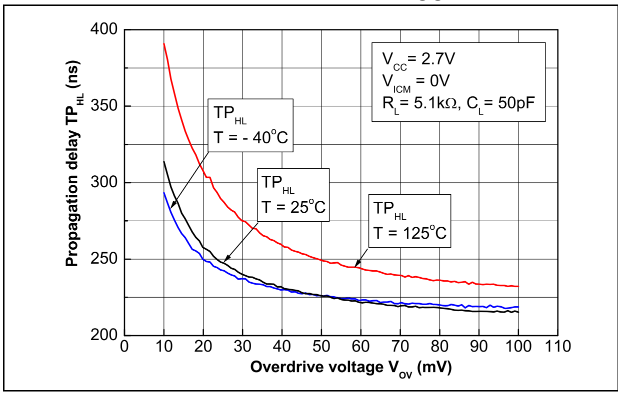


Figure 19. Propagation delay versus overdrive with positive transition, V_{CC} = 2.7 V

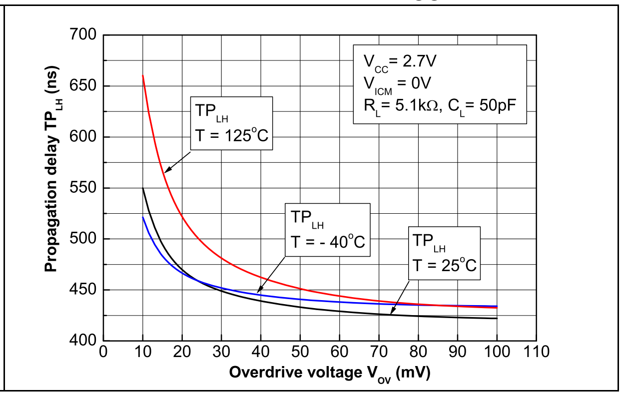


Figure 20. Propagation delay versus common mode voltage, V_{CC} = 2.7 V

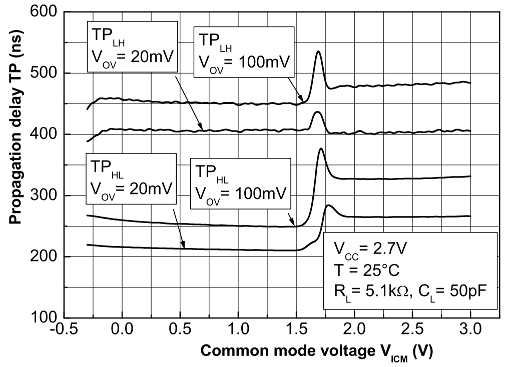


Figure 21. Propagation delay versus overdrive with negative transition, V_{CC} = 5 V

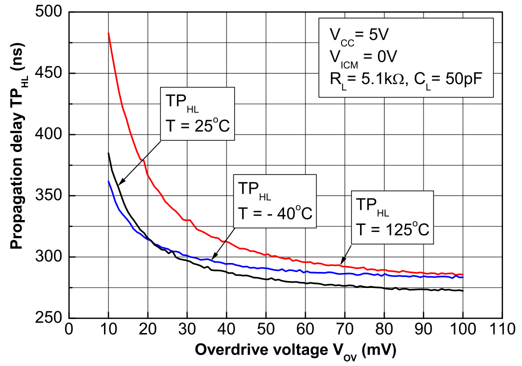


Figure 22. Propagation delay versus overdrive with positive transition, V_{CC} = 5 V

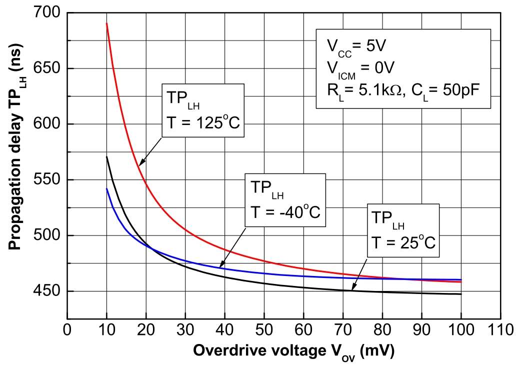


Figure 23. Propagation delay versus common mode voltage, V_{CC} = 5 V

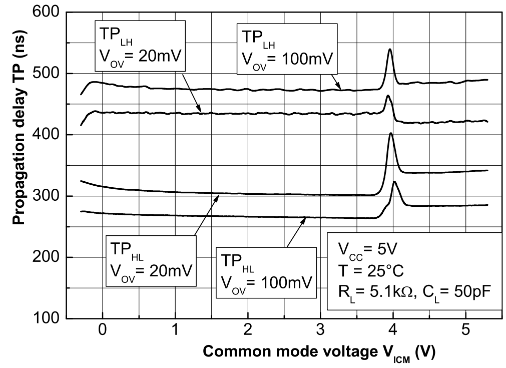


Figure 24. Propagation delay versus time with negative transition

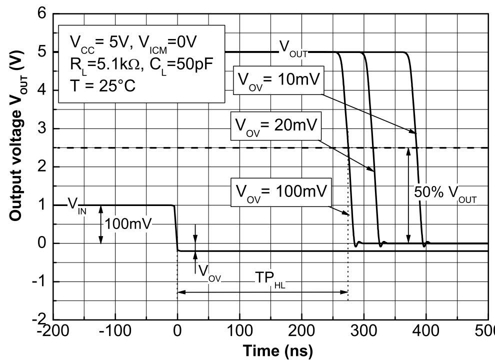
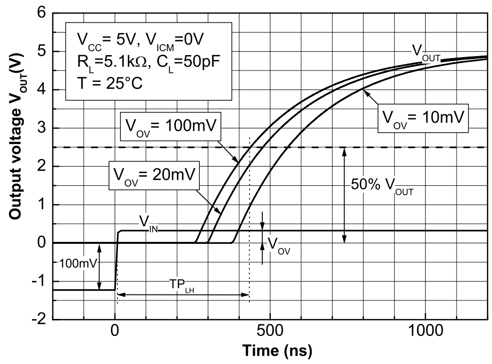


Figure 25. Propagation delay versus time with positive transition



4 Package information

In order to meet environmental requirements, ST offers these devices in different grades of ECOPACK® packages, depending on their level of environmental compliance. ECOPACK® specifications, grade definitions and product status are available at: *www.st.com*. ECOPACK® is an ST trademark.

4.1 SOT23-5 package information

Figure 26. SOT23-5 package mechanical drawing

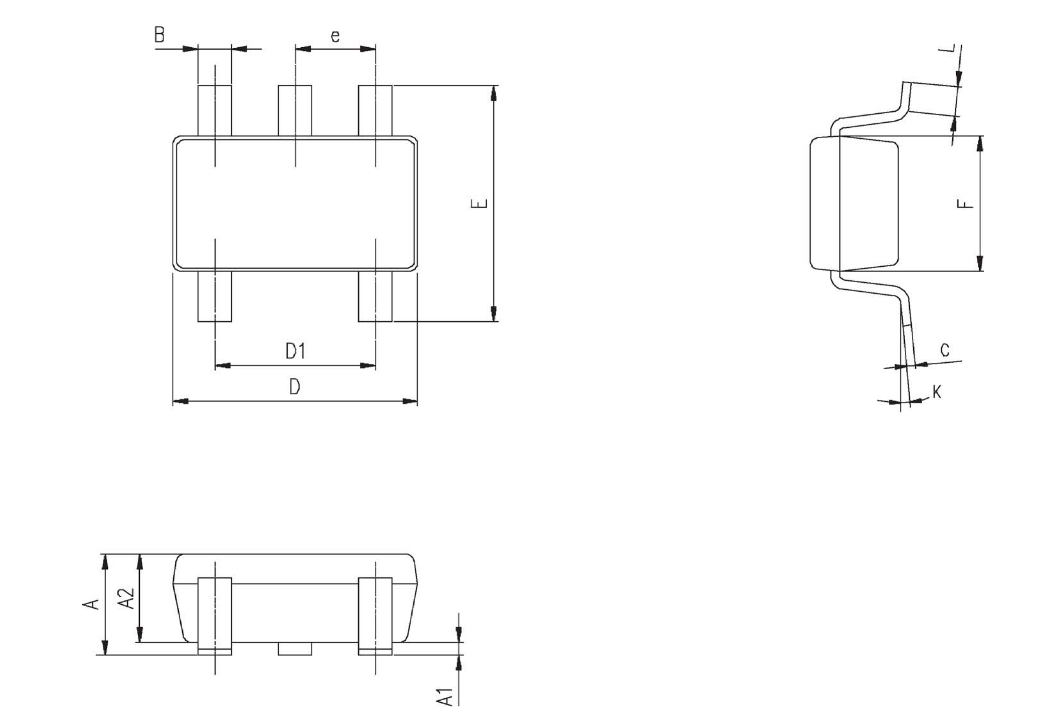


Table 6. SOT23-5 package mechanical data

Ref.	Dimensions					
	Millimeters			Inches(1)		
	Min.	Typ.	Max.	Min.	Typ.	Max.
A	0.90	1.20	1.45	0.035	0.047	0.057
A1			0.15			0.006
A2	0.90	1.05	1.30	0.035	0.041	0.051
B	0.35	0.40	0.50	0.013	0.015	0.019
C	0.09	0.15	0.20	0.003	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	0.35	0.60	0.004	0.013	0.023
K	0°		10°	0°		10°

1. Values in inches are rounded to three decimal digits.

4.2 SC70-5 (SOT323-5) package information

Figure 27. SC70-5 (SOT323-5) package mechanical drawing

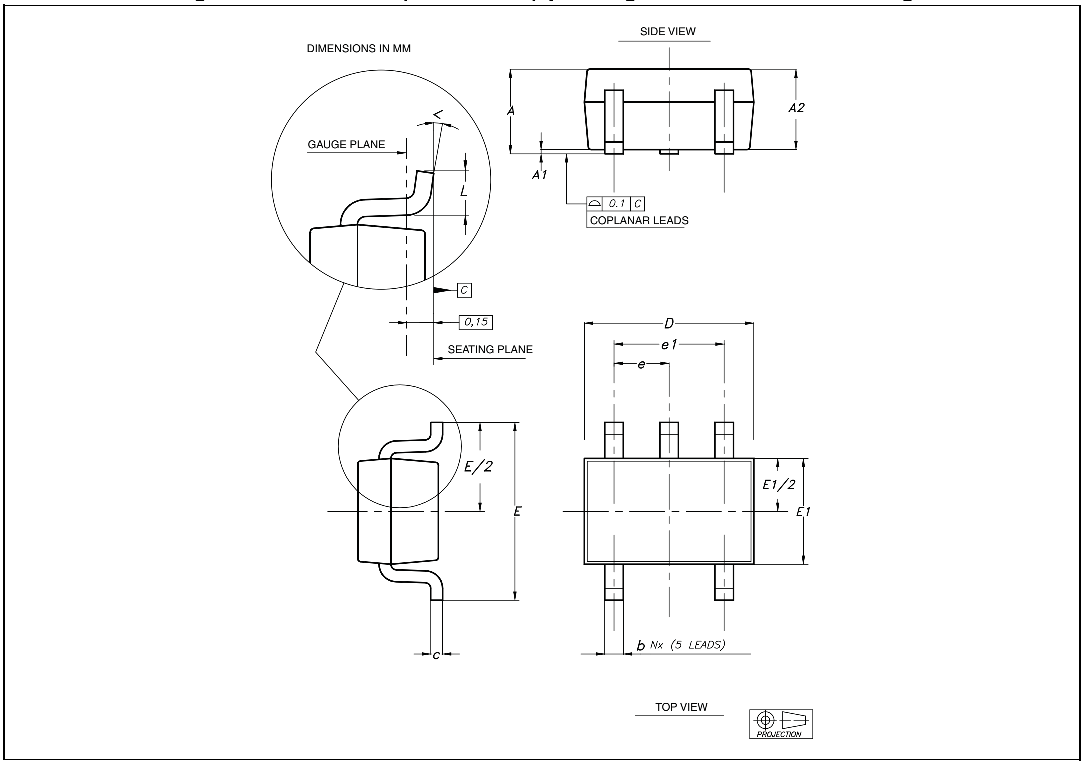


Table 7. SC70-5 (or SOT323-5) package mechanical data

Ref	Dimensions					
	Millimeters			Inches(1)		
	Min	Typ	Max	Min	Typ	Max
A	0.80		1.10	0.315		0.043
A1			0.10			0.004
A2	0.80	0.90	1.00	0.315	0.035	0.039
b	0.15		0.30	0.006		0.012
c	0.10		0.22	0.004		0.009
D	1.80	2.00	2.20	0.071	0.079	0.087
E	1.80	2.10	2.40	0.071	0.083	0.094
E1	1.15	1.25	1.35	0.045	0.049	0.053
e		0.65			0.025	
e1		1.30			0.051	
L	0.26	0.36	0.46	0.010	0.014	0.018
<	0°		8°	0°		8°

1. Values in inches are rounded to three decimal digits.

4.3 DFN6 1.2x1.3 package information

Figure 28. DFN6 1.2x1.3 package mechanical drawing

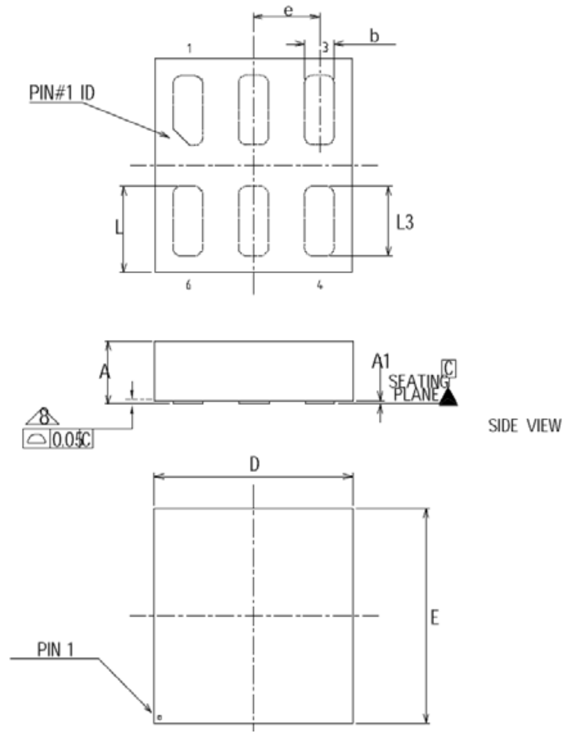


Table 8. DFN6 1.2x1.3 package mechanical data

Ref	Dimensions					
	Millimeters			Inches(1)		
	Min	Typ	Max	Min	Typ	Max
A	0.45	0.50	0.55	0.018	0.020	0.022
A1	0.00	0.02	0.05	0.000	0.001	0.002
b	0.15	0.18	0.25	0.006	0.007	0.002
c		0.05			0.002	
D		1.20			0.047	
E		1.30			0.051	
e		0.4			0.016	
L	0.475	0.525	0.575	0.019	0.021	0.023
L3	0.375	0.425	0.475	0.015	0.017	0.019

1. Values in inches are rounded to three decimal digits.

4.4 DFN8 2x2 package information

Figure 29. DFN8 2x2 package mechanical drawing

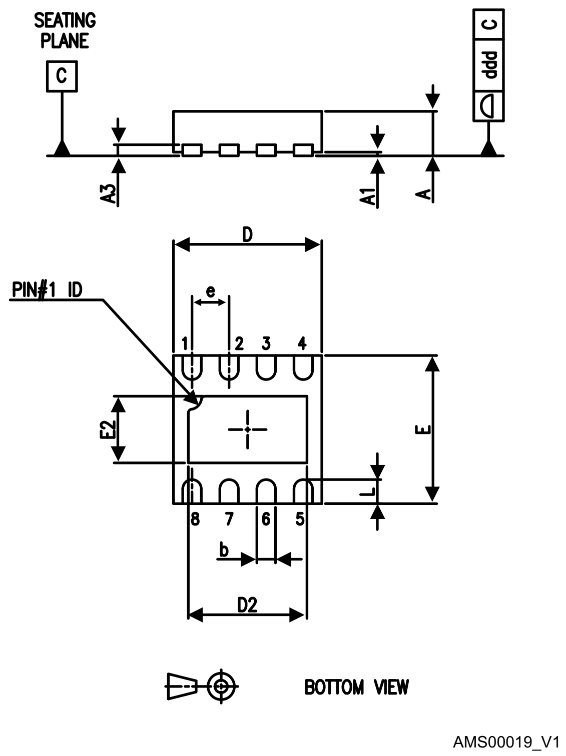
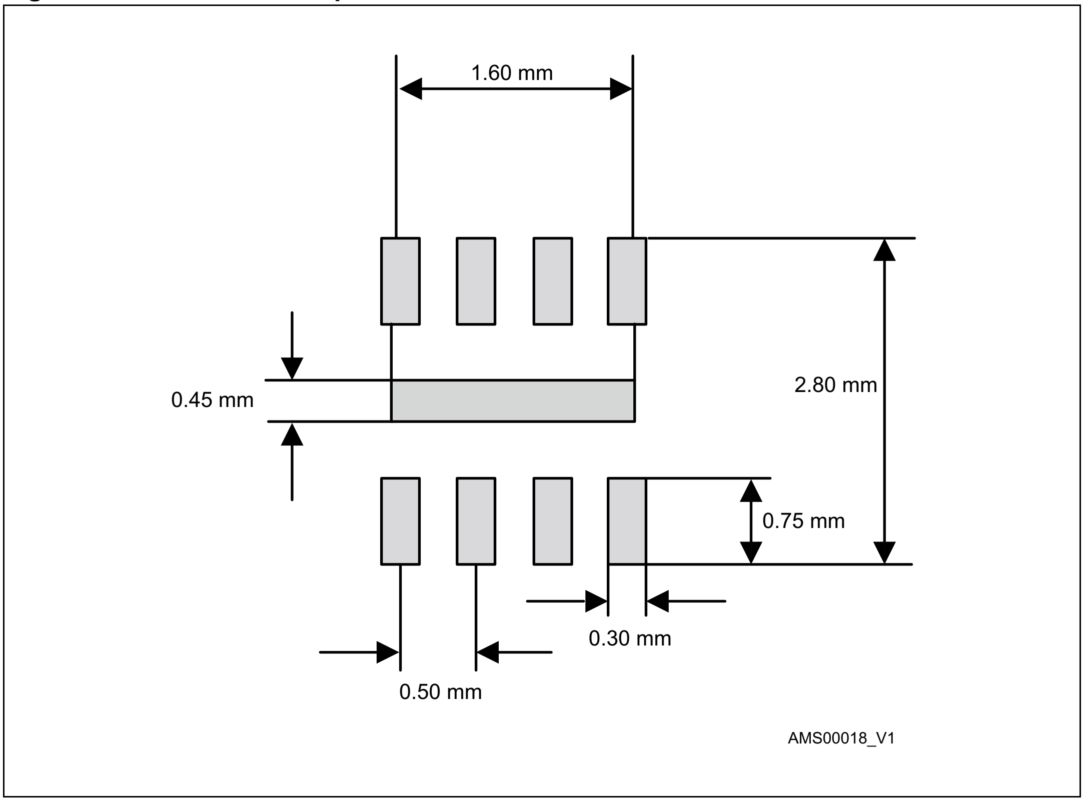


Table 9. DFN8 2x2x0.6 mm package mechanical data (pitch 0.5 mm)

Ref.	Dimensions					
	Millimeters			Inches		
	Min.	Typ.	Max.	Min.	Typ.	Max.
A	0.51	0.55	0.60	0.020	0.022	0.024
A1			0.05			0.002
A3		0.15			0.006	
b	0.18	0.25	0.30	0.007	0.010	0.012
D	1.85	2.00	2.15	0.073	0.079	0.085
D2	1.45	1.60	1.70	0.057	0.063	0.067
E	1.85	2.00	2.15	0.073	0.079	0.085
E2	0.75	0.90	1.00	0.030	0.035	0.039
e		0.50			0.020	
L			0.425			0.017
ddd			0.08			0.003

Figure 30. DFN8 2x2 footprint recommendation



4.5 SO8 package information

Figure 31. SO8 package mechanical drawing

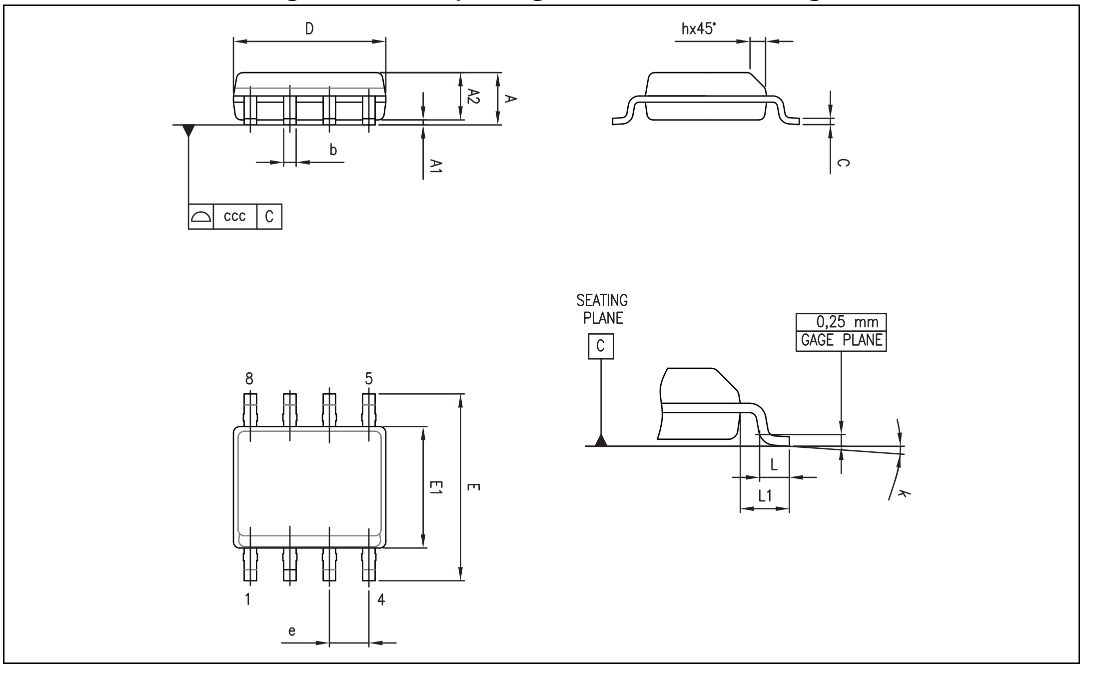


Table 10. SO8 package mechanical data

Ref.	Dimensions					
	Millimeters			Inches(1)		
	Min.	Typ.	Max.	Min.	Typ.	Max.
A			1.75			0.069
A1	0.10		0.25	0.004		0.010
A2	1.25			0.049		
b	0.28		0.48	0.011		0.019
c	0.17		0.23	0.007		0.010
D	4.80	4.90	5.00	0.189	0.193	0.197
E	5.80	6.00	6.20	0.228	0.236	0.244
E1	3.80	3.90	4.00	0.150	0.154	0.157
e		1.27			0.050	
h	0.25		0.50	0.010		0.020
L	0.40		1.27	0.016		0.050
L1		1.04			0.040	
k	0		8°	1°		8°
ccc			0.10			0.004

1. Values in inches are rounded to three decimal digits.

4.6 MiniSO8 package information

Figure 32. MiniSO8 package mechanical drawing

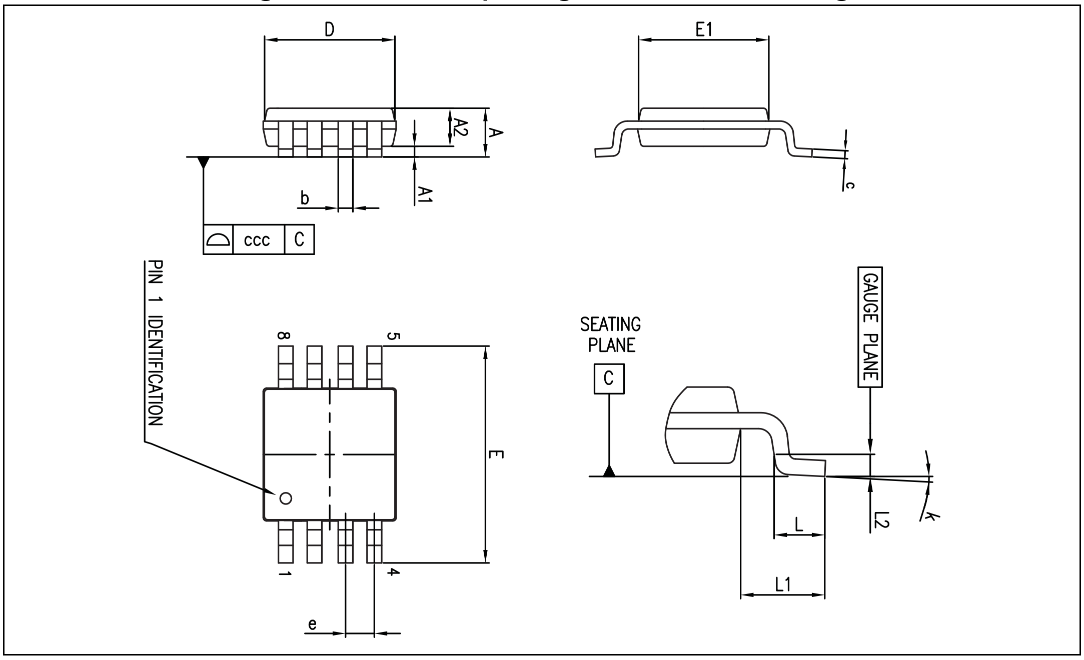


Table 11. MiniSO8 package mechanical data

Ref.	Dimensions					
	Millimeters			Inches(1)		
	Min.	Typ.	Max.	Min.	Typ.	Max.
A			1.1			0.043
A1	0		0.15	0		0.006
A2	0.75	0.85	0.95	0.030	0.033	0.037
b	0.22		0.40	0.009		0.016
c	0.08		0.23	0.003		0.009
D	2.80	3.00	3.20	0.11	0.118	0.126
E	4.65	4.90	5.15	0.183	0.193	0.203
E1	2.80	3.00	3.10	0.11	0.118	0.122
e		0.65			0.026	
L	0.40	0.60	0.80	0.016	0.024	0.031
L1		0.95			0.037	
L2		0.25			0.010	
k	0°		8°	0°		8°
ccc			0.10			0.004

1. Values in inches are rounded to three decimal digits.

4.7 QFN16 3x3 package information

Figure 33. QFN16 3 x 3 mm package mechanical drawing

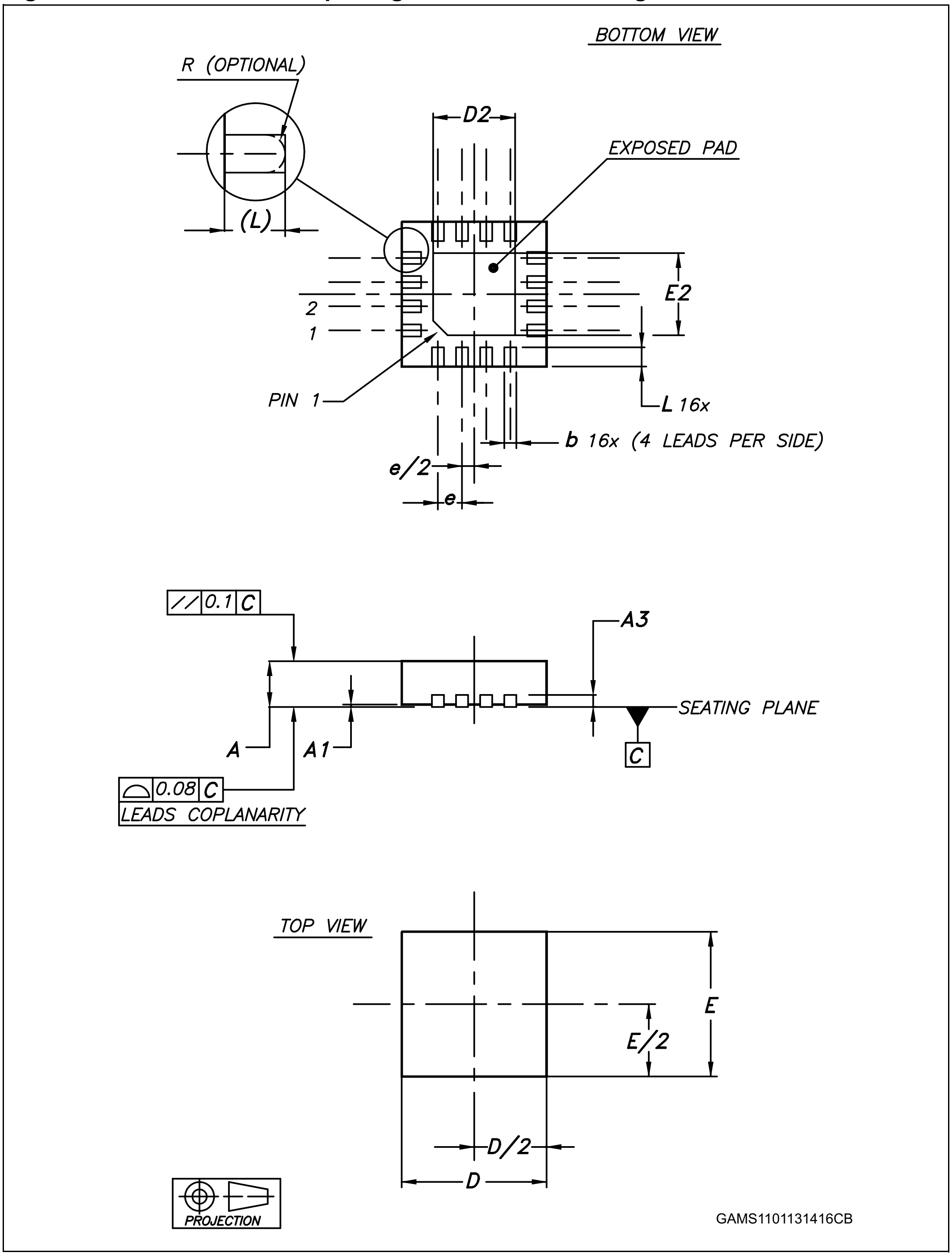
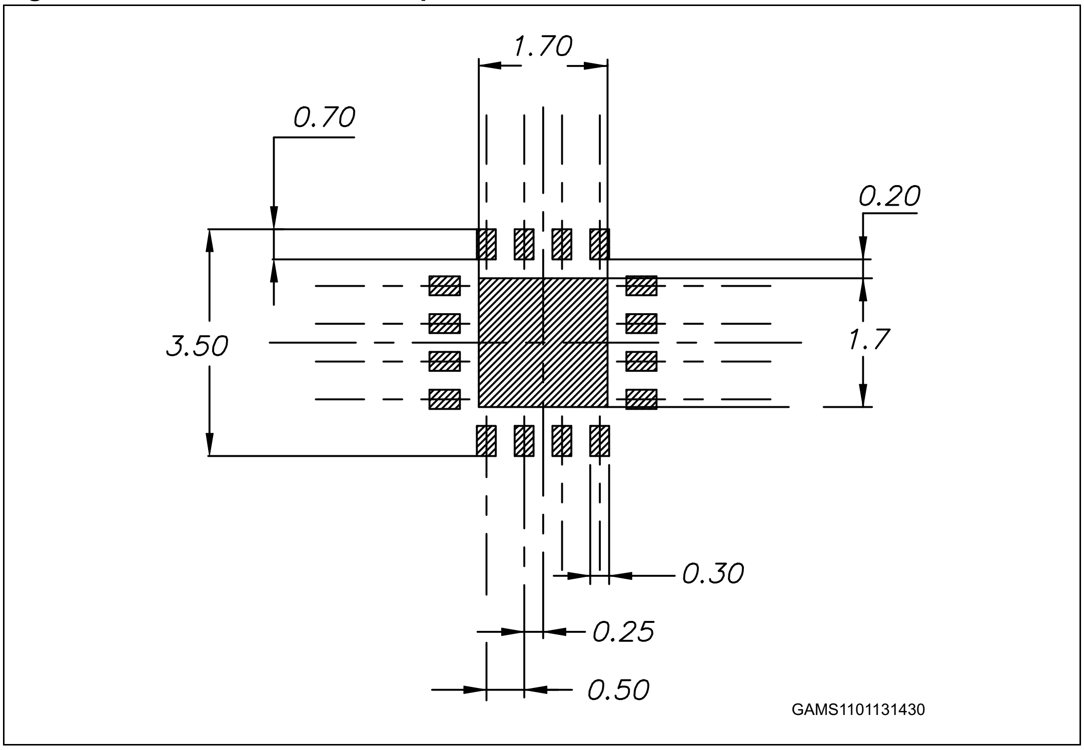


Table 12. QFN16 3 x 3 mm package mechanical data (pitch 0.5 mm)

Ref.	Dimensions					
	Millimeters			Inches		
	Min.	Typ.	Max.	Min.	Typ.	Max.
A	0.80	0.90	1.00	0.031	0.035	0.039
A1	0		0.05	0		0.002
A3		0.20			0.008	
b	0.18		0.30	0.007		0.012
D	2.90	3.00	3.10	0.114	0.118	0.122
D2	1.50		1.80	0.059		0.071
E	2.90	3.00	3.10	0.114	0.118	0.122
E2	1.50		1.80	0.059		0.071
e		0.50			0.020	
L	0.30		0.50	0.012		0.020

Figure 34. QFN16 3 x 3 mm footprint recommendation



4.8 SO14 package information

Figure 35. SO14 package mechanical drawing

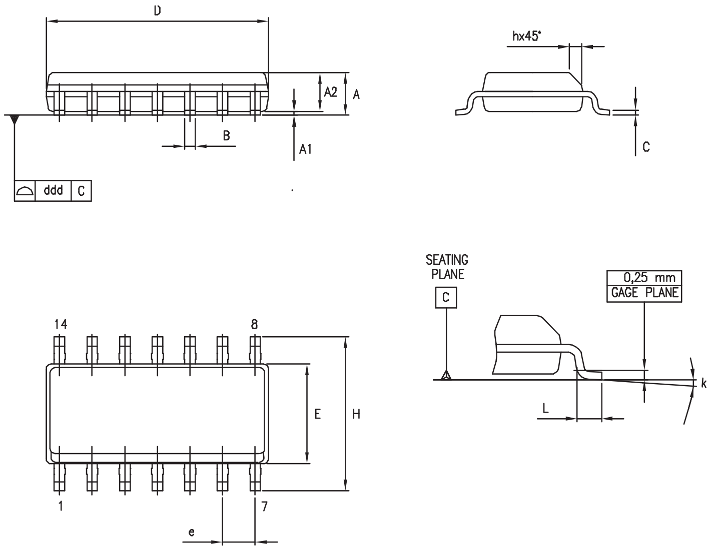


Table 13. SO14 package mechanical data

Dimensions						
Ref.	Millimeters			Inches(1)		
	Min.	Typ.	Max.	Min.	Typ.	Max.
A	1.35		1.75	0.050		0.068
A1	0.10		0.25	0.004		0.009
A2	1.10		1.65	0.040		0.060
B	0.33		0.51	0.010		0.020
C	0.19		0.25	0.007		0.009
D	8.55		8.75	0.330		0.340
E	3.80		4.0	0.150		0.150
e		1.27			0.05	
H	5.80		6.20	0.220		0.240
h	0.25		0.50	0.009		0.020
L	0.40		1.27	0.015		0.050
k	8° (max.)					
ddd			0.10			0.004

1. Values in inches are rounded to three decimal digits.

4.9 TSSOP14 package information

Figure 36. TSSOP14 package mechanical drawing

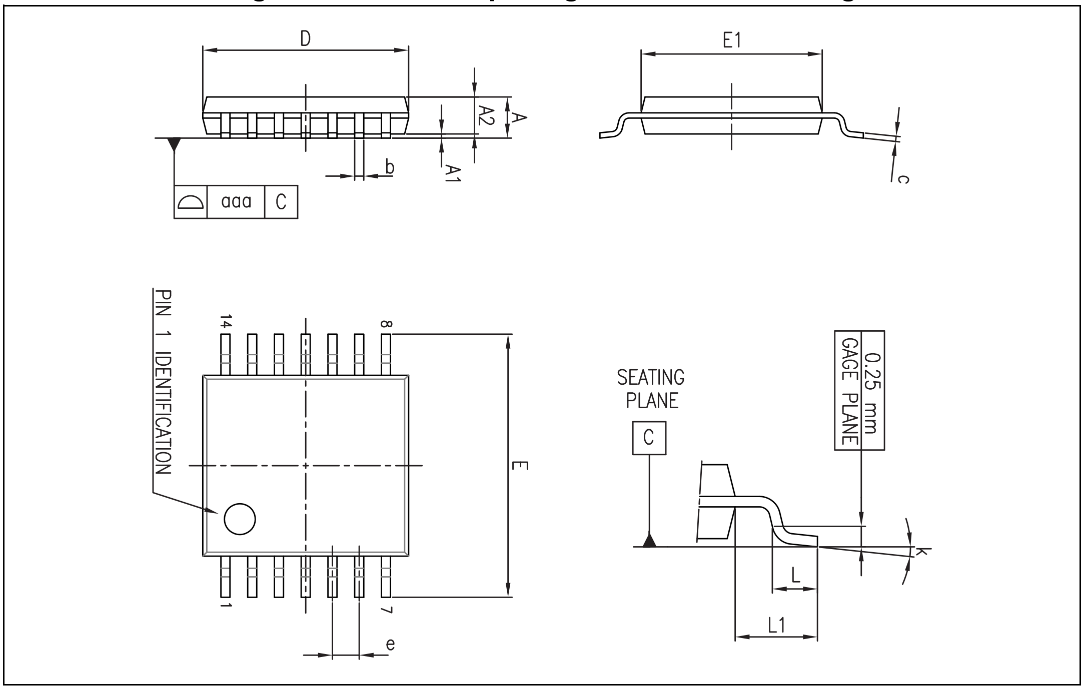


Table 14. TSSOP14 package mechanical data

Ref.	Dimensions					
	Millimeters			Inches[1]		
	Min.	Typ.	Max.	Min.	Typ.	Max.
A			1.20			0.047
A1	0.05		0.15	0.002	0.004	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		0.0089
D	4.90	5.00	5.10	0.193	0.197	0.201
E	6.20	6.40	6.60	0.244	0.252	0.260
E1	4.30	4.40	4.50	0.169	0.173	0.176
e		0.65			0.0256	
L	0.45	0.60	0.75	0.018	0.024	0.030
L1		1.00			0.039	
k	0°		8°	0°		8°
aaa			0.10			0.004

1. Values in inches are rounded to three decimal digits.

5 Ordering information

Table 15. Order codes

Order code	Temperature range	Package	Packaging	Marking
TS331ILT	-40 °C, +125 °C	SOT23-5	Tape and reel	K506
TS331IYLT(1)				K513
TS331ICT		SC70-5		K55
TS331IQT		DFN6 1.2x1.3		K3
TS332IQ2T		DFN8 2x2		K55
TS332IDT		SO8		332I
TS332IYDT(1)				332IY
TS332IST		MiniSO8		K507
TS334IQ4T		QFN16 3x3		K307
TS334IDT		SO14		334I
TS334IYDT(1)				334IY
TS334IPT		TSSOP14		334I
TS334IYPT(1)				334IY

1. Qualified and characterized according to AEC Q100 and Q003 or equivalent, advanced screening according to AEC Q001 and Q 002 or equivalent.

6 Revision history

Table 16. Document revision history

Date	Revision	Changes
29-Mar-2010	1	Initial release.
01-Dec-2011	2	– Added TS332 and TS334 devices. – Added V_{out} parameter in *Table 1: Absolute maximum ratings*. – Removed note "*The magnitude of input and output voltages must never exceed the supply rail ±0.3 V.*" from *Table 1*. – Removed note "*All values over the temperature range are guaranteed through correlation and simulation. No production tests have been performed at the temperature range limits*." from *Table 3*, *Table 4* and *Table 5*. – Removed "*Vicm = 0 V*" from *Test conditions* column in *Table 3*, *Table 4* and *Table 5*. – Modified minimal Isink value in *Table 5*.
29-Oct-2012	3	– Added DFN6 package for TS331 – Modified notes *3*, *4*, and *5* in *Table 1* – Added Automotive grade order codes in *Table 15*
30-Apr-2013	4	– Added DFN8 2x2 and QFN16 3x3 silhouette, pinout, and package information. – *Figure 1*: updated pinout diagrams; added footnote *2.* – *Table 1*: updated R_{thjc} and R_{thjc} – *Table 3*, *Table 4*, *Table 5*: updated symbol for input offset voltage drift. – *Table 15*: added order codes TS332IQ2T, TS334IQ4T, and TS334IYDT.