

Rail-to-rail input/output 20 MHz GBP operational amplifiers

Features

- Low input offset voltage: 1.5 mV max
- Rail-to-rail input and output
- Wide bandwidth 20 MHz, stable for gain ≥ 3
- Low power consumption: 1.1 mA maximum
- High output current: 35 mA
- Operating from 2.5 V to 5.5 V
- Low input bias current, 1 pA typ
- ESD internal protection ≥ 5 kV
- Latch-up immunity

Applications

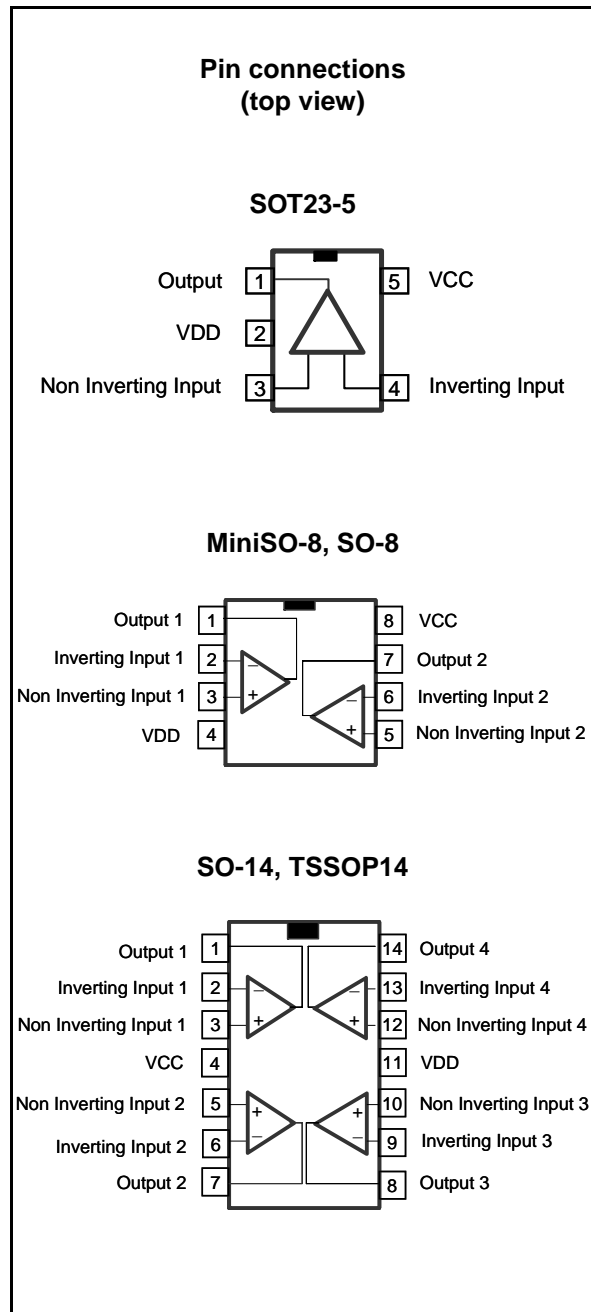
- Battery-powered applications
- Portable devices
- Signal conditioning
- Active filtering
- Medical instrumentation
- Automotive

Description

The TSV991/2/4 family of single, dual and quad operational amplifiers offers low voltage operation and rail-to-rail input and output.

This family features an excellent speed/power consumption ratio, offering a 20 MHz gain-bandwidth, stable for gain above 3 (100 pF capacitive load), while consuming only 1.1 mA max at 5 V supply voltage. It also features an ultra-low input bias current.

These characteristics make the TSV991/2/4 family ideal for sensor interfaces, battery-supplied and portable applications, as well as active filtering.



1 Absolute maximum ratings and operating conditions

Table 1. Absolute maximum ratings (AMR)

Symbol	Parameter	Value	Unit	
V_{CC}	Supply voltage ⁽¹⁾	6	V	
V_{id}	Differential input voltage ⁽²⁾	$\pm V_{CC}$	V	
V_{in}	Input voltage ⁽³⁾	$V_{DD}-0.2$ to $V_{CC}+0.2$	V	
T_{stg}	Storage temperature	-65 to +150	°C	
R_{thja}	Thermal resistance junction to ambient ^{(4) (5)}		°C/W	
	SOT23-5	250		
	SO-8	125		
	MiniSO-8	190		
	SO-14	103		
R_{thjc}	Thermal resistance junction to case		°C/W	
	SOT23-5	81		
	SO-8	40		
	MiniSO-8	39		
	SO-14	31		
T _j	Maximum junction temperature	150	°C	
ESD	HBM: human body model ⁽⁶⁾	5	kV	
	MM: machine model ⁽⁷⁾	400	V	
	CDM: charged device model ⁽⁸⁾	SOT23-5, SO-8, MiniSO-8	1500	V
		TSSOP14	750	
SO-14		500		
	Latch-up immunity	200	mA	

1. Value with respect to V_{DD} pin.
2. Differential voltages are the non-inverting input terminal with respect to the inverting input terminal.
3. $V_{CC}-V_{in}$ must not exceed 6V.
4. Short-circuits can cause excessive heating and destructive dissipation.
5. R_{th} are typical values.
6. Human body model: 100pF discharged through a 1.5kΩ resistor between two pins of the device, done for all couples of pin combinations with other pins floating.
7. Machine model: 200pF is charged to the specified voltage, then discharged directly between two pins of the device with no external series resistor (internal resistor < 5Ω), done for all couples of pin combinations with other pins floating.
8. Charged device model: all pins plus package are charged together to the specified voltage and then discharged directly to the ground.

Table 2. Operating conditions

Symbol	Parameter	Value	Unit
V_{CC}	Supply voltage	2.5 to 5.5	V
V_{icm}	Common mode input voltage range	$V_{DD} - 0.1$ to $V_{CC} + 0.1$	V
T_{oper}	Operating free air temperature range	-40 to +125	°C

2 Electrical characteristics

Table 3. Electrical characteristics at $V_{CC} = +2.5V$, $V_{DD} = 0V$, $V_{icm} = V_{CC}/2$, with R_L connected to $V_{CC}/2$, full temperature range (unless otherwise specified)⁽¹⁾

Symbol	Parameter	Conditions	Min.	Typ.	Max.	Unit
DC performance						
V_{io}	Offset voltage TSV99x	$T = 25^\circ C$ $T_{min} < T_{op} < T_{max}$	-	0.1	4.5	mV
	TSV99xA	$T = 25^\circ C$ $T_{min} < T_{op} < T_{max}$	-	-	7.5	
DV_{io}	Input offset voltage drift		-	2	-	$\mu V/^\circ C$
I_{io}	Input offset current ⁽²⁾ ($V_{out} = V_{CC}/2$)	$T = 25^\circ C$ $T_{min} < T_{op} < T_{max}$	-	1	10	pA
I_{ib}	Input bias current ⁽²⁾ ($V_{out} = V_{CC}/2$)	$T = 25^\circ C$ $T_{min} < T_{op} < T_{max}$	-	1	10	pA
CMR	Common mode rejection ratio $20 \log (\Delta V_{ic}/\Delta V_{io})$	0V to 2.5V, $V_{out} = 1.25V$	58	75	-	dB
A_{vd}	Large signal voltage gain	$R_L = 10k\Omega$, $V_{out} = 0.5V$ to $2V$, $T = 25^\circ C$ $T_{min} < T_{op} < T_{max}$	80	89	-	dB
$V_{CC}-V_{OH}$	High level output voltage	$R_L = 10k\Omega$ $R_L = 600\Omega$		15	40	mV
V_{OL}	Low level output voltage	$R_L = 10k\Omega$ $R_L = 600\Omega$	-	15	40	mV
I_{out}	I_{sink}	$V_o = 2.5V$, $T = 25^\circ C$ $T_{min} < T_{amb} < T_{max}$	18	32	-	mA
	I_{source}	$V_o = 0V$, $T = 25^\circ C$ $T_{min} < T_{amb} < T_{max}$	18	35	-	
I_{CC}	Supply current (per operator)	No load, $V_{out} = V_{CC}/2$	-	0.78	1.1	mA
AC performance						
GBP	Gain bandwidth product	$R_L = 2k\Omega$, $C_L = 100pF$, $f = 100kHz$, $T = 25^\circ C$	-	20	-	MHz
ϕ_m	Phase margin	$R_L = 2k\Omega$, $C_L = 100pF$, $G = 5$, $f = 100kHz$, $T = 25^\circ C$	-	60	-	Degrees
G_m	Gain margin	$R_L = 2k\Omega$, $C_L = 100pF$, $\phi_m = 40^\circ$, $T = 25^\circ C$	-	2.5	-	dB
SR	Slew rate	$R_L = 2k\Omega$, $C_L = 100pF$, $T = 25^\circ C$	-	10	-	V/ μs
e_n	Equivalent input noise voltage	$f = 10kHz$, $T = 25^\circ C$	-	21	-	$\frac{nV}{\sqrt{Hz}}$
THD+ e_n	Total harmonic distortion	$G = 1$, $f = 1kHz$, $R_L = 2k\Omega$, $Bw = 22kHz$, $V_{icm} = (V_{CC} + 1)/2$, $V_{out} = 1.1V_{pp}$, $T = 25^\circ C$	-	0.0017	-	%

1. All parameter limits at temperatures other than $25^\circ C$ are guaranteed by correlation.

2. Guaranteed by design.

Table 4. Electrical characteristics at $V_{CC} = +3.3V$, $V_{DD} = 0V$, $V_{icm} = V_{CC}/2$, with R_L connected to $V_{CC}/2$, full temperature range (unless otherwise specified)⁽¹⁾

Symbol	Parameter	Conditions	Min.	Typ.	Max.	Unit
DC performance						
V_{io}	Offset voltage TSV99x	$T = 25^{\circ}C$ $T_{min} < T_{op} < T_{max}$	-	0.1	4.5	mV
	TSV99xA	$T = 25^{\circ}C$ $T_{min} < T_{op} < T_{max}$	-	-	7.5	
DV_{io}	Input offset voltage drift		-	2	-	$\mu V/^{\circ}C$
I_{io}	Input offset current ⁽²⁾ ($V_{out} = V_{CC}/2$)	$T = 25^{\circ}C$ $T_{min} < T_{op} < T_{max}$	-	1	10	pA
I_{ib}	Input bias current ⁽²⁾ ($V_{out} = V_{CC}/2$)	$T = 25^{\circ}C$ $T_{min} < T_{op} < T_{max}$	-	-	100	pA
CMR	Common mode rejection ratio $20 \log (\Delta V_{ic}/\Delta V_{io})$	$0V$ to $3.3V$, $V_{out} = 1.65V$	60	78	-	dB
A_{vd}	Large signal voltage gain	$R_L = 10k\Omega$, $V_{out} = 0.5V$ to $2.8V$, $T = 25^{\circ}C$ $T_{min} < T_{op} < T_{max}$	80	90	-	dB
$V_{CC}-V_{OH}$	High level output voltage	$R_L = 10k\Omega$ $R_L = 600\Omega$		15	40	mV
V_{OL}	Low level output voltage	$R_L = 10k\Omega$ $R_L = 600\Omega$	-	15	40	mV
I_{out}	I_{sink}	$V_o = 3.3V$, $T = 25^{\circ}C$ $T_{min} < T_{amb} < T_{max}$	18	32	-	mA
	I_{source}	$V_o = 0V$, $T = 25^{\circ}C$ $T_{min} < T_{amb} < T_{max}$	16	-	-	
I_{CC}	Supply current (per operator)	No load, $V_{out} = V_{CC}/2$	-	0.8	1.1	mA
AC performance						
GBP	Gain bandwidth product	$R_L = 2k\Omega$, $C_L = 100pF$, $f = 100kHz$, $T = 25^{\circ}C$	-	20	-	MHz
ϕ_m	Phase margin	$R_L = 2k\Omega$, $C_L = 100pF$, $G = 5$, $T = 25^{\circ}C$	-	60	-	Degrees
G_m	Gain margin	$R_L = 2k\Omega$, $C_L = 100pF$, $f = 100kHz$, $\phi_m = 40^{\circ}$, $T = 25^{\circ}C$	-	2.5	-	dB
SR	Slew rate	$R_L = 2k\Omega$, $C_L = 100pF$, $f = 100kHz$, $T = 25^{\circ}C$	-	10	-	$V/\mu s$
e_n	Equivalent input noise voltage	$f = 10kHz$, $T = 25^{\circ}C$	-	21	-	$\frac{nV}{\sqrt{Hz}}$
THD+ e_n	Total harmonic distortion	$G = 1$, $f = 1kHz$, $R_L = 2k\Omega$, $Bw = 22kHz$, $V_{icm} = (V_{CC} + 1)/2$, $V_{out} = 1.9V_{pp}$, $T = 25^{\circ}C$	-	0.001	-	%

1. All parameter limits at temperatures other than $25^{\circ}C$ are guaranteed by correlation.
2. Guaranteed by design.

Table 5. Electrical characteristics at $V_{CC} = +5V$, $V_{DD} = 0V$, $V_{icm} = V_{CC}/2$, R_L connected to $V_{CC}/2$, full temperature range (unless otherwise specified)⁽¹⁾

Symbol	Parameter	Conditions	Min.	Typ.	Max.	Unit
DC performance						
V_{io}	Offset voltage TSV99x	$T = 25^\circ C$ $T_{min} < T_{op} < T_{max}$	-	0.1	4.5	mV
	TSV99xA	$T = 25^\circ C$ $T_{min} < T_{op} < T_{max}$	-	-	7.5	
DV_{io}	Input offset voltage drift		-	2	-	$\mu V/^\circ C$
I_{io}	Input offset current ⁽²⁾ ($V_{out} = V_{CC}/2$)	$T = 25^\circ C$ $T_{min} < T_{op} < T_{max}$	-	1	10	pA
			-	-	100	
I_{ib}	Input bias current ⁽²⁾ ($V_{out} = V_{CC}/2$)	$T = 25^\circ C$ $T_{min} < T_{op} < T_{max}$	-	1	10	pA
			-	-	100	
CMR	Common mode rejection ratio $20 \log (\Delta V_{ic}/\Delta V_{io})$	0V to 5V, $V_{out} = 2.5V$	62	82	-	dB
SVR	Supply voltage rejection ratio $20 \log (\Delta V_{cc}/\Delta V_{io})$	$V_{CC} = 2.5$ to $5V$	70	86	-	dB
A_{vd}	Large signal voltage gain	$R_L = 10k\Omega$, $V_{out} = 0.5V$ to $4.5V$, $T = 25^\circ C$ $T_{min} < T_{op} < T_{max}$	80	91	-	dB
			75	-	-	dB
$V_{CC}-V_{OH}$	High level output voltage	$R_L = 10k\Omega$ $R_L = 600\Omega$		15 45	40 150	mV
V_{OL}	Low level output voltage	$R_L = 10k\Omega$ $R_L = 600\Omega$	-	15 45	40 150	
I_{out}	I_{sink}	$V_o = 5V$, $T = 25^\circ C$ $T_{min} < T_{amb} < T_{max}$	18 16	32 -	- -	mA
	I_{source}	$V_o = 0V$, $T = 25^\circ C$ $T_{min} < T_{amb} < T_{max}$	18 16	35 -	- -	
I_{CC}	Supply current (per operator)	No load, $V_{out} = 2.5V$	-	0.82	1.1	mA
AC performance						
GBP	Gain bandwidth product	$R_L = 2k\Omega$, $C_L = 100pF$, $f = 100kHz$, $T = 25^\circ C$	-	20	-	MHz
ϕ_m	Phase margin	$R_L = 2k\Omega$, $C_L = 100pF$, $G=5$, $T = 25^\circ C$	-	60	-	Degrees
G_m	Gain margin	$R_L = 2k\Omega$, $C_L = 100pF$, $\phi_m = 40^\circ$, $T = 25^\circ C$	-	2.5	-	dB
SR	Slew rate	$R_L = 2k\Omega$, $C_L = 100pF$, $T = 25^\circ C$	-	10	-	V/ μs
e_n	Equivalent input noise voltage	$f = 10kHz$, $T = 25^\circ C$	-	21	-	$\frac{nV}{\sqrt{Hz}}$
THD+ e_n	Total harmonic distortion	$G=1$, $f=1kHz$, $R_L=2k\Omega$, $Bw=22kHz$, $V_{icm}=(V_{CC}+1)/2$, $V_{out}=3.6V_{pp}$, $T=25^\circ C$	-	0.0007	-	%

1. All parameter limits at temperatures other than $25^\circ C$ are guaranteed by correlation.

2. Guaranteed by design.

Figure 1. Input offset voltage distribution at T = 25°C

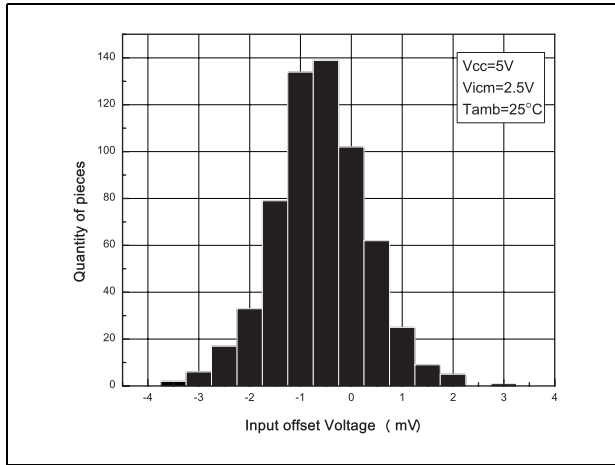


Figure 2. Input offset voltage distribution at T = 125°C

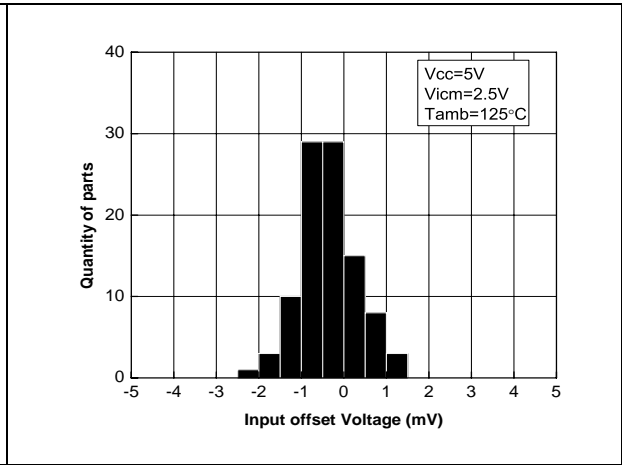


Figure 3. Supply current vs. input common mode voltage at V_{CC} = 2.5V

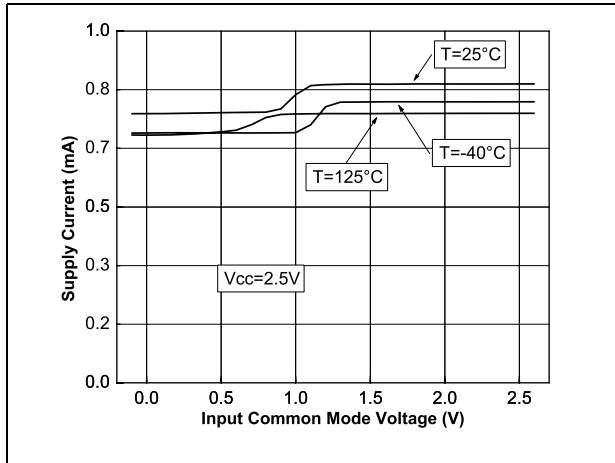


Figure 4. Supply current vs. input common mode voltage at V_{CC} = 5V

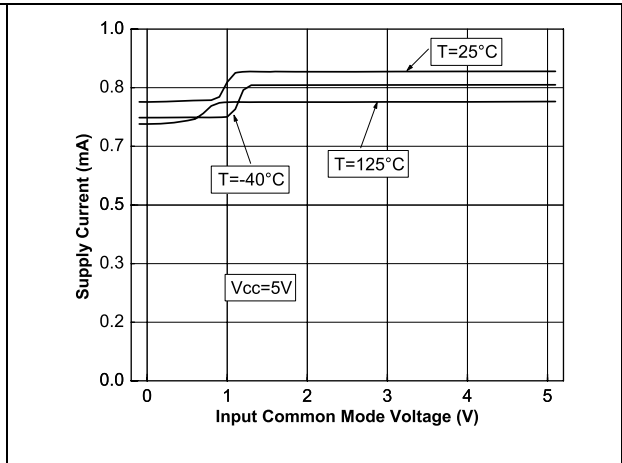


Figure 5. Output current vs. output voltage at V_{CC} = 2.5V

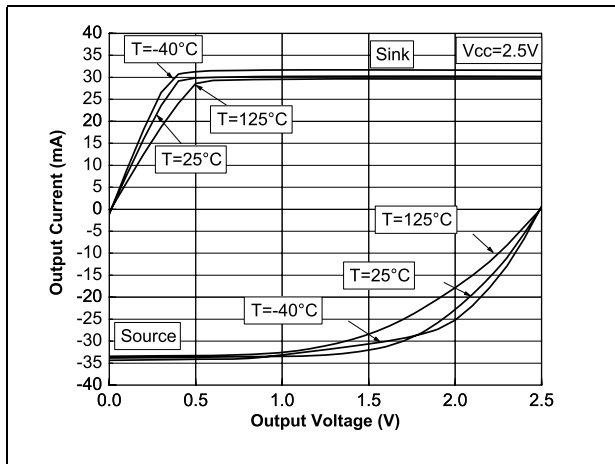


Figure 6. Output current vs. output voltage at V_{CC} = 5V

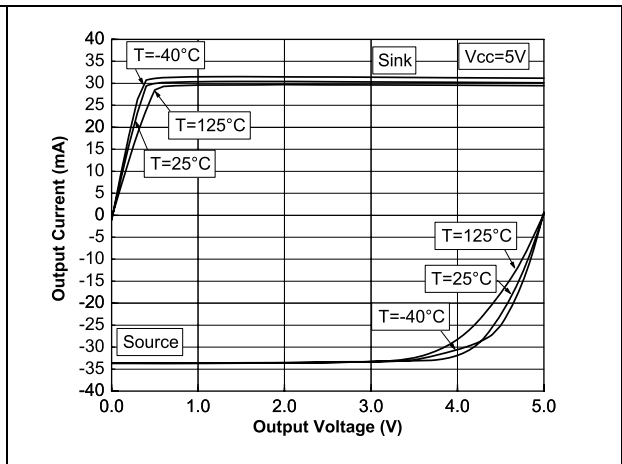


Figure 7. Voltage gain and phase vs frequency at $V_{CC}=5V$ and $V_{icm}=0.5V$

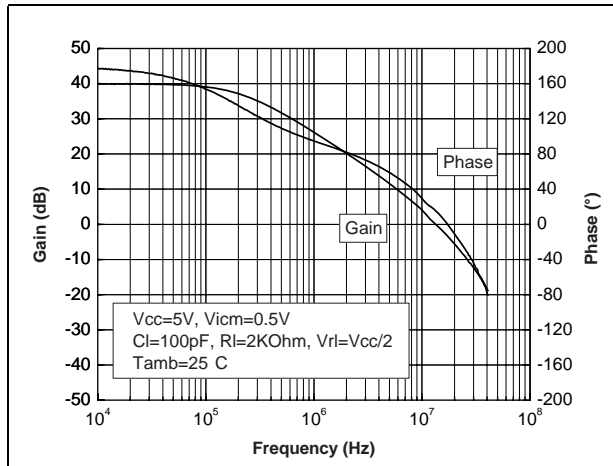


Figure 8. Voltage gain and phase vs frequency at $V_{CC}=5V$ and $V_{icm}=2.5V$

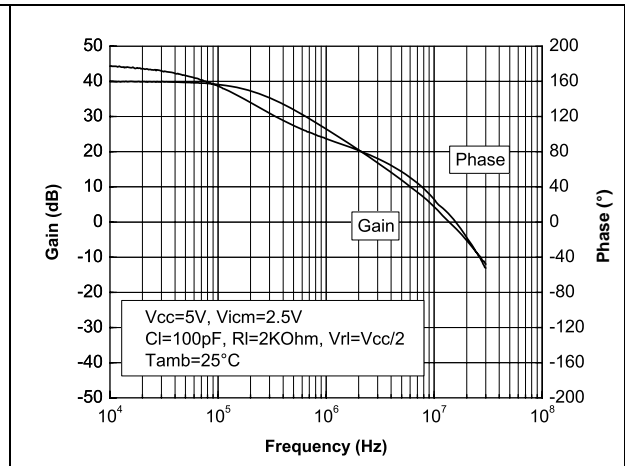


Figure 9. Positive slew rate

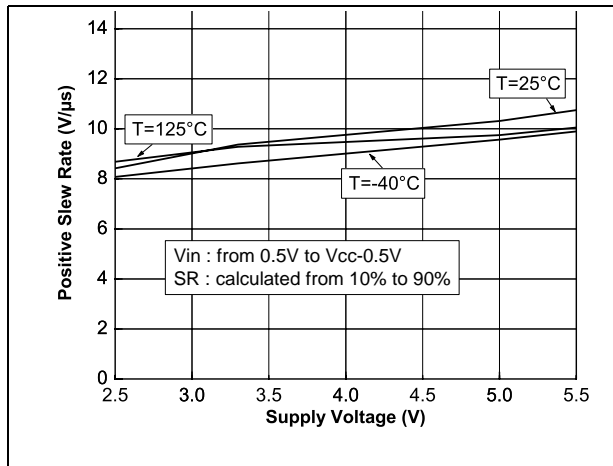


Figure 10. Negative slew rate

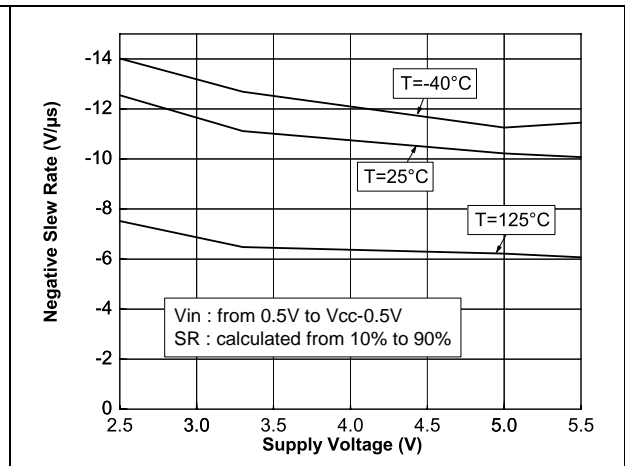


Figure 11. Distortion + noise vs. frequency

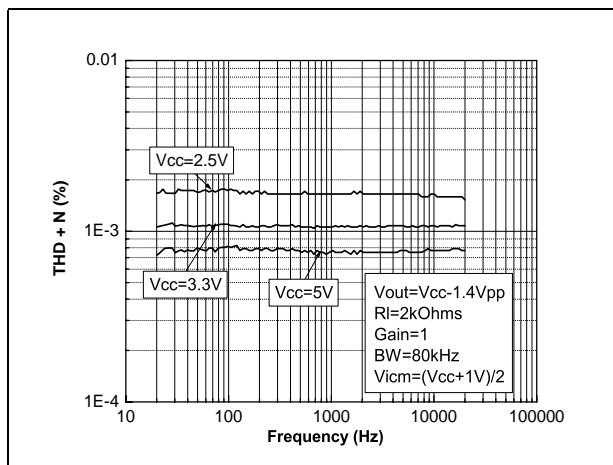


Figure 12. Distortion + noise vs. output voltage

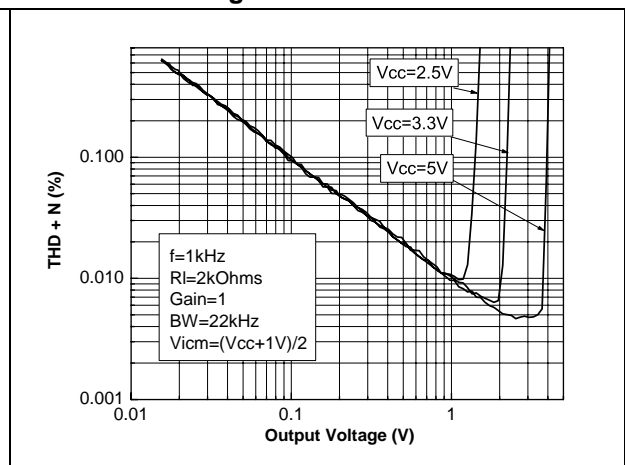
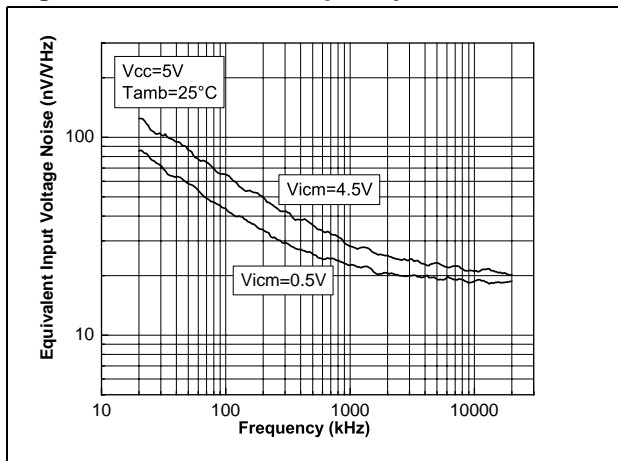


Figure 13. Noise vs. frequency



3 Package information

In order to meet environmental requirements, STMicroelectronics offers these devices in ECOPACK[®] packages. These packages have a lead-free second level interconnect. The category of second level interconnect is marked on the package and on the inner box label, in compliance with JEDEC Standard JESD97. The maximum ratings related to soldering conditions are also marked on the inner box label. ECOPACK is an STMicroelectronics trademark. ECOPACK specifications are available at: www.st.com.

Note: All packages are Moisture Sensitivity Level 1 as per Jedec J-STD-020-C, except SO-14 which is Jedec level 3.

3.1 SOT23-5 package information

Figure 14. SOT23-5 package mechanical drawing

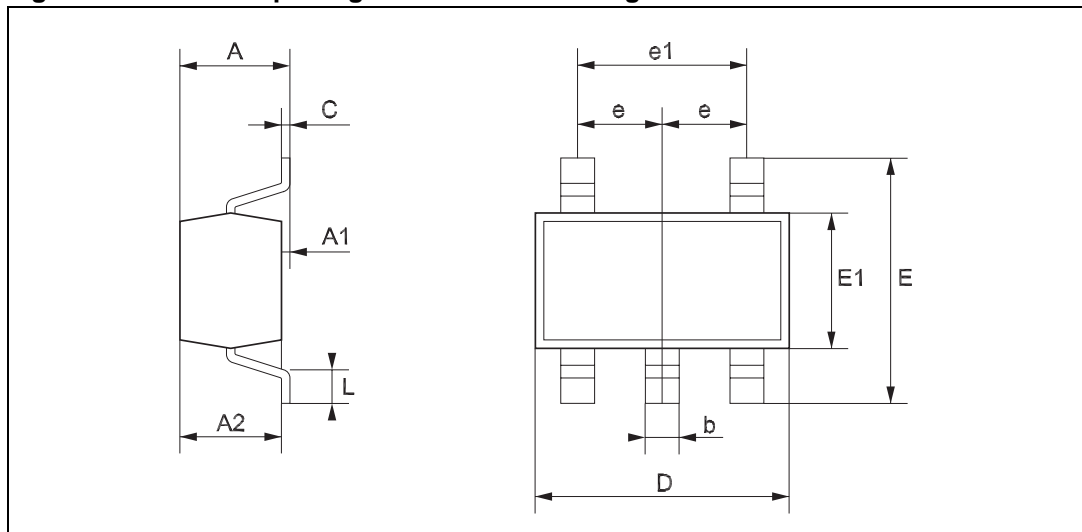


Table 6. SOT23-5 package mechanical data

Ref.	Dimensions					
	Millimeters			Mils		
	Min.	Typ.	Max.	Min.	Typ.	Max.
A	0.90		1.45	35.4		57.1
A1	0.00		0.15	0.00		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

3.2 MiniSO-8 package information

Figure 15. MiniSO-8 package mechanical drawing

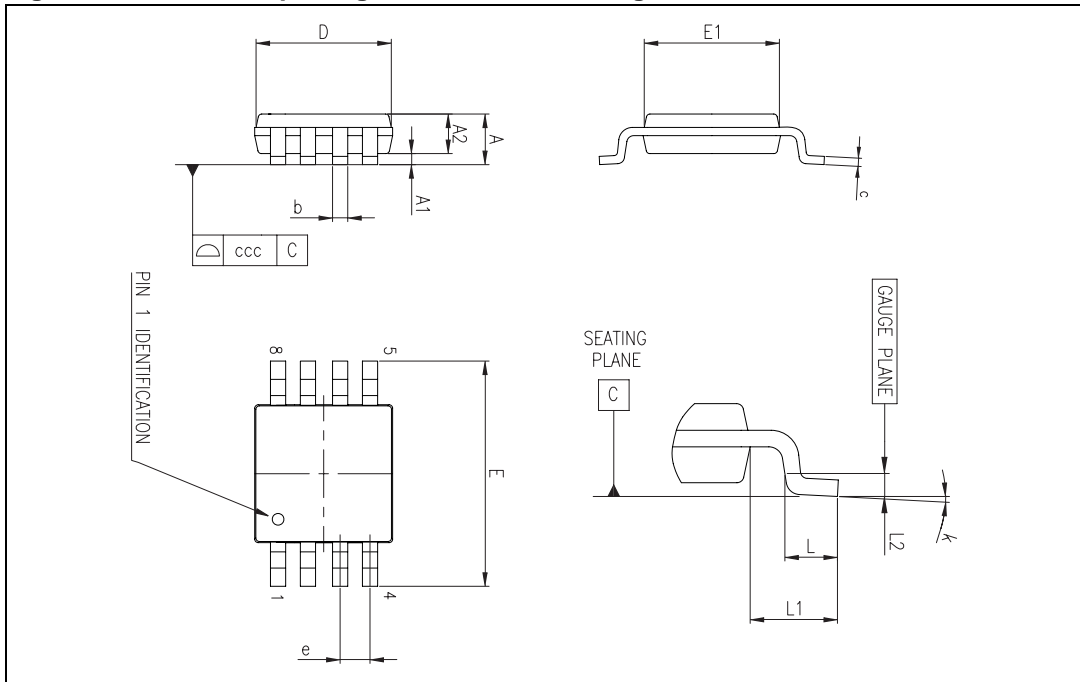
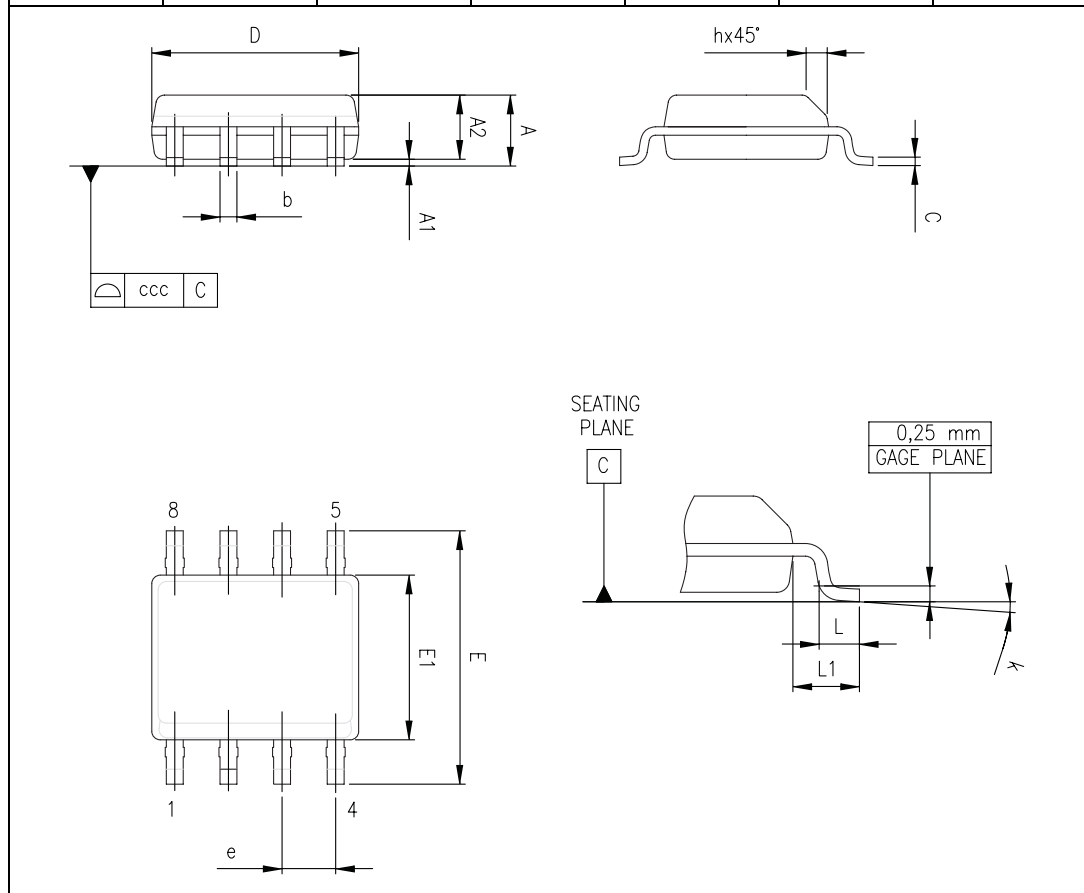


Table 7. MiniSO-8 package mechanical data

Ref.	Dimensions					
	Millimeters			Inches		
	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

Figure 16. SO-8 package mechanical data

Ref.	Dimensions					
	Millimeters			Inches		
	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
H	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
k	1°		8°	1°		8°
ccc			0.10			0.004



3.3 TSSOP14 package information

Figure 17. TSSOP14 package mechanical drawing

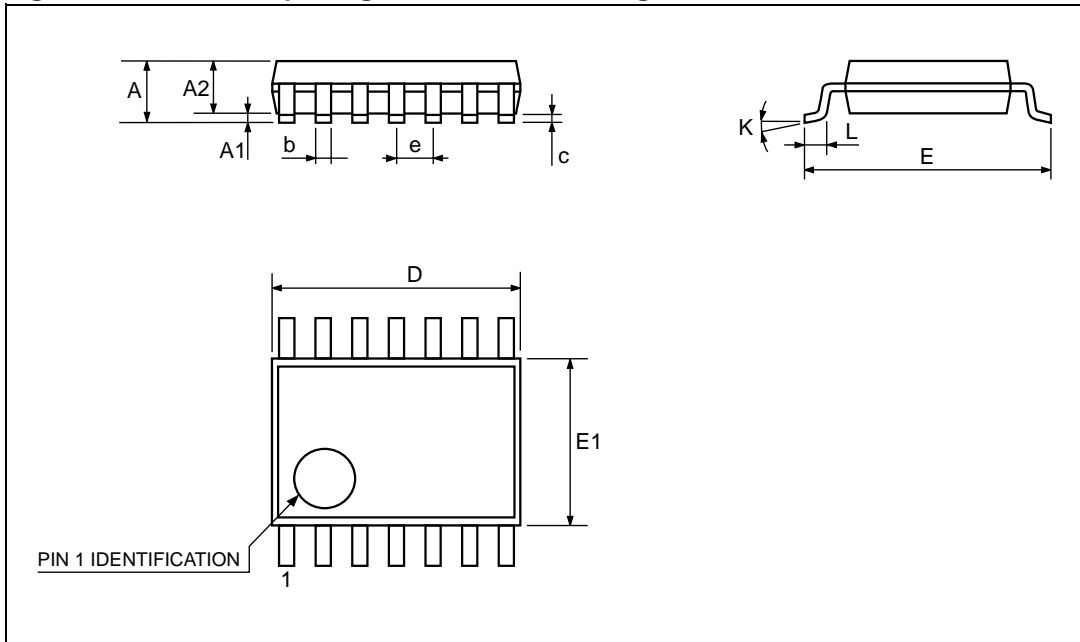
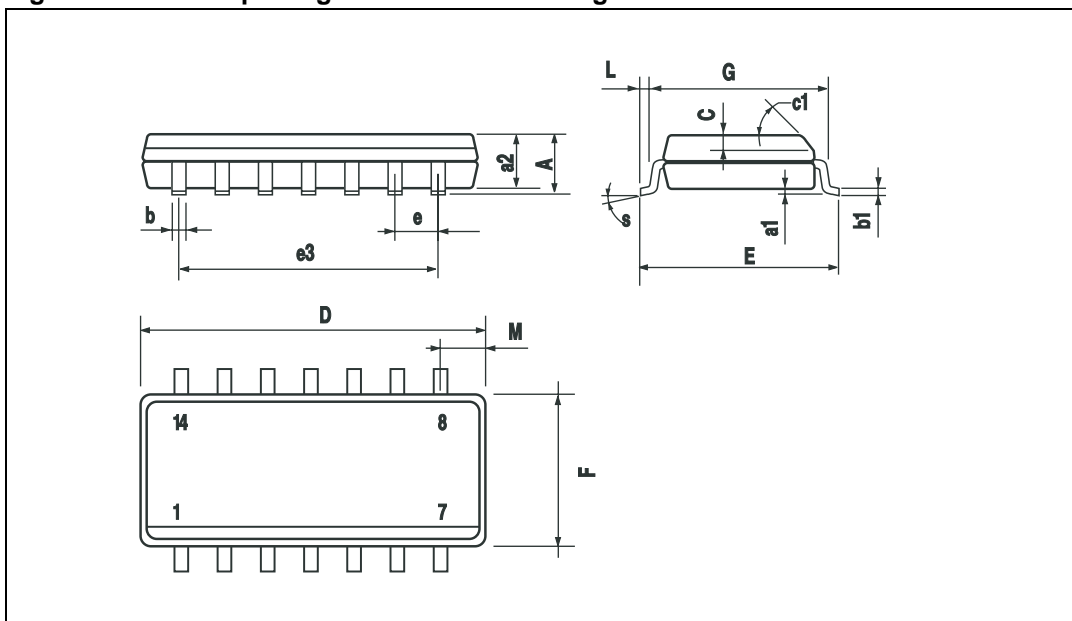


Table 8. TSSOP14 package mechanical data

Ref.	Dimensions					
	Millimeters			Inches		
	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°
L1	0.45	0.60	0.75	0.018	0.024	0.030

3.4 SO-14 package information

Figure 18. SO-14 package mechanical drawing



4 Ordering information

Table 9. Order codes⁽¹⁾

Order code	Temperature range	Package	Packing	Marking
TSV991ILT	-40°C to +125°C	SOT23-5	Tape & reel	K130
TSV991AILT				K129
TSV992IST		MiniSO-8		K132
TSV992AIST				K135
TSV992ID		SO-8	Tube or tape & reel	V992I
TSV992IDT				V992AI
TSV992AID		TSSOP14	Tape & reel	V994I
TSV992AIDT				V994AI
TSV994IPT		SO-14 ⁽¹⁾	Tube or tape & reel	V994I
TSV994IPT				V994AI
TSV994ID		SO-8 Automotive grade	Tube or tape & reel	V991IY
TSV994IDT				V991AY
TSV994AID		V992IY		
TSV994AIDT		V992AY		
TSV994IYD ⁽²⁾		SO-14 ⁽¹⁾ Automotive grade		V994IY
TSV994IYDT ⁽²⁾				V994AY
TSV994AIYD ⁽²⁾				
TSV994AIYDT ⁽²⁾				

- All packages are Moisture Sensitivity Level 1 as per Jecdec J-STD-020-C, except SO-14 which is Jecdec level 3.
- Qualification and characterization according to AEC Q100 and Q003 or equivalent, advanced screening according to AEC Q001 & Q 002 or equivalent are on-going.

5 Revision history

Date	Revision	Changes
31-Jul-2006	1	Preliminary data release for product under development.
07-Nov-2006	2	Final version of datasheet.
12-Dec-2006	3	Noise and distortion figures added.
07-Jun-2007	4	ESD tolerance modified for SO-14, CDM in Table 1: Absolute maximum ratings (AMR) . Automotive grade commercial products added in Table 9: Order codes . Note about SO-14 added in Table 9: Order codes . Limits in temperature added in Section 2: Electrical characteristics .
11-Feb-2008	5	Corrected MiniSO-8 package information. Corrected footnote for automotive grade order codes in order code table. Improved presentation of package information.

Please Read Carefully:

Information in this document is provided solely in connection with ST products. STMicroelectronics NV and its subsidiaries ("ST") reserve the right to make changes, corrections, modifications or improvements, to this document, and the products and services described herein at any time, without notice.

All ST products are sold pursuant to ST's terms and conditions of sale.

Purchasers are solely responsible for the choice, selection and use of the ST products and services described herein, and ST assumes no liability whatsoever relating to the choice, selection or use of the ST products and services described herein.

No license, express or implied, by estoppel or otherwise, to any intellectual property rights is granted under this document. If any part of this document refers to any third party products or services it shall not be deemed a license grant by ST for the use of such third party products or services, or any intellectual property contained therein or considered as a warranty covering the use in any manner whatsoever of such third party products or services or any intellectual property contained therein.

UNLESS OTHERWISE SET FORTH IN ST'S TERMS AND CONDITIONS OF SALE ST DISCLAIMS ANY EXPRESS OR IMPLIED WARRANTY WITH RESPECT TO THE USE AND/OR SALE OF ST PRODUCTS INCLUDING WITHOUT LIMITATION IMPLIED WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE (AND THEIR EQUIVALENTS UNDER THE LAWS OF ANY JURISDICTION), OR INFRINGEMENT OF ANY PATENT, COPYRIGHT OR OTHER INTELLECTUAL PROPERTY RIGHT.

UNLESS EXPRESSLY APPROVED IN WRITING BY AN AUTHORIZED ST REPRESENTATIVE, ST PRODUCTS ARE NOT RECOMMENDED, AUTHORIZED OR WARRANTED FOR USE IN MILITARY, AIR CRAFT, SPACE, LIFE SAVING, OR LIFE SUSTAINING APPLICATIONS, NOR IN PRODUCTS OR SYSTEMS WHERE FAILURE OR MALFUNCTION MAY RESULT IN PERSONAL INJURY, DEATH, OR SEVERE PROPERTY OR ENVIRONMENTAL DAMAGE. ST PRODUCTS WHICH ARE NOT SPECIFIED AS "AUTOMOTIVE GRADE" MAY ONLY BE USED IN AUTOMOTIVE APPLICATIONS AT USER'S OWN RISK.

Resale of ST products with provisions different from the statements and/or technical features set forth in this document shall immediately void any warranty granted by ST for the ST product or service described herein and shall not create or extend in any manner whatsoever, any liability of ST.

ST and the ST logo are trademarks or registered trademarks of ST in various countries.

Information in this document supersedes and replaces all information previously supplied.

The ST logo is a registered trademark of STMicroelectronics. All other names are the property of their respective owners.

© 2008 STMicroelectronics - All rights reserved

STMicroelectronics group of companies

Australia - Belgium - Brazil - Canada - China - Czech Republic - Finland - France - Germany - Hong Kong - India - Israel - Italy - Japan - Malaysia - Malta - Morocco - Singapore - Spain - Sweden - Switzerland - United Kingdom - United States of America

www.st.com