TSV911, TSV912, TSV914
TSV911A, TSV912A, TSV914A

Rail-to-rail input/output 8 MHz operational amplifiers

Features

- Rail-to-rail input and output
- Wide bandwidth
- Low power consumption: 820 µA typ
- Unity gain stability
- High output current: 35 mA
- Operating from 2.5 V to 5.5 V
- Low input bias current, 1 pA typ
- Low input offset voltage: 1.5 mV max (A grade)
- ESD internal protection ≥ 5 kV
- Latch-up immunity

Applications

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

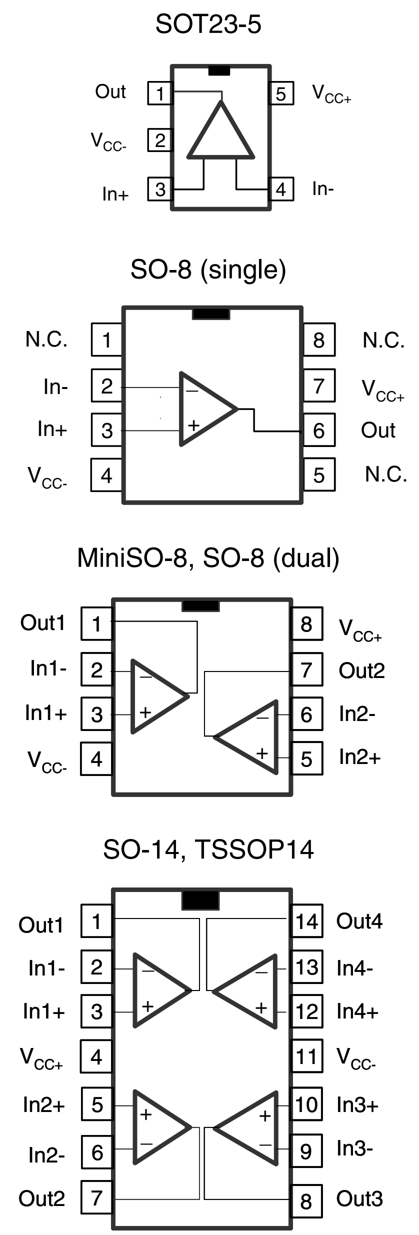
Description

The TSV911/2/4 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 an 8 MHz gain-bandwidth product while consuming only 1.1 mA maximum at 5 V. These op-amps are unity gain stable. They also feature an ultra-low input bias current.

These characteristics make the TSV911/2/4 family ideal for sensor interfaces, battery-supplied and portable applications, as well as active filtering.

Pin connections
(top view)



1 Absolute maximum ratings and operating conditions

Table 1. **Absolute maximum ratings**

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_{CC-} -0.2 to V_{CC+} +0.2	V
I_{in}	Input current (4)	10	mA
T_{stg}	Storage temperature	-65 to +150	°C
R_{thja}	Thermal resistance junction to ambient(5) (6) SOT23-5 SO-8 MiniSO-8 SO-14 TSSOP14	 250 125 190 103 100	°C/W
R_{thjc}	Thermal resistance junction to case(5) (6) SOT23-5 SO-8 MiniSO-8 SO-14 TSSOP14	 81 40 39 31 32	°C/W
T_j	Maximum junction temperature	150	°C
ESD	HBM: human body model(7)	5	kV
	MM: machine model(8)	400	V
	CDM: charged device model(9) SOT23-5, SO-8, MiniSO-8 TSSOP14 SO-14	 1500 750 500	V
	Latch-up immunity	200	mA

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. V_{CC}-V_{in} must not exceed 6 V.
4. Input current must be limited by a resistor in series with the inputs.
5. Short-circuits can cause excessive heating and destructive dissipation.
6. R_{th} are typical values.
7. Human body model: a 100 pF capacitor is charged to the specified voltage, then discharged through a 1.5kΩ resistor between two pins of the device. This is done for all couples of connected pin combinations while the other pins are floating.
8. Machine model: a 200 pF capacitor is charged to the specified voltage, then discharged directly between two pins of the device with no external series resistor (internal resistor < 5 Ω). This is done for all couples of connected pin combinations while the other pins are floating.
9. Charged device model: all pins and the package are charged together to the specified voltage and then discharged directly to the ground through only one pin. This is done for all pins.

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_{CC-} -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+} = +2.5 V with V_{CC-} = 0 V, 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 TSV91x	T_{op} = 25°C $T_{min} < T_{op} < T_{max}$	- -	0.1 -	4.5 7.5	mV
	TSV91xA	T = 25°C $T_{min} < T_{op} < T_{max}$	- -	- -	1.5 3	
DV_{io}/DT	Input offset voltage drift		-	2	-	µV/°C
I_{io}	Input offset current	T_{op} = 25°C $T_{min} < T_{op} < T_{max}$	- -	1 -	10(2) 100	pA
I_{ib}	Input bias current	T_{op} = 25°C $T_{min} < T_{op} < T_{max}$	- -	1 -	10(2) 100	pA
CMR	Common mode rejection ratio 20 log ($\Delta V_{ic}/\Delta V_{io}$)	0V to 2.5V, V_{out} = 1.25V, T_{op}= 25°C $T_{min} < T_{op} < T_{max}$	58 53	75	-	dB
A_{vd}	Large signal voltage gain	R_L= 10kΩ, V_{out}= 0.5V to 2V, T= 25°C $T_{min} < T_{op} < T_{max}$	80 75	89 -	-	dB
$V_{CC}-V_{OH}$	High level output voltage	R_L = 10kΩ R_L = 600Ω		15 45	40 150	mV
V_{OL}	Low level output voltage	R_L = 10kΩ R_L = 600Ω	-	15 45	40 150	mV
I_{out}	I_{sink}	V_o = 2.5V, T_{op} = 25°C $T_{min} < T_{op} < T_{max}$	18 16	32 -	- -	mA
	I_{source}	V_o = 0V, T_{op} = 25°C $T_{min} < T_{op} < T_{max}$	18 16	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= 2kΩ, C_L=100pF, f =100kHz, T_{op} =25°C	-	8	-	MHz
F_u	Unity gain frequency	R_L= 2kΩ, C_L= 100pF, T_{op} = 25°C		7.2		MHz
ϕm	Phase margin	R_L= 2kΩ, C_L= 100pF, T_{op} = 25°C	-	45	-	Degrees
G_m	Gain margin	R_L= 2kΩ, C_L= 100pF, T_{op} = 25°C	-	8	-	dB
SR	Slew rate	R_L= 2kΩ, C_L=100pF, A_v=1, T_{op} = 25°C	-	4.5	-	V/µs
e_n	Equivalent input noise voltage	f= 10kHz, T_{op} = 25°C	-	21	-	$\frac{nV}{\sqrt{Hz}}$
THD+e_n	Total harmonic distortion	G=1, f=1kHz, R_L=2kΩ, Bw= 22kHz, T_{op} =25°C, $V_{icm}=(V_{CC}+1)/2$, $V_{out}=1.1V_{pp}$	-	0.001	-	%

1. All parameter limits at temperatures other than 25°C are guaranteed by correlation.
2. Guaranteed by design.

Table 4. Electrical characteristics at V_{CC+} = +3.3 V with V_{CC-} = 0 V, 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 TSV91x	T_{op} = 25°C $T_{min} < T_{op} < T_{max}$	- -	0.1 -	4.5 7.5	mV
	TSV91xA	T_{op} = 25°C $T_{min} < T_{op} < T_{max}$	- -	- -	1.5 3	
DV_{io}	Input offset voltage drift		-	2	-	µV/°C
I_{io}	Input offset current	T_{op} = 25°C $T_{min} < T_{op} < T_{max}$	- -	1 -	10[2] 100	pA
I_{ib}	Input bias current	T_{op} = 25°C $T_{min} < T_{op} < T_{max}$	- -	1	10[2] 100	pA
CMR	Common mode rejection ratio 20 log ($\Delta V_{ic}/\Delta V_{io}$)	0V to 3.3V, V_{out} = 1.65V $T_{min} < T_{op} < T_{max}$	60 55	78	-	dB
A_{vd}	Large signal voltage gain	R_L=10kΩ, V_{out}= 0.5V to 2.8V, T=25°C $T_{min} < T_{op} < T_{max}$	80 75	90	-	dB
V_{CC}-V_{OH}	High level output voltage	R_L = 10kΩ R_L = 600Ω		15 45	40 150	mV
V_{OL}	Low level output voltage	R_L = 10kΩ R_L = 600Ω	-	15 45	40 150	mV
I_{out}	I_{sink}	V_o = 3.3V, T_{op} = 25°C $T_{min} < T_{op} < T_{max}$	18 16	32 -	- -	mA
	I_{source}	V_o = 0V, T_{op} = 25°C $T_{min} < T_{op} < T_{max}$	18 16	35 -	- -	
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= 2kΩ, C_L= 100pF, f = 100kHz, T_{op} = 25°C	-	8	-	MHz
F_u	Unity gain frequency	R_L= 2kΩ, C_L=100pF, T_{op} = 25°C	-	7.2	-	MHz
ϕm	Phase margin	R_L= 2kΩ, C_L=100pF, T_{op} = 25°C	-	45	-	Degrees
G_m	Gain margin	R_L= 2kΩ, C_L=100pF, T_{op} = 25°C	-	8	-	dB
SR	Slew rate	R_L= 2kΩ, C_L= 100pF, A_v=1, T_{op} = 25°C	-	4.5	-	V/µs
e_n	Equivalent input noise voltage	f= 10kHz, T_{op}= 25°C	-	21	-	$\frac{nV}{\sqrt{Hz}}$
THD+e_n	Total harmonic distortion	G=1, f=1kHz, R_L=2kΩ, BW= 22kHz, $V_{icm}=(V_{CC}+1)/2$, V_{out}=1.9V_{pp}, T_{op} =25°C	-	0.0007	-	%

1. All parameter limits at temperatures other than 25°C are guaranteed by correlation.
2. Guaranteed by design.

Table 5. Electrical characteristics at V_{CC+} = +5 V with V_{CC-} = 0 V, 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 TSV91x	T_{op} = 25°C $T_{min} < T_{op} < T_{max}$	- -	0.1 -	4.5 7.5	mV
	TSV91xA	T_{op} = 25°C $T_{min} < T_{op} < T_{max}$	- -	- -	1.5 3	
DV_{io}	Input offset voltage drift		-	2	-	µV/°C
I_{io}	Input offset current	T_{op} = 25°C $T_{min} < T_{op} < T_{max}$	- -	1 -	10(2) 100	pA
I_{ib}	Input bias current	T_{op} = 25°C $T_{min} < T_{op} < T_{max}$	- -	1 -	10(2) 100	pA
CMR	Common mode rejection ratio 20 log ($\Delta V_{ic}/\Delta V_{io}$)	0V to 5V, V_{out} = 2.5V $T_{min} < T_{op} < T_{max}$	62 58	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=10kΩ, V_{out}= 0.5V to 4.5V, T= 25°C $T_{min} < T_{op} < T_{max}$	80 75	91	-	dB
V_{CC}-V_{OH}	High level output voltage	R_L = 10kΩ R_L = 600Ω		15 45	40 150	mV
V_{OL}	Low level output voltage	R_L = 10kΩ R_L = 600Ω	-	15 45	40 150	mV
I_{out}	I_{sink}	V_o = 5V, T_{op} =25°C $T_{min} < T_{op} < T_{max}$	18 16	32 -	- -	mA
	I_{source}	V_o = 0V, T_{op} = 25°C $T_{min} < T_{op} < T_{max}$	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= 2kΩ, C_L= 100pF, f = 100kHz, T_{op} =25°C	-	8	-	MHz
F_u	Unity gain frequency	R_L = 2kΩ, C_L=100pF, T_{op} = 25°C	-	7.5	-	MHz
φm	Phase margin	R_L = 2kΩ, C_L=100pF, T_{op} = 25°C	-	45	-	Degrees
G_m	Gain margin	R_L = 2kΩ, C_L=100pF, T_{op} = 25°C	-	8	-	dB

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

Symbol	Parameter	Conditions	Min.	Typ.	Max.	Unit
SR	Slew rate	R_L= 2kΩ, C_L= 100pF, A_V = 1, T_{op} = 25°C	-	4.5	-	V/µs
e_n	Equivalent input noise voltage	f=1kHz, T= 25°C f=10kHz, T_{op} = 25°C	- -	27 21	- -	$\frac{nV}{\sqrt{Hz}}$
THD+e_n	Total harmonic distortion	G=1, f=1kHz, R_L=2kΩ, Bw= 22kHz, T_{op} =25°C, V_{icm}=(V_{CC}+1)/2, V_{out}=3.6V_{pp}	-	0.0004	-	%

1. All parameter limits at temperatures other than 25°C are guaranteed by correlation.
2. Guaranteed by design.

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

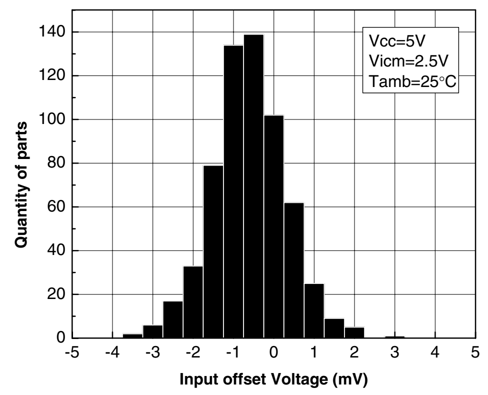


Figure 2. Input offset voltage distribution at T = 125° C

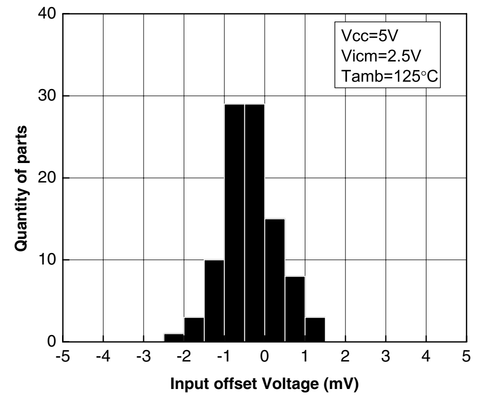


Figure 3. Supply current vs. input common mode voltage at V_{CC} = 2.5 V

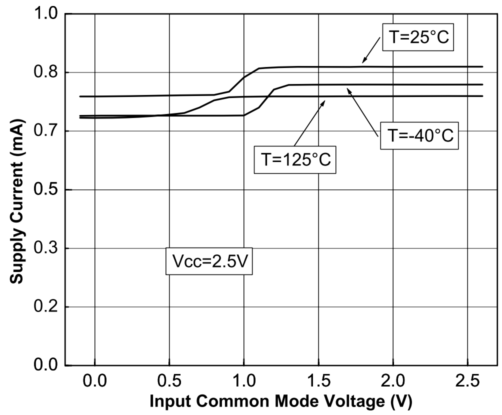


Figure 4. Supply current vs. input common mode voltage at V_{CC} = 5 V

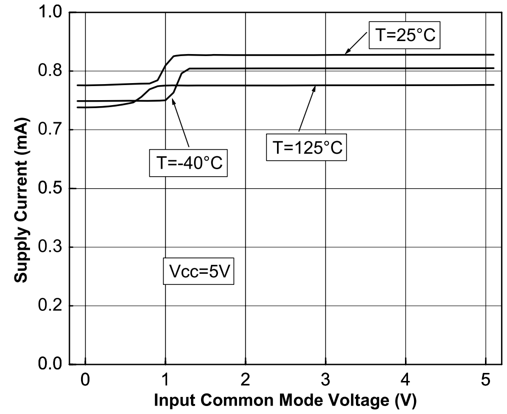


Figure 5. Output current vs. output voltage at V_{CC} = 2.5 V

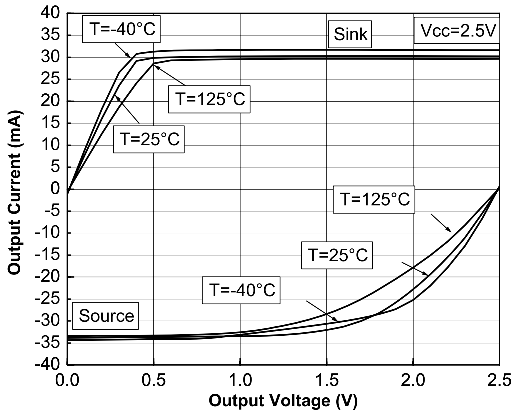


Figure 6. Output current vs. output voltage at V_{CC} = 5 V

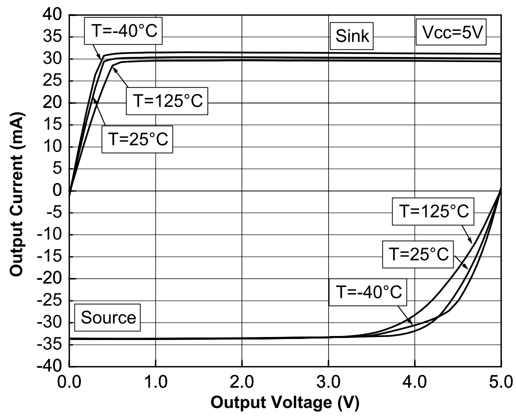


Figure 7. Voltage gain and phase vs frequency at V_{CC} = 2.5 V and V_{icm} = 0.5 V

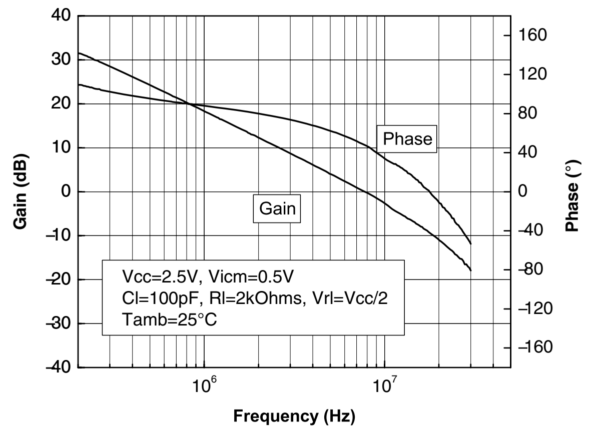


Figure 8. Voltage gain and phase vs frequency at V_{CC} = 5.5V and V_{icm} = 0.5 V

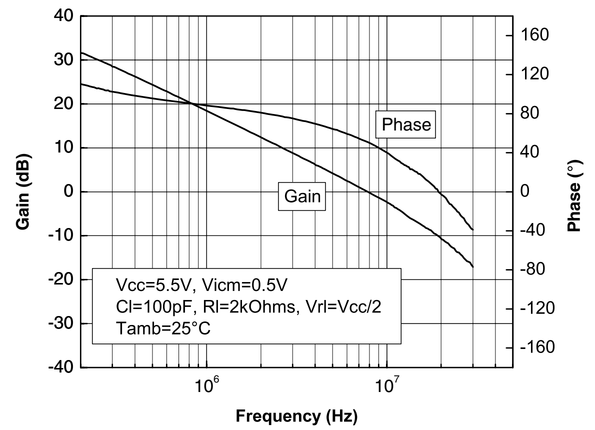


Figure 9. Phase margin vs. capacitive load

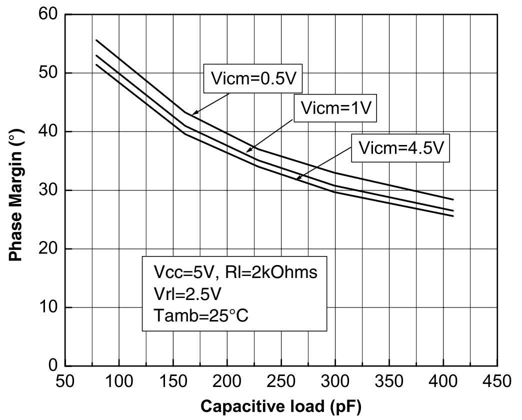


Figure 10. Phase margin vs. output current

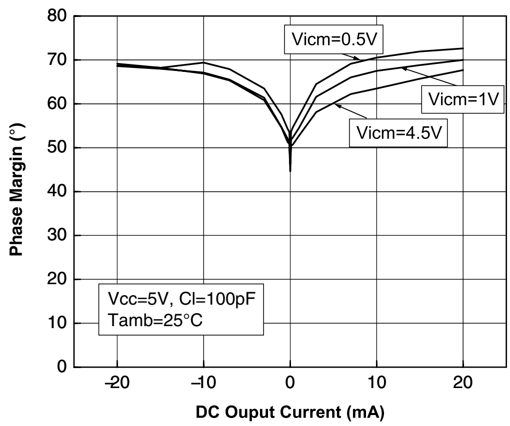


Figure 11. Positive slew rate

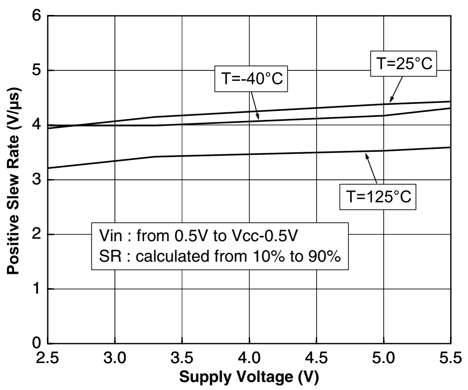


Figure 12. Negative slew rate

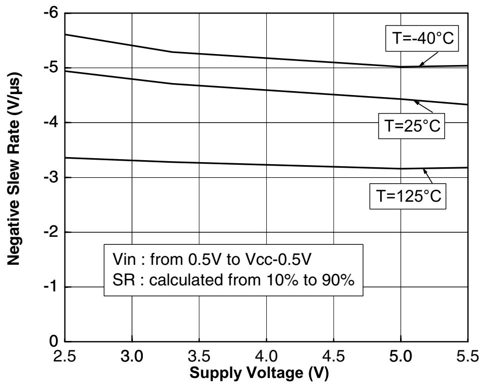


Figure 13. Distortion + noise vs. frequency

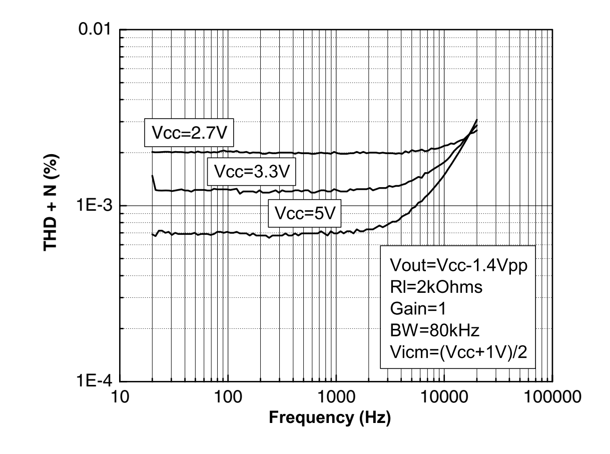


Figure 14. Distortion + noise vs. output voltage

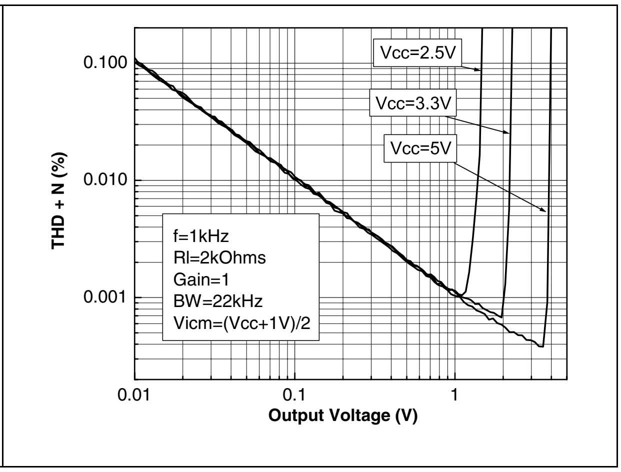


Figure 15. Noise vs. frequency

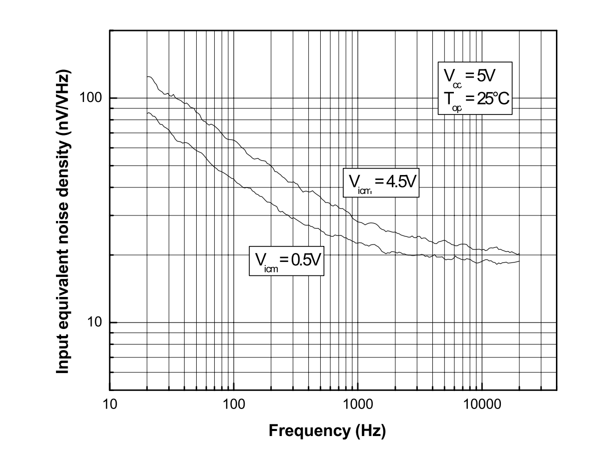


Figure 16. Phase margin vs. capacitive load and serial resistor

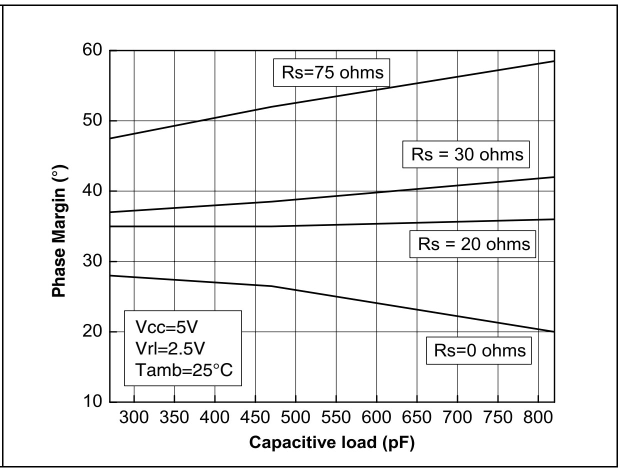
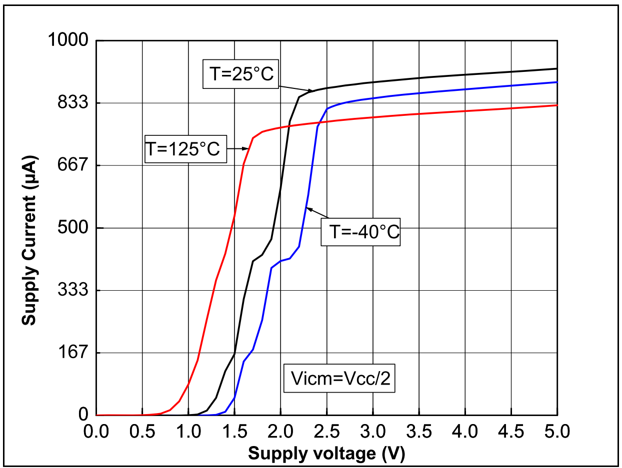


Figure 17. Supply current vs. supply voltage



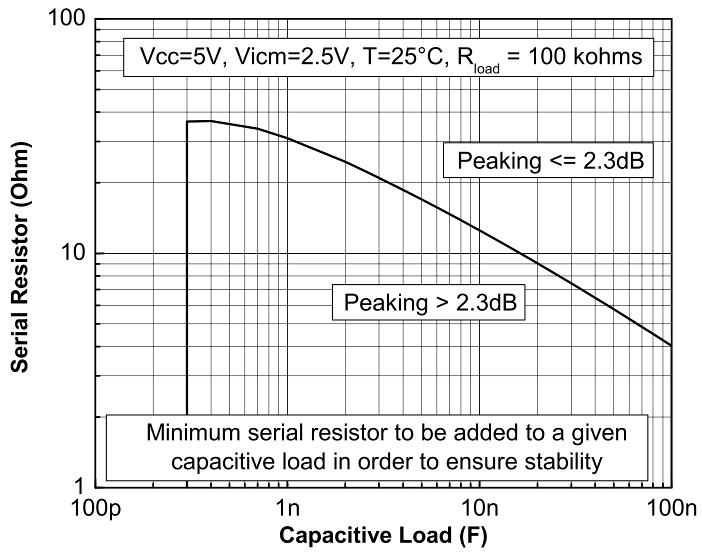
3 Application information

3.1 Driving resistive and capacitive loads

These products are low-voltage, low-power operational amplifiers optimized to drive rather large resistive loads, above 2 kΩ

In a *follower* configuration, these operational amplifiers can drive capacitive loads up to 100 pF with no oscillations. When driving larger capacitive loads, adding a small in-series resistor at the output can improve the stability of the device (see *Figure 18* for recommended in-series resistor values). Once the in-series resistor value has been selected, the stability of the circuit should be tested on bench and simulated with the simulation model.

Figure 18. In-series resistor vs. capacitive load



3.2 PCB layouts

For correct operation, it is advised to add 10 nF decoupling capacitors as close as possible to the power supply pins.

3.3 Macromodel

An accurate macromodel of the TSV91x is available on STMicroelectronics' web site at www.st.com. This model is a trade-off between accuracy and complexity (that is, time simulation) of the TSV91x operational amplifiers. It emulates the nominal performances of a typical device within the specified operating conditions mentioned in the datasheet. It helps to validate a design approach and to select the right operational amplifier, *but it does not replace on-board measurements*.

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 19. SOT23-5 package mechanical drawing

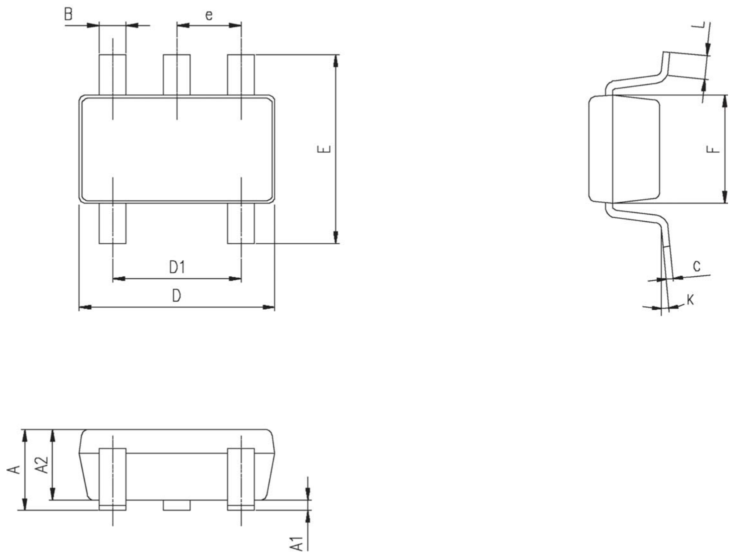


Table 6. SOT23-5 package mechanical data

Ref.	Dimensions					
	Millimeters			Inches		
	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 degrees		10 degrees			

4.2 MiniSO-8 package information

Figure 20. MiniSO-8 package mechanical drawing

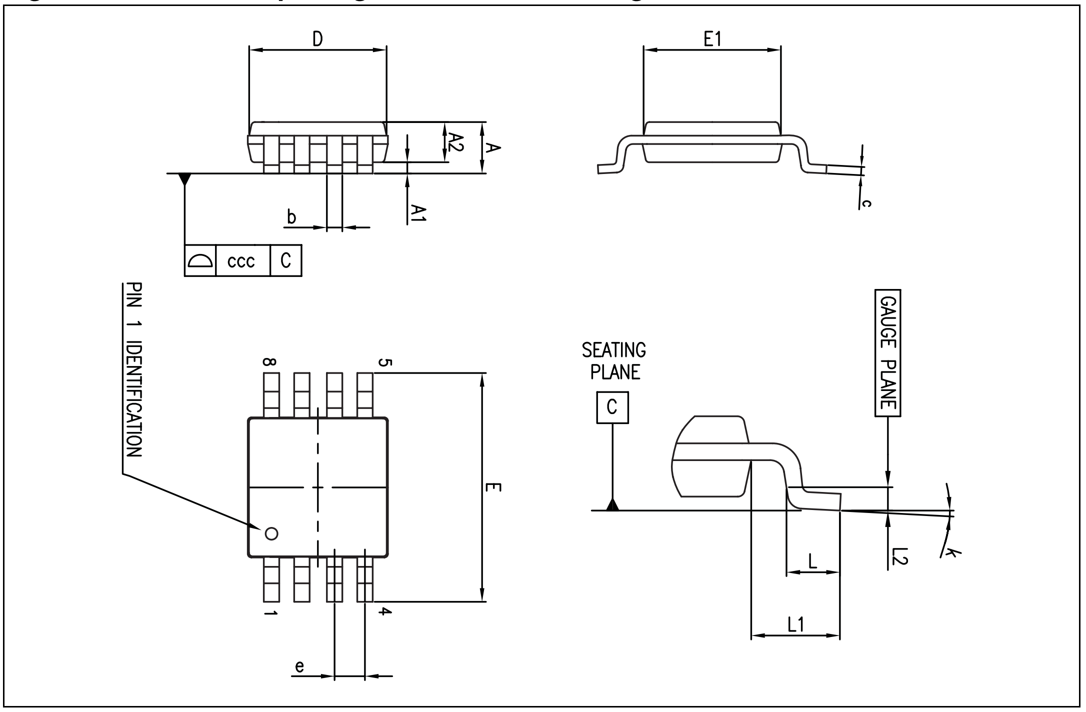


Table 7. MiniSO-8 package mechanical data

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

4.3 SO-8 package information

Figure 21. SO-8 package mechanical drawing

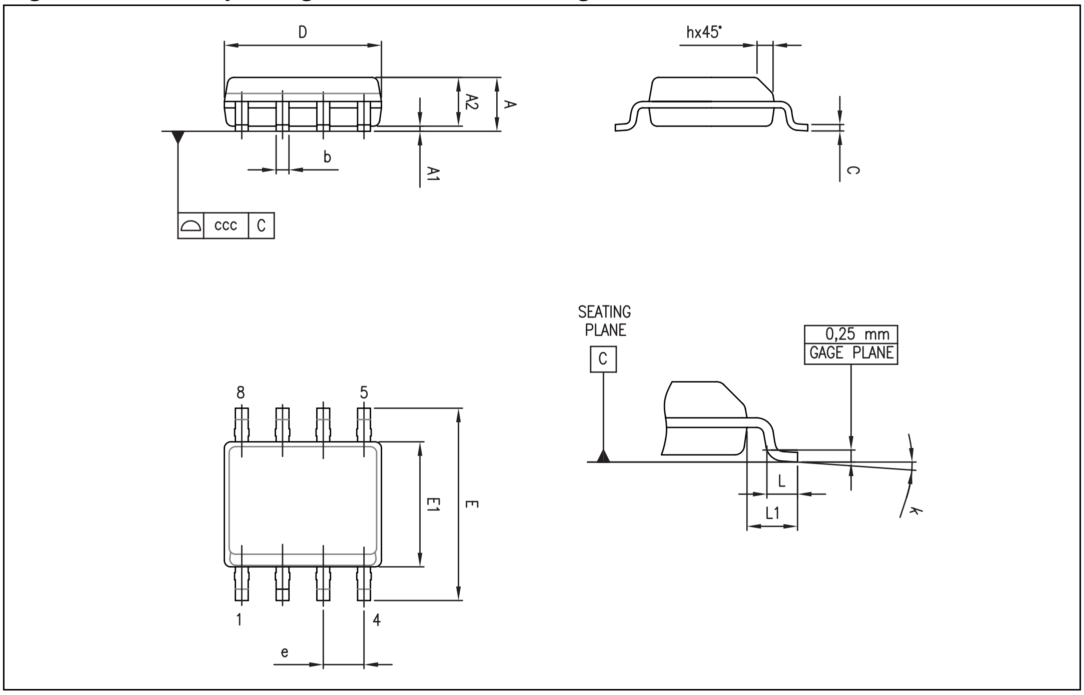


Table 8. SO-8 package mechanical data

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
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

4.4 TSSOP14 package information

Figure 22. TSSOP14 package mechanical drawing

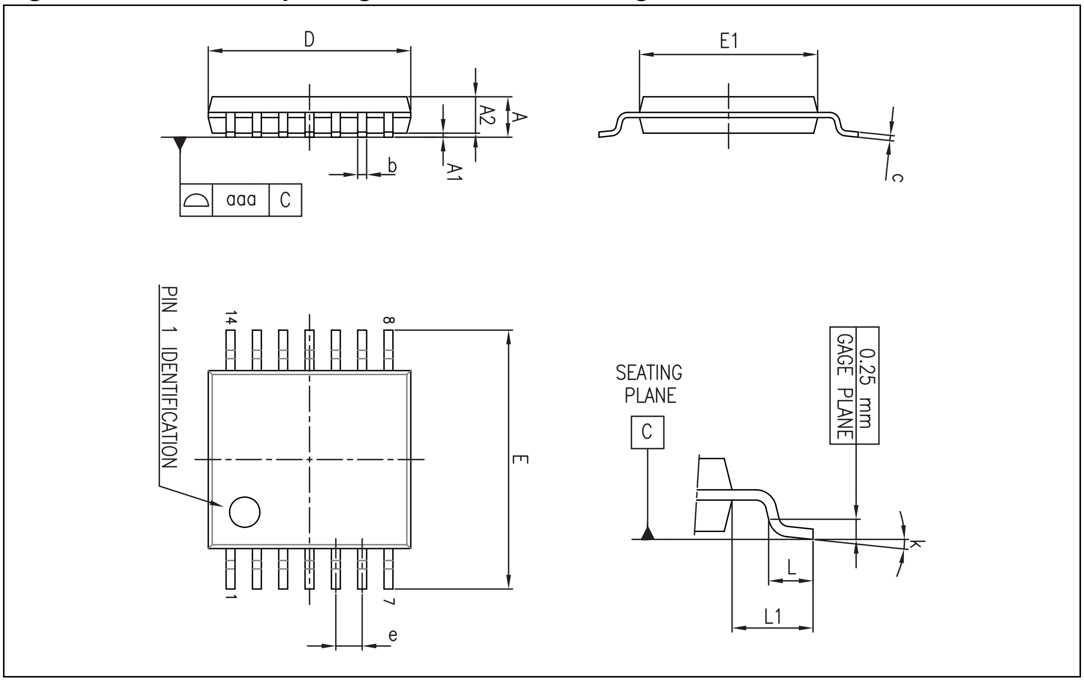


Table 9. TSSOP14 package mechanical data

Ref.	Dimensions					
	Millimeters			Inches		
	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

4.5 SO-14 package information

Figure 23. SO-14 package mechanical drawing

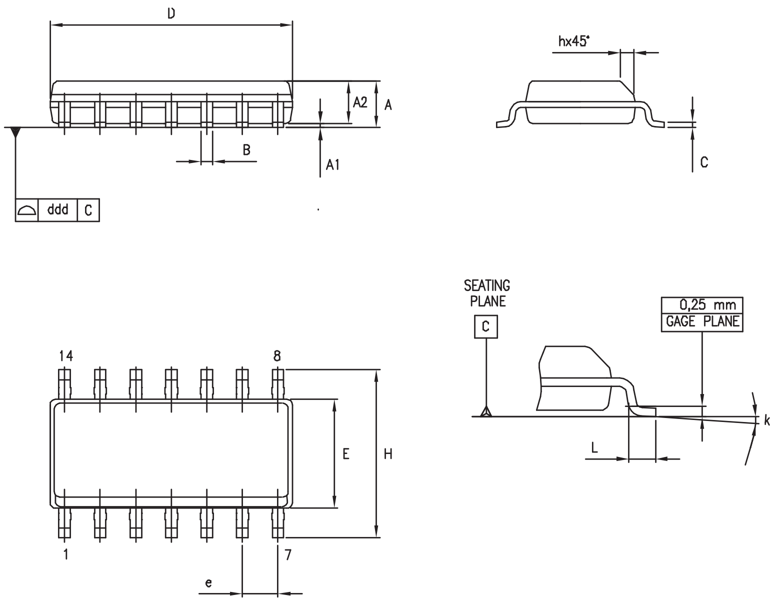


Table 10. SO-14 package mechanical data

Ref.	Dimensions					
	Millimeters			Inches		
	Min.	Typ.	Max.	Min.	Typ.	Max.
A	1.35		1.75	0.05		0.068
A1	0.10		0.25	0.004		0.009
A2	1.10		1.65	0.04		0.06
B	0.33		0.51	0.01		0.02
C	0.19		0.25	0.007		0.009
D	8.55		8.75	0.33		0.34
E	3.80		4.0	0.15		0.15
e		1.27			0.05	
H	5.80		6.20	0.22		0.24
h	0.25		0.50	0.009		0.02
L	0.40		1.27	0.015		0.05
k	8° (max.)					
ddd			0.10			0.004

5 Ordering information

Table 11. Order codes(1)

Order code	Temperature range	Package	Packing	Marking
TSV911ID TSV911IDT	-40°C to +125°C	SO-8	Tube o Tape & reel	V911I
TSV911AID TSV911AIDT				V911AI
TSV911ILT		SOT23-5	Tape & reel	K127
TSV911AILT				K128
TSV912IST		MiniSO-8	Tape & reel	K125
TSV912AIST				K126
TSV912ID TSV912IDT		SO-8	Tube or Tape & reel	V912I
TSV912AID TSV912AIDT				V912AI
TSV914IPT		TSSOP14	Tape & reel	V914I
TSV914AIPT				V914AI
TSV914ID TSV914IDT		SO-14(1)	Tube or Tape & reel	V914I
TSV914AID TSV914AIDT				V914AI
TSV911IYLT(2)		SOT23-5 Automotive grade	Tape & reel	K147
TSV911AIYLT(2)				K148
TSV912IYDT(2)		SO-8 Automotive grade	Tape & reel	V912IY
TSV912AIYDT(2)				V912AY
TSV912IYST(2)		MiniSO-8 Automotive grade	Tape & reel	K147
TSV912AIYST(2)				K148
TSV914IYDT(2)		SO-14(1) Automotive grade	Tape & reel	V914IY
TSV914AIYDT(2)				V914AY
TSV914IYPT(2)		TSSOP14 Automotive grade	Tape & reel	V914IY
TSV914AIYPT(2)				V914AY

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

6 Revision history

Table 12. Document revision history

Date	Revision	Changes
28-Aug-2006	1	First release.
07-Jun-2007	2	Modified ESD CDM parameter for SO-14 package in *Table 1: Absolute maximum ratings*. Noise parameters updated in *Section 2: Electrical characteristics*. Added limits in temperature in *Section 2: Electrical characteristics*. Added automotive grade level description in *Table 11: Order codes*. Added footnote about SO-14 package in *Table 11: Order codes*. Added *Figure 16: Phase margin vs. capacitive load and serial resistor*.
11-Feb-2008	3	Updated footnotes for ESD parameters in *Table 1: Absolute maximum ratings*. Corrected MiniSO-8 package information in *Table 7: MiniSO-8 package mechanical data*. Added missing markings for order codes TSV911AILT and TSV912AILT in *Table 11: Order codes*.
22-Jun-2009	4	Added input current information in *Table 1: Absolute maximum ratings*. Changed *Figure 7* and *Figure 8*. Added *Chapter 3: Application information*. Updated package information in *Chapter 4*. Added automotive order codes: TSV911IYLT, TSV911AIYLT, TSV912IYST, TSV912AIYST, TSV914IYPT and TSV914AIYPT in *Table 11: Order codes*.
17-Sep-2009	5	Added A versions of devices in title on cover page. Modified ESD value for machine model in *Table 1: Absolute maximum ratings*. Added *Figure 17: Supply current vs. supply voltage on page 10*.

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