



# TSV912H, TSV912AH

High temperature  
rail-to-rail input/output 8 MHz operational amplifiers

## Features

- Rail-to-rail input and output
- Wide bandwidth
- Low power consumption: 820  $\mu$ A typ
- Unity gain stability
- High output current: 35 mA
- Operating range from 2.5 to 5.5 V
- Low input bias current, 1 pA typ
- ESD internal protection  $\geq 5$  kV
- Latch-up immunity

## Applications

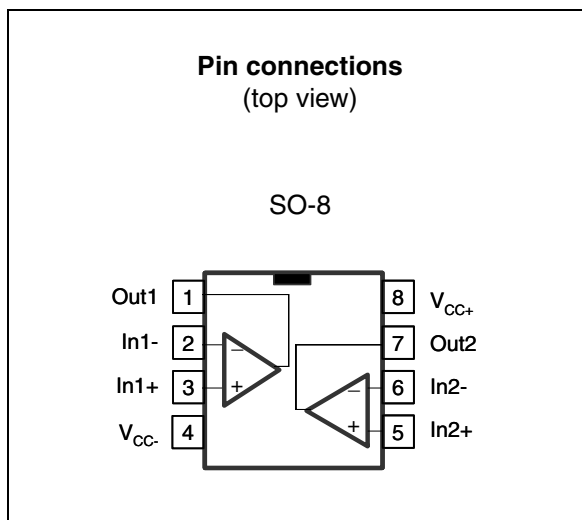
- Automotive products

## Description

The TSV912H and TSV912AH operational amplifiers offer low voltage operation and rail-to-rail input and output.

The devices feature an excellent speed/power consumption ratio, offering an 8 MHz gain-bandwidth product while consuming only 1.1 mA maximum at 5 V. They are unity gain stable and feature an ultra-low input bias current.

The TSV912H is a high temperature version of the TSV912, and can operate from  $-40^{\circ}\text{C}$  to  $+150^{\circ}\text{C}$  with unique characteristics. Its main target applications are automotive, but the device is also 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**

Symbol	Parameter	Value	Unit
$V_{CC}$	Supply voltage <sup>(1)</sup> ( $V_{CC+} - V_{CC-}$ )	6	V
$V_{id}$	Differential input voltage <sup>(2)</sup>	$\pm V_{CC}$	V
$V_{in}$	Input voltage <sup>(3)</sup>	$V_{CC-} - 0.2$ to $V_{CC+} + 0.2$	V
$I_{in}$	Input current <sup>(4)</sup>	10	mA
$T_{stg}$	Storage temperature	-65 to +150	°C
$R_{thja}$	Thermal resistance junction to ambient <sup>(5)</sup> (6) SO-8	125	°C/W
$R_{thjc}$	Thermal resistance junction to case <sup>(5)</sup> (6) SO-8	40	°C/W
$T_j$	Maximum junction temperature	160	°C
ESD	HBM: human body model <sup>(7)</sup>	5	kV
	MM: machine model <sup>(8)</sup>	400	V
	CDM: charged device model <sup>(9)</sup>	1500	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 1.5k $\Omega$  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  $\Omega$ ). 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 ( $V_{CC+} - V_{CC-}$ )	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 +150	°C

## 2 Electrical characteristics

**Table 3. Electrical characteristics at  $V_{CC+} = +2.5\text{ V}$  with  $V_{CC-} = 0\text{ V}$ ,  $V_{icm} = V_{CC}/2$ ,  $R_L$  connected to  $V_{CC}/2$ ,  $T = 25^\circ\text{C}$  (unless otherwise specified)**

Symbol	Parameter	Conditions	Min.	Typ.	Max.	Unit
<b>DC performance</b>						
$V_{io}$	Input offset voltage	TSV912H, $T=25^\circ\text{C}$ TSV912H, $T_{min} < T < T_{max}$		0.1	4.5 7.5	mV
		TSV912AH, $T=25^\circ\text{C}$ TSV912AH, $T_{min} < T < T_{max}$			1.5 3	
$DV_{io}/DT$	Input offset voltage drift	$-40^\circ\text{C} < T < +125^\circ\text{C}$ $+125^\circ\text{C} < T < +150^\circ\text{C}$		2 20		$\mu\text{V}/^\circ\text{C}$
$I_{io}$	Input offset current	$V_{out} = V_{CC}/2$ $T=25^\circ\text{C}$ $T_{min} < T < T_{max}$		1	$10^{(1)}$ 5	pA nA
$I_{ib}$	Input bias current	$V_{out} = V_{CC}/2$ $T=25^\circ\text{C}$ $T_{min} < T < T_{max}$		1	$10^{(1)}$ 5	pA nA
CMR	Common mode rejection ratio $20 \log (\Delta V_{ic}/\Delta V_{io})$	$0\text{V}$ to $2.5\text{V}$ , $V_{out} = 1.25\text{V}$ $T=25^\circ\text{C}$ $T_{min} < T < T_{max}$	58 53	75		dB
$A_{vd}$	Large signal voltage gain	$R_L = 10\text{k}\Omega$ , $V_{out} = 0.5\text{V}$ to $2\text{V}$ $T=25^\circ\text{C}$ $T_{min} < T < T_{max}$	80 70	89		dB
$V_{CC}-V_{OH}$	High level output voltage	$R_L = 10\text{k}\Omega$ , $T=25^\circ\text{C}$ $R_L = 10\text{k}\Omega$ , $T_{min} < T < T_{max}$		15	40 60	mV
		$R_L = 600\Omega$ , $T=25^\circ\text{C}$ $R_L = 600\Omega$ , $T_{min} < T < T_{max}$		45	150 250	
$V_{OL}$	Low level output voltage	$R_L = 10\text{k}\Omega$ , $T=25^\circ\text{C}$ $R_L = 10\text{k}\Omega$ , $T_{min} < T < T_{max}$		15	40 60	mV
		$R_L = 600\Omega$ , $T=25^\circ\text{C}$ $R_L = 600\Omega$ , $T_{min} < T < T_{max}$		45	150 250	
$I_{out}$	$I_{sink}$	$V_{out} = 2.5\text{V}$ $T=25^\circ\text{C}$ $T_{min} < T < T_{max}$	18 14	32		mA
	$I_{source}$	$V_{out} = 0\text{V}$ $T=25^\circ\text{C}$ $T_{min} < T < T_{max}$	18 14	35		
$I_{CC}$	Supply current (per operator)	No load, $V_{out} = V_{CC}/2$ $T=25^\circ\text{C}$ $T_{min} < T < T_{max}$		0.78	1.1 1.1	mA
<b>AC performance</b>						
GBP	Gain bandwidth product	$R_L = 2\text{k}\Omega$ , $C_L = 100\text{pF}$ , $f = 100\text{kHz}$ $T=25^\circ\text{C}$ $T_{min} < T < T_{max}$		8 4		MHz

**Table 3. Electrical characteristics at  $V_{CC+} = +2.5\text{ V}$  with  $V_{CC-} = 0\text{ V}$ ,  $V_{icm} = V_{CC}/2$ ,  $R_L$  connected to  $V_{CC}/2$ ,  $T = 25^\circ\text{C}$  (unless otherwise specified) (continued)**

Symbol	Parameter	Conditions	Min.	Typ.	Max.	Unit
$F_u$	Unity gain frequency	$R_L = 2\text{k}\Omega$ , $C_L = 100\text{pF}$		7.2		MHz
$\phi_m$	Phase margin	$R_L = 2\text{k}\Omega$ , $C_L = 100\text{pF}$		45		Degrees
$G_m$	Gain margin	$R_L = 2\text{k}\Omega$ , $C_L = 100\text{pF}$		8		dB
SR	Slew rate	$R_L = 2\text{k}\Omega$ , $C_L = 100\text{pF}$ , $A_v = 1$ $T = 25^\circ\text{C}$ $T_{\min} < T < T_{\max}$		4.5 3.5		V/ $\mu\text{s}$
$e_n$	Equivalent input noise voltage	$f = 10\text{kHz}$		21		$\frac{\text{nV}}{\sqrt{\text{Hz}}}$
THD+ $e_n$	Total harmonic distortion	$G = 1$ , $f = 1\text{kHz}$ , $R_L = 2\text{k}\Omega$ , $Bw = 22\text{kHz}$ , $V_{icm} = (V_{CC} + 1)/2$ , $V_{out} = 1.1V_{pp}$		0.001		%

1. Guaranteed by design.

**Table 4. Electrical characteristics at  $V_{CC+} = +3.3\text{ V}$  with  $V_{CC-} = 0\text{ V}$ ,  $V_{icm} = V_{CC}/2$ ,  $R_L$  connected to  $V_{CC}/2$ ,  $T = 25^\circ\text{C}$  (unless otherwise specified)**

Symbol	Parameter	Conditions	Min.	Typ.	Max.	Unit
<b>DC performance</b>						
$V_{io}$	Input offset voltage	TSV912H, $T = 25^\circ\text{C}$		0.1	4.5	mV
		TSV912H, $T_{\min} < T < T_{\max}$			7.5	
		TSV912AH, $T = 25^\circ\text{C}$			1.5	
		TSV912AH, $T_{\min} < T < T_{\max}$			3	
$DV_{io}$	Input offset voltage drift	$-40^\circ\text{C} < T < +125^\circ\text{C}$ $+125^\circ\text{C} < T < +150^\circ\text{C}$		2 20		$\mu\text{V}/^\circ\text{C}$
$I_{io}$	Input offset current	$V_{out} = V_{CC}/2$ $T = 25^\circ\text{C}$ $T_{\min} < T < T_{\max}$		1	$10^{(1)}$ 5	pA nA
$I_{ib}$	Input bias current	$V_{out} = V_{CC}/2$ $T = 25^\circ\text{C}$ $T_{\min} < T < T_{\max}$		1	$10^{(1)}$ 5	pA nA
CMR	Common mode rejection ratio $20 \log (\Delta V_{ic}/\Delta V_{io})$	$0\text{V}$ to $3.3\text{V}$ , $V_{out} = 1.65\text{V}$ $T = 25^\circ\text{C}$ $T_{\min} < T < T_{\max}$	60 55	78		dB
$A_{vd}$	Large signal voltage gain	$R_L = 10\text{k}\Omega$ , $V_{out} = 0.5\text{V}$ to $2.8\text{V}$ $T = 25^\circ\text{C}$ $T_{\min} < T < T_{\max}$	80 70	90		dB
$V_{CC} - V_{OH}$	High level output voltage	$R_L = 10\text{k}\Omega$ , $T = 25^\circ\text{C}$		15	40	mV
		$R_L = 10\text{k}\Omega$ , $T_{\min} < T < T_{\max}$			60	
		$R_L = 600\Omega$ , $T = 25^\circ\text{C}$		45	150	
		$R_L = 600\Omega$ , $T_{\min} < T < T_{\max}$			250	

**Table 4. Electrical characteristics at  $V_{CC+} = +3.3\text{ V}$  with  $V_{CC-} = 0\text{ V}$ ,  $V_{icm} = V_{CC}/2$ ,  $R_L$  connected to  $V_{CC}/2$ ,  $T = 25^\circ\text{C}$  (unless otherwise specified) (continued)**

Symbol	Parameter	Conditions	Min.	Typ.	Max.	Unit
$V_{OL}$	Low level output voltage	$R_L = 10\text{k}\Omega$ , $T=25^\circ\text{C}$ $R_L = 10\text{k}\Omega$ , $T_{min} < T < T_{max}$  $R_L = 600\Omega$ , $T=25^\circ\text{C}$ $R_L = 600\Omega$ , $T_{min} < T < T_{max}$		15  45	40 60 150 250	mV
$I_{out}$	$I_{sink}$	$V_{out} = 3.3\text{V}$ $T=25^\circ\text{C}$ $T_{min} < T < T_{max}$	18 14	32		mA
	$I_{source}$	$V_{out} = 0\text{V}$ $T=25^\circ\text{C}$ $T_{min} < T < T_{max}$	18 14	35		
$I_{CC}$	Supply current (per operator)	No load, $V_{out} = V_{CC}/2$ $T=25^\circ\text{C}$ $T_{min} < T < T_{max}$		0.8	1.1 1.1	mA
<b>AC performance</b>						
GBP	Gain bandwidth product	$R_L = 2\text{k}\Omega$ , $C_L = 100\text{pF}$ , $f = 100\text{kHz}$ , $T=25^\circ\text{C}$ $T_{min} < T < T_{max}$		8 4.2		MHz
$F_u$	Unity gain frequency	$R_L = 2\text{k}\Omega$ , $C_L = 100\text{pF}$		7.2		MHz
$\phi_m$	Phase margin	$R_L = 2\text{k}\Omega$ , $C_L = 100\text{pF}$		45		Degrees
$G_m$	Gain margin	$R_L = 2\text{k}\Omega$ , $C_L = 100\text{pF}$		8		dB
SR	Slew rate	$R_L = 2\text{k}\Omega$ , $C_L = 100\text{pF}$ , $A_v = 1$ , $T=25^\circ\text{C}$ $T_{min} < T < T_{max}$		4.5 3.5		V/ $\mu\text{s}$
$e_n$	Equivalent input noise voltage	$f = 10\text{kHz}$		21		$\frac{\text{nV}}{\sqrt{\text{Hz}}}$
THD+ $e_n$	Total harmonic distortion	$G=1$ , $f=1\text{kHz}$ , $R_L=2\text{k}\Omega$ , $BW=22\text{kHz}$ , $V_{icm}=(V_{CC+1})/2$ , $V_{out}=1.9V_{pp}$		0.0007		%

1. Guaranteed by design.

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

Symbol	Parameter	Conditions	Min.	Typ.	Max.	Unit
<b>DC performance</b>						
$V_{io}$	Input offset voltage	TSV912H, $T=25^{\circ}\text{C}$ TSV912H, $T_{\min} < T < T_{\max}$		0.1	4.5 7.5	mV
		TSV912AH, $T=25^{\circ}\text{C}$ TSV912AH, $T_{\min} < T < T_{\max}$			1.5 3	
$DV_{io}$	Input offset voltage drift	$-40^{\circ}\text{C} < T < +125^{\circ}\text{C}$ $+125^{\circ}\text{C} < T < +150^{\circ}\text{C}$		2 20		$\mu\text{V}/^{\circ}\text{C}$
$I_{io}$	Input offset current	$V_{out} = V_{CC}/2$ $T=25^{\circ}\text{C}$ $T_{\min} < T < T_{\max}$		1	$10^{(1)}$ 5	pA nA
$I_{ib}$	Input bias current	$V_{out} = V_{CC}/2$ $T=25^{\circ}\text{C}$ $T_{\min} < T < T_{\max}$		1	$10^{(1)}$ 5	pA nA
CMR	Common mode rejection ratio $20 \log (\Delta V_{ic}/\Delta V_{io})$	$0\text{V}$ to $5\text{V}$ , $V_{out} = 2.5\text{V}$ $T=25^{\circ}\text{C}$ $T_{\min} < T < T_{\max}$	62 58	82		dB
SVR	Supply voltage rejection ratio $20 \log (\Delta V_{CC}/\Delta V_{io})$	$V_{CC} = 2.5$ to $5\text{V}$ $T=25^{\circ}\text{C}$ $T_{\min} < T < T_{\max}$	70 65	86		dB
$A_{vd}$	Large signal voltage gain	$R_L = 10\text{k}\Omega$ , $V_{out} = 0.5\text{V}$ to $4.5\text{V}$ $T=25^{\circ}\text{C}$ $T_{\min} < T < T_{\max}$	80 70	91		dB
$V_{CC}-V_{OH}$	High level output voltage	$R_L = 10\text{k}\Omega$ , $T=25^{\circ}\text{C}$ $R_L = 10\text{k}\Omega$ , $T_{\min} < T < T_{\max}$  $R_L = 600\Omega$ , $T=25^{\circ}\text{C}$ $R_L = 600\Omega$ , $T_{\min} < T < T_{\max}$		15  45	40 60 150 250	mV
$V_{OL}$	Low level output voltage	$R_L = 10\text{k}\Omega$ , $T=25^{\circ}\text{C}$ $R_L = 10\text{k}\Omega$ , $T_{\min} < T < T_{\max}$  $R_L = 600\Omega$ , $T=25^{\circ}\text{C}$ $R_L = 600\Omega$ , $T_{\min} < T < T_{\max}$		15  45	40 60 150 250	mV
$I_{out}$	$I_{sink}$	$V_{out} = 5\text{V}$ $T=25^{\circ}\text{C}$ $T_{\min} < T_{op} < T_{\max}$	18 14	32		mA
	$I_{source}$	$V_{out} = 0\text{V}$ $T=25^{\circ}\text{C}$ $T_{\min} < T_{op} < T_{\max}$	18 14	35		
$I_{CC}$	Supply current (per operator)	No load, $V_{out} = 2.5\text{V}$ $T=25^{\circ}\text{C}$ $T_{\min} < T_{op} < T_{\max}$		0.82	1.1 1.1	mA

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

Symbol	Parameter	Conditions	Min.	Typ.	Max.	Unit
<b>AC performance</b>						
GBP	Gain bandwidth product	$R_L = 2\text{k}\Omega$ , $C_L = 100\text{pF}$ , $f = 100\text{kHz}$ $T = 25^\circ\text{C}$ $T_{\min} < T_{\text{op}} < T_{\max}$		8 4.5		MHz
$F_u$	Unity gain frequency	$R_L = 2\text{k}\Omega$ , $C_L = 100\text{pF}$		7.5		MHz
$\phi_m$	Phase margin	$R_L = 2\text{k}\Omega$ , $C_L = 100\text{pF}$		45		Degrees
$G_m$	Gain margin	$R_L = 2\text{k}\Omega$ , $C_L = 100\text{pF}$		8		dB
SR	Slew rate	$R_L = 2\text{k}\Omega$ , $C_L = 100\text{pF}$ , $A_V = 1$ $T = 25^\circ\text{C}$ $T_{\min} < T_{\text{op}} < T_{\max}$		4.5 3.5		V/ $\mu\text{s}$
$e_n$	Equivalent input noise voltage	$f = 1\text{kHz}$ $f = 10\text{kHz}$		27 21		$\frac{\text{nV}}{\sqrt{\text{Hz}}}$
THD+ $e_n$	Total harmonic distortion	$G = 1$ , $f = 1\text{kHz}$ , $R_L = 2\text{k}\Omega$ , $BW = 22\text{kHz}$ , $V_{icm} = (V_{CC+} + 1)/2$ , $V_{\text{out}} = 3.6V_{\text{pp}}$		0.0004		%

1. Guaranteed by design.

Figure 1. Input offset voltage distribution at  $T = 25^{\circ}\text{C}$

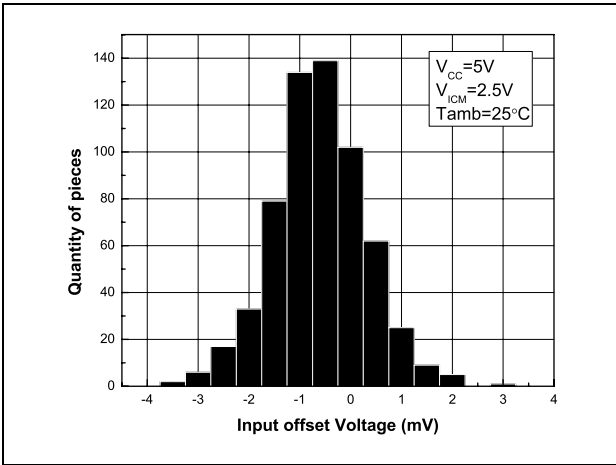


Figure 2. Input offset voltage distribution at  $T = 150^{\circ}\text{C}$

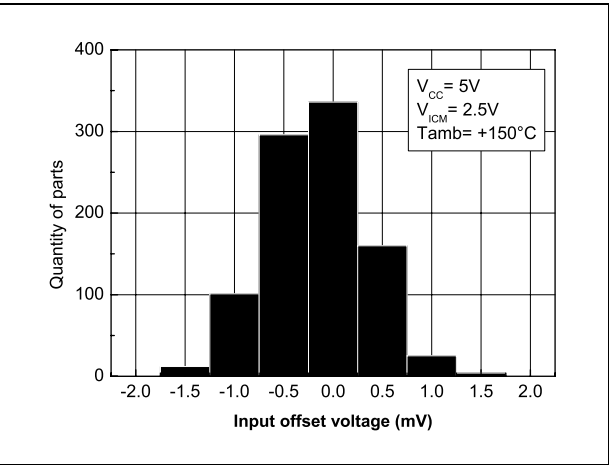


Figure 3. Supply current vs. input common-mode voltage at  $V_{CC} = 2.5\text{V}$

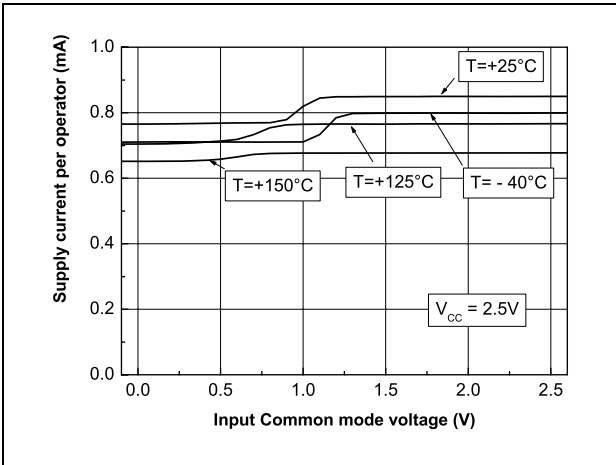


Figure 4. Supply current vs. input common-mode voltage at  $V_{CC} = 5\text{V}$

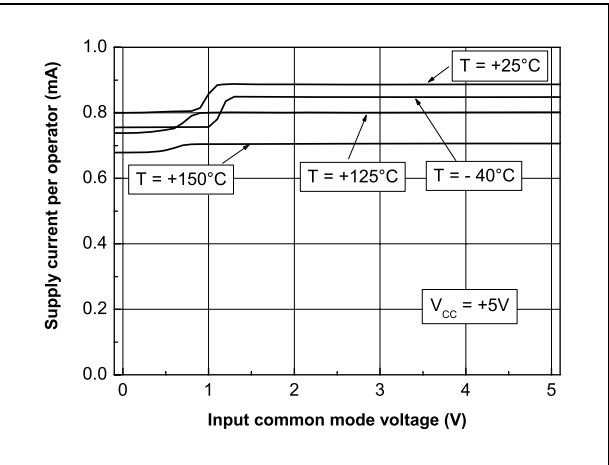


Figure 5. Output current vs. output voltage at  $V_{CC} = 2.5\text{V}$

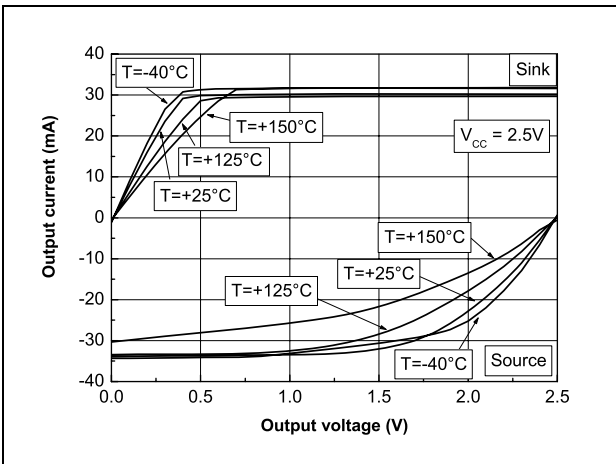
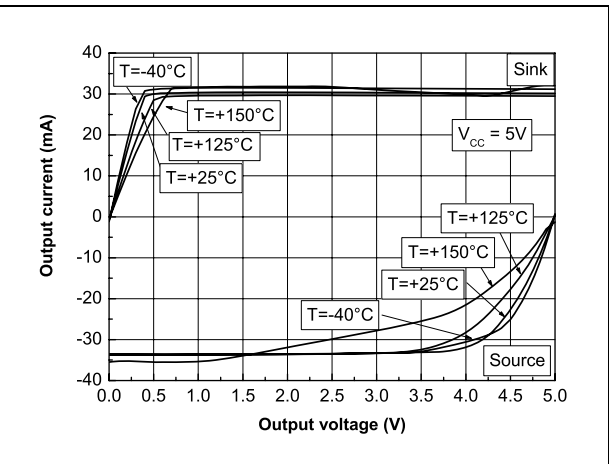
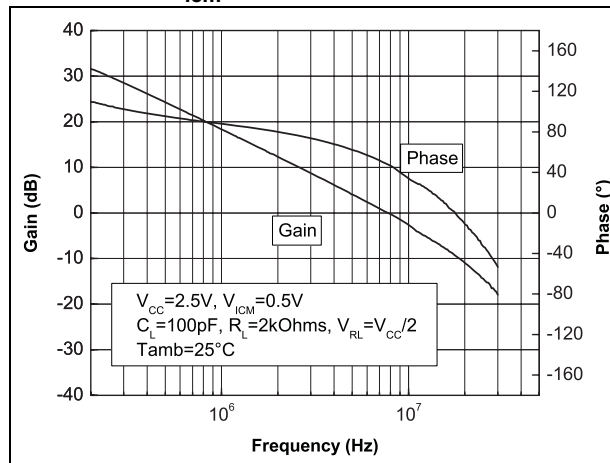


Figure 6. Output current vs. output voltage at  $V_{CC} = 5\text{V}$

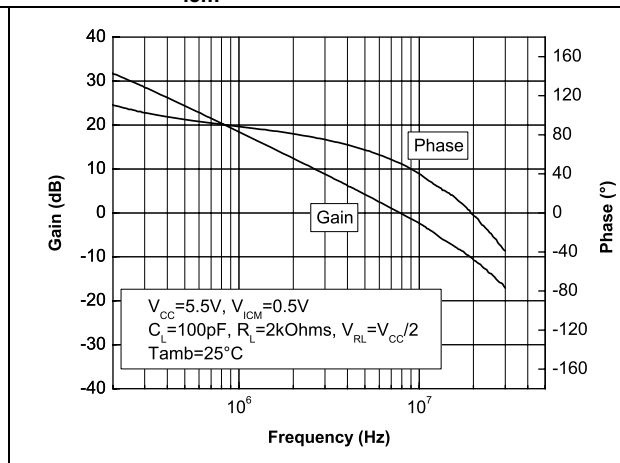




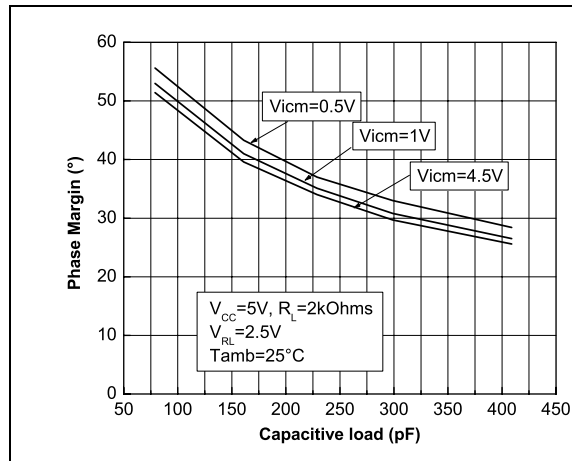
**Figure 7. Voltage gain and phase vs frequency at  $V_{CC} = 2.5\text{ V}$  and  $V_{icm} = 0.5\text{ V}$**



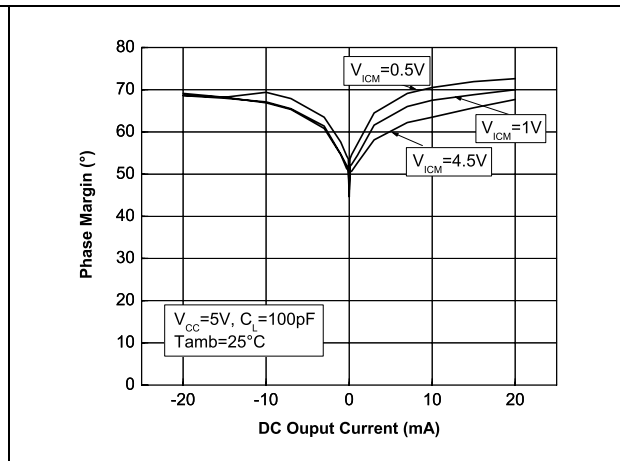
**Figure 8. Voltage gain and phase vs frequency at  $V_{CC} = 5.5\text{ V}$  and  $V_{icm} = 0.5\text{ V}$**



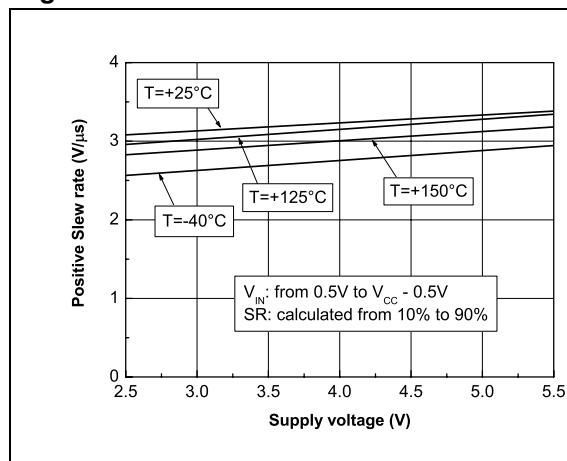
**Figure 9. Phase margin vs. capacitive load**



**Figure 10. Phase margin vs. output current**



**Figure 11. Positive slew rate**



**Figure 12. Negative slew rate**

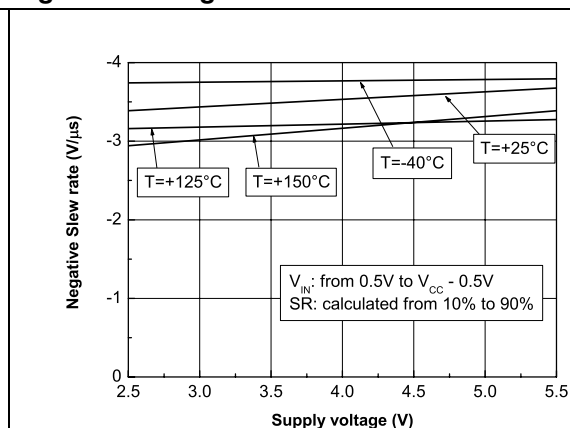


Figure 13. Distortion + noise vs. frequency

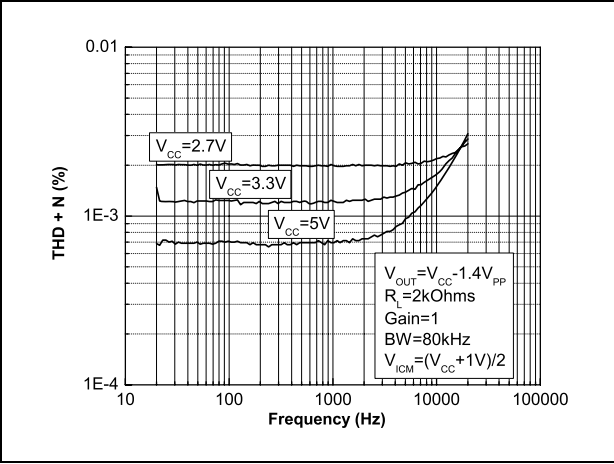


Figure 14. Distortion + noise vs. output voltage

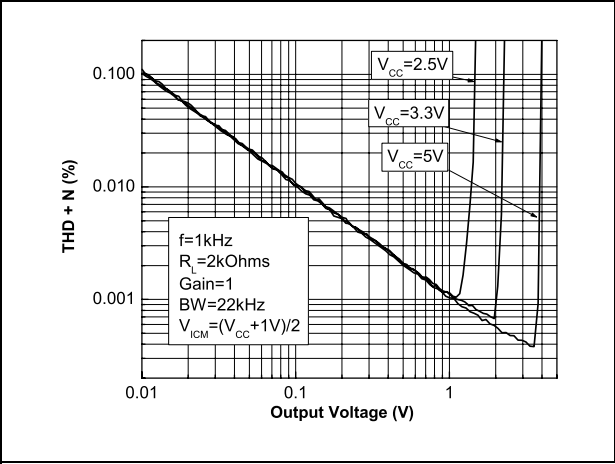


Figure 15. Noise vs. frequency

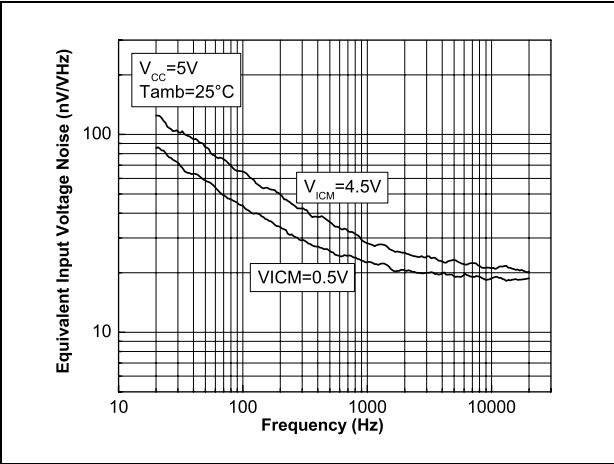


Figure 16. Phase margin vs. capacitive load and serial resistor

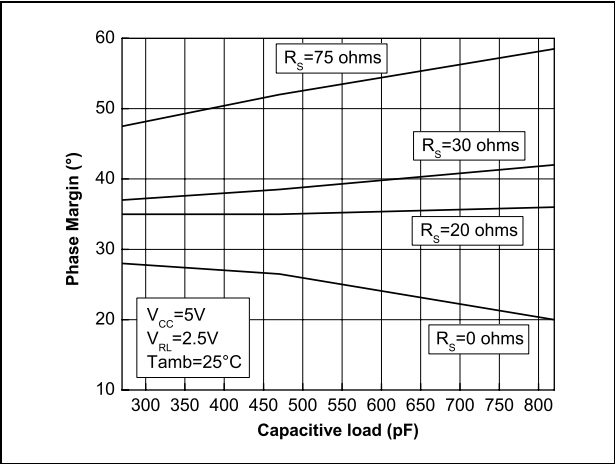
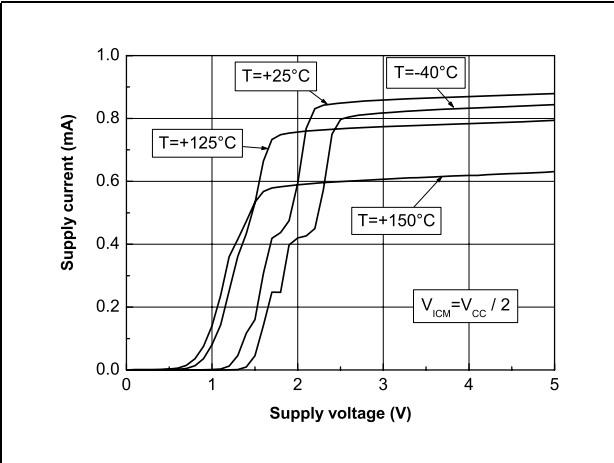


Figure 17. Supply current vs. supply voltage



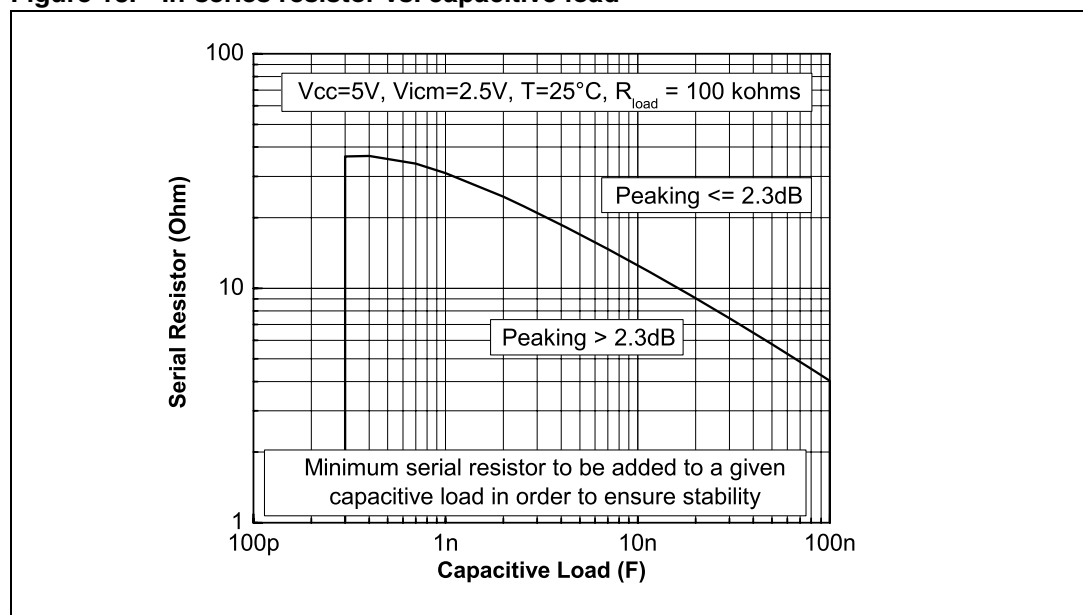
## 3 Application information

### 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 k $\Omega$

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 devices (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.

## 4 Package information

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

## 4.1 SO-8 package information

Figure 19. SO-8 package mechanical drawing

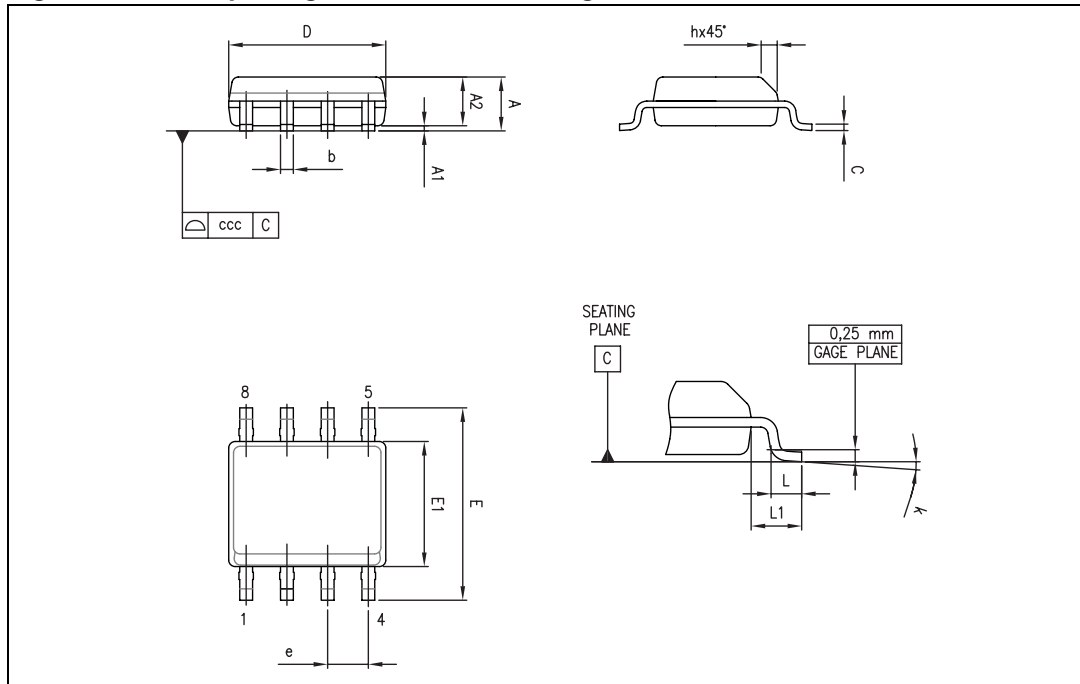


Table 6. SO-8 package mechanical data

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

## 5 Ordering information

**Table 7. Order codes**

Order code	Temperature range	Package	Packing	Marking
TSV912HYDT <sup>(1)</sup>	-40°C to +150°C	SO-8 <sup>(2)</sup> (automotive grade level)	Tape & reel	V912HY
TSV912AHYDT <sup>(1)</sup>				V912AHY

1. Qualification and characterization according to AEC Q100 and Q003 or equivalent, advanced screening according to AEC Q001 & Q 002 or equivalent.
2. SO8 package is Moisture Sensitivity Level 1 as per Jedec J-STD-020-C.

## 6 Revision history

**Table 8. Document revision history**

Date	Revision	Changes
08-Jul-2010	1	Initial release.

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