LM2904, LM2904A

Low-power dual operational amplifier

Features

- Internally frequency-compensated
- Large DC voltage gain: 100 dB
- Wide bandwidth (unity gain): 1.1 MHz (temperature compensated)
- Very low supply current/amplifier, essentially independent of supply voltage
- Low input bias current: 20 nA (temperature compensated)
- Low input offset current: 2 nA
- Input common-mode voltage range includes negative rail
- Differential input voltage range equal to the power supply voltage
- Large output voltage swing 0 V to (V_{CC+} -1.5 V)

Description

This circuit consists of two independent, high gain, internally frequency-compensated operational amplifiers designed specifically for automotive and industrial control systems. It operates from a single power supply over a wide range of voltages. The low power supply drain is independent of the magnitude of the power supply voltage.

Application areas include transducer amplifiers, DC gain blocks and all the conventional op-amp circuits which can now be more easily implemented in single power supply systems. For example, these circuits can be directly supplied from the standard +5 V which is used in logic systems and easily provides the required interface electronics without requiring any additional power supply.

In the linear mode, the input common-mode voltage range includes ground and the output voltage can also swing to ground, even though operated from a single power supply.

N
DIP8
(Plastic package)

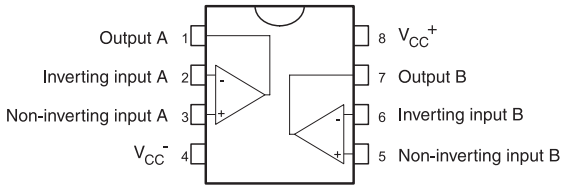
D
SO-8
(Plastic micropackage)

P
TSSOP8
(Thin shrink small outline package)

S
MiniSO-8

Q2
DFN8 2 x 2 mm
(Plastic micropackage)

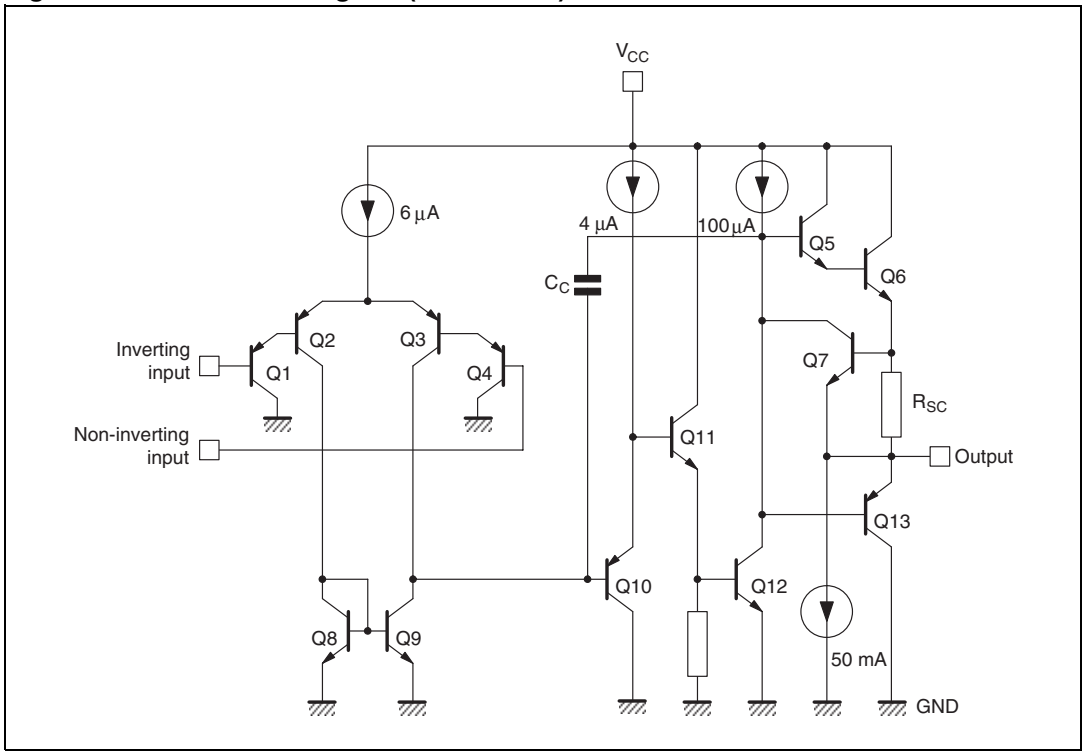
Pin connections (top view)



Contents

1 Schematic diagram

Figure 1. Schematic diagram (1/2 LM2904)



2 Absolute maximum ratings and operating conditions

Table 1. Absolute maximum ratings

Symbol	Parameter	Value	Unit
V_{CC}	Supply voltage (1)	±16 or 32	V
V_{id}	Differential input voltage(2)	±32	V
V_{in}	Input voltage	-0.3 to 32	V
	Output short-circuit duration (3)	Infinite	s
I_{in}	Input current (4): V_{in} driven negative Input current (5): V_{in} driven positive above AMR value	5 mA in DC or 50 mA in AC (duty cycle = 10%, T = 1s) 0.4	mA
T_{oper}	Operating free-air temperature range	-40 to +125	°C
T_{stg}	Storage temperature range	-65 to +150	°C
T_j	Maximum junction temperature	150	°C
R_{thja}	Thermal resistance junction to ambient(6) SO-8 TSSOP8 DIP8 MiniSO-8 DFN8 2x2	 125 120 85 190 57	°C/W
R_{thjc}	Thermal resistance junction to case(6) SO-8 TSSOP8 DIP8 MiniSO-8	 40 37 41 39	°C/W
ESD	HBM: human body model(7)	300	V
	MM: machine model(8)	200	V
	CDM: charged device model(9)	1.5	kV

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. Short-circuits from the output to V_{CC} can cause excessive heating if V_{cc+} > 15 V. The maximum output current is approximately 40 mA, independent of the magnitude of V_{CC}.
Destructive dissipation can result from simultaneous short-circuits on all amplifiers.
4. This input current only exists when the voltage at any of the input leads is driven negative. It is due to the collector-base junction of the input PNP transistor becoming forward-biased and thereby acting as input diode clamp. In addition to this diode action, there is NPN parasitic action on the IC chip. This transistor action can cause the output voltages of the Op-amps to go to the V_{CC} voltage level (or to ground for a large overdrive) for the time during which an input is driven negative. This is not destructive and normal output is restored for input voltages above -0.3 V.
5. The junction base/substrate of the input PNP transistor polarized in reverse must be protected by a resistor in series with the inputs to limit the input current to 400 µA max (R = (Vin-32 V)/400 µA).
6. Short-circuits can cause excessive heating and destructive dissipation. Values are typical.
7. Human body model: a 100 pF capacitor is charged to the specified voltage, then discharged through a 1.5 kΩ 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	3 to 30	V
V_{icm}	Common mode input voltage range	0 to V_{CC+} - 1.5	V
T_{oper}	Operating free-air temperature range	-40 to +125	°C

3 Electrical characteristics

Table 3. V_{CC+} = 5 V, V_{CC-} = ground, V_O = 1.4 V, T_{amb} = 25° C (unless otherwise specified)

Symbol	Parameter	Min.	Typ.	Max.	Unit
V_{io}	Input offset voltage (1) T_{amb} = 25° C LM2904 T_{amb} = 25° C LM2904A $T_{min} \le T_{amb} \le T_{max}$ LM2904 $T_{min} \le T_{amb} \le T_{max}$ LM2904A		 2 1	 7 2 9 4	mV
DV_{io}	Input offset voltage drift		7	30	µV/°C
I_{io}	Input offset current T_{amb} = 25° C $T_{min} \le T_{amb} \le T_{max}$		2	 30 40	nA
DI_{io}	Input offset current drift		10	300	pA/°C
I_{ib}	Input bias current (2) T_{amb} = 25° C $T_{min} \le T_{amb} \le T_{max}$		20	 150 200	nA
A_{vd}	Large signal voltage gain V_{CC+} = +15 V, R_L = 2 kΩ, V_o = 1.4 V to 11.4 V T_{amb} = 25° C $T_{min} \le T_{amb} \le T_{max}$	 50 25	 100		V/mV
SVR	Supply voltage rejection ratio (R_S ≤10 kΩ) T_{amb} = 25° C $T_{min} \le T_{amb} \le T_{max}$	 65 65	 100		dB
I_{CC}	Supply current, all amp, no load T_{amb} = 25°C, V_{CC+} = +5 V $T_{min} \le T_{amb} \le T_{max}$, V_{CC+} = +30 V		0.7	1.2 2	mA
V_{icm}	Input common mode voltage range (V_{CC+}= +30 V) (3) T_{amb} = 25° C $T_{min} \le T_{amb} \le T_{max}$	0 0		V_{CC+} -1.5 V_{CC+} -2	V
CMR	Common-mode rejection ratio (R_S = 10 kΩ) T_{amb} = 25° C $T_{min} \le T_{amb} \le T_{max}$	 70 60	 85		dB
I_{source}	Output short-circuit current V_{CC+} = +15 V, V_o = +2 V, V_{id} = +1 V	20	40	60	mA
I_{sink}	Output sink current V_O = 2 V, V_{CC+} = +5 V V_O = +0.2 V, V_{CC+} = +15 V	 10 12	 20 50		mA µA
V_{OH}	High level output voltage (V_{CC+} = + 30 V) T_{amb} = +25° C, R_L = 2 kΩ $T_{min} \le T_{amb} \le T_{max}$ T_{amb} = +25° C, R_L = 10 kΩ $T_{min} \le T_{amb} \le T_{max}$	 26 26 27 27	 27 28		V

Table 3. V_{CC+} = 5 V, V_{CC-} = ground, V_O = 1.4 V, T_{amb} = 25° C (unless otherwise specified) (continued)

Symbol	Parameter	Min.	Typ.	Max.	Unit
V_{OL}	Low level output voltage (R_L = 10 kΩ) T_{amb} = +25° C $T_{min} \le T_{amb} \le T_{max}$		5	20 20	mV
SR	Slew rate V_{CC+} = 15 V, V_{in} = 0.5 to 3 V, R_L = 2 kΩ, C_L =100 pF, unity gain $T_{min} \le T_{amb} \le T_{max}$	0.3 0.2	0.6		V/µs
GBP	Gain bandwidth product f = 100 kHz V_{CC+} = 30 V, V_{in} = 10 mV, R_L = 2 kΩ, C_L = 100 pF	0.7	1.1		MHz
THD	Total harmonic distortion f = 1 kHz, A_V = 20 dB, R_L = 2 kΩ, V_o = 2 V_{pp}, C_L = 100 pF, V_{CC+} = 30 V		0.02		%
e_n	Equivalent input noise voltage f = 1 kHz, R_S = 100 Ω, V_{CC+} = 30 V		55		nV/√Hz
V_{O1}/V_{O2}	Channel separation (4) 1 kHz ≤ f ≤ 20 kHz		120		dB

1. V_O = 1.4 V, R_S = 0 Ω, 5 V < V_{CC+} < 30 V, 0 V < V_{ic} < V_{CC+} - 1.5 V.
2. The direction of the input current is out of the IC. This current is essentially constant, independent of the state of the output, so there is no change in the loading charge on the input lines.
3. The input common-mode voltage of either input signal voltage should not be allowed to go negative by more than 0.3 V. The upper end of the common-mode voltage range is V_{CC+} –1.5 V, but either or both inputs can go to +32 V without damage.
4. Due to the proximity of external components, ensure that the stray capacitance does not cause coupling between these external parts. This can typically be detected at higher frequencies because this type of capacitance increases.

Figure 2. Open-loop frequency response

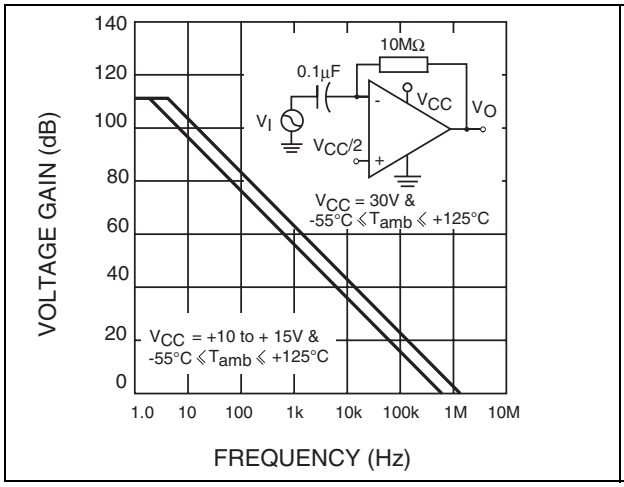


Figure 3. Large signal frequency response

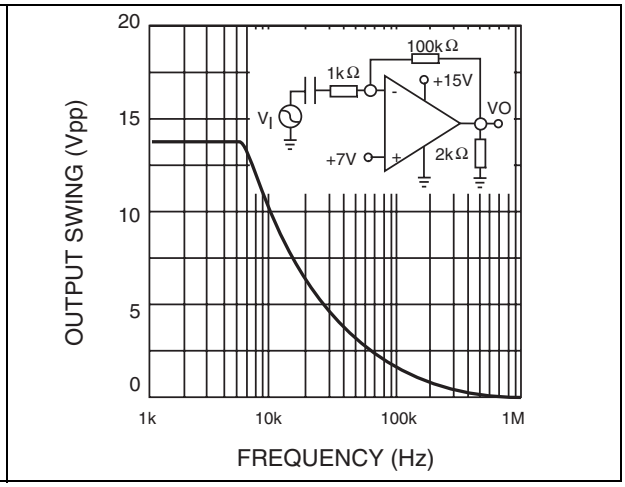


Figure 4. Voltage follower large signal response

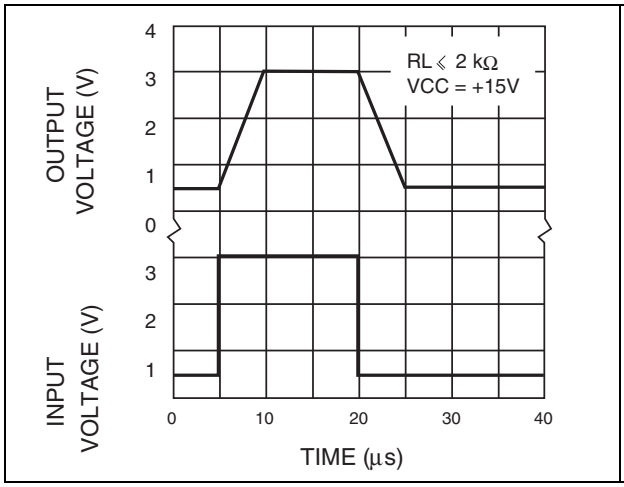


Figure 5. Current sinking output characteristics

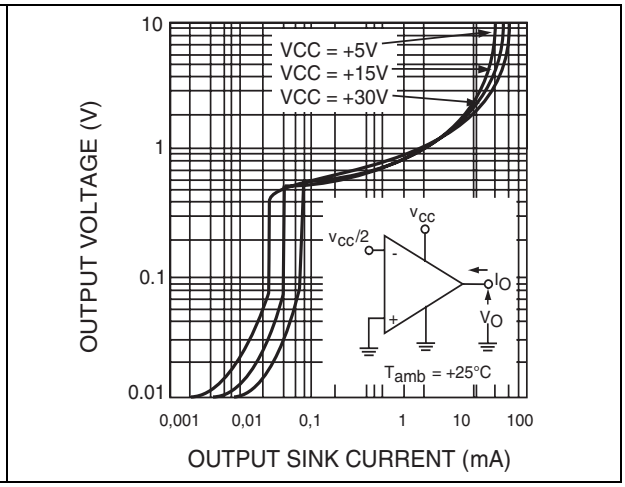


Figure 6. Voltage follower small signal response

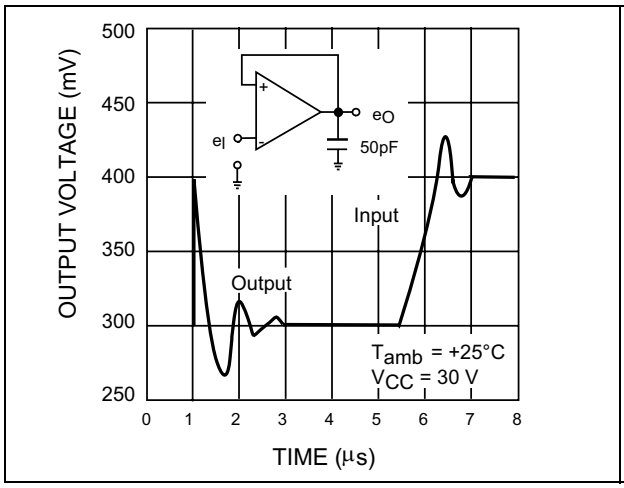


Figure 7. Current sourcing output characteristics

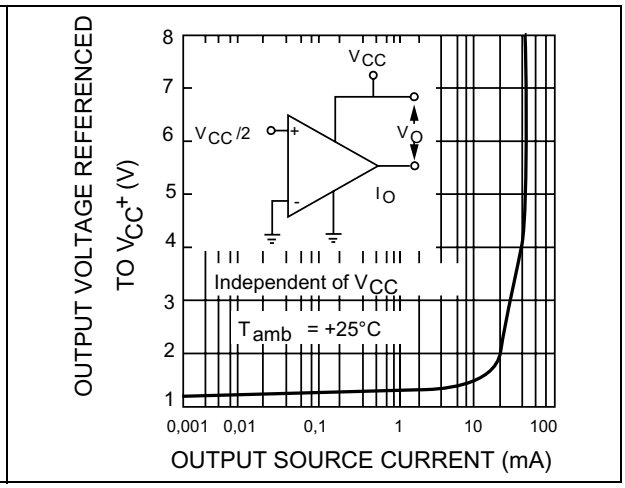


Figure 8. Input current versus temperature

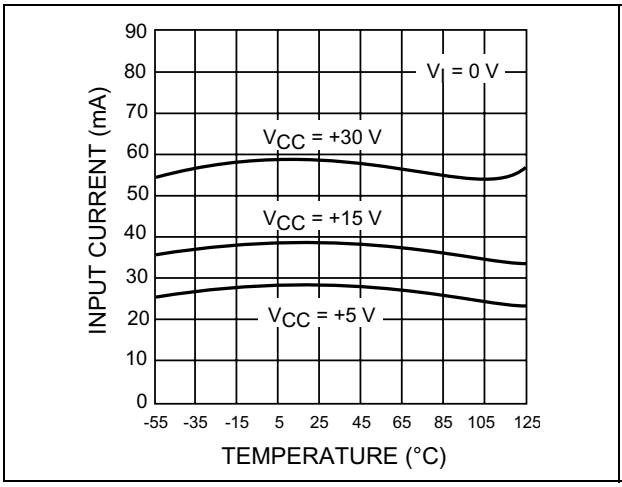


Figure 9. Current limiting

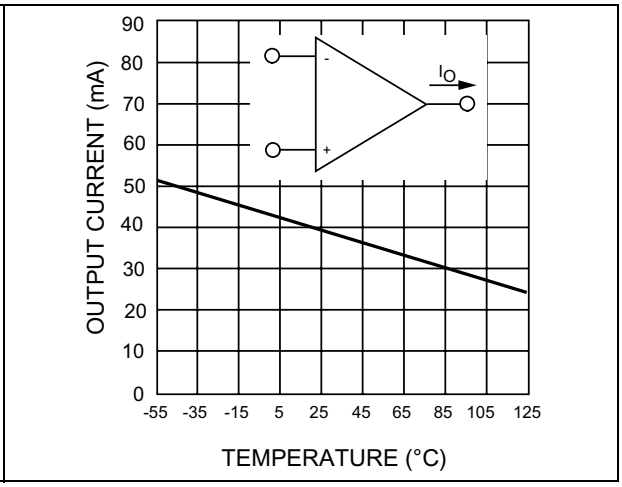


Figure 10. Input voltage range

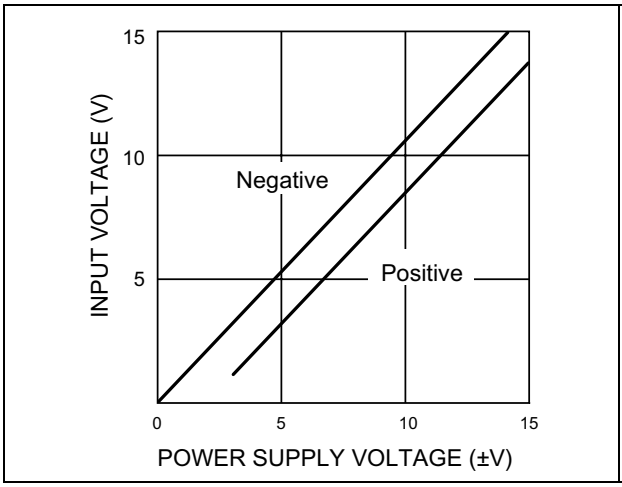


Figure 11. Supply current

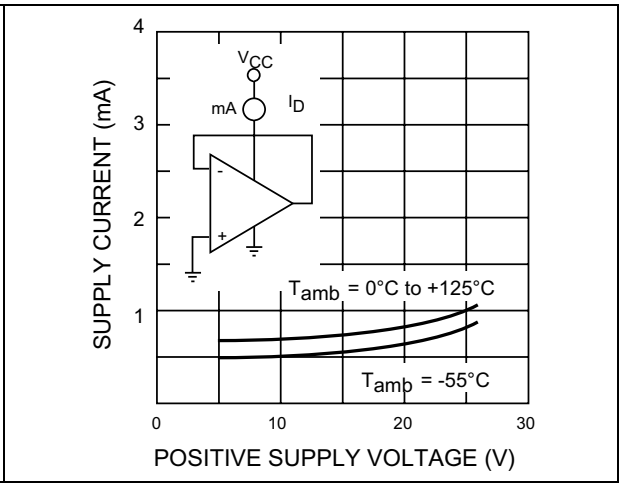


Figure 12. Voltage gain

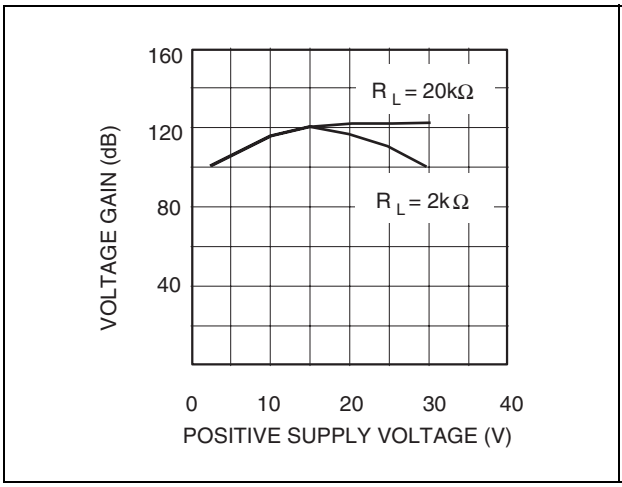


Figure 13. Input current versus supply voltage

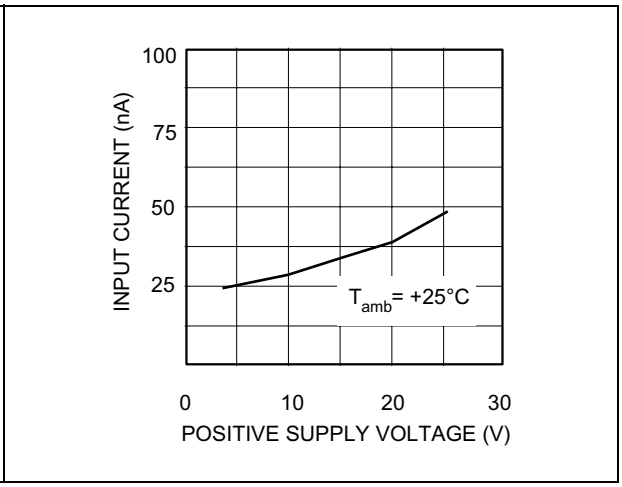


Figure 14. Gain bandwidth product

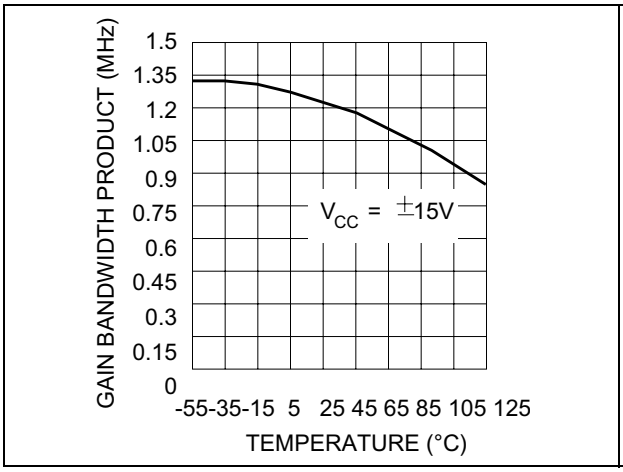


Figure 15. Power supply rejection ratio

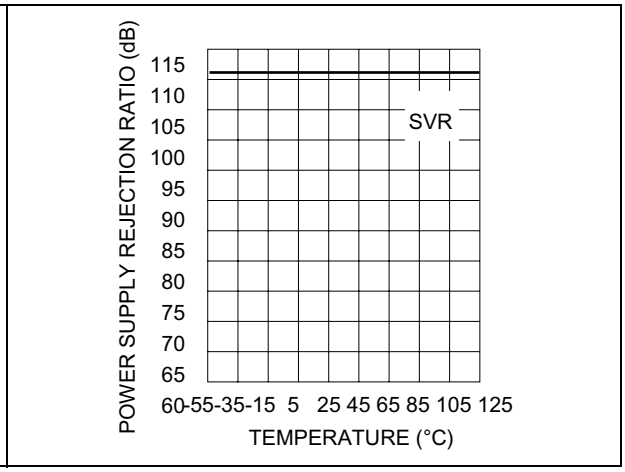


Figure 16. Common-mode rejection ratio

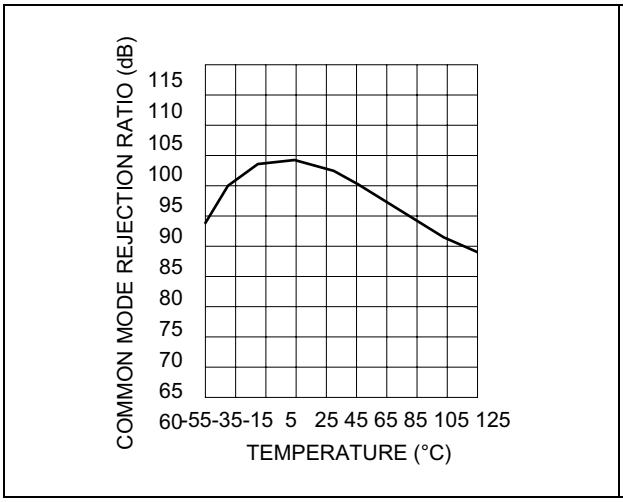
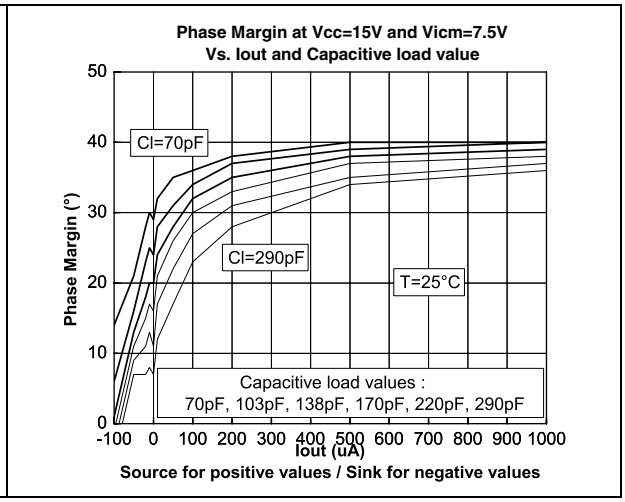


Figure 17. Phase margin vs capacitive load



3.1 Typical single-supply applications

Figure 18. AC coupled inverting amplifier

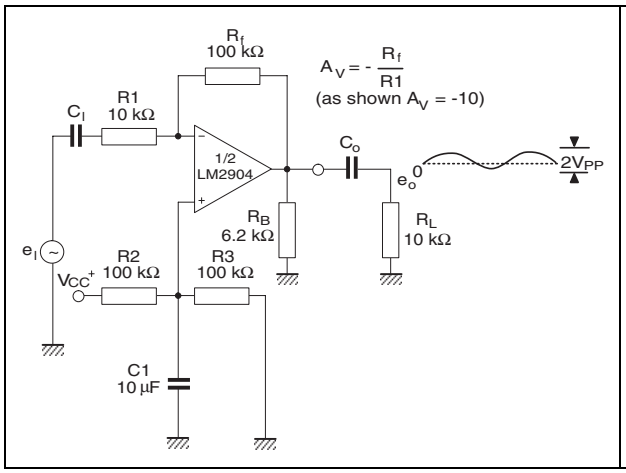


Figure 19. AC coupled non-inverting amplifier

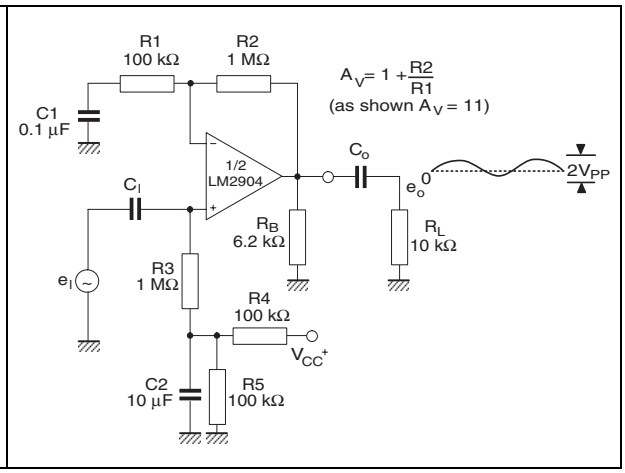


Figure 20. Non-inverting DC gain

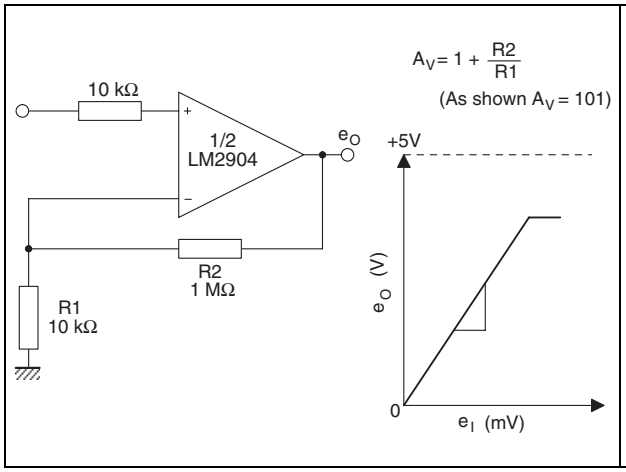


Figure 21. DC summing amplifier

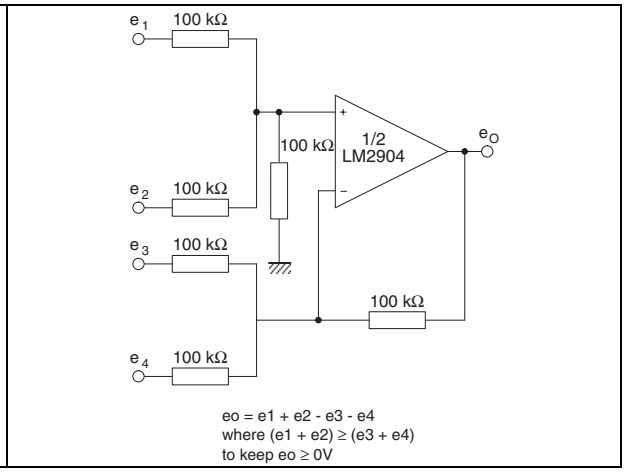


Figure 22. High input Z, DC differential amplifier

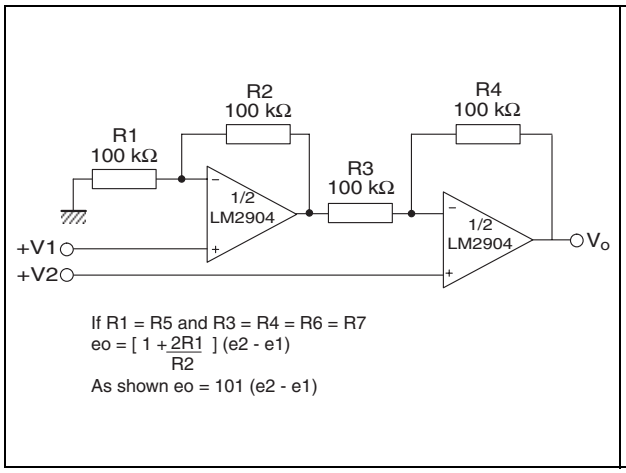


Figure 23. Using symmetrical amplifiers to reduce input current

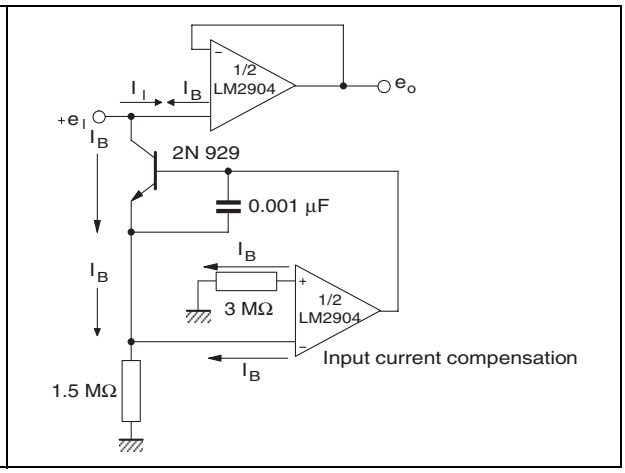


Figure 24. Low drift peak detector

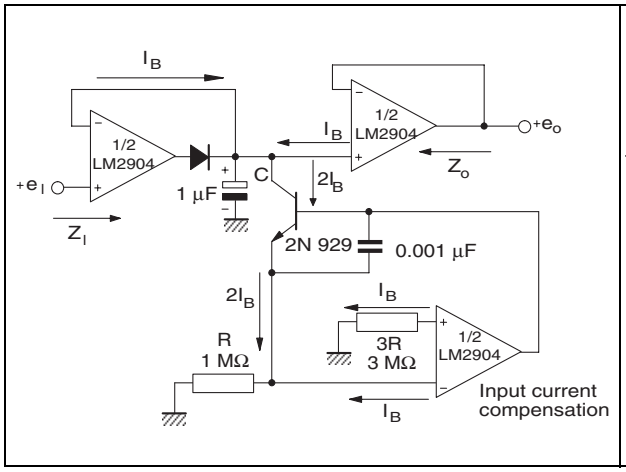
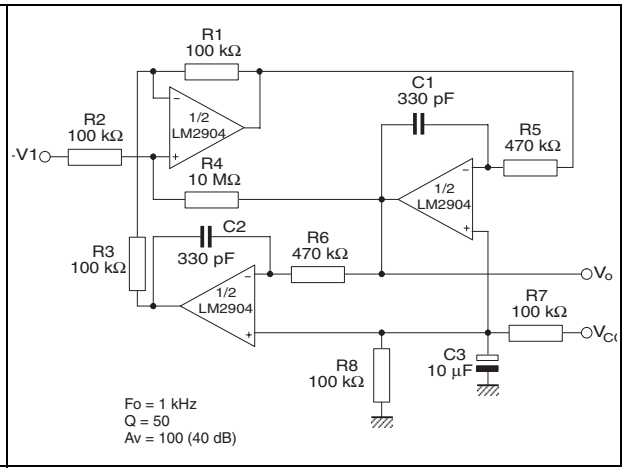


Figure 25. Active bandpass filter



4 Macromodel

An accurate macromodel of the LM2904 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 LM2904 operational amplifier. It emulates the nominal performances of a typical device within the specified operating conditions mentioned in the datasheet. It also helps to validate a design approach and to select the right operational amplifier, *but it does not replace on-board measurements*.

5 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.

5.1 DIP8 package information

Figure 26. DIP8 package mechanical drawing

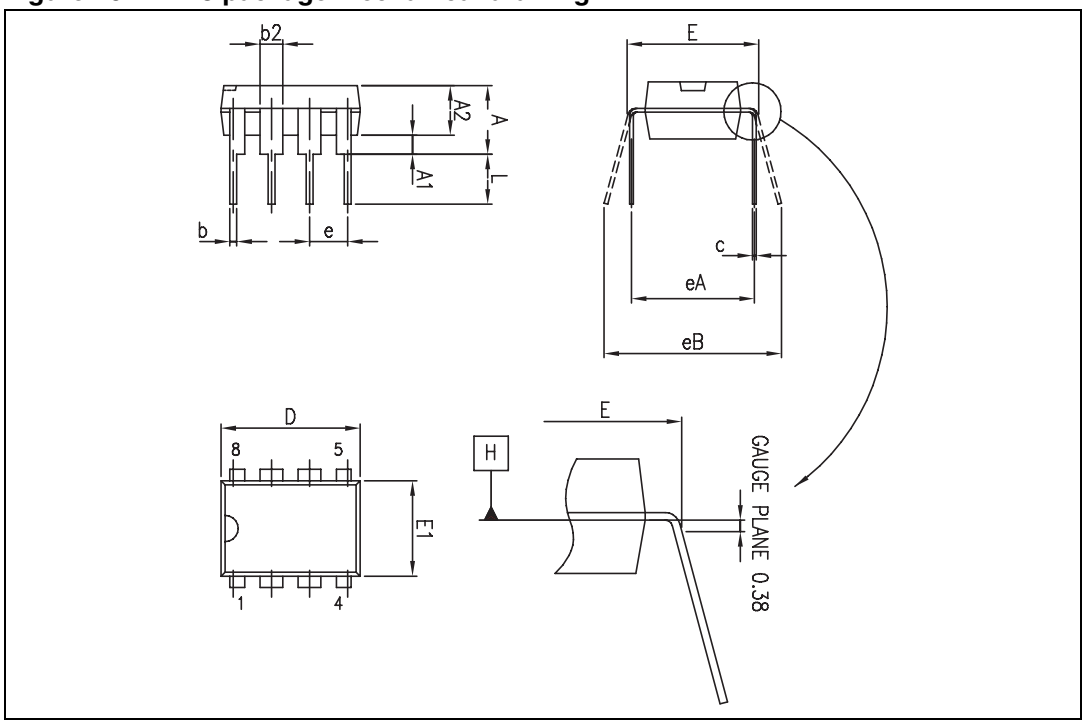


Table 4. DIP8 package mechanical data

Ref.	Dimensions					
	Millimeters			Inches		
	Min.	Typ.	Max.	Min.	Typ.	Max.
A			5.33			0.210
A1	0.38			0.015		
A2	2.92	3.30	4.95	0.115	0.130	0.195
b	0.36	0.46	0.56	0.014	0.018	0.022
b2	1.14	1.52	1.78	0.045	0.060	0.070
c	0.20	0.25	0.36	0.008	0.010	0.014
D	9.02	9.27	10.16	0.355	0.365	0.400
E	7.62	7.87	8.26	0.300	0.310	0.325
E1	6.10	6.35	7.11	0.240	0.250	0.280
e		2.54			0.100	
eA		7.62			0.300	
eB			10.92			0.430
L	2.92	3.30	3.81	0.115	0.130	0.150

5.2 SO-8 package information

Figure 27. SO-8 package mechanical drawing

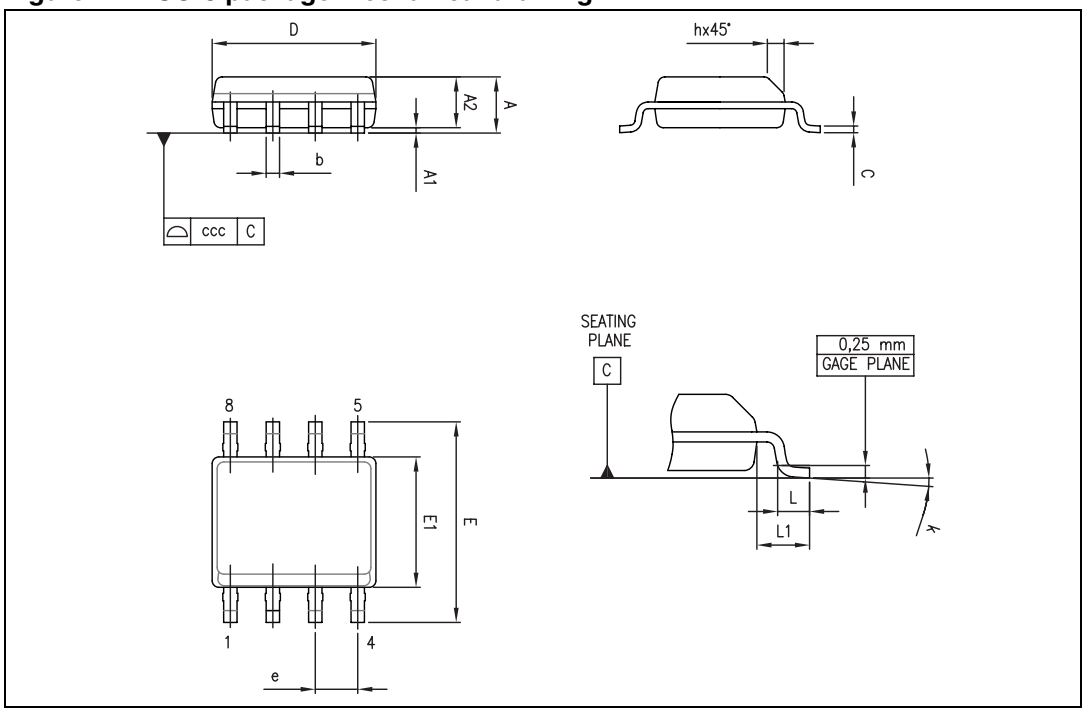


Table 5. SO-8 package mechanical data

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	1°		8°	1°		8°
ccc			0.10			0.004

5.3 DFN8 2 x 2 mm package mechanical data

Figure 28. DFN8 2 x 2 mm package mechanical drawing

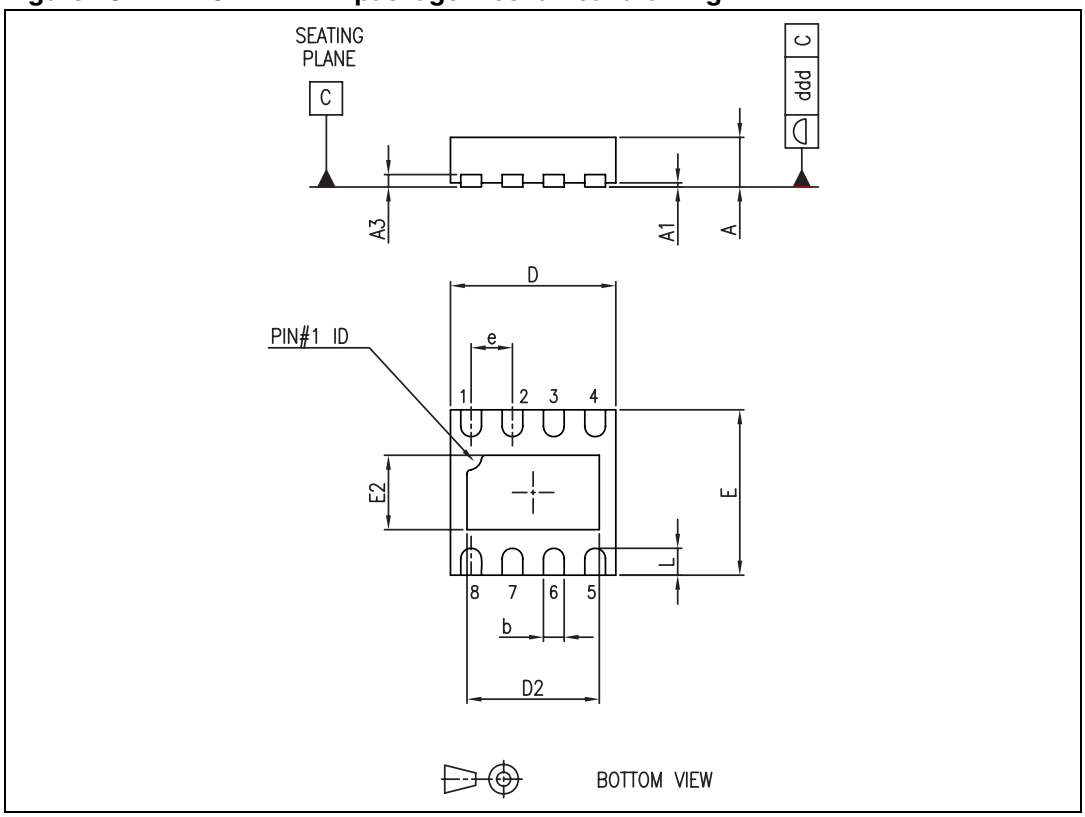
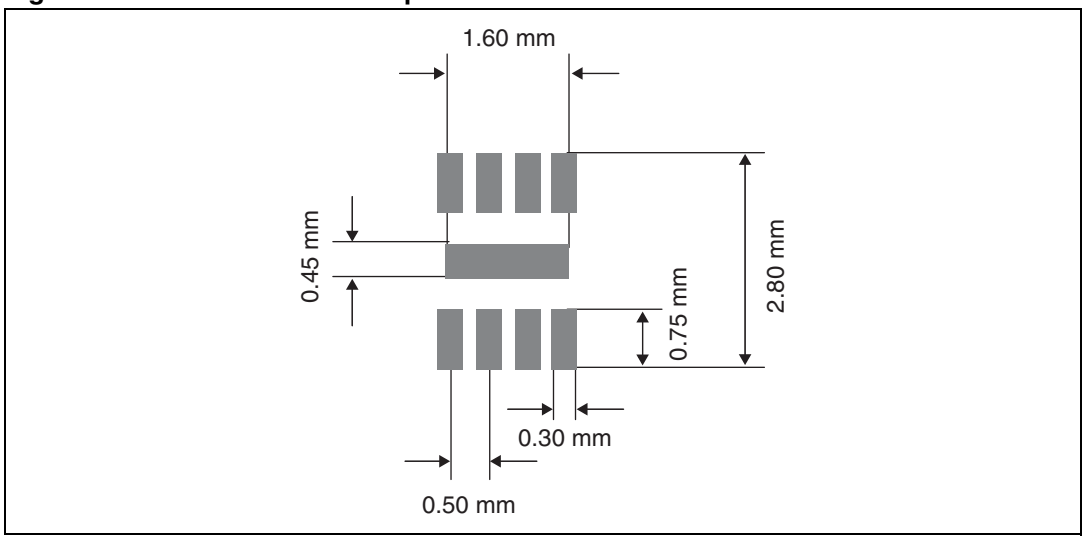


Table 6. DFN8 2 x 2 mm package mechanical data (pitch 0.5 mm)

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			0.50			0.020
ddd			0.08			0.003

Figure 29. DFN8 2 x 2 mm footprint recommendation



5.4 TSSOP8 package information

Figure 30. TSSOP8 package mechanical drawing

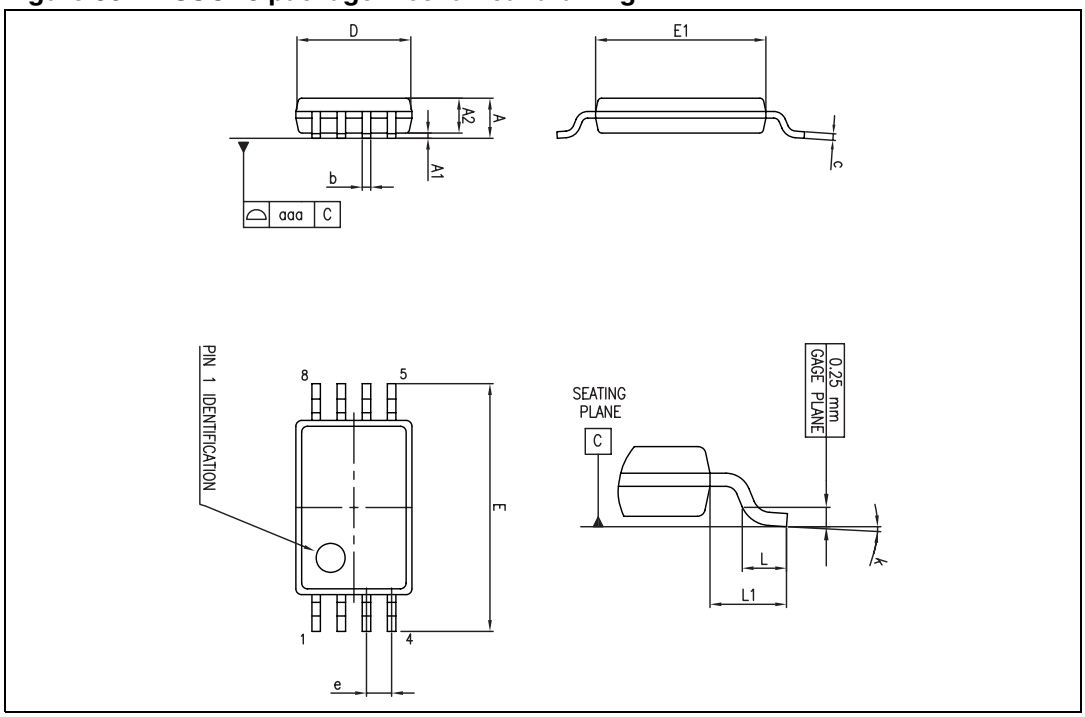


Table 7. TSSOP8 package mechanical data

Ref.	Dimensions					
	Millimeters			Inches		
	Min.	Typ.	Max.	Min.	Typ.	Max.
A			1.20			0.047
A1	0.05		0.15	0.002		0.006
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		0.008
D	2.90	3.00	3.10	0.114	0.118	0.122
E	6.20	6.40	6.60	0.244	0.252	0.260
E1	4.30	4.40	4.50	0.169	0.173	0.177
e		0.65			0.0256	
k	0°		8°	0°		8°
L	0.45	0.60	0.75	0.018	0.024	0.030
L1		1			0.039	
aaa			0.10			0.004

5.5 MiniSO-8 package information

Figure 31. MiniSO-8 package mechanical drawing

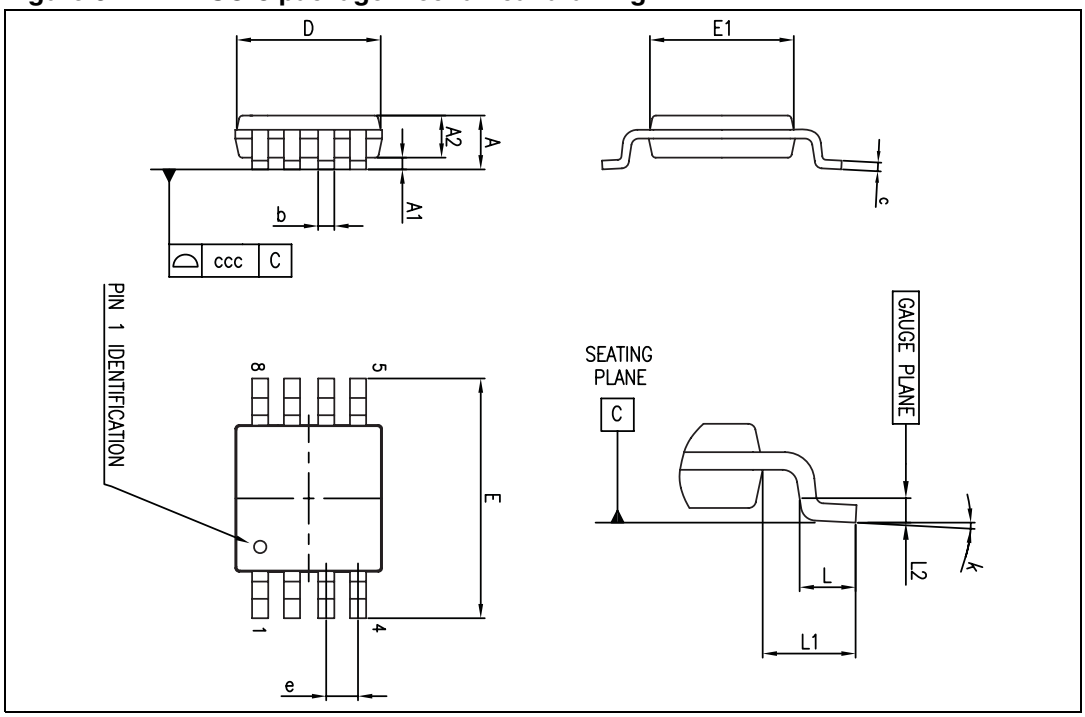


Table 8. MiniSO-8 package mechanical data

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

6 Ordering information

Table 9. Order codes

Order code	Temperature range	Package	Packing	Marking
LM2904N	-40° C to +125° C	DIP8	Tube	LM2904N
LM2904D/DT		SO-8	Tube or tape & reel	2904
LM2904PT		TSSOP8 (thin shrink outline package)	Tape & reel	
LM2904ST		MiniSO-8	Tape & reel	K403
LM2904Q2T		DFN8 2 x 2	Tape & reel	K1Y
LM2904YDT(1)		SO-8 (automotive grade level)	Tape & reel	2904Y
LM2904AYDT(1)				2904AY
LM2904YPT(2)		TSSOP8 (automotive grade level)	Tape & reel	2904Y
LM2904AYPT(2)				2904AY
LM2904YST(1)		MiniSO-8 (automotive grade level)	Tape & reel	K409

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

7 Revision history

Table 10. Document revision history

Date	Revision	Changes
02-Jan-2002	1	Initial release.
20-Jun-2005	2	PPAP references inserted in the datasheet, see *Table 9 on page 21*. ESD protection inserted in *Table 1 on page 4*.
10-Oct-2005	3	PPAP part numbers added in table *Table 9 on page 21*.
12-Dec-2005	4	Pin connections identification added on cover page figure. Thermal resistance junction to case information added see *Table 1 on page 4*.
01-Feb-2006	5	Maximum junction temperature parameter added in *Table 1 on page 4*.
02-May-2006	6	Minimum slew rate parameter in temperature *Table 3 on page 6*.
13-Jul-2006	7	Modified ESD values and added explanation on V_{CC}, V_{id} in *Table 1 on page 4*. Added macromodel information.
28-Feb-2007	8	Modified ESD/HBM values in *Table 1 on page 4*. Updated MiniSO-8 package information. Added note relative to automotive grade level part numbers in *Table 9 on page 21*.
18-Jun-2007	9	Power dissipation value corrected in *Table 1: Absolute maximum ratings*. *Table 2: Operating conditions* added. Equivalent input noise voltage parameter added in *Table 3*. Electrical characteristics curves updated. *Figure 17: Phase margin vs capacitive load* added. *Section 5: Package information* updated.
18-Dec-2007	10	Removed power dissipation parameter from *Table 1: Absolute maximum ratings*. Removed V_{opp} from electrical characteristics in *Table 3*. Corrected MiniSO-8 package mechanical data in *Section 5.5: MiniSO-8 package information*.
08-Apr-2008	11	Added table of contents. Corrected the scale of *Figure 5* (mA not µA). Corrected SO-8 package information.
02-Jun-2009	12	Added input current information in *Table 1: Absolute maximum ratings*. Added L1 parameters in *Table 5: SO-8 package mechanical data*. Added new order codes, LM2904AYD/DT, LM2904AYPT and LM2904AYST in *Table 9: Order codes*.

Table 10. Document revision history (continued)

Date	Revision	Changes
13-Apr-2010	13	Added LM2904A on cover page. Corrected footnote (5) in *Table 1: Absolute maximum ratings*. Removed order code LM2904AYST from *Table 9: Order codes*.
24-Jan-2012	14	Removed macromodel from *Chapter 4* (now available on *www.st.com*). Added DFN8 2 x 2 mm package information in *Chapter 5* and related order codes in *Chapter 6*. Removed LM2904YD and LM2904AYD order codes from *Table 9*. Changed note for LM2904YST order code in *Table 9*.