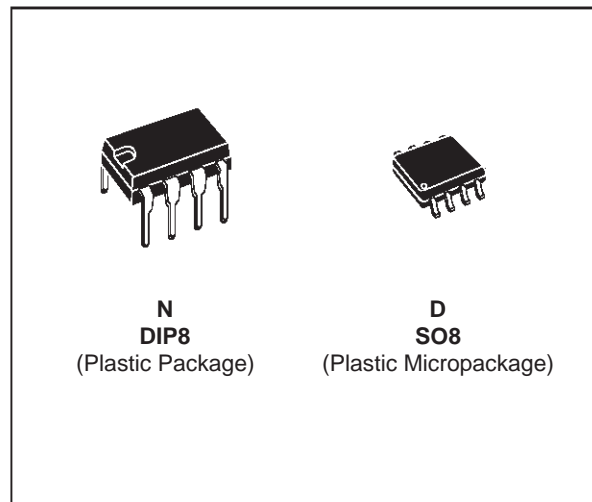


**HIGH PERFORMANCE  
DUAL OPERATIONAL AMPLIFIERS**

- LOW POWER CONSUMPTION
- SHORT CIRCUIT PROTECTION
- LOW DISTORTION, LOW NOISE
- HIGH GAIN-BANDWIDTH PRODUCT
- HIGH CHANNEL SEPARATION



**DESCRIPTION**

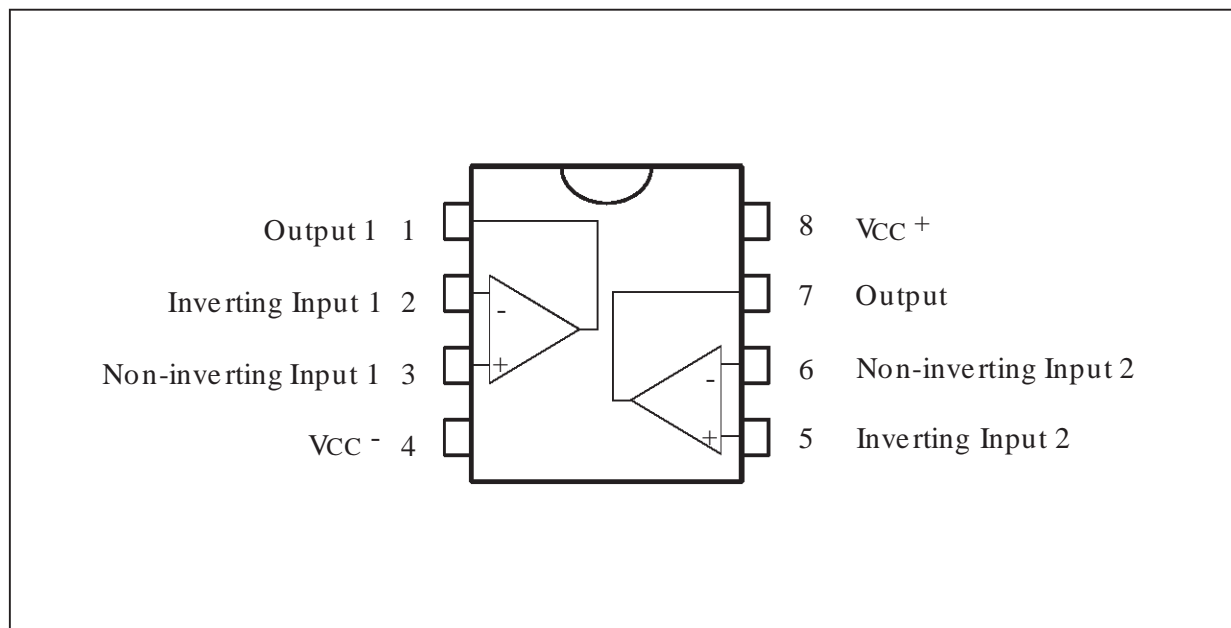
The LS204 is a high performance dual operational amplifier with frequency and phase compensation built into the chip. The internal phase compensation allows stable operation as voltage follower in spite of its high Gain-Bandwidth Product.

The circuit presents very stable electrical characteristics over the entire supply voltage range, and is particularly intended for professional and telecom applications (active filter, etc).

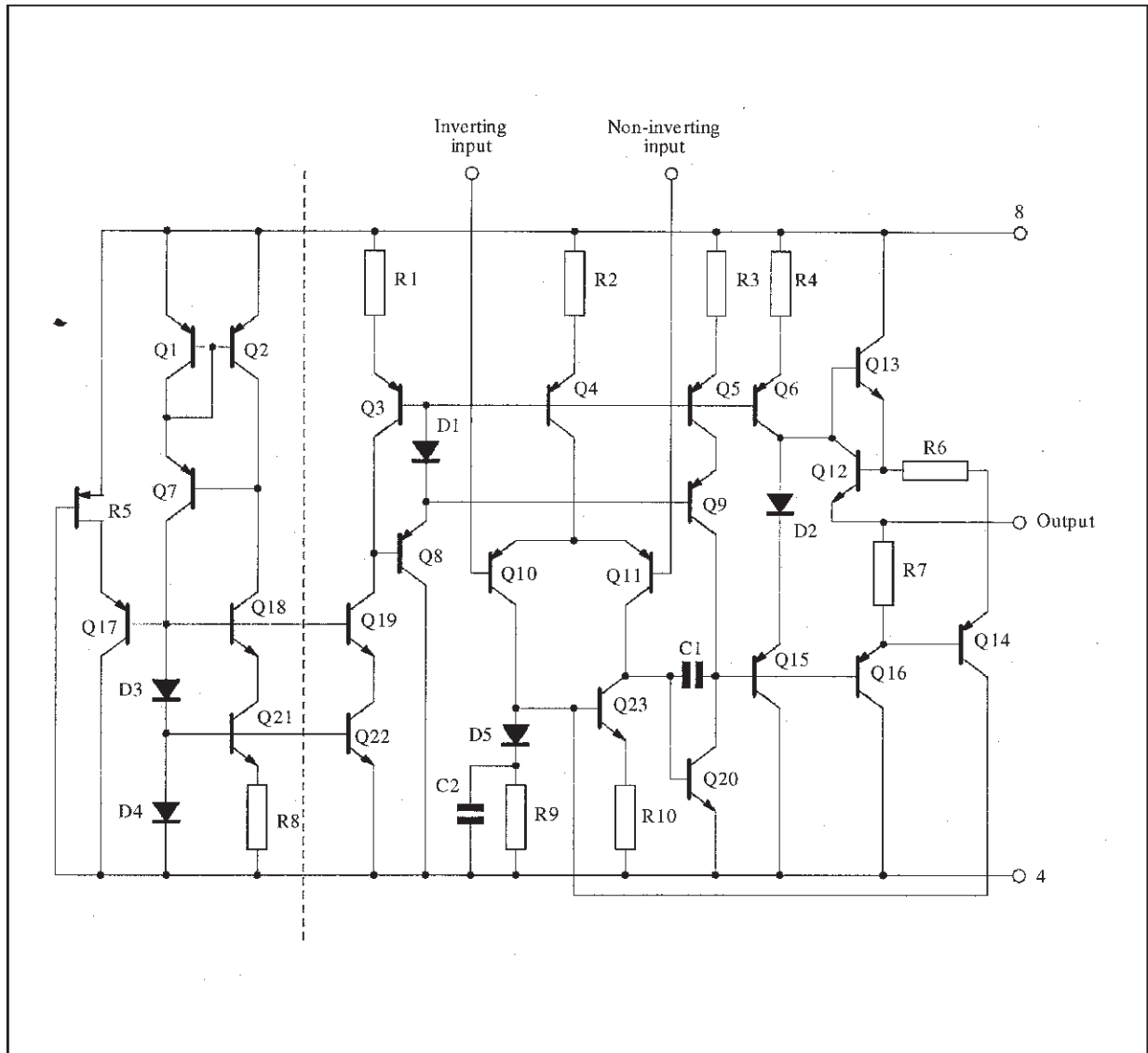
**ORDER CODES**

Part Number	Temperature Range	Package	
		N	D
LS204C	0, +70°C	•	•
LS204I	-40, +105°C	•	•

**PIN CONNECTIONS (top view)**



SCHMATIC DIAGRAM (1/2 LS204)



ABSOLUTE MAXIMUM RATINGS

Symbol	Parameter	Value	Unit
V <sub>CC</sub>	Supply Voltage	±18	V
V <sub>i</sub>	Input Voltage	±V <sub>CC</sub>	
V <sub>id</sub>	Differential Input Voltage	±(V <sub>CC</sub> - 1)	
T <sub>oper</sub>	Operating Temperature Range	LS204C LS204I	°C
P <sub>tot</sub>	Power Dissipation at T <sub>amb</sub> = 70°C	500	mW
T <sub>j</sub>	Junction Temperature	150	°C
T <sub>stg</sub>	Storage Temperature Range	-65 to +150	°C

**ELECTRICAL CHARACTERISTICS** ( $V_{CC} = \pm 15V$ ,  $T_{amb} = 25^{\circ}C$ , unless otherwise specified)

Symbol	Parameter	Test Conditions	LS204I			LS204C			Unit
			Min.	Typ.	Max.	Min.	Typ.	Max.	
$I_{CC}$	Supply Current			0.7	1.2		0.8	1.5	mA
$I_{ib}$	Input Bias Current			50	150		100	300	nA
		$T_{min.} < T_{op} < T_{max.}$			300			700	nA
$R_i$	Input Resistance	$f = 1kHz$		1			1		$M\Omega$
$V_{io}$	Input Offset Voltage	$R_S \leq 10k\Omega$		0.5	2.5		0.5	3.5	mV
		$R_S \leq 10k\Omega$ $T_{min.} < T_{op} < T_{max.}$			3.5			5	mV
$DV_{io}$	Input Offset Voltage Drift	$R_S \leq 10k\Omega$ $T_{min.} < T_{op} < T_{max.}$		2			2		$\mu V/^{\circ}C$
$I_{io}$	Input Offset Current			5	20		12	50	nA
		$T_{min.} < T_{op} < T_{max.}$			40			100	nA
$DI_{io}$	Input Offset Current Drift	$T_{min.} < T_{op} < T_{max.}$		0.08			0.1		$\frac{nA}{^{\circ}C}$
$I_{os}$	Output Short Circuit Current			23			23		mA
$A_{vd}$	Large Signal Voltage Gain	$T_{min.} < T_{op} < T_{max.}$ $R_L = 2k\Omega$ $V_{CC} = \pm 15V$ $V_{CC} = \pm 4V$	90	100 95		86	100 95		dB
GBP	Gain-Bandwidth Product	$f = 100kHz$	1.8	3		1.5	2.5		MHz
$e_n$	Equivalent Input Noise Voltage	$f = 1kHz$ $R_S = 50\Omega$ $R_S = 1k\Omega$ $R_S = 10k\Omega$		8 10 18	15		10 12 20		$\frac{nV}{\sqrt{Hz}}$
THD	Total Harmonic Distortion	$A_V = 20dB$ $R_L = 2k\Omega$ $V_O = 2V_{PP}$ $f = 1kHz$		0.03	0.1		0.03	0.1	%
$\pm V_{opp}$	Output Voltage Swing	$R_L = 2k\Omega$ $V_{CC} = \pm 15V$ $V_{CC} = \pm 4V$	$\pm 13$	$\pm 3$		$\pm 13$	$\pm 3$		V
$V_{opp}$	Large Signal Voltage Swing	$R_L = 10k\Omega$ $f = 10kHz$		28			28		$V_{PP}$
SR	Slew Rate	Unity Gain, $R_L = 2k\Omega$	0.8	1.5			1		$V/\mu s$
CMR	Common Mode Rejection Ratio	$V_{ic} = 10V$ $T_{min.} < T_{op} < T_{max.}$	90			86			dB
SVR	Supply Voltage Rejection Ratio	$V_{ic} = 1V$ $f = 100Hz$ $T_{min.} < T_{op} < T_{max.}$	90			86			dB
$V_{O1}/V_{O2}$	Channel Separation	$f = 1kHz$	100	120			120		dB

Figure 1 : Supply Current versus Supply Voltage

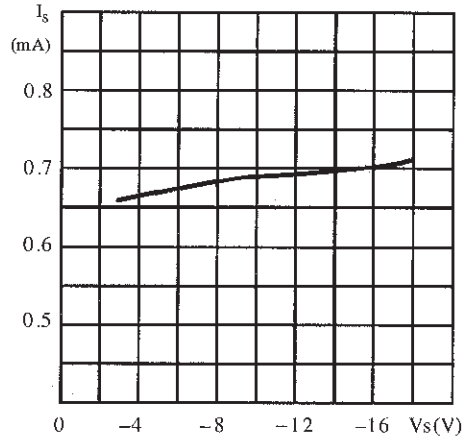


Figure 2 : Supply Current versus Ambient Temperature

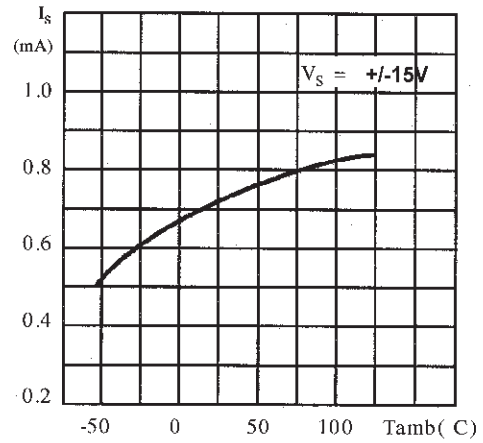


Figure 3 : Output Short Circuit Current versus Ambient Temperature

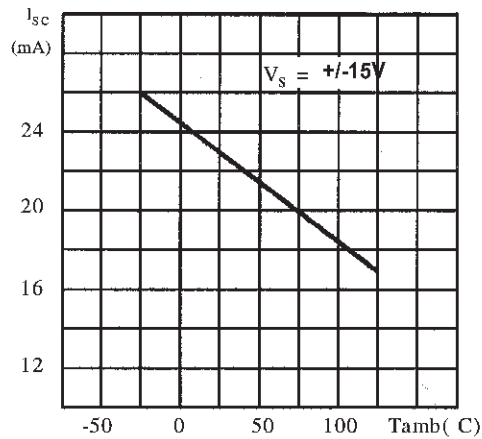


Figure 4 : Open Loop Frequency and Phase Response

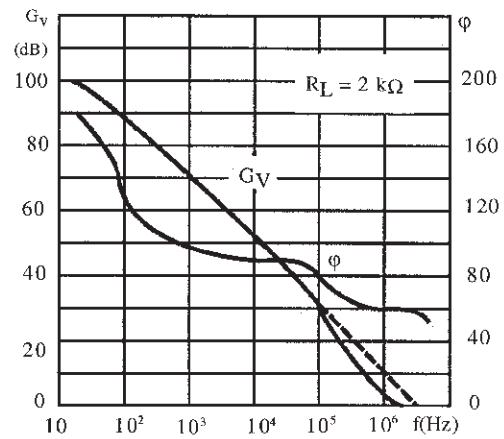


Figure 5 : Output Loop Gain versus Ambient Temperature

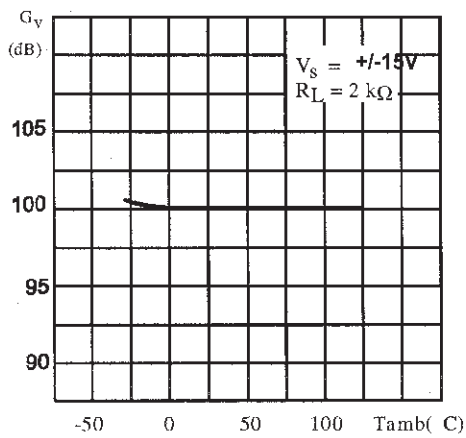


Figure 6 : Supply Voltage Rejection versus Frequency

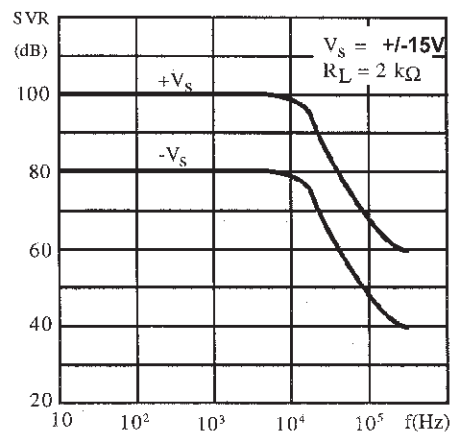


Figure 7 : Large Signal Frequency Response

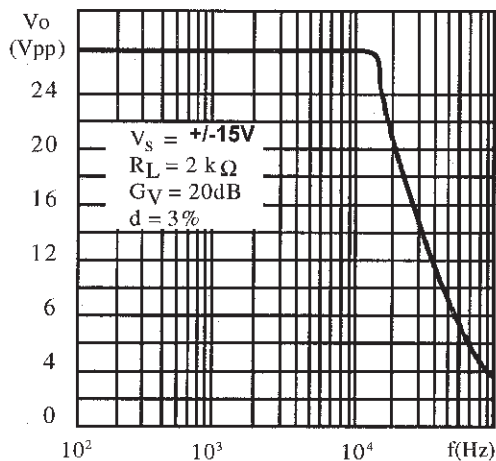


Figure 8 : Output Voltage Swing versus Load Resistance

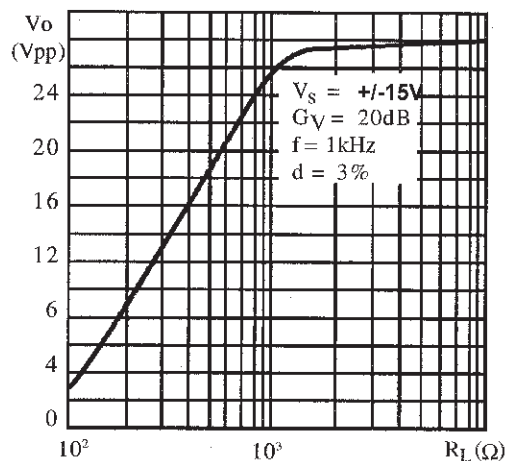


Figure 9 : Total Input Noise versus Frequency

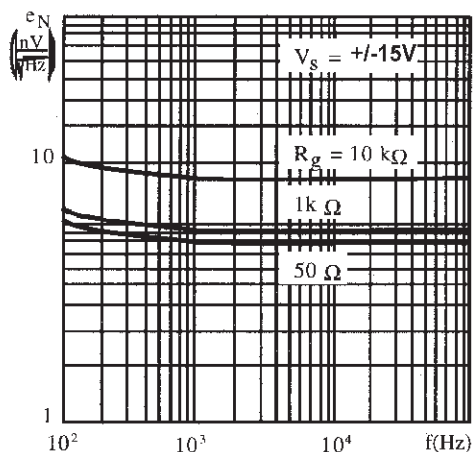


Figure 10 : Amplitude Response

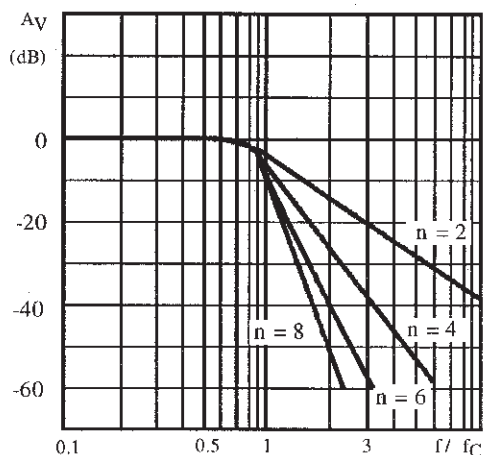
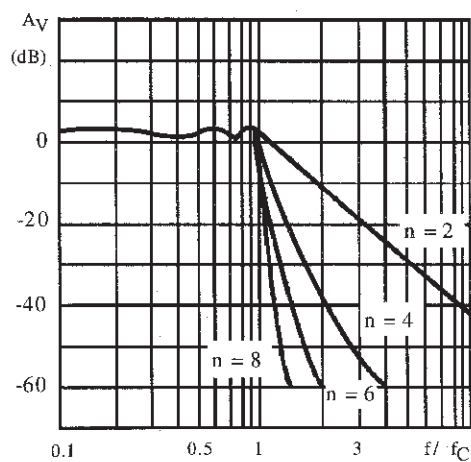


Figure 11 : Amplitude Response ( ±1dB ripple)



**APPLICATION INFORMATION :**

**Active low-pass filter**

**BUTTERWORTH**

The Butterworth is a "maximally flat" amplitude response filter (figure 10) Butterworth filters are used for filtering signals in data acquisition systems to prevent aliasing errors in samples-data applications and for general purpose low-pass filtering.

The cut-off frequency  $F_c$ , is the frequency at which the amplitude response is down 3dB. The attenuation rate beyond the cutoff frequency is  $n6$  dB per octave of frequency where  $n$  is the order (number of poles) of the filter.

Other characteristics :

- Flattest possible amplitude response
- Excellent gain accuracy at low frequency end of passband

**BESSEL**

The Bessel is a type of "linear phase" filter. Because of their linear phase characteristics, these filters approximate a constant time delay over a limited frequency range. Bessel filters pass transient waveforms with a minimum of distortion. They are also used to provide time delays for low pass filtering of modulated waveforms and as a "running average" type filter.

The maximum phase shift is  $\frac{-n\pi}{2}$  radians where  $n$  is the order (number of poles) of the filter. The

cut-off frequency  $f_c$ , is defined as the frequency at which the phase shift is one half of this value. For accurate delay, the cut-off frequency should be twice the maximum signal frequency.

The following table can be used to obtain the -3dB frequency of the filter.

	2 Pole	4 Pole	6 Pole	8 Pole
-3dB Frequency	0.77 $f_c$	0.67 $f_c$	0.57 $f_c$	0.50 $f_c$

Other characteristics :

- Selectivity not as great as Chebyshev or Butterworth
- Very little overshoot response to step inputs
- Fast rise time

**CHEBYSHEV**

Chebyshev filters have greater selectivity than either Bessel or Butterworth at the expense of ripple in the passband (figure 11).

Chebyshev filters are normally designed with peak-to-peak ripple values from 0.2dB to 2dB.

Increased ripple in the passband allows increased attenuation above the cut-off frequency.

The cut-off frequency is defined as the frequency at which the amplitude response passes through the specified maximum ripple band and enters the stop band.

Other characteristics :

- Greater selectivity
- Very non-linear phase response
- High overshoot response to step inputs

The table below shows the typical overshoot and settling time response of the low pass filters to a step input.

	Number of Poles	Peak Overshoot	Settling Time (% of final value)		
		% Overshoot	±1%	±0.1%	±0.01%
Butterworth	2	4	1.1 $F_c$ sec.	1.7 $F_c$ sec.	1.9 $F_c$ sec.
	4	11	1.7 $f_c$	2.8 $f_c$	3.8 $f_c$
	6	14	2.4 $f_c$	3.9 $f_c$	5.0 $f_c$
	8	16	3.1 $f_c$	5.1 $f_c$	7.1 $f_c$
Bessel	2	0.4	0.8 $f_c$	1.4 $f_c$	1.7 $f_c$
	4	0.8	1.0 $f_c$	1.8 $f_c$	2.4 $f_c$
	6	0.6	1.3 $f_c$	2.1 $f_c$	2.7 $f_c$
	8	0.1	1.6 $f_c$	2.3 $f_c$	3.2 $f_c$
Chebyshev (ripple ±0.25dB)	2	11	1.1 $f_c$	1.6 $f_c$	-
	4	18	3.0 $f_c$	5.4 $f_c$	-
	6	21	5.9 $f_c$	10.4 $f_c$	-
	8	23	8.4 $f_c$	16.4 $f_c$	-
Chebyshev (ripple ±1dB)	2	21	1.6 $f_c$	2.7 $f_c$	-
	4	28	4.8 $f_c$	8.4 $f_c$	-
	6	32	8.2 $f_c$	16.3 $f_c$	-
	8	34	11.6 $f_c$	24.8 $f_c$	-

Design of 2nd order active low pass filter (Sallen and Key configuration unity gain-op-amp)

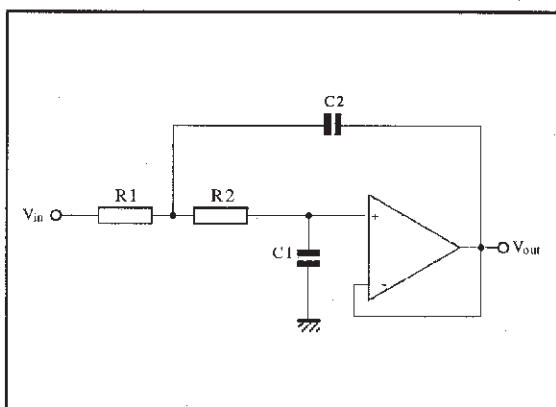
Fixed  $R = R_1 = R_2$ , we have (see fig. 12):

$$C1 = \frac{1}{R} \frac{\xi}{\omega_c}$$

$$C2 = \frac{1}{R} \frac{1}{\xi \omega_c}$$

The diagram of fig. 14 shows the amplitude response for different values of damping factor  $\xi$  in 2nd order filters.

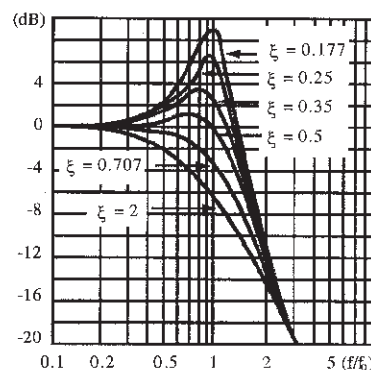
**Figure 12** : Filter Configuration



Three parameters are needed to characterize the frequency and phase response of a 2<sup>nd</sup> order active filter : the gain ( $G_v$ ), the damping factor ( $\xi$ ) or the Q-factor ( $Q = (2 \xi)^{-1}$ ), and the cutoff frequency ( $f_c$ ).

The higher order responses are obtained with a se-

**Figure 13** : Filter Respons versus Damping Factor



ries of 2<sup>nd</sup> order sections. A simple RC section is introduced when an odd filter is required.

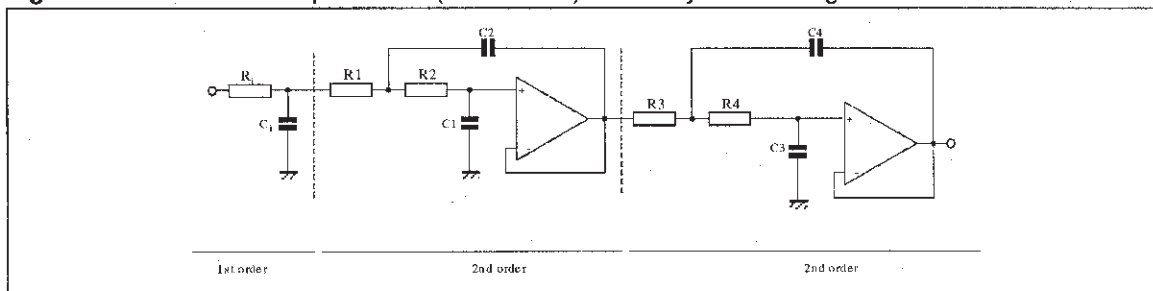
The choice of ' $\xi$ ' (or Q-factor) determines the filter response (see table 1).

**Table 1**

Filter Response	$\xi$	Q	Cutoff Frequency $f_c$
Bessel	$\frac{\sqrt{3}}{2}$	$\frac{\sqrt{1}}{3}$	Frequency at which Phase Shift is $-90^\circ$
Butterworth	$\frac{\sqrt{2}}{2}$	$\frac{\sqrt{1}}{2}$	Frequency at which $G_v = -3\text{dB}$
Chebyshev	$\frac{\sqrt{2}}{2}$	$\frac{\sqrt{1}}{2}$	Frequency at which the amplitude response passes through specified max. ripple band and enters the stop band.

**EXAMPLE**

**Figure 14** : 5th Order Low-pass Filter (Butterworth) with Unity Gain Configuration



In the circuit of fig. 15, for  $f_c = 3.4\text{kHz}$  and  $R_i = R_1 = R_2 = R_3 = R_4 = 10\text{k}\Omega$ , we obtain :

$$C_i = 1.354 \cdot \frac{1}{R} \cdot \frac{1}{2\pi f_c} = 6.33\text{nF}$$

$$C_1 = 0.421 \cdot \frac{1}{R} \cdot \frac{1}{2\pi f_c} = 1.97\text{nF}$$

$$C_2 = 1.753 \cdot \frac{1}{R} \cdot \frac{1}{2\pi f_c} = 8.20\text{nF}$$

$$C_3 = 0.309 \cdot \frac{1}{R} \cdot \frac{1}{2\pi f_c} = 1.45\text{nF}$$

$$C_4 = 3.325 \cdot \frac{1}{R} \cdot \frac{1}{2\pi f_c} = 15.14\text{nF}$$

The attenuation of the filter is 30dB at 6.8kHz and better than 60dB at 15kHz.

The same method, referring to Tab. 2 and fig. 16, is used to design high-pass filter. In this case the damping factor is found by taking the reciprocal of the numbers in Tab. 2. For  $f_c = 5\text{kHz}$  and  $C_i = C_1 = C_2 = C_3 = C_4 = 1\text{nF}$  we obtain :

$$R_i = \frac{1}{0.354} \cdot \frac{1}{C} \cdot \frac{1}{2\pi f_c} = 25.5\text{k}\Omega$$

$$R_1 = \frac{1}{0.421} \cdot \frac{1}{C} \cdot \frac{1}{2\pi f_c} = 75.6\text{k}\Omega$$

$$R_2 = \frac{1}{1.753} \cdot \frac{1}{C} \cdot \frac{1}{2\pi f_c} = 18.2\text{k}\Omega$$

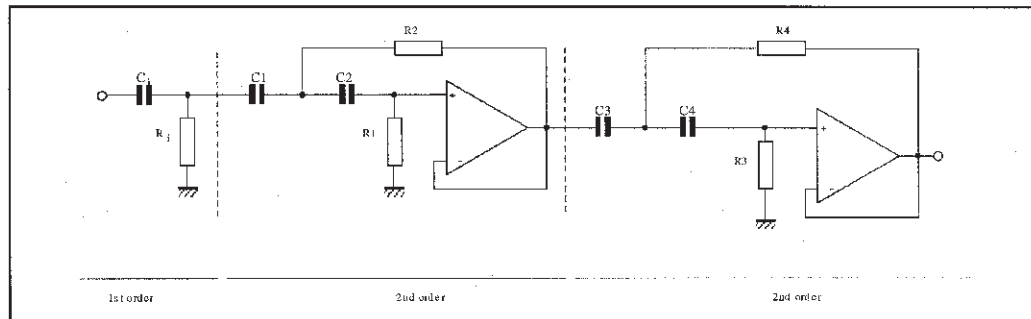
$$R_3 = \frac{1}{0.309} \cdot \frac{1}{C} \cdot \frac{1}{2\pi f_c} = 103\text{k}\Omega$$

$$R_4 = \frac{1}{3.325} \cdot \frac{1}{C} \cdot \frac{1}{2\pi f_c} = 9.6\text{k}\Omega$$

Table 2 : Damping Factor for Low-pass Butterworth Filters

Order	$C_i$	$C_1$	$C_2$	$C_3$	$C_4$	$C_5$	$C_6$	$C_7$	$C_8$
2		0.707	1.41						
3	1.392	0.202	3.54						
4		0.92	1.08	0.38	2.61				
5	1.354	0.421	1.75	0.309	3.235				
6		0.966	1.035	0.707	1.414	0.259	3.86		
7	1.336	0.488	1.53	0.623	1.604	0.222	4.49		
8		0.98	1.02	0.83	1.20	0.556	1.80	0.195	5.125

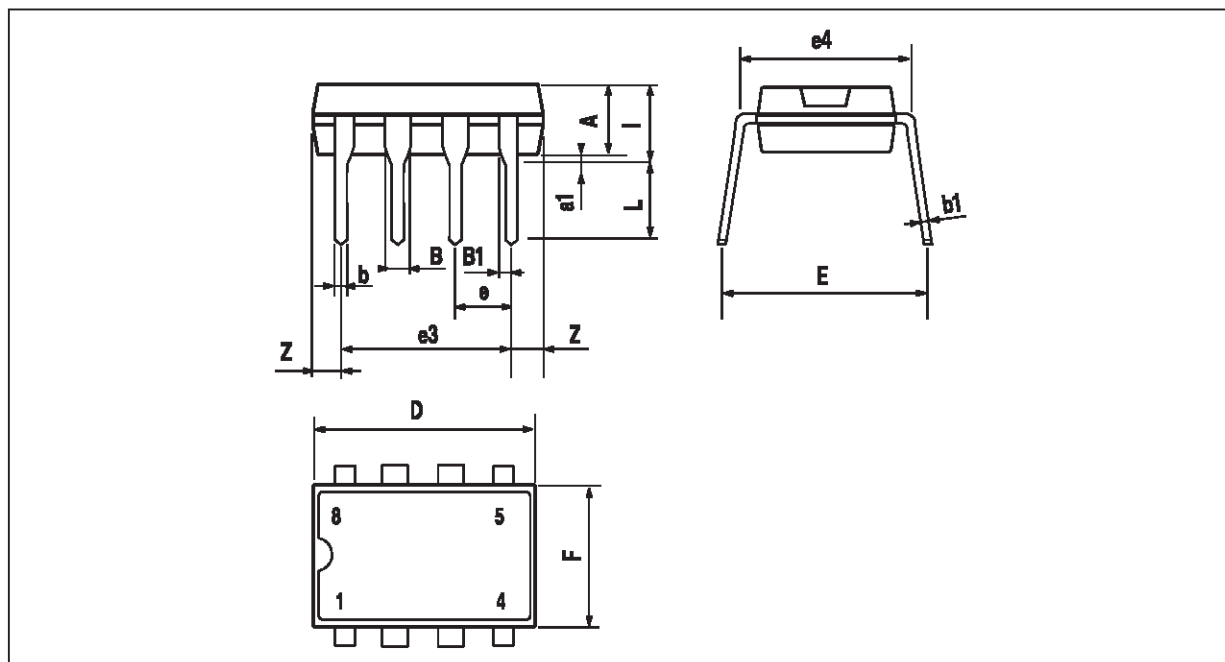
Figure 15 : 5th Order High-pass Filter (Butterworth) with Unity Gain Configuration





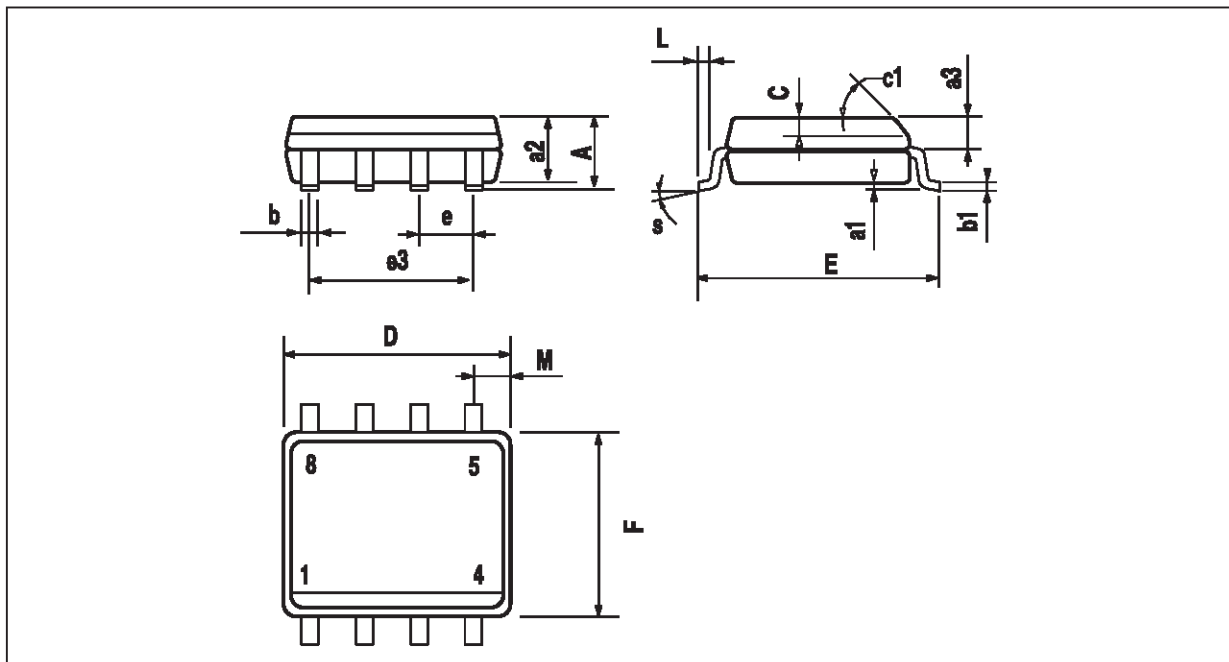
## PACKAGE MECHANICAL DATA

8 PINS - PLASTIC DIP



Dim.	Millimeters			Inches		
	Min.	Typ.	Max.	Min.	Typ.	Max.
A		3.32			0.131	
a1	0.51			0.020		
B	1.15		1.65	0.045		0.065
b	0.356		0.55	0.014		0.022
b1	0.204		0.304	0.008		0.012
D			10.92			0.430
E	7.95		9.75	0.313		0.384
e		2.54			0.100	
e3		7.62			0.300	
e4		7.62			0.300	
F			6.6			0.260
i			5.08			0.200
L	3.18		3.81	0.125		0.150
Z			1.52			0.060

**PACKAGE MECHANICAL DATA**  
8 PINS - PLASTIC MICROPACKAGE (SO)



Dim.	Millimeters			Inches		
	Min.	Typ.	Max.	Min.	Typ.	Max.
A			1.75			0.069
a1	0.1		0.25	0.004		0.010
a2			1.65			0.065
a3	0.65		0.85	0.026		0.033
b	0.35		0.48	0.014		0.019
b1	0.19		0.25	0.007		0.010
C	0.25		0.5	0.010		0.020
c1	45° (typ.)					
D	4.8		5.0	0.189		0.197
E	5.8		6.2	0.228		0.244
e		1.27			0.050	
e3		3.81			0.150	
F	3.8		4.0	0.150		0.157
L	0.4		1.27	0.016		0.050
M			0.6			0.024
S	8° (max.)					

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