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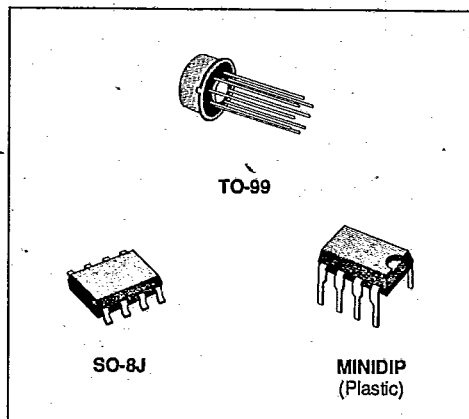
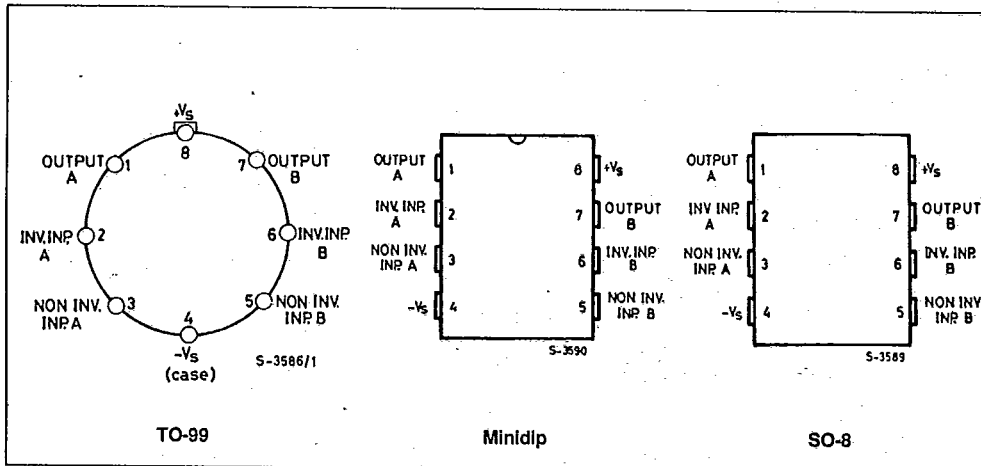
HIGH PERFORMANCE DUAL OPERATIONAL AMPLIFIER

- SINGLE OR SPLIT SUPPLY OPERATION
- 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 products.

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

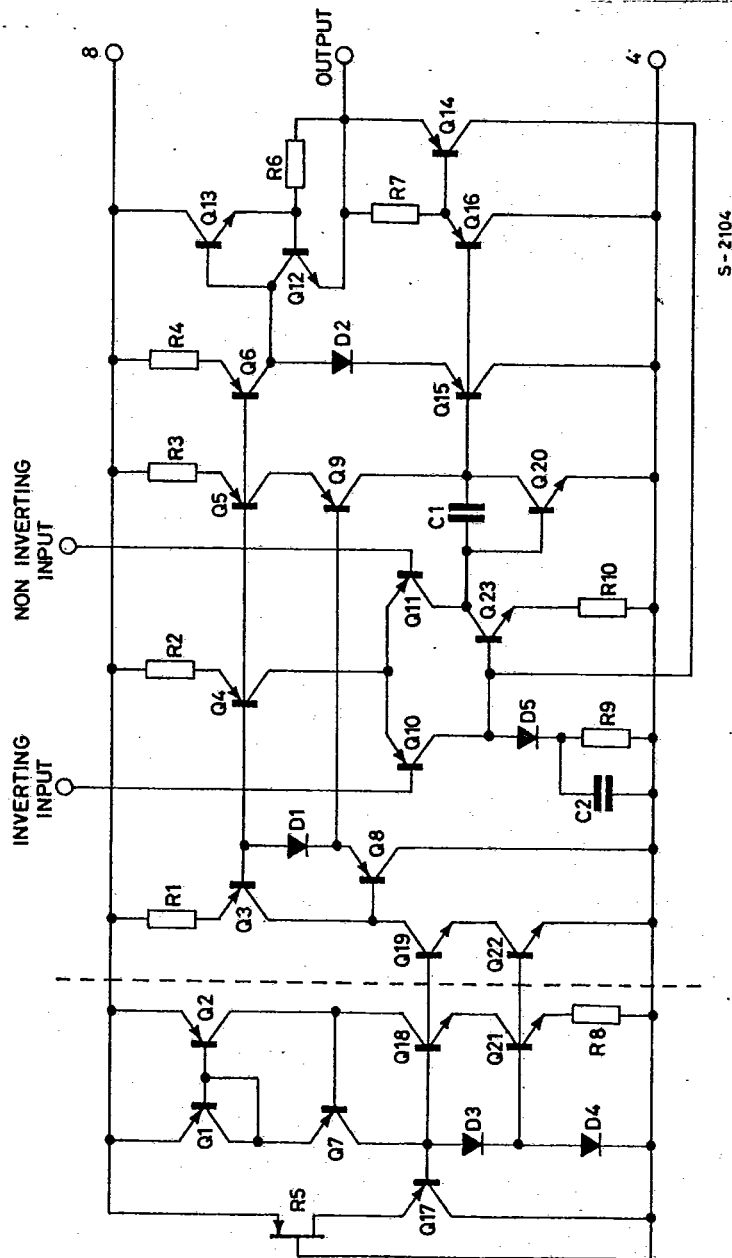
**PIN CONNECTIONS (top views)****ORDER CODES**

Type	TO-99	Minidip	SO-8
LS204	LS204TB	—	LS204M
LS204A	LS204ATB	—	—
LS204C	LS204CTB	LS204CB	LS204CM

SCHEMATIC DIAGRAM

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ABSOLUTE MAXIMUM RATINGS

Symbol	Parameter	TO-99	Minidip	μ Package
V_s	Supply Voltage	$\pm 18V$		
V_i	Input Voltage	$\pm V_s$		
V_i	Differential Input Voltage	$\pm (V_s - 1)$		
T_{op}	Operating Temperature for LS204 LS204A LS204C	- 25 to 85°C - 55 to 125°C 0 to 70°C		
P_{tot}	Power Dissipation at $T_{amb} = 70^\circ C$	520mW	665mW	400mW
T_j	Junction Temperature	150°C	150°C	150°C
T_{stg}	Storage Temperature	- 65 to 150°C	- 55 to 150°C	- 55 to 150°C

THERMAL DATA

		TO-99	Minidip	SO-8J
$R_{thj-amb}$	Thermal Resistance Junction-ambient Max	155°C/W	120°C/W	200°C/W

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

Symbol	Parameter	Test Conditions	LS204/LS204A			LS204C			Unit
			Min.	Typ.	Max.	Min.	Typ.	Max.	
I_s	Supply Current			0.7	1.2		0.8	1.5	mA
I_b	Input Bias Current			50	150		100	300	nA
		$T_{min} < T_{op} < T_{max}$			300			700	nA
R_i	Input Resistance	$f = 1KHz$		1			0.5		M Ω
V_{os}	Input Offset Voltage	$R_g \leq 10K\Omega$		0.5	2.5		0.5	3.5	mV
		$R_g \leq 10K\Omega$			3.5			5	mV
		$T_{min} < T_{op} < T_{max}$							
$\frac{\Delta V_{os}}{\Delta T}$	Input Offset Voltage Drift	$R_g = 10K\Omega$ $T_{min} < T_{op} < T_{max}$		5			5		$\mu V/^\circ C$
I_{os}	Input Offset Current			5	20		12	50	nA
		$T_{min} < T_{op} < T_{max}$			40			100	nA
$\frac{\Delta I_{os}}{\Delta T}$	Input Offset Current Drift	$T_{min} < T_{op} < T_{max}$		0.08			0.1		$\frac{nA}{^\circ C}$
I_{sc}	Output Short Circuit Current			23			23		mA
G_v	Large Signal Open Loop Voltage Gain	$T_{min} < T_{op} < T_{max}$ $R_L = 2K\Omega$ $V_s = \pm 15V$ $V_s = \pm 4V$	90	100 95		86	100 95		dB
B	Gain-bandwidth Product	$f = 20KHz$	1.8	3		1.5	2.5		MHz
e_N	Total Input Noise Voltage	$f = 1KHz$							nV
		$R_g = 50\Omega$		8	15		10		$\sqrt{Hz}$
		$R_g = 1K\Omega$		10			12		
		$R_g = 10K\Omega$		18			20		

ELECTRICAL CHARACTERISTICS (continued)

Symbol	Parameter	Test Conditions	LS204/LS204A			LS204C			Unit
			Min.	Typ.	Max.	Min.	Typ.	Max.	
d	Distortion	$G_v = 20\text{dB}$ $R_L = 2\text{K}\Omega$ $V_o = 2V_{PP}$ $f = 1\text{KHz}$		0.03	0.1		0.03	0.1	%
V_o	DC Output Voltage Swing	$R_L = 2\text{K}\Omega$ $V_s = \pm 15\text{V}$ $V_s = \pm 4\text{V}$	± 13	± 3		± 13	± 3		V
V_o	Large Signal Voltage Swing	$R_L = 10\text{K}\Omega$ $f = 10\text{KHz}$		28		28			V_{PP}
SR	Slew Rate	Unity Gain $R_L = 2\text{K}\Omega$	0.8	1.5		1			V/ μs
CMR	Common Mode Rejection	$V_i = 10\text{V}$ $T_{min} < T_{op} < T_{max}$	90			86			dB
SVR	Supply Voltage Rejection	$V_i = 1\text{V}$ $f = 100\text{Hz}$ $T_{min} < T_{op} < T_{max}$	90			86			dB
CS	Channel Separation	$f = 1\text{KHz}$ 100	120			120			dB

Note :

Temp.	LS204	LS204A	LS204C
$T_{min.}$	-25°C	-55°C	0°C
$T_{max.}$	+85°C	+125°C	+70°C

Figure 1: Supply Current vs. Supply Voltage.

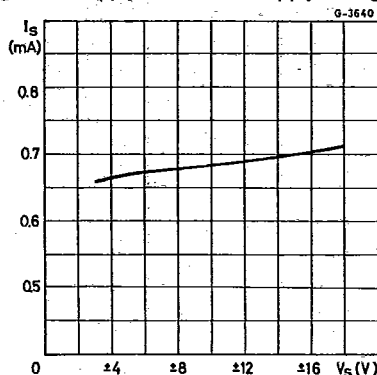


Figure 2 : Supply Current vs. Ambient Temperature.

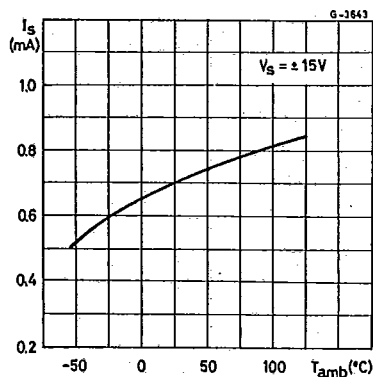


Figure 3 : Output Short Circuit Current vs. Ambient Temperature.

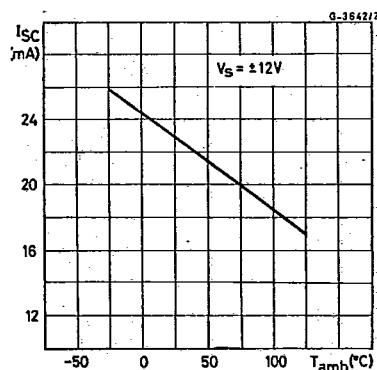


Figure 4: Open Loop Frequency and Phase Response.

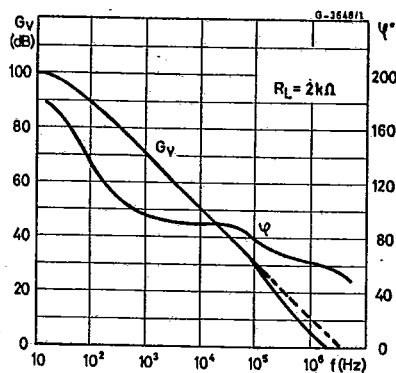


Figure 5: Open Loop Gain vs. Ambient Temperature.

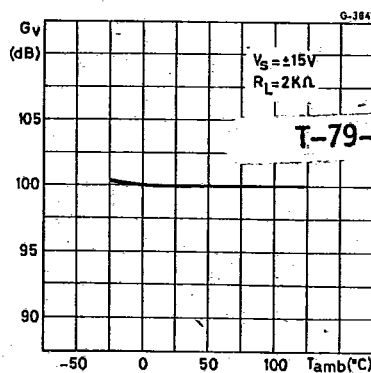


Figure 6 : Supply Voltage Rejection vs. Frequency.

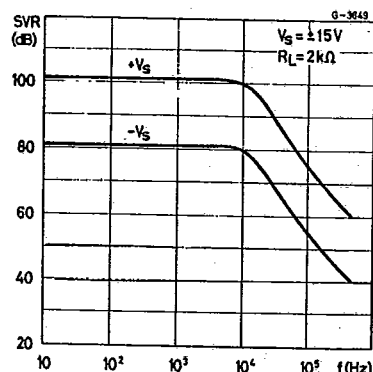


Figure 7 : Large Signal Frequency Response.

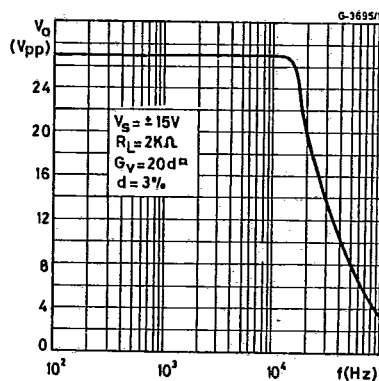


Figure 8 : Output Voltage Swing vs. Load Resistance.

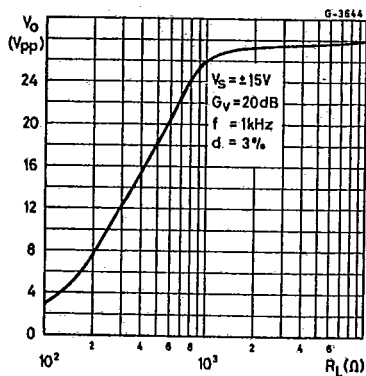
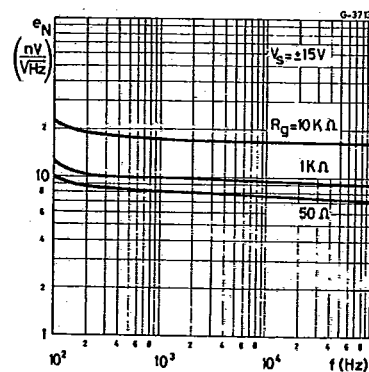


Figure 9 : Total Input Noise vs. Frequency.



APPLICATION INFORMATION

Active low-pass filter :

BUTTERWORTH

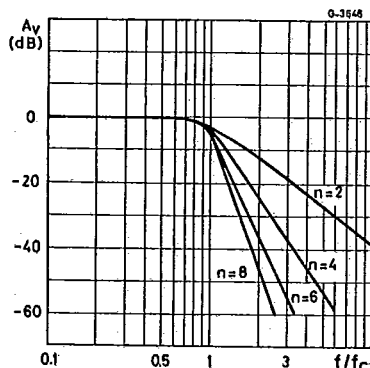
The Butterworth is a "maximally flat" amplitude response filter. Butterworth filters are used for filtering signals in data acquisition systems to prevent aliasing errors in sampled-data applications and for general purpose low-pass filtering.

The cutoff frequency, f_c , is the frequency at which the amplitude response is down 3 dB. The attenuation rate beyond the cutoff frequency is n 6 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.

Figure 10 : Amplitude Response.



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 cutoff frequency, f_c , is defined as the frequency at which the phase shift is one half of this value. For accurate delay, the cutoff frequency should be twice the maxi-

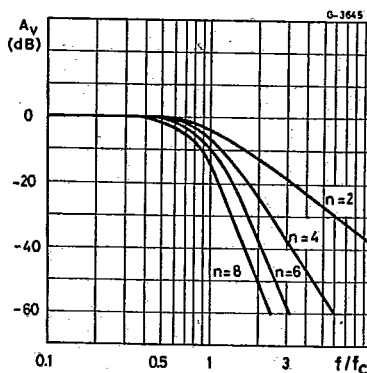
um signal frequency. The following table can be used to obtain the -3dB frequency of the filter

	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 :

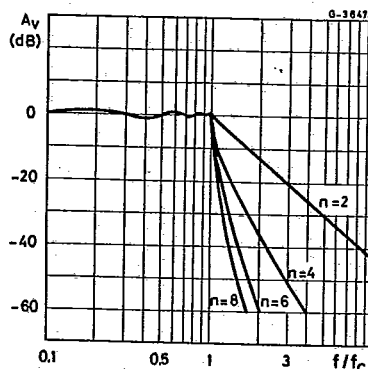
- Selectivity not as great as Chebyshev or Butterworth.
- Very little overshoot response to step inputs.
- Fast rise time.

Figure 11 : Amplitude Response.



CHEBYSHEV

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

Figure 12 : Amplitude Response (± 1 dB ripple).

APPLICATION INFORMATION (continued)

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

Increased ripple in the passband allows increased attenuation above the cutoff frequency.

The cutoff frequency is defined as the frequency at which the amplitude response passes through the

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specified maximum ripple band and enters the stop band.

Other characteristics :

- Greater selectivity
- Very nonlinear phase response
- High overshoot response to step inputs

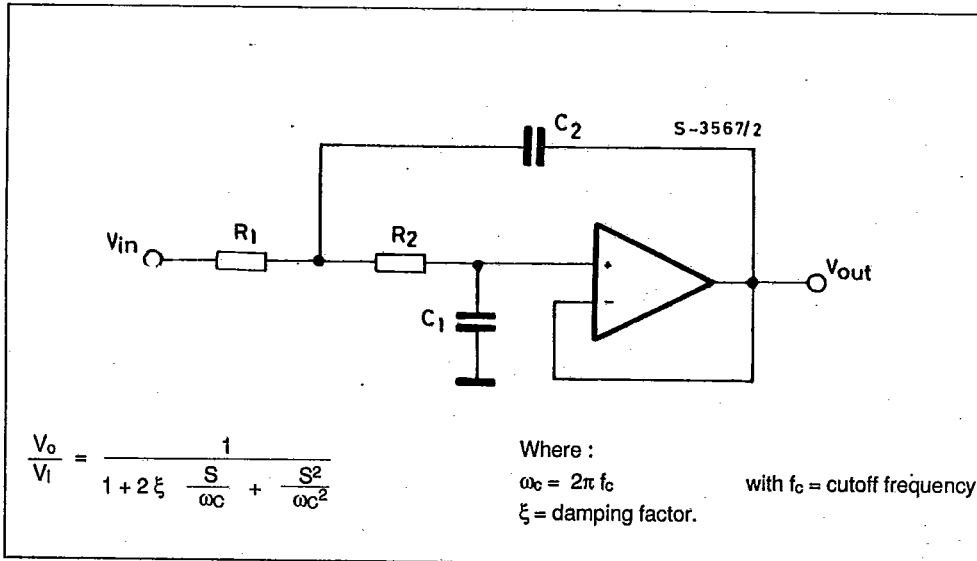
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The table below shows the typical overshoot and settling time response of the low pass filters to a step input.

	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	0.3	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).

Figure 13 : Filter Configuration.



APPLICATION INFORMATION (continued)

Three parameters are needed to characterise the frequency and phase response of a 2nd order active filter : the gain (G_v), the damping factor (ξ) or the Q-factor ($Q = (2\xi)^{-1}$), and the cutoff frequency (f_c). The higher order responses are obtained with a se-

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

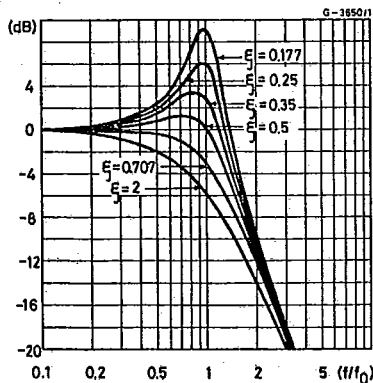
The choice of ' ξ ' (or Q-factor) determines the filter response (see table).

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Table 1.

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

Figure 14 : Filter Response vs. Damping Factor.



Fixed $R = R_1 = R_2$, we have (see fig. 13)

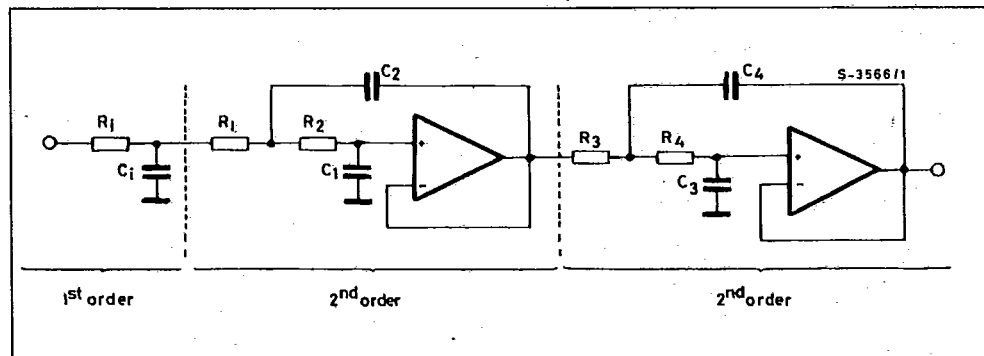
$$C_1 = \frac{1}{R} \frac{\xi}{\omega_c}$$

$$C_2 = \frac{1}{R} \frac{1}{\xi \omega_c}$$

The diagram of fig.14 shows the amplitude response for different values of damping factor ξ in

EXAMPLE

Figure 15 : 5th Order Low Pass Filter (Butterworth) with Unity Gain Configuration.



APPLICATION INFORMATION (continued)

In the circuit of fig. 15, for $f_c = 3.4$ KHz and $R_1 = R_2 = R_3 = R_4 = 10$ K Ω , we obtain :

$$C_1 = 1.354 \cdot \frac{1}{R} \cdot \frac{1}{2\pi f_c} = 6.33\text{nF}$$

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

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

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

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

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

Table 2 : Damping Factor for Low-pass Butterworth Filters.

Order	C ₁	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

The same method, referring to Tab. II 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. II. For $f_c = 5$ KHz and $C_1 = C_1 = C_2 = C_3 = C_4 = 1$ nF we obtain :

$$R_1 = \frac{1}{1.354} \cdot \frac{1}{C} \cdot \frac{1}{2\pi f_c} = 23.5\text{K}\Omega$$

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

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

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

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

Figure 16 : 5th Order High-pass Filter (Butterworth) with Unity Gain Configuration.

