LS 204
LS 204A
LS 204C

LINEAR INTEGRATED CIRCUITS

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

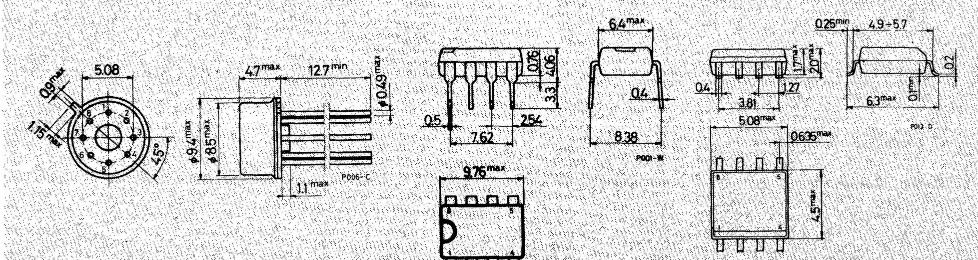
The LS 204 is a high performance dual operational amplifier with frequency and phase compensation built into the chip. The internal phase compensation allows stable operation as voltage follower in spite of its high gain-bandwidth products. The circuit presents very stable electrical characteristics over the entire supply voltage range, and it is particularly intended for professional and telecom applications (active filters, etc.). The LS 204 series is available with hermetic gold chip (8000 series).

ABSOLUTE MAXIMUM RATINGS

		TO-99	Minidip	μpackage
V_s	Supply voltage		± 18V	
V_i	Input voltage		$\pm V_s$	
V_i	Differential input voltage		$\pm (V_s - 1)$	
T_{op}	Operating temperature for **LS 204**		-25 to 85°C	
	LS 204A		-55 to 125°C	
	LS 204C		0 to 70 °C	
P_{tot}	Power dissipation at T_{amb} = 70°C	520 mW	665 mW	400 mW
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

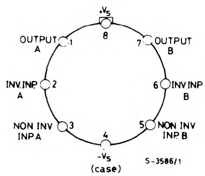
MECHANICAL DATA

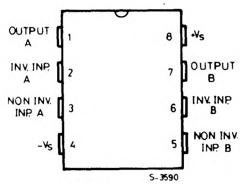
Dimensions in mm

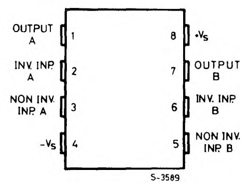


TO-99 **Minidip** **SO-8**

CONNECTION DIAGRAMS AND ORDERING NUMBERS
(top views)

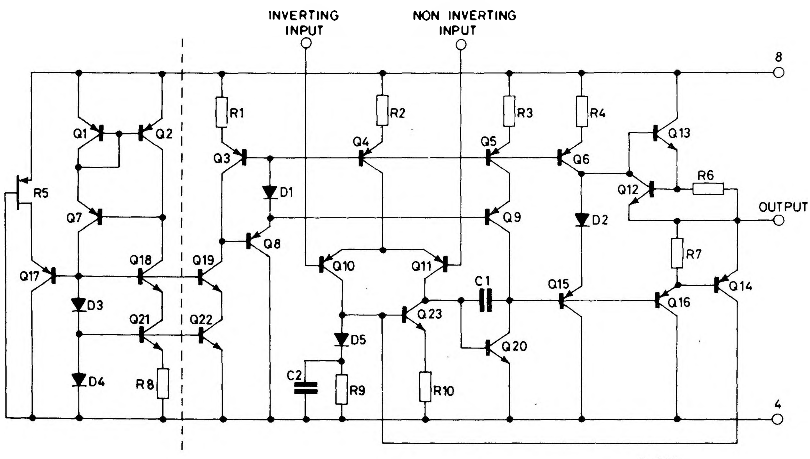






Type	TO-99	Minidip	SO-8
LS 204	LS 204 T	—	LS 204 M
LS 204 A	LS 204 AT	—	—
LS 204 C	LS 204 CT	LS 204 CB	LS 204 CM
LS 8204	—	—	LS 8204 M
LS 8204 A	—	—	LS 8204 AM
LS 8204 C	—	—	LS 8204 CM

SCHEMATIC DIAGRAM (one section)



THERMAL DATA		TO-99	Minidip	SO-8
$R_{th\ j\text{-}amb}$ Thermal resistance junction-ambient	max	155 °C/W	120 °C/W	200* °C/W

* Measured with the device mounted on a ceramic substrate (25x16x96 mm)

SGS

LS 204
LS 204A
LS 204C

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

Parameter		Test conditions	LS 204/LS204A			LS 204C			Unit
			Min.	Typ.	Max.	Min.	Typ.	Max.	
I_s	Supply current			0.7	1		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 = 1 KHz		1			0.5		MΩ
V_{os}	Input offset voltage	$R_g \leq 10\ K\Omega$		0.5	2.5		0.5	3.5	mV
		$R_g \leq 10\ K\Omega$ $T_{min} < T_{op} < T_{max}$			3.5			5	mV
$\frac{\Delta V_{os}}{\Delta T}$	Input offset voltage drift	$R_g = 10\ K\Omega$ $T_{min} < T_{op} < T_{max}$		5			5		μV/°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		$\frac{nA}{°C}$
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 = 20 KHz	1.8	3		1.5	2.5		MHz
e_N	Total input noise voltage	f = 1 KHz $R_g = 50\Omega$ $R_g = 1\ K\Omega$ $R_g = 10\ K\Omega$		8 10 18	15		10 12 20		$\frac{nV}{\sqrt{Hz}}$
d	Distortion	$G_v = 20$ dB $R_L = 2K\Omega$ $V_o = 2$ Vpp f = 1 KHz		0.03	0.1		0.03	0.1	%
V_o	DC output voltage swing	$R_L = 2K\Omega$ $V_s = \pm 15V$ $V_s = \pm\ 4V$	±13	±3		±13	±3		V
V_o	Large signal voltage swing	$R_L = 10\ K\Omega$ f = 10 KHz		28			28		Vpp
SR	Slew rate	unity gain $R_L = 2K\Omega$	0.8	1.5			1		V/μs
CMR	Common mode rejection	$V_i = 10V$ $T_{min} < T_{op} < T_{max}$	90			86			dB
SVR	Supply voltage rejection	$V_i = 1V$ f = 100 Hz $T_{min} < T_{op} < T_{max}$	90			86			dB
CS	Channel separation	f = 1 KHz	100	120			120		dB

Note:

	LS 204	LS 204A	LS 204C
$T_{min.}$	-25°C	-55°C	0°C
$T_{max.}$	+85°C	+125°C	+70°C

Fig. 1 - Supply current vs. supply voltage

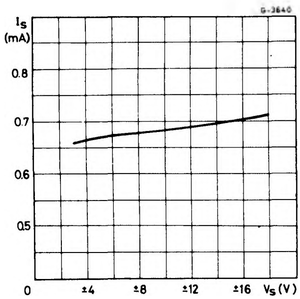


Fig. 2 - Supply current vs. ambient temperature

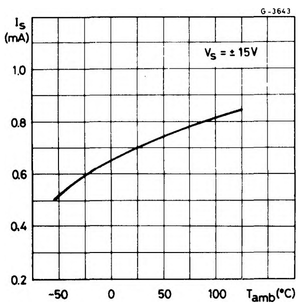


Fig. 3 - Output short circuit current vs. ambient temperature

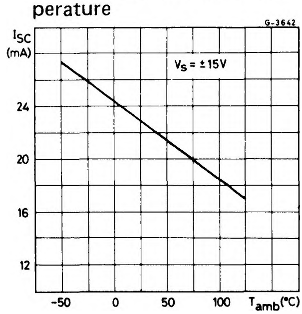


Fig. 4 - Open loop frequency and phase response

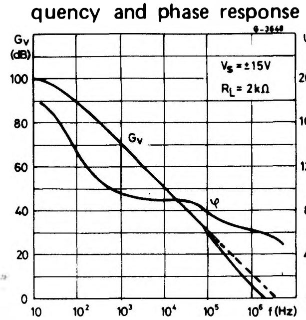


Fig. 5 - Open loop gain vs. ambient temperature

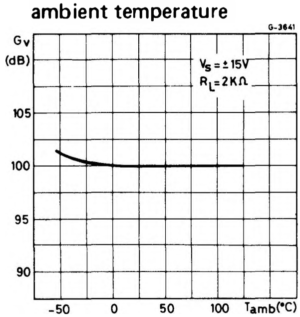


Fig. 6 - Supply voltage rejection vs. frequency

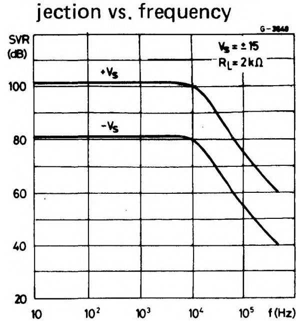


Fig. 7 - Large signal frequency response

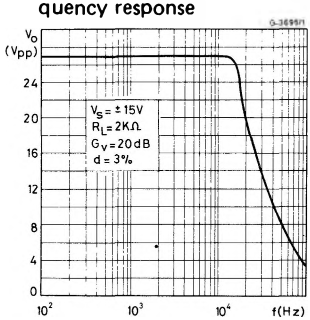


Fig. 8 - Output voltage swing vs. load resistance

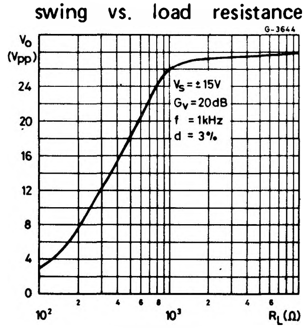
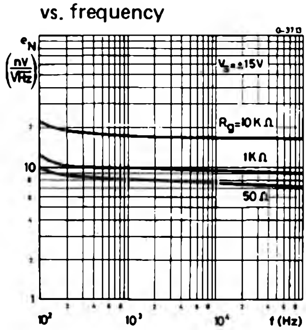


Fig. 9 - Total input noise vs. frequency



APPLICATION INFORMATION

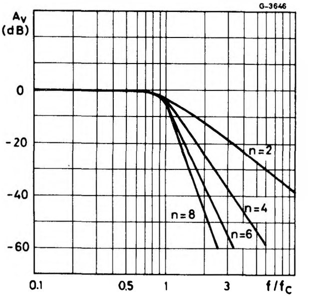
Active low-pass filter:

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 -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

Fig. 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.

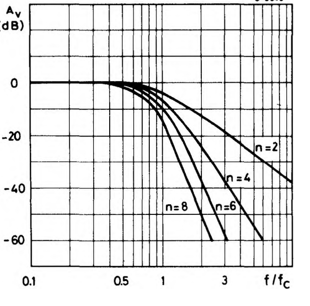
The maximum phase shift is $\frac{-n\pi}{2}$ radians where n is the order (number of poles) of the filter. The cutoff frequency, f_c, is defined as the frequency at which the phase shift is one half of this value. For accurate delay, the cutoff frequency should be twice the maximum signal frequency. The following table can be used to obtain the -3 dB frequency of the filter.

	2 pole	4 pole	6 pole	8 pole
-3 dB frequency	0.77 f_c	0.67 f_c	0.57 f_c	0.50 f_c

Other characteristics:

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

Fig. 11 - Amplitude response

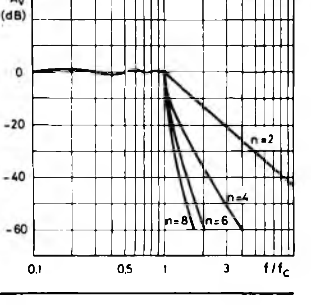


CHEBYSCHEV

Chebyschev filters have greater selectivity than either Bessel or Butterworth at the expense of ripple in the passband.
Chebyschev 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 specified maximum ripple band and enters the stop band.
Other characteristics:

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

Fig. 12 - Amplitude response (± 1 dB ripple)



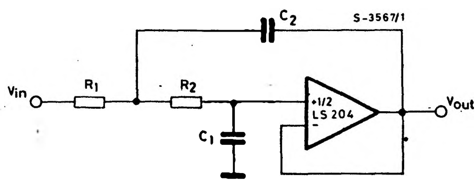
APPLICATION INFORMATION (continued)

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	$1.6/f_c$	$2.3/f_c$	$3.2/f_c$
CHEBYSCHEV (RIPPLE ± 0.25 dB)	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	$8.4/f_c$	$16.4/f_c$	-
CHEBYSCHEV (RIPPLE ± 1 dB)	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)

Fig. 13 - Filter configuration



$$\frac{V_o}{V_i} = \frac{1}{1 + 2\,\xi\,\frac{S}{\omega_c} + \frac{S^2}{\omega_c^2}}$$

where:

$\omega_c = 2\pi\ f_c$ with f_c = cutoff frequency

ξ = damping factor.

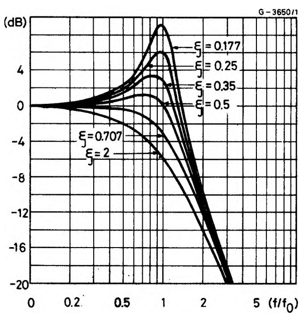
APPLICATION INFORMATION (continued)

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 series 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).

Tab. I

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 dB
Chebyschev	$<\frac{\sqrt{2}}{2}$	$>\frac{1}{\sqrt{2}}$	Frequency at which the amplitude response passes through specified max. ripple band and enters the stop band

Fig. 14 - Filter response vs. damping factor



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

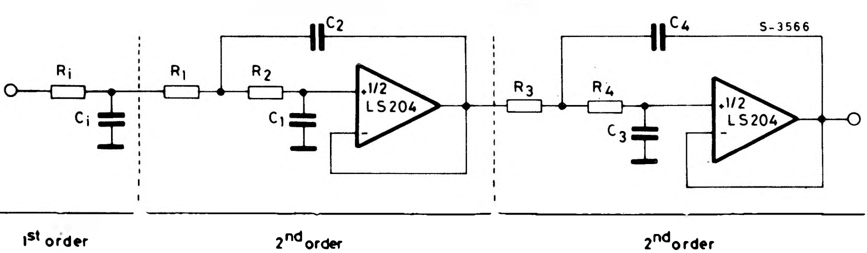
$$C_1 = \frac{1}{R}\ \frac{\xi}{\omega_c}$$

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

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

EXAMPLE:

Fig. 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 $R_i = R_1 = R_2 = R_3 = R_4 = 10\ K\Omega$, we obtain:

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

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

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

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

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

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

Tab. II
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

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 = 5KHz and $C_i = C_1 = C_2 = C_3 = C_4 = 1\ nF$ we obtain:

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

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

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

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

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

Fig. 16 - 5th order high-pass filter (Butterworth) with unity gain configuration.