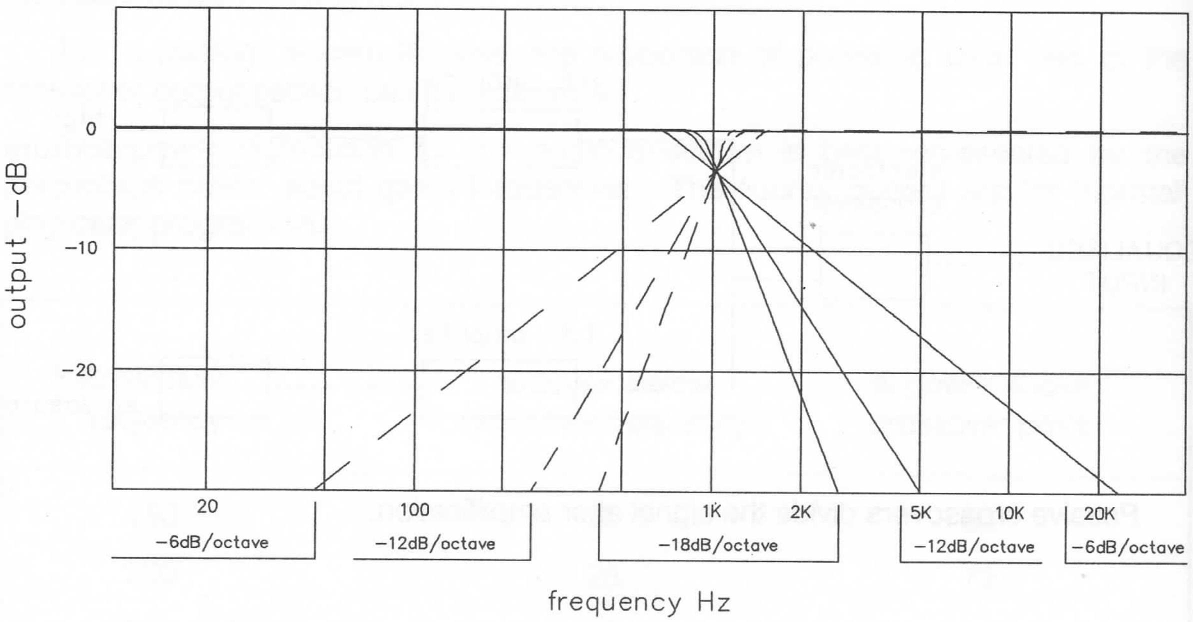
The electrical output from a crossover is defined in terms of:

Crossover frequency	-	at the -3dB point
Attenuation slope	-	as decibel per octave
Pass band	-	output section



Electrical output for 2 way crossover

The principal crossover slopes are:

6dB/octave	-	1st order
12dB/octave	-	2nd order
18dB/octave	-	3rd order
24dB/octave	-	4th order

1st and 2nd slopes are usually adequate for most applications, the use of 3rd order sections being confined to high frequency units requiring good suppression of excursion near the main diaphragm resonances to prevent mechanical overload.

Also it is not necessary for each crossover section to have the same slope, a 6dB/octave low pass section is quite common and is usually used with an 18dB/octave high pass section.

The selection of crossover frequency points is determined by the enclosure design and the specification of the loudspeaker used. However the most usual crossover frequency ranges are as follows:

2 way systems -	Bass to H.F.	2 KHz - 5 KHz
3 way systems -	Bass to Mid	400 Hz - 1.5 KHz
	Mid to H.F.	3 KHz - 6 KHz
4 way systems -	Bass to Mid	200 Hz - 400 Hz
	LoMid to Mid	800 Hz - 1.5 KHz
	Mid to H.F.	3 KHz - 5 KHz
	Super H.F.	6 KHz - 10 KHz

According to the maximum power output of the system as a whole and the power distribution spectrum of the programme material used the power handling and the number of loudspeakers to be used on each section can be determined.

For the electronic crossover system final balancing is relatively easy provided that the amplifier selection is made approximately according to the proportions of power in each frequency band from the power distribution section. As most electronic crossovers have section individual output controls, it is recommended that adequate loudspeaker handling capacity is made for each section, according to the amplifier used.

For the passive crossover system, the total system input power will be divided according to the frequencies listed under the power distribution section, and the loudspeakers on each section will be required to handle that power respectively.

Ideally, the different section's sensitivies should in practice be equal on the final measured system as only moderate attenuation should be used on the mid or H.F. ranges.

In order to avoid heavy power losses within the crossover itself or adversely affect the loudspeaker Q value, the D.C. resistance of the inductors used should be less than 0.5 ohms. Two types of inductors are commonly used: the air-cored or metal (usually ferrite) types.

Because the metal cored types can saturate and cause distortion at high operating levels, these should be avoided. Their use should be restricted to high frequency or extreme low frequency applications (where air cored inductors are large and therefore expensive) for cost effectiveness.

The choice of capacitors for use in loudspeaker crossovers is determined by cost and availability. Plastic film type capacitors can be used for low values but in many instances, bi-polar or reversible electrolytes are the only choice. The voltage ratings should well exceed the expected peak power capacity of the crossover, particularly for all series connected elements.

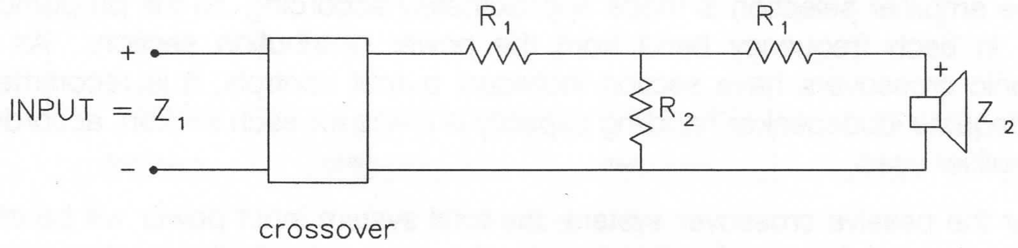
In actively driven systems, it is wise to incorporate a high pass filter to eliminate switch -on transients burning out the H.F. drivers. Alternatively a single capacitor can be used.

$$\text{The value} = \frac{40{,}000}{fc} \mu F$$

where fc is the crossover frequency in Hertz. The capacitor should be bi-polar with a voltage rating equivalent to the amplifier output.

Constant Impedence Attenuation

In order to enable proper H.F. and mid-range attenuation for balancing passive network sensitivity, attenuation resistors can be used in the following configuration between crossover output and the loudspeaker:



Z_1 will be equal to Z_2, ie. constant impedance.

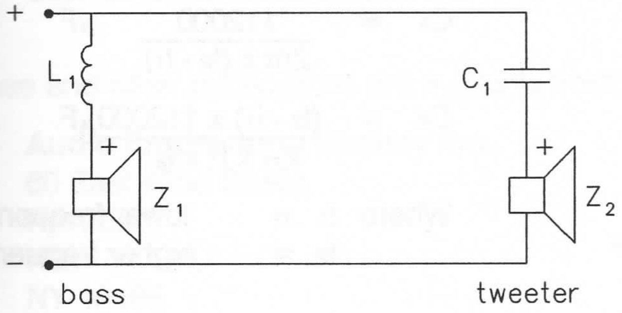
dB of Loss	16 ohm system		8 ohm system	
	R1	R2	R1	R2
0.5	0.5	266	0.25	133
1	0.9	136	0.45	68
2	1.8	72	0.9	36
3	2.7	43	1.35	21.5
4	3.5	32	1.75	16
5	4.3	27	2.15	13.5
6	5.3	22	2.65	11

Ceramic wire wound resistors should be used. At -6dB, half of the total high frequency power will be dissipated in the resistors R_1, so for 20 watts, R_1 should be at least 11 watts each.

1.5.5 Useful Formulae

Two Way Crossover Diagrams:

First Order Butterworth

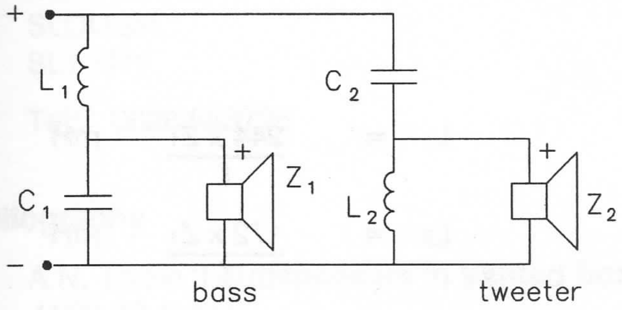


$$L_1 = \frac{Z_1 \times 225}{f} \quad \text{mH}$$

$$C_1 = \frac{112000}{f \times Z_2} \quad \mu\text{F}$$

f = frequency crossover (Hertz)

Second Order Butterworth



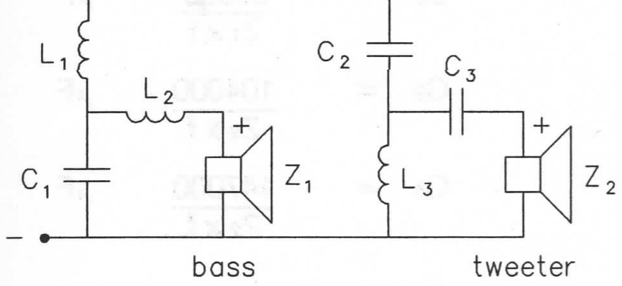
$$L_1 = \frac{Z_1 \times 225}{f} \quad \text{mH}$$

$$L_2 = \frac{Z_2 \times 225}{f} \quad \text{mH}$$

$$C_1 = \frac{112000}{f \times Z_1} \quad \mu\text{F}$$

$$C_2 = \frac{112000}{f \times Z_2} \quad \mu\text{F}$$

Third Order Butterworth



$$L_1 = \frac{Z_1 \times 239}{f} \quad \text{mH}$$

$$L_2 = \frac{Z_1 \times 80}{f} \quad \text{mH}$$

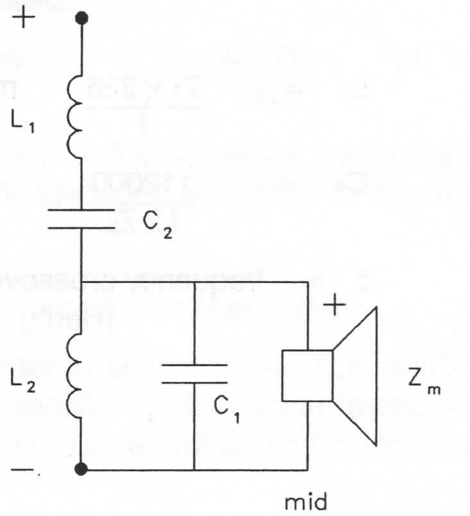
$$L_3 = \frac{Z_2 \times 480}{f} \quad \text{mH}$$

$$C_1 = \frac{212246}{Z_1 \times f} \quad \mu\text{F}$$

$$C_2 = \frac{106123}{Z_2 \times f} \quad \mu\text{F}$$

$$C_3 = \frac{318370}{Z_2 \times f} \quad \mu\text{F}$$

Second Order Butterworth Bandpass



$$L_1 = \frac{Z_m \times 225}{(f_2 - f_1)} \text{ mH}$$

$$L_2 = \frac{(f_2 - f_1)Z_m \times 225}{f_1 \times f_2} \text{ mH}$$

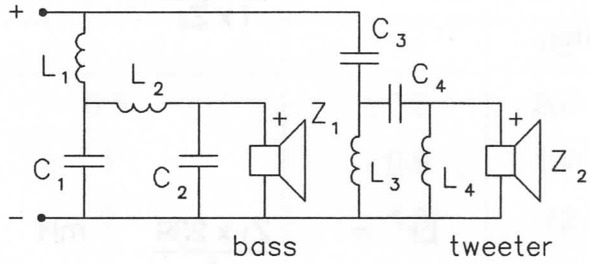
$$C_1 = \frac{112000}{Zm \times (f_2 - f_1)} \ \mu F$$

$$C_2 = \frac{(f_2 - f_1) \times 112000}{Z_m \times f_1 \times f_2} \ \mu F$$

Where f_1 = lower frequency
f_2 = higher frequency

This bandpass section could therefore be used with First Bass and Third Order Tweeter Section, using the appropriate values for f_1 and f_2 for calculation.

Fourth Order Butterworth



$$L_1 = \frac{244 \times Z_1}{f} \text{ mH}$$

$$L_2 = \frac{172 \times Z_1}{f} \text{ mH}$$

$$L_3 = \frac{101 \times Z_2}{f} \text{ mH}$$

$$L_4 = \frac{416 \times Z_2}{f} \text{ mH}$$

$$C_1 = \frac{250900}{Z_1 \times f} \ \mu F$$

$$C_2 = \frac{60900}{Z_1 \times f} \ \mu F$$

$$C_3 = \frac{104000}{Z_2 \times f} \ \mu F$$

$$C_4 = \frac{147000}{Z_2 \times f} \ \mu F$$

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