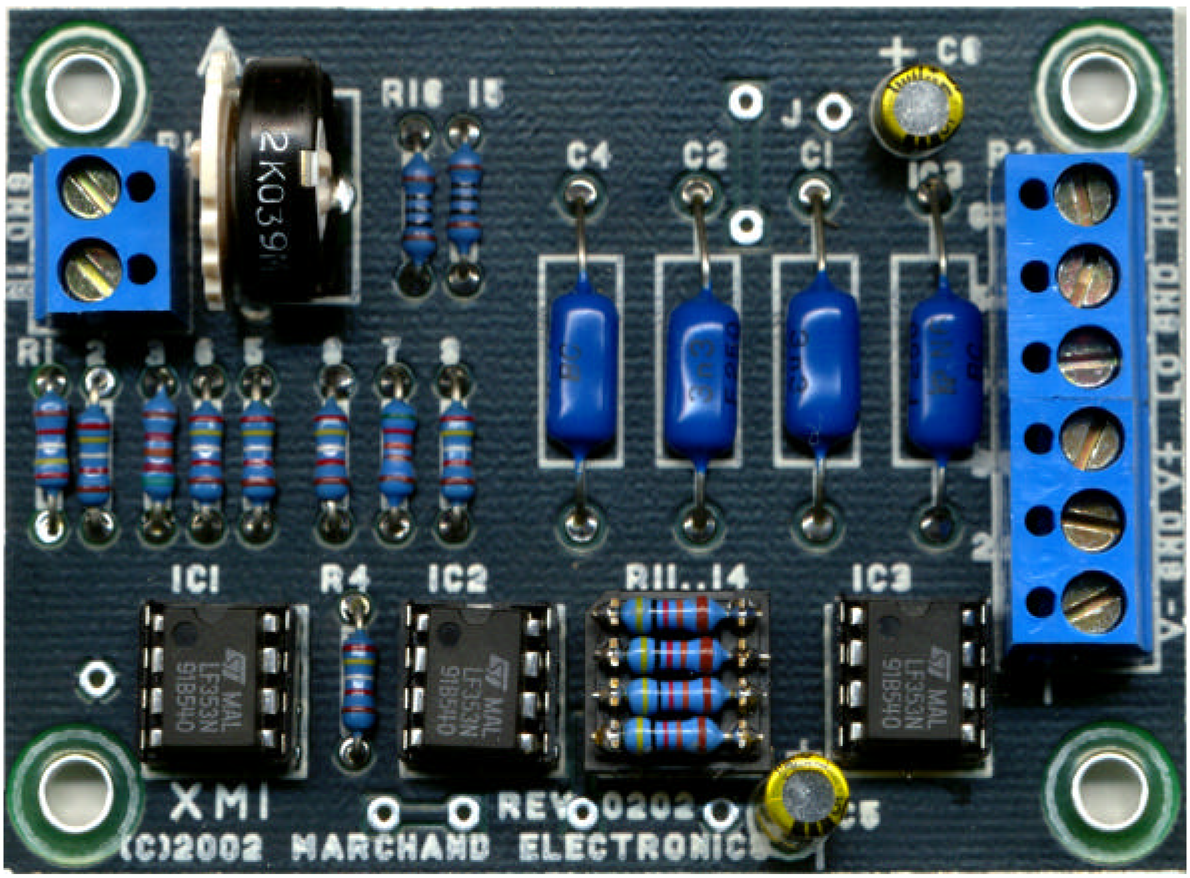
Marchand Electronics Inc.

P.O. Box 18099, Rochester, NY 14618. TEL:(585) 423 0462
www.marchandelec.com

Electronic Crossover
XM1



XM1 ELECTRONIC CROSSOVER NETWORK

GENERAL

In many high performance loudspeaker systems the individual loudspeaker drivers (woofer, mid-range and tweeter) are each driven by an individual power amplifier. The high, mid and low frequencies are separated from each other by an electronic cross over network. In a bi-amplified system there are two power amplifiers per channel, one for the low frequencies, and one for the high's. A tri-amplified system has individual power amplifiers for the low, mid and high frequencies. Quad systems have four, and so on. The advantages of electronic cross-over are many, including lower intermodulation distortion, better loudspeaker damping and more precise cross-over performance.
The XM1 electronic crossover network module is a fourth order constant voltage crossover design. The module provides both low-pass and high-pass outputs. The slope of both outputs is 24 dB/octave. Because of the fourth order design the high-pass and low-pass outputs of the crossover are always in phase with each other. The crossover network is implemented as a fourth order state variable filter. This filter provides both the high-pass and low-pass function simultameously, guaranteeing a near perfect match of the high-pass and low-pass responses.
One crossover network is neded for each channel of a bi-amplified system. A tri-amplified system needs two networks, one to separate the high frequencies from the mid-low frequencies and another one to separate the low and mid frequencies. A quad system needs 3, and so on. The filter can also be used to drive a subwoofer, where the subwoofer is shared by the two channels of the stereo system.

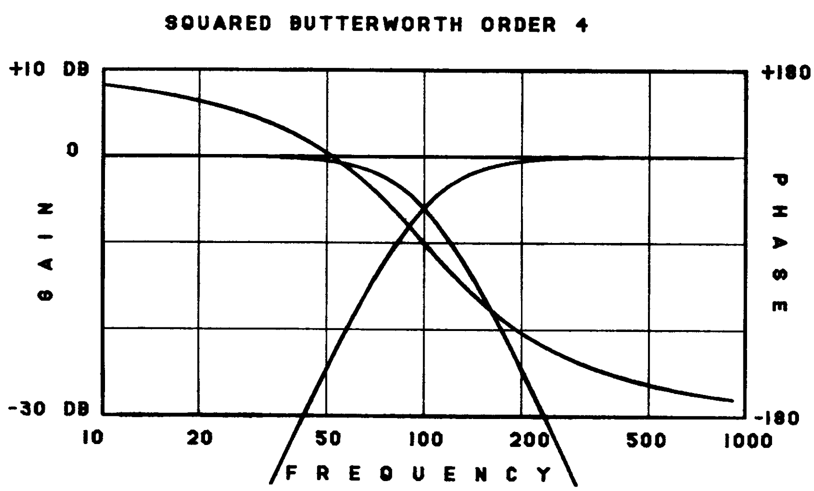


Fig 1. XM-1 High-pass, Low-pass, and sum functions.

The crossover frequency of the XM1 electronic crossover can easily be changed by changing the value of four resistors. These four resistors are mounted on an 8 pin DIP header plug for ease of change. A trimmer potentiometer on the circuit board allows for adjustment of the frequency response at the cross-over frequency. A boost and cut of up to +/- 4 dB at the cross over frequency can compensate for a dip or bump in the response at the cross-over frequency found in some systems.
The XM1 electronic crossover is built on a 2" * 3" printed circuit board of high quality glass-epoxy material. A silk screen on the component side makes assembly very easy. The kit uses only high grade components: 1% metal film resistors, 1% polypropylene film capacitors for the filter capacitors and three dual FET input operational amplifiers. Terminal blocks for input, output and power make for easy assembly.

SPECIFICATIONS.

Frequency response:	DC to 100 KHz, +/- 0.2 dB.
Cross over frequency:	20 Hz - 5 KHz.
Signal to noise ratio:	110 dB min (ref. 8VRMS signal, BW=20 KHz)
Insertion gain:	0dB (1X).
Filterslope:	24 dB/octave
Output load capability:	2K min.
Input impedance:	25 KOhm.
Output impedance:	100 Ohm.
Maximum Input voltage:	25 V p-p (8.8 V RMS).
Power supply requirement:	+15V and -15V @15 mA, typ.

DESCRIPTION

The XM1 implements a fourth order constant voltage low-pas and high-pass filter. The filter has a square-butterworth transfer function, the same as two second order butterworth filters connected in series. The complex frequency transfer functions of the high-pass and low-pass filters are given by:

$$HP(s) = \frac{S^4}{(Wc^2 + 1.414 \cdot Wc \cdot s + s^2)^2}$$

Wc= j*2*pi*Fc.
Fc= crossover frequency
s= j*2*pi*F
F= frequency in Hz

$$LP(s) = \frac{Wc^4}{(Wc^2 + 1.414 \cdot Wc \cdot s + s^2)^2}$$

Wc= j*2*pi*Fc.
Fc= crossover frequency
s= j*2*pi*F

The amplitude of the transfer functions are given by:

$$| HP(F) | = \frac{1}{1 + (Fc/F)^4} \quad ; \quad | LP(F) | = \frac{1}{1 + (F/Fc)^4}$$

This represents a 24 dB/octave attenuation slope in the stopband.

Observe that: $HP(F) + LP(F) = 1.$

The sum of the high-pass and low-pass output signal of the filter is thus equal to the input signal. Also, the two output signals are always in phase. This means that the output soundwaves of the loudspeakers at the crossover frequency add up in phase. Note however that at the crossover frequency the total power equals to half the power far from the crossover point:

$$P(F) = H(F)^2 \quad Ptot = Plp + Php.$$

at crossover frequency:

$$Ptot(Fc) = 1/4 + 1/4 = 1/2$$

In some cases the total sound pressure at the crossover frequency will show a dip, because the sum of the output power of the loudspeakers is not unity. The XM1 has an potentiometer that allows adjustment of the frequency response at the cross-over point. At max(CCW, direction of arrow), a 4dB peaking is realised, and at min(clockwise) there is a 4 dB dip. When the potentiometer is centered the frequency response is flat. Fig-1 shows the frequency response without adjustment. The high-pass, low-pass and sum of these are shown. The phase function is the same for all three transfer functions. Fig-2 shows the same transfer functions, but with the correction potentiometer at maximum(CCW) and at minimum(CW).

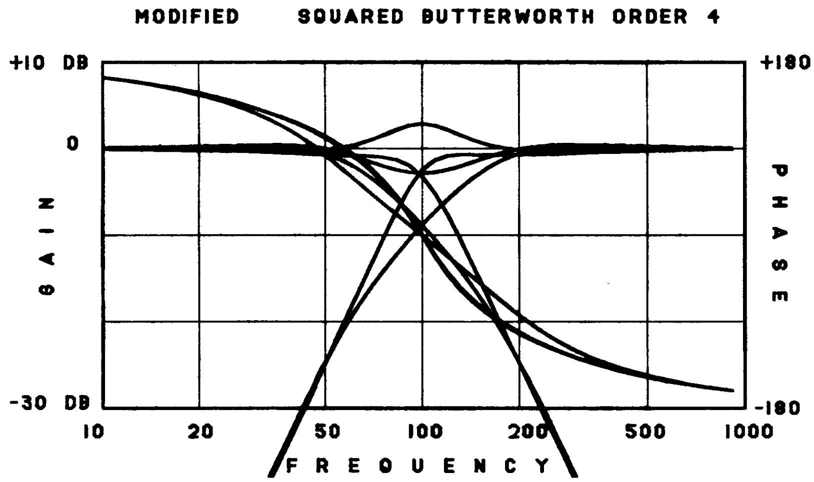


Fig 2. XM-1 High-pass, Low-pass, and sum functions, with correction.

Fig-3 shows some typical arrangements for 2-way, 3-way and 4-way installations. The XM-1 crossover network can also be used to drive a common subwoofer by adding the outputs together with a simple resistive summing network (see fig 4). For driving long lines a line driver buffer amplifier may be needed. The XM-1 outputs can drive shielded cable lines of up to about fifty feet.

The XM-1 is implemented with a fourth order state variable filter,(see schematic diagram). The filter is implemented with the Bi-Fet op-amp's IC1b, IC2a, IC2b, IC3a and IC3b. The great virtue of this type of filter is that it provides simultaneous high-pass and low-pass functions at the two ends of the chain of four integrators. This means that only 4 precision capacitors are needed in order to implement both fourth order functions. Also, and maybe more importantly, both high-pass and low-pass functions will be perfectly matched, because they are derived from the same network.

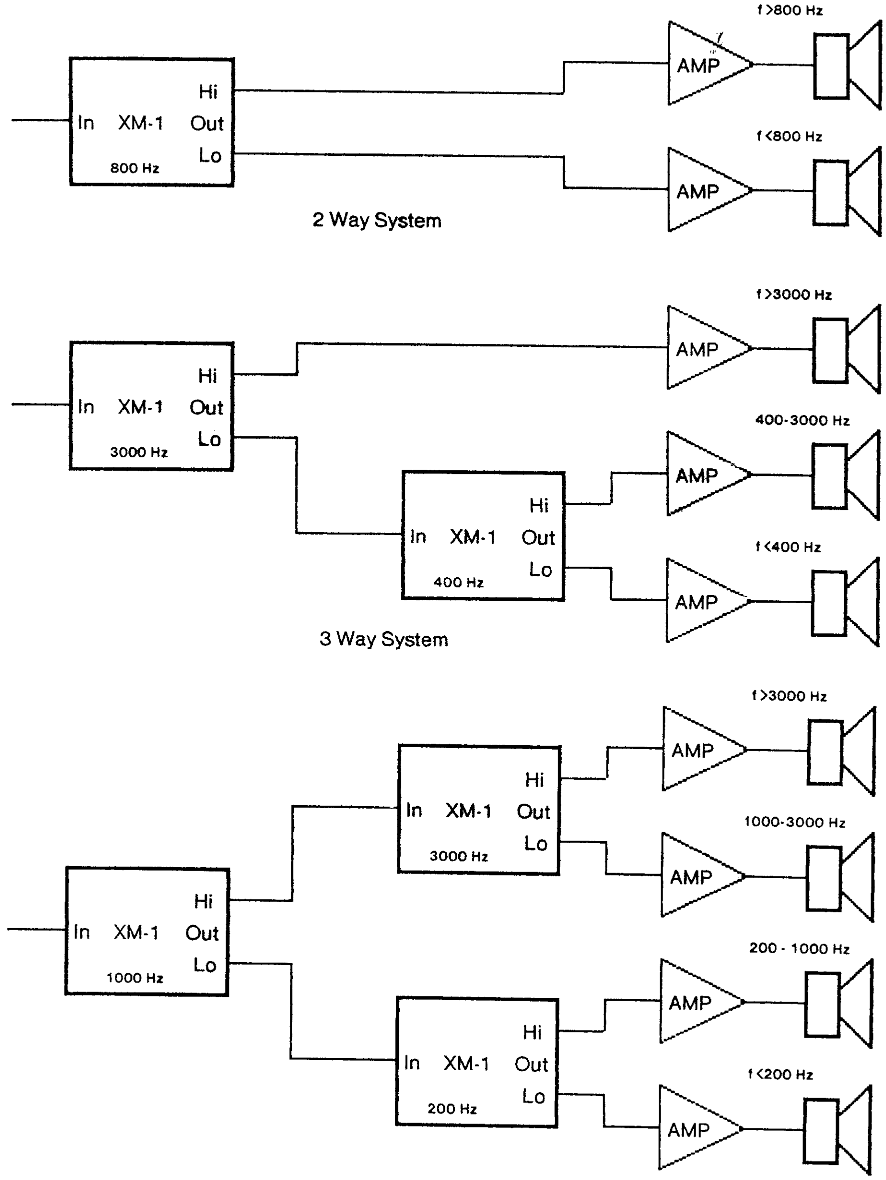


Fig 3. Typical uses of XM1 crossover network.

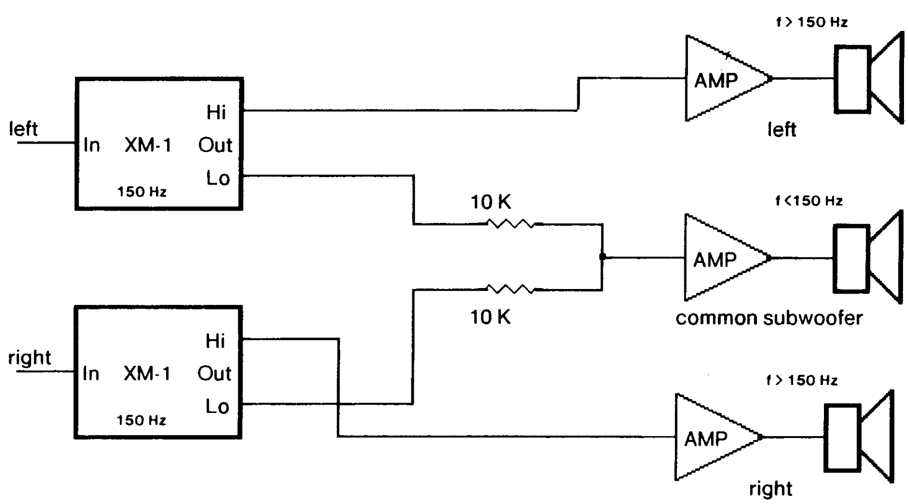


Fig 4. Example of subwoofer application.

PARTS LIST

The XM1 electronic crossover kit should include the parts listed below. Please check the contents of your kit to make sure no parts are missing. All parts are available separately; please consult factory.

Table 1.
XM-1, Electronic Crossover Network, parts list

part	#	Description
R1,2,4,5, 6,8,9	7	24.9K, 1% Metal Film
R3	1	52.3K, 1% Metal Film
R7	1	5.23K, 1% Metal Film
R10	1	2K, Trimmer potentiometer.
R15,R16	2	100 Ohm, 1% Metal Film
C1-4	4	3300pF typ., 250 WVDC, 1% Polypropylene
C5,C6	2	10 uF, 50 WVDC, Alum. Electrolytic
IC1,IC2,IC3	3	LF353 Dual Bi-Fet Op Amp
P1	1	2 pin terminal block
P2	1	6 pin terminal block
M1	4	8 pin DIP sockets
M5	1	2" x 3" circuit board, XM1-B
R11-14	4	100K typ., 1% Metal Film (in frequency)
M2	1	8 pin DIP header (module)

ASSEMBLY INSTRUCTIONS.

The assembly of the crossover filter is made very easy by the silk screen guide on the circuit board. The schematic diagram of the electronic crossover is shown in fig-1. All components should be installed on the side of the board that has the silk screen; this side is called the component side. The parts are then soldered in place on the foil side of the board.

Step 1 removed.

Step 2 ___ Install resistor R1. Use a 1% ,24.9K metal film resistor. The resistor is marked with a color code to indicate the value. The code is Red - Yellow - White - Red -- Brown. The orientation of the resistor is not important. Solder and trim leads.

Step 3 ___ Install R2, 24.9K, 1% Metal Film resistor. Proceed as with R1. Red - Yellow - White - Red -- Brown.

Step 4 ___ R3, 52.3K, 1% MF. Green-Red-Orange-Red--Brown.

Step 5 ___ R4, 24.9K, 1% MF. Red-Yellow-White-Red--Brown.

Step 6 ___ R5, 24.9K, 1% MF. Red-Yellow-White-Red--Brown.

Step 7 ___ R6, 24.9K, 1% MF. Red-Yellow-White-Red--Brown.

Step 8 ___ R7, 5.23K, 1% MF. Green-Red-Orange-Brown--Brown.

Step 9 ___ R8, 24.9K, 1% MF. Red-Yellow-White-Red--Brown.

Step 10 __ R9, 24.9K, 1% MF. Red-Yellow-White-Red--Brown.

Step 11 __ R15, 100 Ohm, 1% MF. Brown-Black-Black-Black--Brown.

Step 12 __ R16, 100 Ohm, 1% MF. Brown-Black-Black-Black--Brown.

Step 13 __ Install the 8-Pin Dual In Line socket for IC1. Insert the socket into the PC board and make sure all 8 pins go through the holes in the board. Also make sure that the pin-1 marker on the socket corresponds with the marking on the board; this side is identified with the half-circle at one side of the rectangle of on the silk screen. Solder.

Step 14 __ Install socket for IC2.

Step 15 __ Install socket for IC3.

Step 16 __ Install socket for Frequency module. This is also an 8-pin DIP socket. Install as above in position marked R11-14.

Step 17 __ Install connector P1 and P2. These male header connectors are best installed together. Insert the 2 pin header at P1 and the 6 pin header at P2. The angled connector contact pins are mounted in a plastic support strip. When installed the plastic strip should rest on the PC board, the long ends of the contacts should face outwards of the board and the short, angled sides of the pins must be inserted in the holes of the board. Insert both headers,turn the board upside down and solder. Make sure the long pins are parallel with the board.

Step 18 __ Install C1, 3300pF,1% Polypropylene Capacitor. The value of C1,C2,C3,C4 may differ, according to the crossover-frequency chosen.

Step 19 __ Install C2, 3300pF,1% Polypropylene Capacitor.

Step 20 __ Install C3, 3300pF,1% Polypropylene Capacitor.

Step 21 __ Install C4, 3300pF,1% Polypropylene Capacitor.

Step 22 __ Install C5, 10uF, 50 WVDC, aluminum electrolytic capacitor,radial leads. The capacitor must be mounted with negative terminal lead as indicated on the board. This is important! The negative lead is indicated on the capacitor with a minus (-) sign. This lead must be inserted in the hole on the board also indentified with a minus sign. The minus sign on the capacitor will be facing the outside of the circuit board.

Step 23 __ Install C6, 10uF, 50 WVDC, as C5, above. Capacitor faces same direction.

Step 24 __ Install R10, 2K trimmer potentiometer. This one can go on in only one way. Solder.

Step 25 __ Assemble frequency module. This module has the 4 resistors R11..R14 that set the crossover frequency. Use the four remaining 1%, MF resistors (value depends on cross-over frequency chosen; typically 100K),place them on the 8-pin DIP header, solder and trim leads. Insert the module into the 8-pin DIP socket at position marked R11-14.

Step 26 __ Install IC1. Insert one of the 8-pin LM353 Dual Bi-Fet Op Amp integrated circuits into the socket at position IC1. Be sure to insert with the pin 1 marking as indicated. The pin 1 side of the IC is indicated with a dot near pin 1, a notch in the package near pin one or a band marking at that side, or a combination of those. Make sure all 8 leads are properly inserted into the DIP socket.

Step 27 __ Install IC2, LM353 Dual Bi-Fet OP Amp.

Step 28 __ Install IC3, LM353 Dual Bi-Fet OP Amp.

Step 29 __ Double check orientation of IC1,IC2,IC3,C5,C6. Operation of these components with reverse power voltage applied will result in destruction of the part.

This completes the assembly of the XM1 crossover network.

INSTALLATION AND USE.

The typical application for the XM1 electronic cross-over filter is to separate the frequency bands in a multy-way audio system. Fig-6 shows the application in a two-way amplifier setup. The signal from the pre-amp is connected to the input of the crossover at P1. The two outputs from the cross-over from P2 are connected to the input of the power amplfiers.

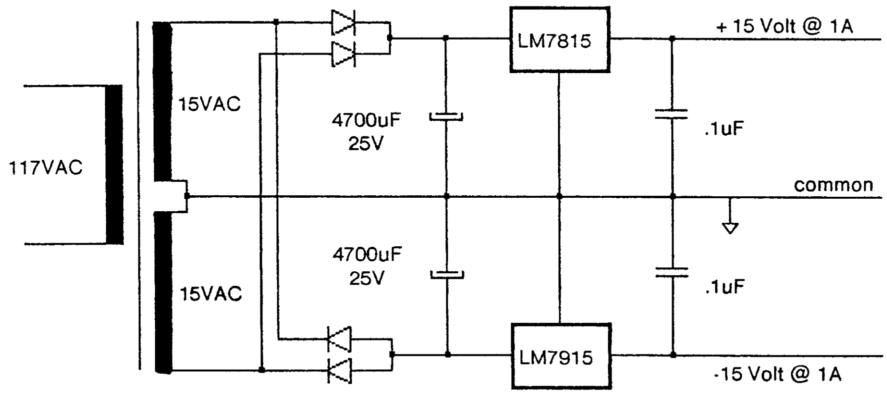


Fig 5. Simple regulated power supply for XM1.

The XM1 needs a dual +15V/-15V power supply for operation. The best choice for power supply is a regulated one. A typical power supply could be built as in fig-5. This supply can deliver 1 amp. of current; this will be sufficient for powering many crossover networks. The potentiometer control on the cross-over sets the frequency response of the filter at the cross-over frequency. With the pot in the center position the frequency response will be a flat constant voltage function. The sum of the output of both channels will equal the voltage at the input. A peaking in the sum-voltage at the crossover will result when the pot is adjusted in the direction of the arrow (CCW)(Fig 4). The maximum peaking is +4dB. This is to compensate for a possible dip in the frequency response of the loudspeakers at the crossover frequency, when driven with a constant voltage cross-over. With the pot turned fully against the direction of the arrow (min resisistance,clockwise) there will be a 4 dB dip in the frequency response.

Table 2.
Connector pin assignments.

Connector	Pin #	Signal description
P1	1	Input signal ground
P1	2	Input signal
P2	1	-15 Volt power, 15 mA, typ.
P2	2	Power ground
P2	3	+15 Volt power, 15 mA, typ.
P2	4	Low-pass output
P2	5	Output signal ground
P2	6	High-pass output

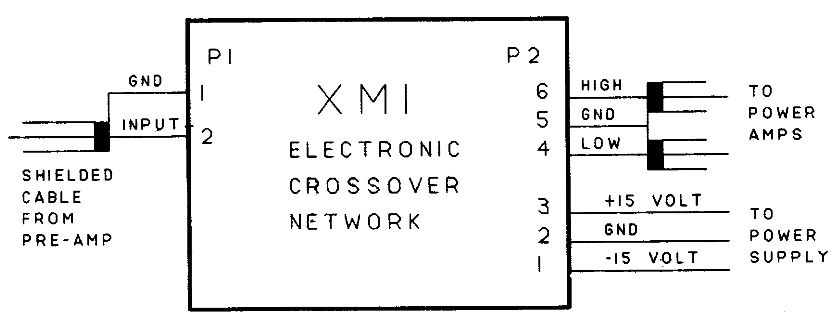


Fig 6. XM1 hookup.

Volume controls can be hooked to the high anw low pass outputs of the XM1, as shown in figure 7. This allows balancing of the outputs where the power amplifiers have no volume control. Best results are achieved when using 10 K potentiometers with linear taper. When using this arrangement care should be taken not to drive cables with a length of more than about 30 feet, or the high frequencies will be attenuated. Shielded cable should be used.

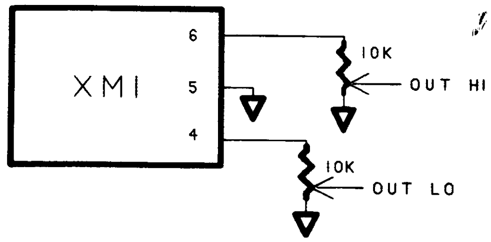


Fig 7. Using volume controls on the outputs.

Figure 8 shows the use of volume controls with two crossovers driving a common subwoofer.

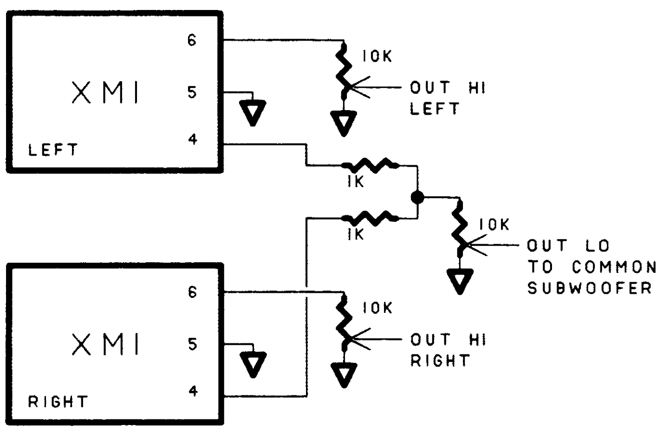


Fig 8. Common subwoofer with volume controls.

AUTOMOTIVE APPLICATIONS

The XM1 can also be used with the sound system of a car. The problem here is that most cars have a single 12 volt battery as a power source, and the XM1 requires positive and negative supply voltages. Figure 9 shows a simple solution where the 12 volt supply is used directly to drive the crossover; the ground reference is derived from the battery voltage through a simple voltage divider. This circuit works well if AC coupling of the signals is allowed and the signal levels do not excede 2.5 volt RMS (4 volts peak).Resistors R1, R2 and capacitors C2, C3 remove noise signals from the power supply to avoid alternator whine to be passed on to the output signals. R3, R4 and C4 define the ground reference for the crossover. The input signal is AC coupled with C1, and the output signals are AC coupled with C5 and C6. Using film capacitors for C5 and C6 should be considered with high performance systems. A better solution is to use a DC to DC converter to generate the neative supply voltage from the positive battery voltage. The circiut of figure 10 uses a power amplifier IC to generate a square wave signal with a frequency of about 40 KHz. Rectification of this signal yields the negative supply voltage. No voltage regulation is used. The frequency fo oscillation is set with C1. R1 provides proper bias to the input of IC1. IC1 should be mounted on a heatsink of at least 2 square inches. The diodes D1, D2 and capacitors C2, C6 make the power rectifier. R2..R5, C3, C4, C5, C7 and C8 provide power filtering in order to eliminate aternator whine, etc. from the supply. Figure 11 shows the output voltage as function of the load current, for a typical battery voltage of 13 volt. The negative power supply will be a few volt less than the positive value, but in most applications this should be no problem. With each XM1 drawing about 15 mA of supply current, this power supply is good for a load of up to 4 crossover networks.

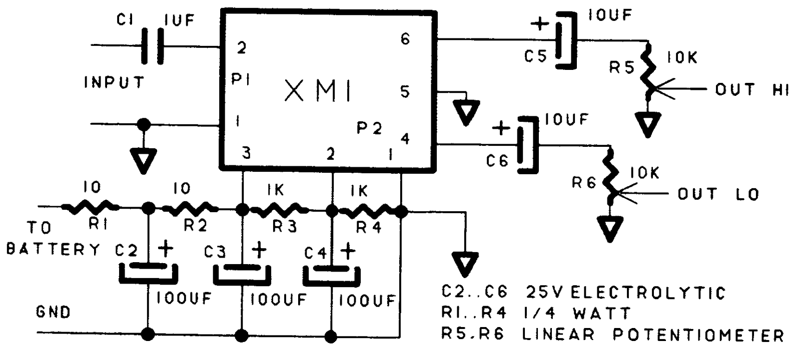


Fig 9. Simple automotive power supply.

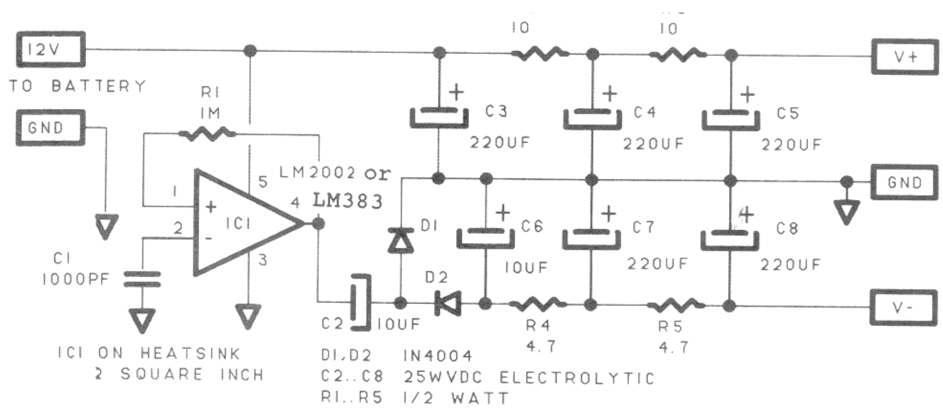


Fig 10. Dual power supply for automotive use.

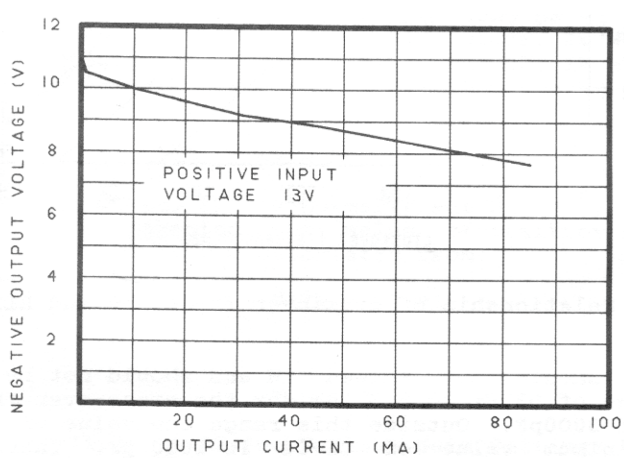


Fig 11. Output voltage vs. load for supply of fig 10.

CROSS-OVER FREQUENCY.

The cross-over frequency of the XM1 is easily changed by replacing the frequency module. This 8-pin dip header holds the 4 resistors R11-14 that determine the frequency of the cross-over point. The four resistors should have a tolerance of 1%, and be of equal value. The value of the resistors is given by:

$$R = \frac{1}{6.283 \times F \times C},$$

F=cross-over frequency in Hz
R=resistance of R11..R14 in Ohm
C=capacitance of C1..C4 in Farad.

For a typical value of C1,C2,C3,C4 of 3300 pF, the value of R is given by

$$R = \frac{48.2}{F},$$

F=cross-over frequency in KHz
R=resistance of R11..R14 in K.

For example, a resistor value of 100K will give a cross-over frequency of 482 Hz. Fig 12 shows the relationship between cross-over frequency and R11 .. R14 for three different values of C1 .. C4.

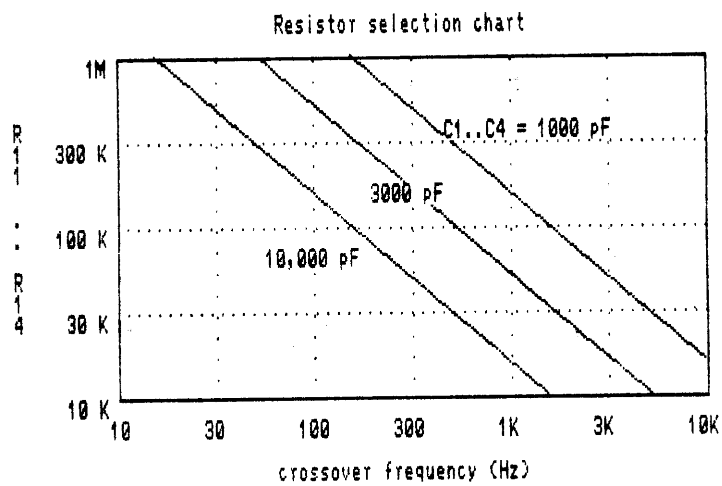


Fig 12. Relationship of crossover frequency and R11..R14.

The value of R should not exceed 1M and should not be less than 10K. This gives a range of 48 Hz to 4.8 KHz for the cross-over frequency with a value of C1-C4 of 3300pF. Outside this range the value of C1-C4 should be adjusted. The minimum value of C1-C4 is 1000 pF. There is no maximum allowed value. The components used for R and C should be audio grade. Recommended are1% Metal Film for R11-R14 and 1% matched Polypropylene film for C1-C4. Polypropylene film capacitors match Polypropylene in performance. Other types of film capacitors are less perfect, because they have much higher absorption coefficients. Never use electrolytic capacitors for C1-C4!

MODIFICATIONS FOR FIRST, SECOND AND THIRD ORDER OPERATION

With some changes in component values the XM1 can be used as a first, second or third order filter. The changes are shown in table 3. In these modes the trimmer resistor R10 is removed and replaced with a jumper, and the vaiable damping is not functional any more. Some of the poystyrene filter capacitors are replaced with 24.9K, 1/4 watt, 1% metal film resistors. Resistors R12,R13 and R14 are located on the frequency module header, between pins (4,5), (2,7) and (1,8) respectively. For the second and third order filter a standard Butterwoth slope was chosen; for most applications this will be a good choice.

Table 3.

Component changes for lower order filter applications.

Component	Fourth order Constant V. 24 db/oct.	First order 6 db/oct.	Second order Butterworth 12 db/oct.	Third order Butterworth 18 db/oct.
R3	52.3K, 1% MF	24.9K, 1% MF	22.1K, 1% MF	24.9K, 1% MF
R5	24.9K, 1% MF	24.9K, 1% MF	24.9K, 1% MF	12.4K, 1% MF
R6	24.9K, 1% MF	deleted	deleted	24.9K, 1% MF
R7	5.23K, 1% MF	deleted	24.9K, 1% MF	12.4K, 1% MF
R9	24.9K, 1% MF	deleted	deleted	deleted
R10	2K trimmer	jumpered	jumpered	jumpered
R12	variable	24.9K, 1% MF	variable	variable
R13	variable	24.9K, 1% MF	24.9K, 1% MF	variable
R14	variable	24.9K, 1% MF	24.9K, 1% MF	24.9K, 1% MF
C2	3300 pF	24.9K, 1% MF	3300 pF	3300 pF
C3	3300 pF	24.9K, 1% MF	24.9K, 1% MF	3300 pF
C4	3300 pF	24.9K, 1% MF	24.9K, 1% MF	24.9K, 1% MF

GAIN ADJUSTMENT

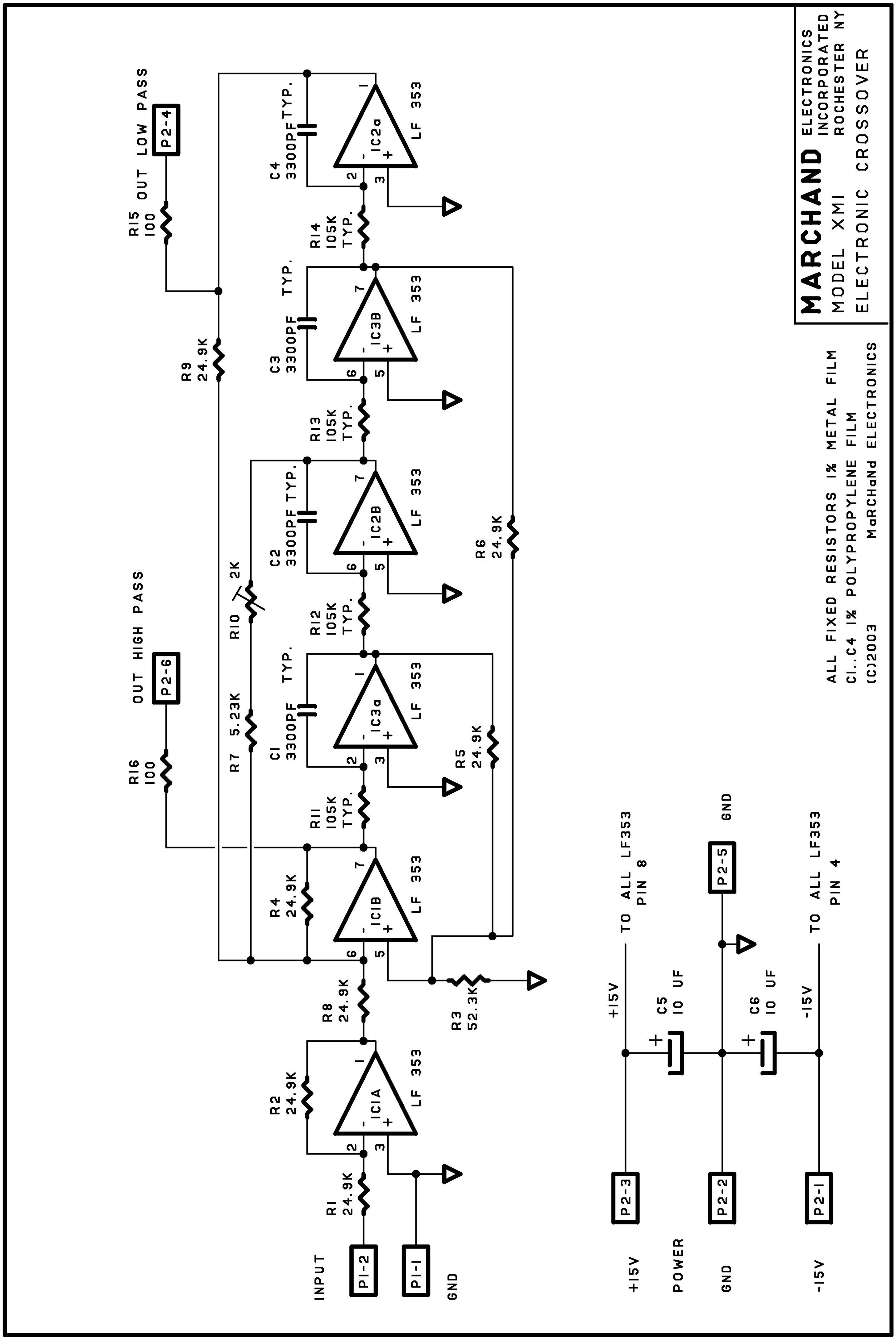
The voltage gain of the XM1 is normally set at unity (0 dB). Other gains can be obtained by changing the value of resitror R2. The gain can be calculated from:

GAIN = R2/R1.

Table 4.

Value of R2 for Various Gain Settings

Gain	(dB)	R2
1	0	24.9K, 1% MF
2	6	49.9K, 1% MF
4	12	100K, 1% MF
10	20	249K, 1% MF


MARCHAND ELECTRONICS INCORPORATED ROCHESTER NY
MODEL XMI
ELECTRONIC CROSSOVER
ALL FIXED RESISTORS 1% METAL FILM
C1..C4 1% POLYPROPYLENE FILM
(C)2003 MaRCHaNd ELECTRONICS
INPUT
P1-2
P1-1
GND
R1 24.9K
R2 24.9K
IC1A
LF 353
R8 24.9K
R3 52.3K
R4 24.9K
IC1B
R7 5.23K
R10 2K
R9 24.9K
R16 100
OUT HIGH PASS
P2-6
R15 100
OUT LOW PASS
P2-4
R11 105K TYP.
C1 3300PF TYP.
IC3a
R5 24.9K
R12 105K TYP.
C2 3300PF TYP.
IC2B
R6 24.9K
R13 105K TYP.
C3 3300PF TYP.
IC3B
R14 105K TYP.
C4 3300PF TYP.
IC2a
+15V
C5 10 UF
C6 10 UF
-15V
TO ALL LF353 PIN 8
TO ALL LF353 PIN 4
P2-5
GND
P2-3
P2-2
P2-1
+15V
POWER
GND
-15V