PASS LABORATORIES XVR1 ELECTRONIC CROSSOVER NETWORK OWNERS MANUAL

4/24/02

INTRODUCTION

Some audio products are designed for anybody who can put batteries in a flashlight. This product is not like that.

Some audio products are designed so that you don't have to study the manual. This product is not like that, either.

Some audio products are designed so that you plug them in and you don't have to fool around with them for a year before the system is greatly improved….

Some Basics:

As you may already know, most loudspeaker drivers have specialized tasks and are designed to operate over only a portion of the audio spectrum. They do not perform well outside their given range, and are not usually designed to be driven outside this range without bad results.

A filter system called a crossover network divides the audio spectrum into frequency bands appropriate for the drivers. There are passive networks, usually found inside the speaker, which are placed between the amplifier and the loudspeaker driver to create this effect.

Alternatively, there are active electronic crossover filters placed in the signal path before multiple power amplifiers. Each amplifier then amplifies only a portion of the audio band and powers the speakers associated with that frequency range.

There are many performance advantages offered by active crossover networks. They give better performance in the following ways:

Higher power. Typically two amplifiers driving a speaker with an electronic crossover will deliver peak wattages almost 4 times the peak (8 times the rms) wattage rating of a single amplifier of the same power rating. This is because the voltage waveforms coming off the high and low pass filters are not mixed, and the high pass voltage does not ride on top of the low pass voltages. When the waveform of a low frequency approaches the limit of the amplifier, there is no voltage left over for the high frequency. With an electronic crossover, the available voltage is nearly doubled, and power is quadrupled.

Better use of power. Passive crossover networks divide down the power output of the amplifiers, both in adjusting the efficiency of a driver against the other drivers used, but also by dividing down the output signal as the frequency leaves the bandpass frequency range. Very often this means that only a fraction of the power available from the amplifier can get to the loudspeaker driver. It also means that the least efficient driver sets the efficiency standard for all the drivers. Active crossovers do not suffer from this effect.

Higher damping factor. Many loudspeaker drivers depend on a low source impedance from the amplifier to deliver their best performance. Even moderately good amplifiers have a quite low source impedance, also known as high damping factor, and this quality helps the loudspeaker driver to start and stop its motion more quickly and also evens out the frequency response. Any passive crossover introduces significant impedance between the amplifier and the speaker, and can reduce damping factor from 1,000 to as low as 1.

Lower distortion. In addition to lowering the distortion of individual drivers and eliminating the linear and nonlinear distortions of high power passive filter components, active filters dramatically lower the intermodulation distortion of the amplifiers. Since the high frequencies share the same amplifier as the low frequencies, the low frequencies can modulate, or change the amplitude, of the high frequencies, particularly under high power conditions.

More control and flexibility. It is difficult and time consuming to adjust the characteristics of a passive crossover filter. It is easy with an electronic crossover to adjust the crossover frequencies, the filter cutoff rate (slope), the “Q” or sharpness of the cutoff knee, and the volume level of the loudspeaker driver. Unlike a passive crossover, these characteristics do not depend on the driver’s impedance which varies considerably at different frequencies. The XVR1 is probably the most flexible electronic crossover in existence. It has literally millions of possible settings, most of which you will never want, but they are available just in case.

Tailoring amplifiers to speakers. Some amplifiers are more appropriate for powering different frequencies and loudspeaker drivers. As an example, you might prefer to drive your woofer with a big powerful solid state amplifier which will deliver the maximum damping and control and drive your midrange and tweeter with a tube amplifier chosen for its ambience and the sweet character if its high frequencies.

In any case, for those seeking the utmost performance from acoustic transducers (that’s loudspeakers), an active filter system carries the most promise, and is particularly necessary for those doing custom work and design.

Using an electronic crossover is not necessarily easy. Getting what you truly want requires effort and patience and the ability to tell what you want when you hear it (or measure it). While this crossover can execute a “canned” setting recommended by a speaker driver manufacturer or a system designer, its true value lies in being able to do anything you want to try.

There are several sections to this owner's manual: Introduction, Product Description, Quick Installation, Some Real Basic Theory, Some Real Tips, Some Real Projects, and Some Product Specs.

Cautions:

Remove the AC power cord from the XVR1 power supply before opening the enclosure of the XVR1 in order to adjust the filter settings. When the power supply is connected to the AC wall socket there are high voltages inside.

Do not open the enclosure to the XVR1 power supply. There are no adjustable parts inside the power supply, and there are dangerously high voltages inside.

It is fairly easy to set the crossover filters with characteristics which will damage loudspeaker drivers. Follow the instructions closely and double check the settings before powering up the amplifiers.

Please read the Quick Install section before attempting to operate the XVR1. Even if you are a big time expert in audio, you will probably need this information if you need to adjust any characteristic of the filters.

Unless you are provided with a document indicating otherwise, the following are the default settings of the filters that ship with the XVR1:

Low Pass:	1060 Hz,	12 dB/oct,	Q = MEDIUM	AS SEEN ON PAGE 9
High Pass:	1060 Hz,	12 dB/oct,	Q = MEDIUM	AS SEEN ON PAGE 13

Thank you for purchasing this product. It was created over a period of several years for our own loudspeaker design efforts, and it is the design that ultimately performed with the most flexibility and quality, and gave us the most satisfaction with the end result. Many of the practical things we learned about what makes an effective active crossover are described in the Theory of Operation section of this manual. Remember that it takes patience and persistence to get the absolute best out of an active system, but the results will be worth it.

You will may have additional questions not covered in this manual. Please feel free to contact us at WWW.PASSLABS.COM

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PRODUCT DESCRIPTION

The XVR1 is a two channel crossover filter for bi-amplification. It offers two channels of either balanced (XLR) or single-ended (RCA) input, and divides the input signal of each channel into two frequency bands, the low pass band and the high pass band. These filtered signals can be adjusted for loudness on four knobs on the front panel, one each for two channels of low pass, and one each for two channels of high pass. The low pass and high pass signal outputs are presented both as balanced (XLR) and unbalanced (RCA).

The characteristics of each of the crossover filters is extremely flexible and adjustable, offering approximately 20 million possibilities. Each filter offers 1,2,3 or 4 poles for 6, 12, 18, or 24 deciBels per octave (dB/oct) slopes at 39 frequencies ranging from 22 Hz to 18,000 Hz. The 4 poles are independently adjustable, meaning that they can each be at 39 different frequency values, and are not required to have the same value as with conventional crossover networks. This is of particular value in fine adjustment of crossover points and custom equalization of loudspeaker drivers and phase compensation. In addition, the sharpness of the frequency curve or “Q” is available in low, medium, or high characteristic. These filters are adjustable through clearly marked jumpers on the main board of the XVR1.

The XVR1 circuitry is completely discrete single-ended Class A, using matched JFET input devices and bipolar current sources. The input circuit features a high input impedance and, when used balanced, a very high rejection of common mode noise. The distortion and noise imposed on a signal running through all possible circuits in the system is typically less than .05% at 30 volts balanced output from 20 Hz to 20 KHz, and less than .005% at 3 volts output. Provision has been made to completely bypass unused 3 and 4 pole portions of the filters, so as to absolutely minimize distortion and noise.

The outputs of the XVR1 are designed to drive balanced (XLR) or single-ended (RCA) cables and will drive ordinary amplifier impedances to 45 volts peak balanced, or 22 volts single-ended. The outputs of the XVR1 are muted to ground through relays to prevent turn-on noise through the speakers when the unit is initially powered up. When power is interrupted or when AC line voltage is too low to support supply regulation, the relays mute again, preventing turn-off transient noise.

The XVR1 comes with a physically separate power supply which carries provision for powering two XVR1 chassis for tri-amp filter configurations. Each XVR1 chassis draws approximately 15 watts, and is designed to operate continuously. Additional XVR1’s and supplies are used in cascade to create crossover filters for 4 amplifier and 5 amplifier systems.

INSTALLATION AND SETUP

You can put the XVR1 and its power supply anywhere you like, but keep in mind that they should be close enough so that the power cord will reach from the XVR1 to the power supply. You can place the XVR1 on top of the supply if you like.

You may occasionally want to adjust the filter characteristics of the XVR1 (see sections below) and to do so it will be necessary to have access through the top cover, and so you might want to consider placing the XVR1 so that you can easily access the top cover.

The XVR1 power supply is designed to power one or two XVR1 filter networks. Each XVR1 is provided with a 25 pin cable for connection from the XVR1 to the power supply. Attach the cable to the appropriate 25 pin connector on the back of the XVR1 and connect the other end to either of the two 25 pin connectors on the back of the power supply. Do not plug in the AC power line yet.

There are two sets of input connectors for the Left and Right channels; single ended RCA audio connectors and balanced XLR connectors. On the XLR connector, pin 1 is grounded, pin 2 is positive signal, and pin 3 is negative signal. Pin 2 of the XLR connector is the same as the “tip” or “hot” pin of the RCA connector. If you are using the RCA input connection, you will obtain best results with pins 1 and 3 of the XLR connector shorted together with the jumper provided. The XVR1 will work without the jumper when you use the RCA input, but the jumper gives lower noise and is preferred. If you remove this jumper when using the XLR connection, save it for future use. If you lose it, contact Pass Labs for a replacement, which we will cheerfully send.

By the way, the input impedance for RCA connection is 44.2 K ohms, and is 66.3 K ohms for balanced connection.

Each of the four filters, two Low Pass and two High Pass, has a set of output jacks on the back of the XVR1. Each set of output connections has a single-ended RCA jack with which you are probably familiar, designed to accept an ordinary audio cable which connects the output of the filter to the input of a power amplifier. Also included is an XLR balanced output connector for driving balanced lines and intended to connect to a similar connector on the input of a power amplifier. On the XLR connector, pin 1 is grounded, pin 2 is positive signal, and pin 3 is negative signal. Both pin 2 and 3 are driven actively with an output impedance of 100 ohms.

You may use either or both RCA and XLR output jacks without adjusting anything, keeping in mind that they share a common ground and also have the positive output in common, so that pin 2 output of the XLR is the same connection as the “tip” of the RCA connector.

Ground noise is a common problem with active crossovers as there is more opportunity for ground loops when you have multiple amplifiers. Use of balanced operation commonly avoids these problems, but you may find that you have to break the earth ground connection of one or more components in order to eliminate the ground loop. If you do this, it is advisable to leave at least one component, preferably the XVR1, earth grounded through the AC power connection so that electrical safety can be assured.

Setting Up the Filters

The XVR1 is shipped with a hex or “allen” wrench for the purpose of opening the top cover of the XVR1 for adjustment of the filters.

DO NOT OPERATE THE XVR1 WITH THE COVER REMOVED. THERE ARE HIGH VOLTAGES INSIDE WHICH ARE HAZARDOUS. ALWAYS UNPLUG THE AC LINE CORD OF THE XVR1 POWER SUPPLY WHEN THE COVER IS OPEN.

If you have any hesitation about your expertise or ability to perform the internal adjustments to the XVR1 filters, then get a qualified technician to do the work.

This section assumes that you are planning a filter with medium “Q”, or corner sharpness, and that all poles for each high or low pass filter are at the same frequency. For information on using different Q values or different pole frequencies, refer to the MORE OPERATION DETAILS section of this manual.

This section also assumes that you know what frequency and slope you want each filter to have. The choices are 22, 25, 29, 36, 48, 53, 59, 66, 75, 88, 106, 133, and 180 Hz. Each of the four poles available has a labeled spot for a shorting plug to set the frequency of that pole. Each pole also has three sets of pins for shorting plugs to set the frequency multiplier, **X1**, **X10**, and **X100**.

When a pole is not used, there are two spots to place the shorting jumpers, both marked **OUT** which disable that pole of the filter.

The poles of each filter are to be used in sequence, that is to say we use the bank of pins labeled **POLE 1** first, then **POLE 2** and so on. A 6 dB/octave single pole filter uses only the frequency and multiplier settings of **POLE 1** and the jumpers of **POLE 2**, **3**, and **4** are set to the **OUT** positions.

A 12 dB/octave 2 pole filter uses the banks of pins labeled **POLE 1** and **POLE 2**.

An 18 dB/octave 3 pole filter uses the banks of pins of **POLE 1**, **2** and **3**.

A 24 dB/octave 4 pole filter uses the banks of pins of **POLE 1**, **2**, **3**, and **4**.

Again, the two jumpers for each unused pole of any filter should be placed on the two sets of **OUT** pins provided.

Under no circumstances should you use **POLE 2** with **POLE 1** in the **OUT** setting, and you should never use **POLE 4** with **POLE 3** in the **OUT** setting. Doing so will not hurt the XVR1, but we make no guarantees that your loudspeaker will appreciate the result. Observe the following cautions whenever adjusting the filter characteristics of the XVR1:

Remove the AC power cord from the XVR1 power supply before opening the enclosure of the XVR1 in order to adjust the filter settings. When the power supply is connected to the AC wall socket there are high voltages inside.

It is fairly easy to set the crossover filters with characteristics which will damage loudspeaker drivers. The XVR1 is sufficiently flexible that it can be made into an oscillator through some combinations of filter values. For this reason, set the front panel level controls of the XVR1 to minimum and double check the settings before powering up the amplifiers. After powering up both the XVR1 and the power amplifiers, gently raise the level controls of the XVR1 while listening for any potential noise.

Each filter of the XVR1 actually consists of two filters cascaded, each capable of 6 or 12 dB/octave slopes and each capable of its own "Q" setting. For this reason, you will see that each filter has two sets of "Q" pin settings, **L**, **M**, and **H** (Low, Medium, and High). These can be set independently, and in this section, it is assumed that the jumpers of both are in the **M** (medium) or middle position.

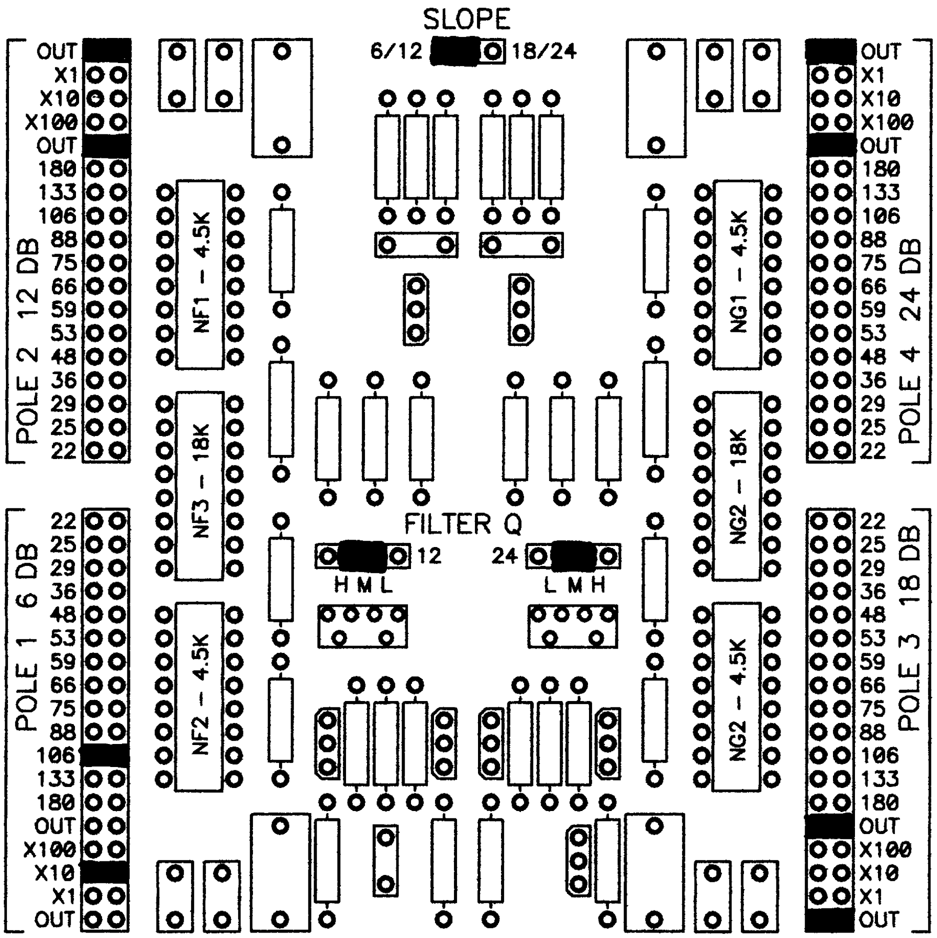
As the two parts of each filter are cascaded, signal runs through both of them in series, however when using only one or two poles for 6 or 12 dB/octave, it is not necessary to also run the signal through the second part and pick up the extra noise and distortion that the second part contributes. To enhance performance, each filter also offers a means of bypassing the second part when you are using 6 or 12 dB/octave slopes. In the middle at the top of each filter you will see a 3 pin jumper switch which allows selection of either **6/12** or **18/24**. Selecting **6/12** bypasses the second part of the filter circuit, and selecting **18/24** enables the second part also. It is not essential to bypass the second part of the filter circuit; it will work fine on **18/24** even if you are only using a 6 dB/octave filter, but it will have a bit more noise and distortion.

In the following pages we are going to show you four different setups each for high pass and low pass filters, along with the resulting curves for each. Note the positions of the jumpers in each of these examples, and we hope you will gain the proper insight as to how these jumpers work. All of the examples assume a crossover frequency of 1060 Hz, which has the frequency jumpers on **106** and the multipliers on **X10**.

In each of these cases, we are going to show you a set of 4 response lines in each frequency response graph. These are the characteristics for the 6, 12, 18, and 24 dB/octave settings. We do this so you can get a sense of the comparative response of these four different slopes, and we will be indicating which of the four lines matches the filter setting shown on that page.

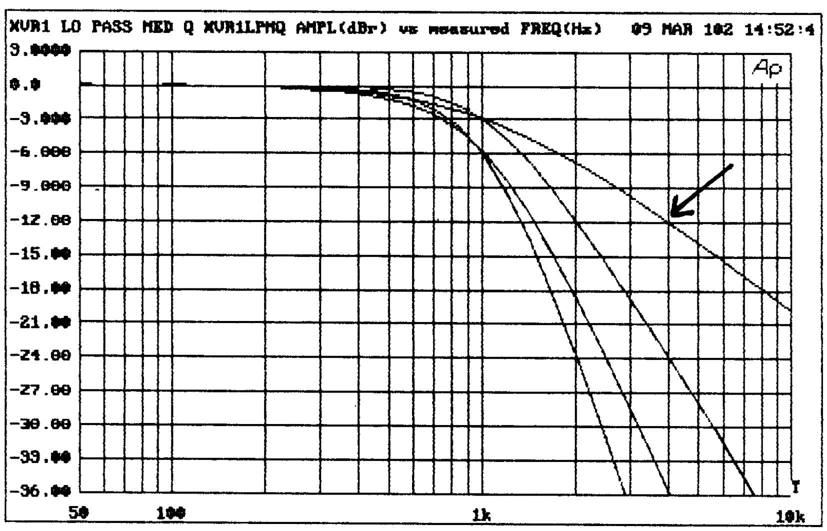
Please note that only one channel of the crossover is shown here. You will need to set the filters for both the LEFT and RIGHT sets of filters. The LEFT channels are in the front of the XVR1 and the RIGHT channels are in the back, and both are labeled on the left of the main board.

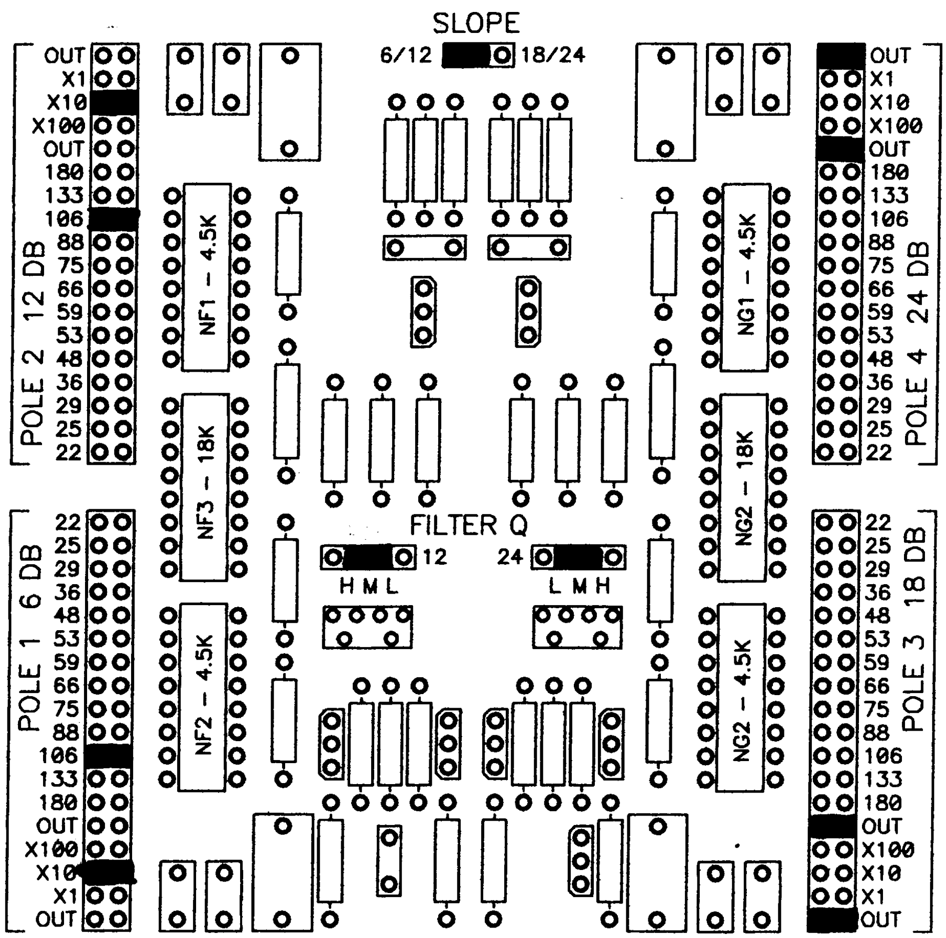
By the way, we provide some extra shorting plugs packed with the XVR1 in case you lose or break any. If you come up short, contact Pass Labs, and we will provide you with some in exchange for a smile.



LOW PASS FILTER

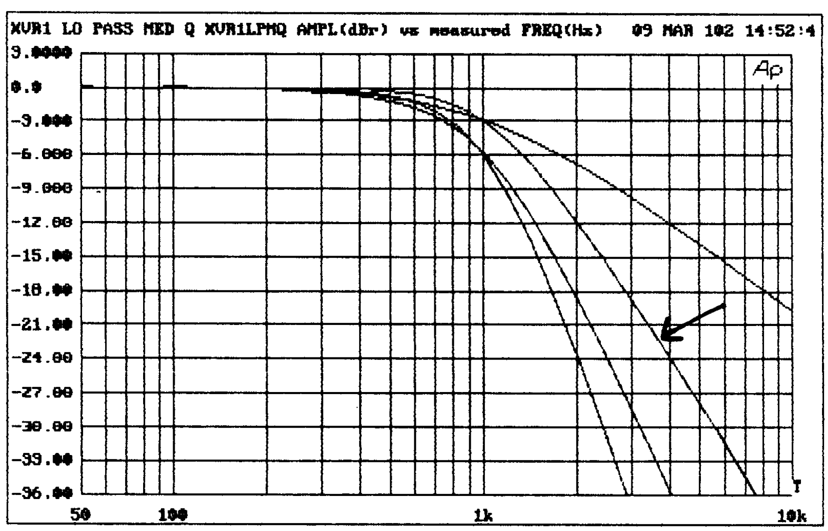
6 DB/OCT (1 POLE) @ 1060 Hz

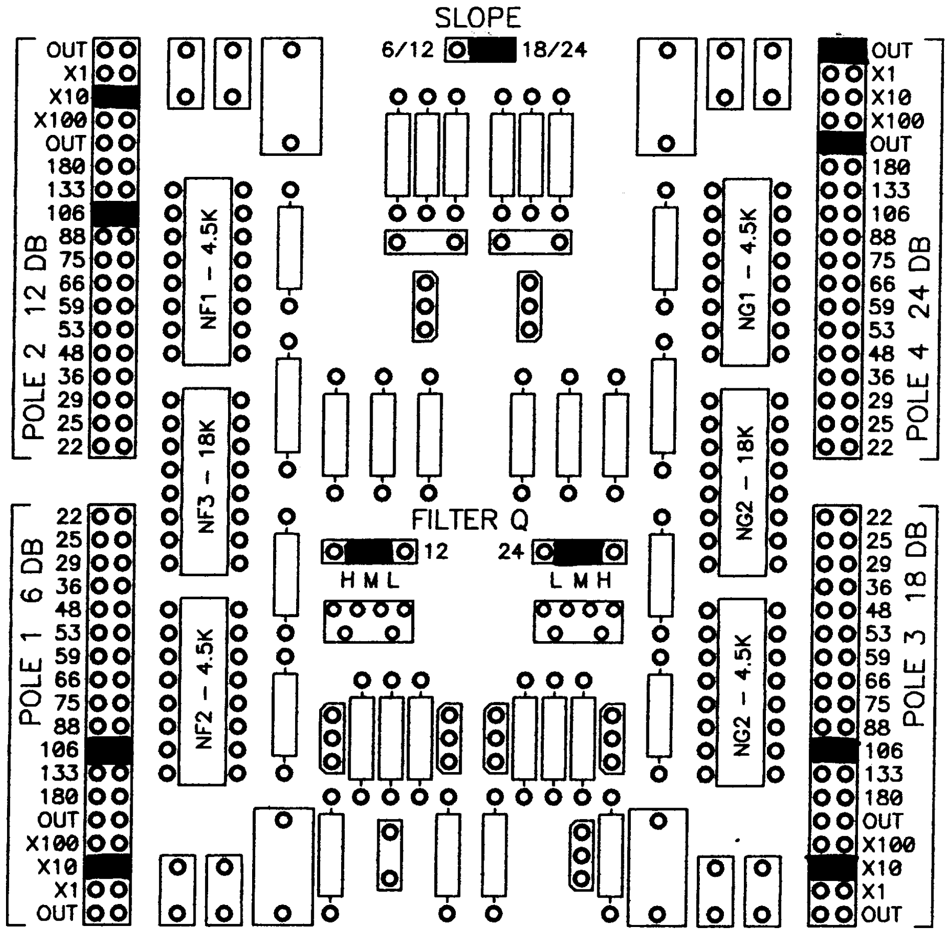




LOW PASS FILTER

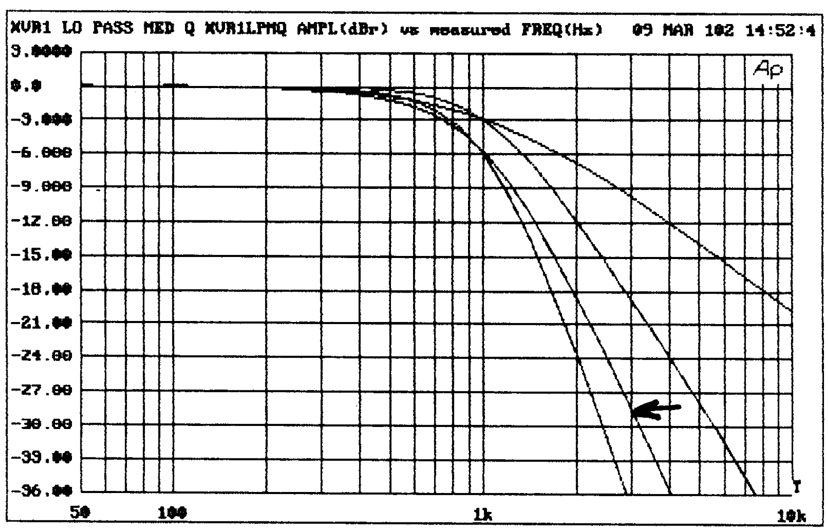
12 DB/OCT (2 POLE) @ 1060 Hz

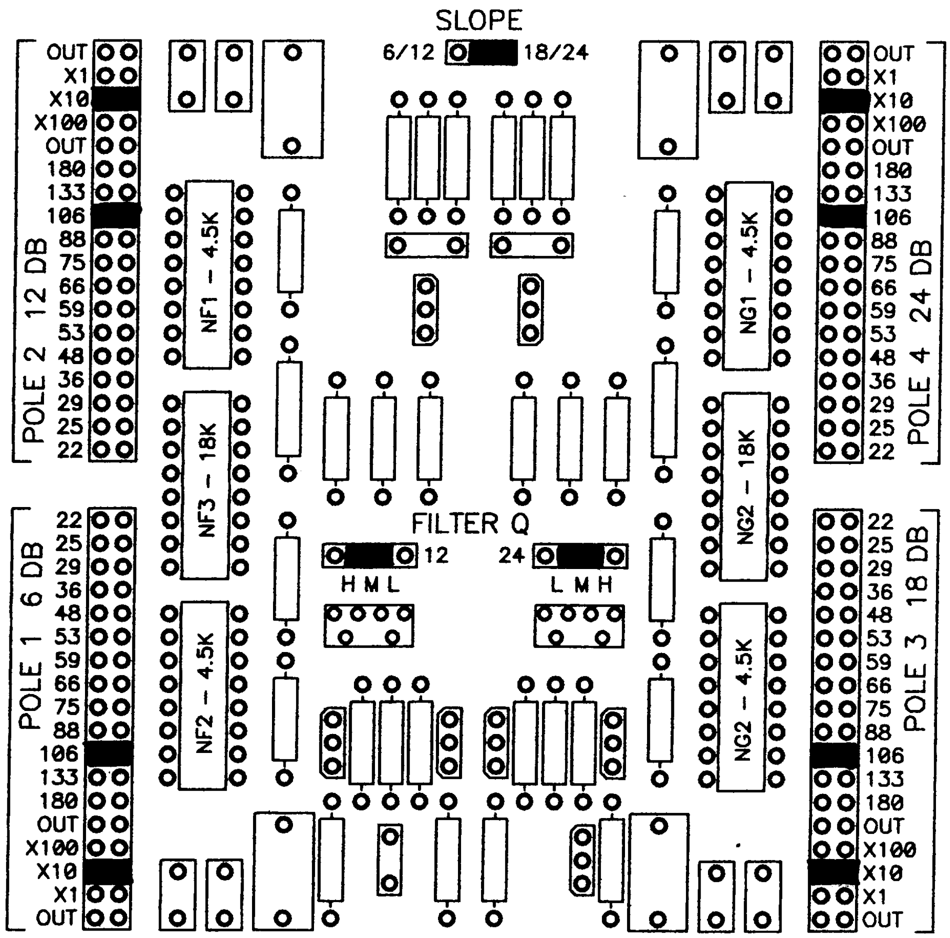




LOW PASS FILTER

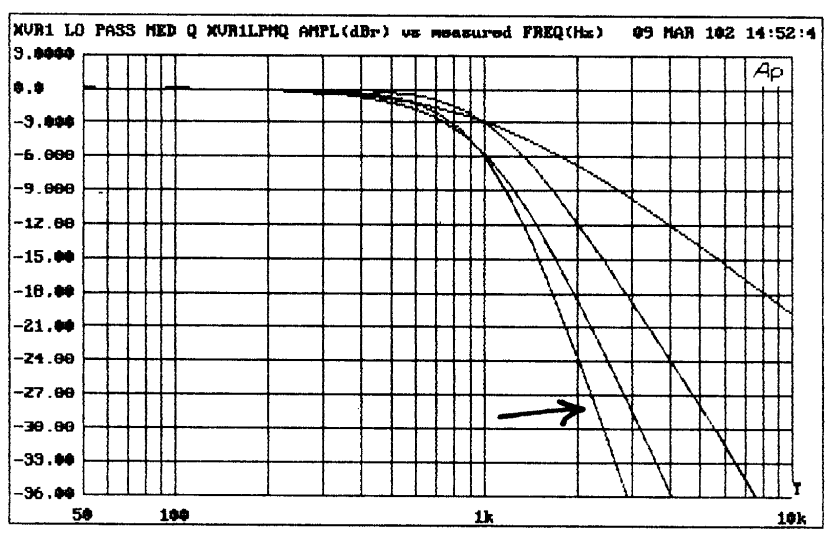
18 DB/OCT (3 POLE) @ 1060 Hz

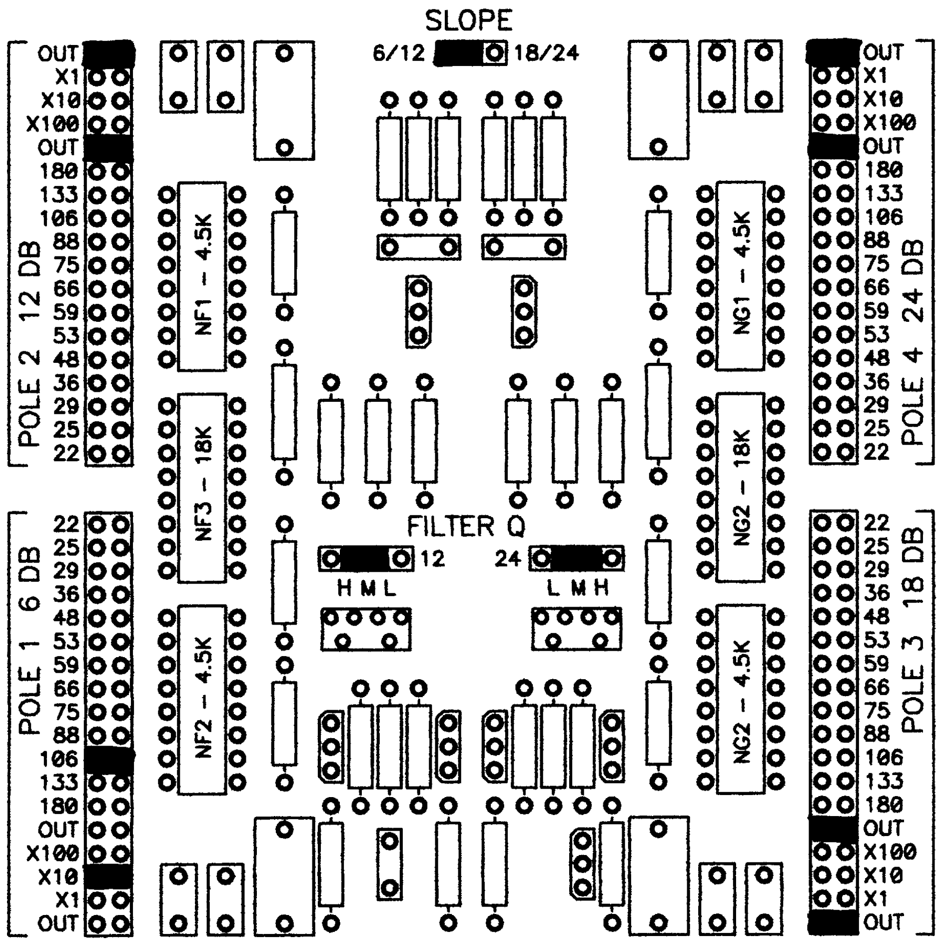




LOW PASS FILTER

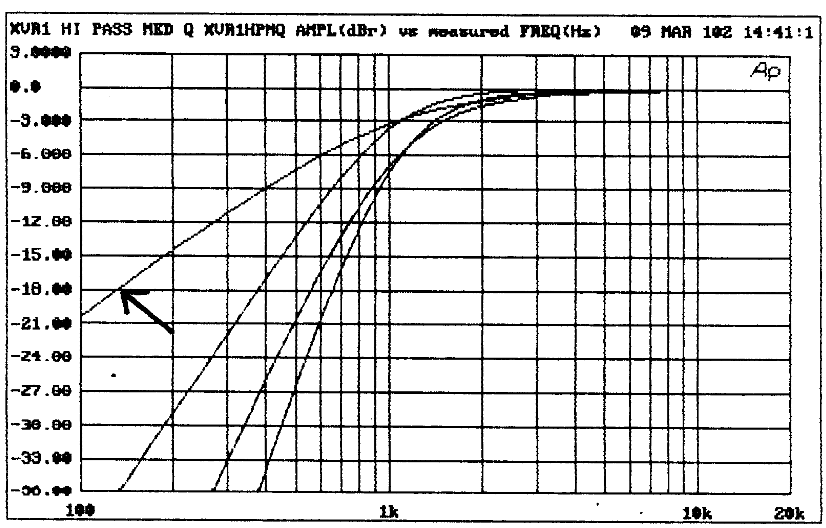
24 DB/OCT (4 POLE) @ 1060 Hz

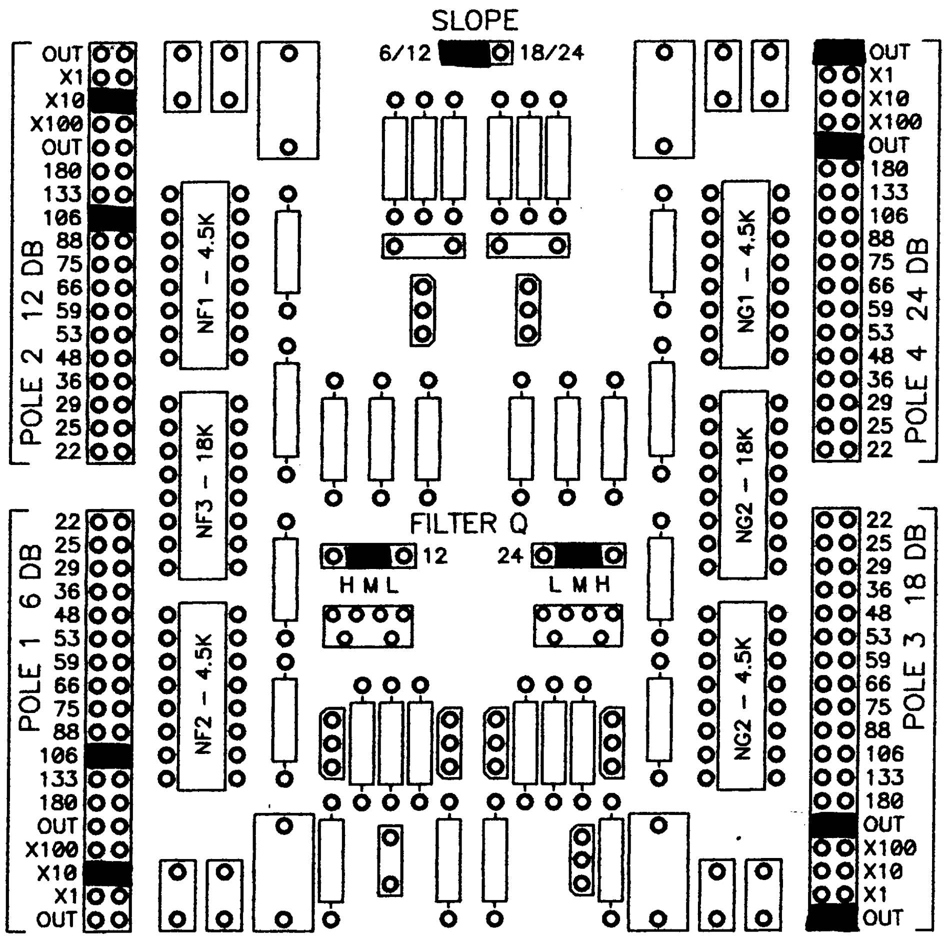




HIGH PASS FILTER

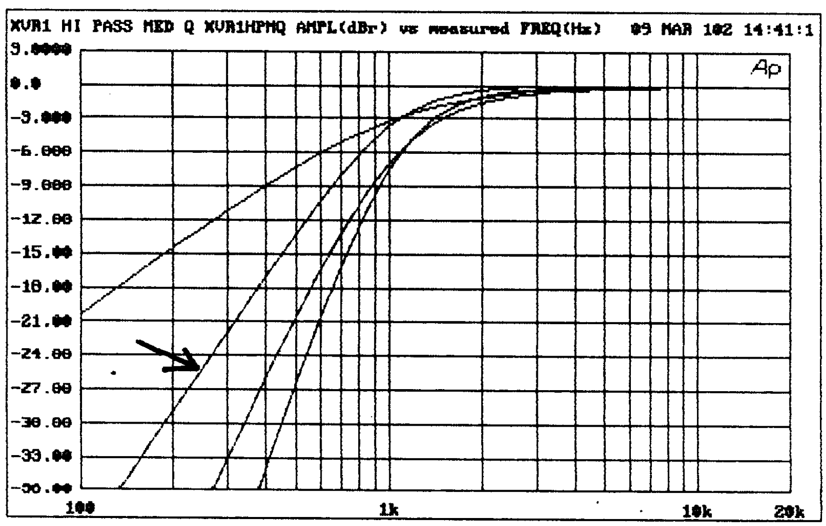
6 DB/OCT (1 POLE) @ 1060 Hz

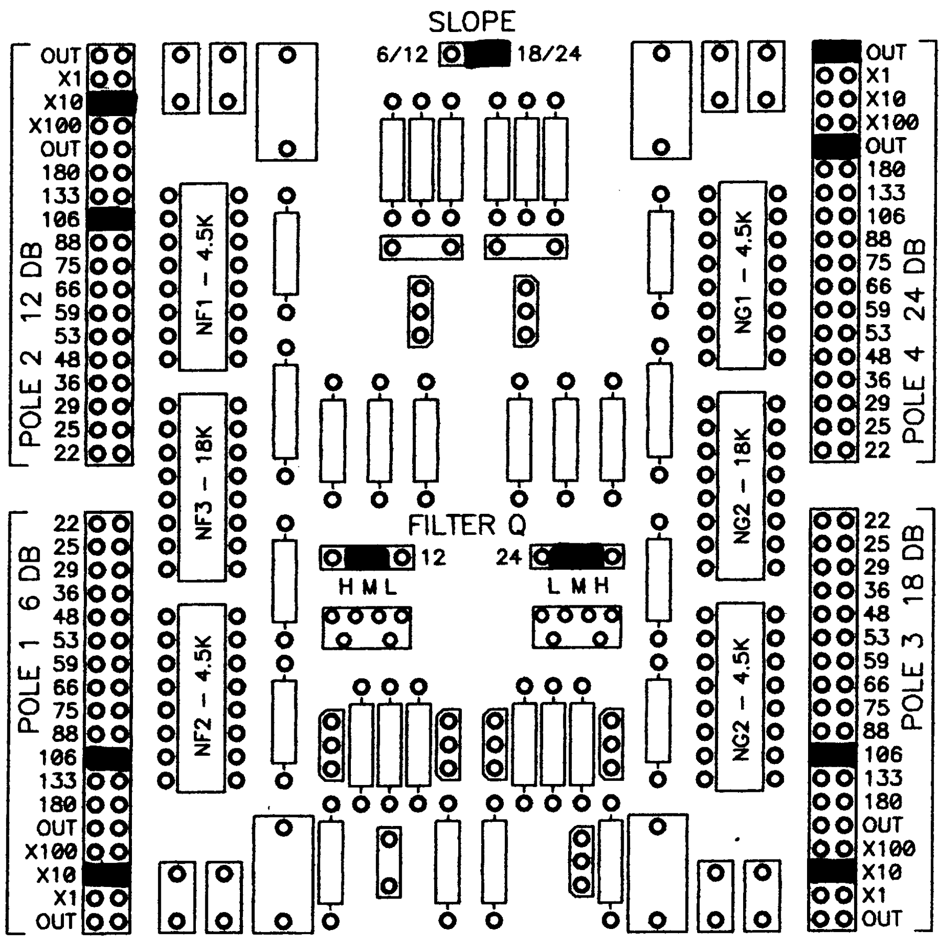




HIGH PASS FILTER

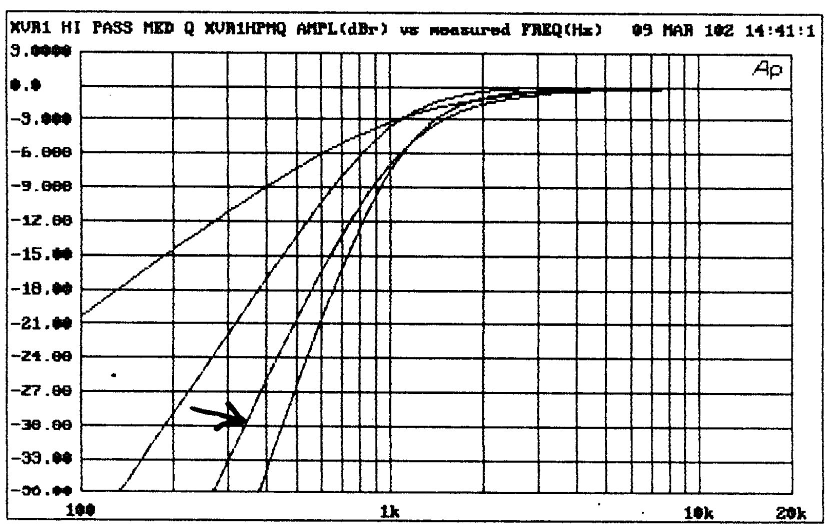
12 DB/OCT (2 POLE) @ 1060 Hz

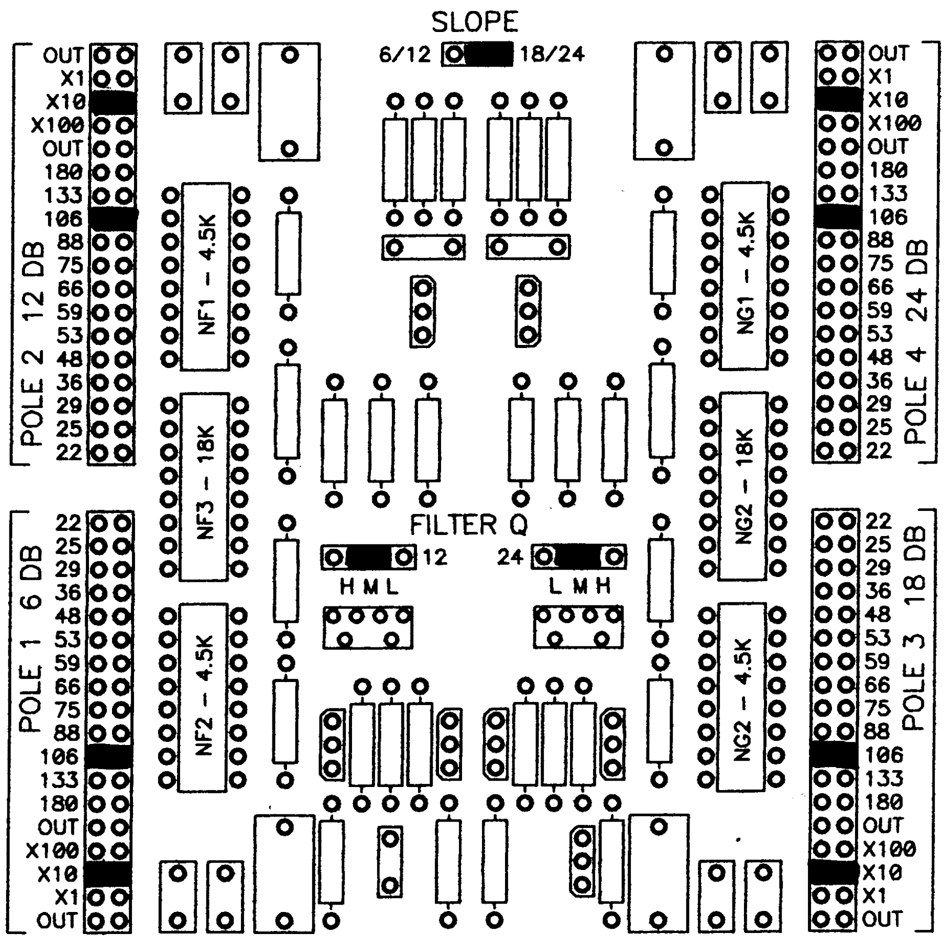




HIGH PASS FILTER

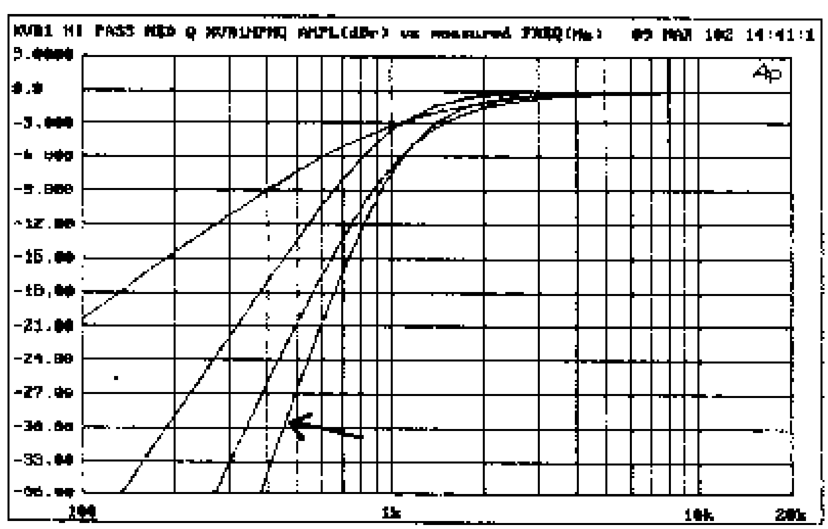
18 DB/OCT (3 POLE) @ 1060 Hz





HIGH PASS FILTER

24 DB/OCT (4 POLE) @ 1060 Hz



Powering Up the First Time

Presuming that the XVR1 filters are set as desired, It is time to power up the system. Begin by setting all four Level Controls on the front panel to minimum (counterclockwise). This will help prevent any damage due to mistakes in setting up the filters or source material which is too loud.

Plug the AC power cord of the XVR1 into the wall socket. The blue front panel light will light up on both the power supply and the XVR1. After a few seconds you may hear the faint click of the output relays of the XVR1 engaging. These relays give a delay on turn-on to prevent transients from reaching the speakers, and also mute the output at shutoff or when there is not enough AC line voltage to properly power the XVR1.

At this point, send some audio signal through the system, and then turn on the low frequency amplifier. Slowly raise the Low Pass level controls of each channel and confirm that there is proper low frequency output from the loudspeakers. Then turn the low frequency amplifier levels down.

If the low frequency amplification seems to be OK, then turn on the high frequency amplifiers and slowly raise their level controls. If everything seems OK and there is no strange noises and distortion, then you may again raise the level of the Low Pass level controls until a proper balance is achieved between the drivers.

As mentioned earlier, ground loops are more common in Bi- and Tri- amplified systems because there are more power amplifiers. If you encounter hum in the system, first attempt to isolate it. Is it in both channels, left and right? If so, it is probably a ground loop. Is it also on both top and bottom? If it is only on the high or low, you will want to consider obtaining one or more “cheater” plugs for the AC power connection which convert a 3 prong earth grounded wall socket to a 2 prong connection without earth ground. Try it on the amplifier which has the hum. If the hum and noise is on both high and low, then try using the “cheater” plug on both top and bottom amplifiers.

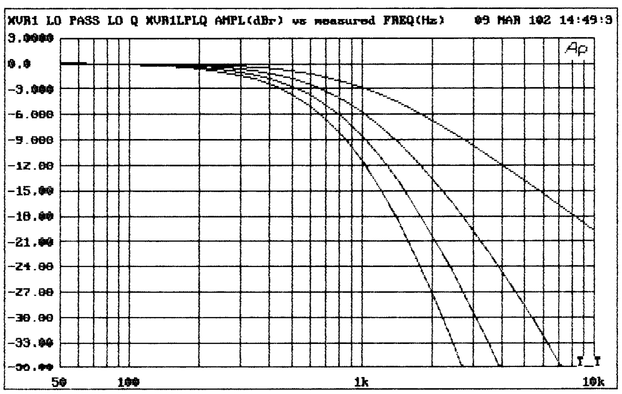
In any case, when you encounter a problem like this, it usually pays to try different things out and see how the problem is affected, so that you can get a clue as to where it comes from. When using “cheater” plugs, it is important that at least one component in the system is attached to the earth ground at the wall socket so as to ensure safety from electrical shock should the AC wiring isolation fail in one of the components.

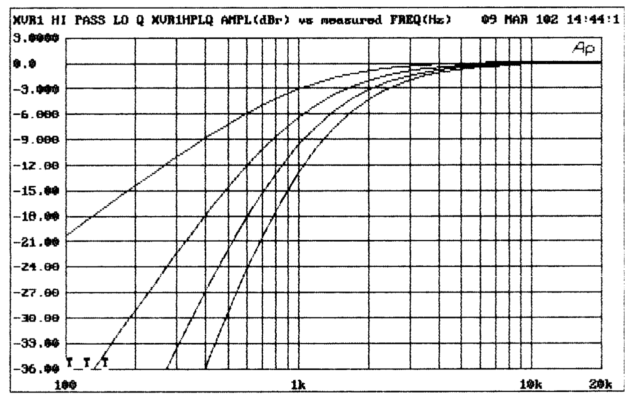
If you have a problem in one channel and not the other, for example in the Right channel but not the Left channel, try switching Left for Right in the interconnection between components. For example, if there is no sound coming out of the Right channel but there is sound coming from the Left, then start with the source, for example where the CD player connects to the cables going to the preamplifier and switch Left for Right. If the problem does not change, then the fault is in a component “downstream”. If the problem does change Left for Right, then the fault is in the CD player. If not, then proceed “downstream” to the place where the cables reach the next component, say the preamplifier, and switch Left for Right. If the problem changes, then it was in the cable. Then go to the output of the next component and so on until you get a change. Then the fault will be in the previous component.

SOME REAL BASIC THEORY

How we look at filter characteristics (dB vs Frequency):

If you look at the two curves below you will see a Low pass filter on the left and a High pass filter on the right. On the left of each graph we see numbers representing the level expressed in decibels and on the bottom axis we see numbers expressing the audio frequency. And so the primary picture of such a filter is in decibel level versus frequency. To cover a wide range and reflect physical reality, both axes on these curves are logarithmic, that is to say a constant distance along the axis represent multiplication by some value. On the vertical axis, decibels are such that each 3 dB represents a loudness factor of 2 and each 10 dB represents a loudness factor of 10.





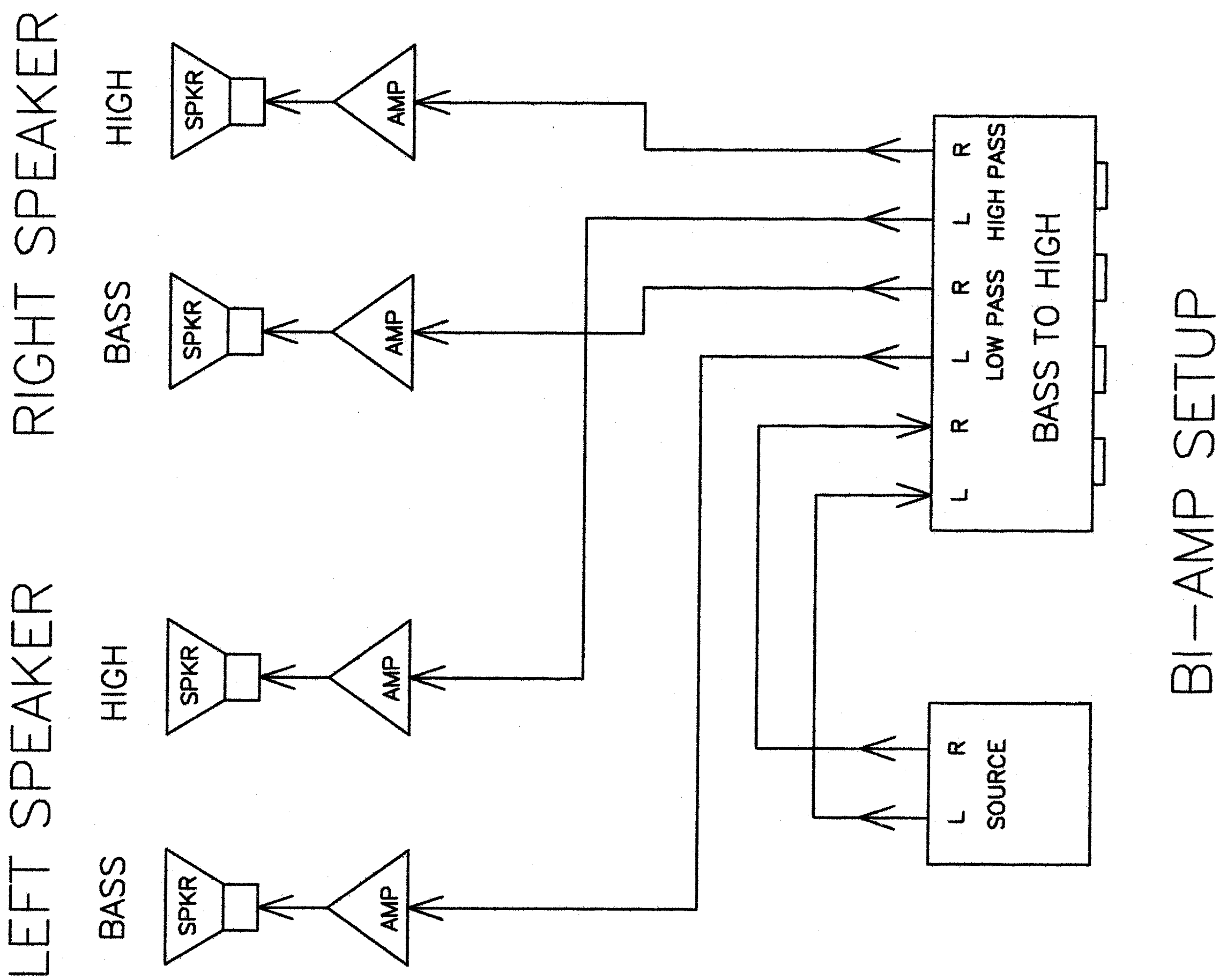
When we look at the curves in the graph on the left, we see the character of four different Low pass filters, so called because they let the low frequencies through and attenuate, or remove, the higher frequencies. The different slopes of these curves show how rapidly the attenuation occurs as the frequency rises. The most gentle is 6 dB/octave, and then there is 12 dB/oct, 18 dB/oct, and 24 dB/oct. The same applies to the curve on the right, except that the signal is attenuated more as the frequency goes down, and these are thus known as High pass filters; they let the high frequencies through.

The cutoff frequency, also known as the crossover frequency, is that frequency where the filter begins reducing the signal. In this particular design, the point at which the response is down 3 dB is the crossover frequency for 6 dB/oct and 12 dB/oct slopes, and –6 dB is the crossover frequency for 18 dB/oct and 24 dB/oct slopes. You might imagine that the 24 dB/oct slopes might be better as they remove unwanted signal more rapidly as you move away from the desired frequencies, but in fact a price is paid for this steep character, which is some phase, or timing, distortion, which is greater for sharper slopes. Sometimes the price is worth the steep slope, sometimes not.

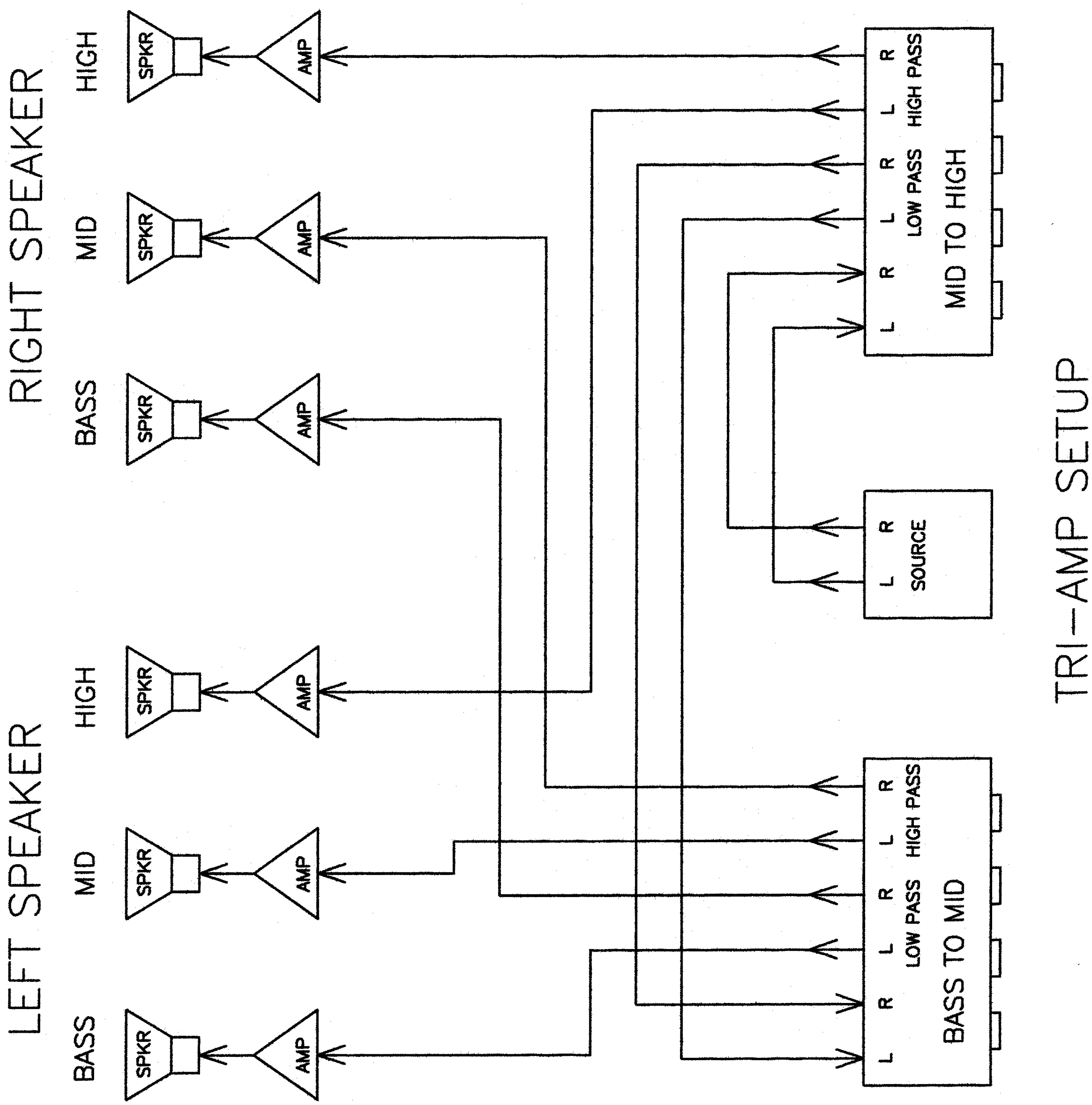
The sharpness of the “knee” in the curve for the region of the crossover point is known as the “Q” of the filter. A low “Q” gives a very gentle transition between the flat and sloped regions of the curve, and a high “Q” gives a sharper transition. As with higher slopes, one might also imagine that higher “Q” would be more desirable, but as with slopes, higher “Q” is accompanied with higher phase shift. To find out which setting is best, you just have to try it out.

Bi-amping

In this and the following three pages are diagrams showing typical interconnection of the XVR1 with source, amplifiers, and loudspeaker driver in two-way, three-way, four-way and five-way loudspeaker systems. These are not the only ways in which more than one XVR1 can be arranged, but they are chosen to minimize the signal path and maximize the performance.

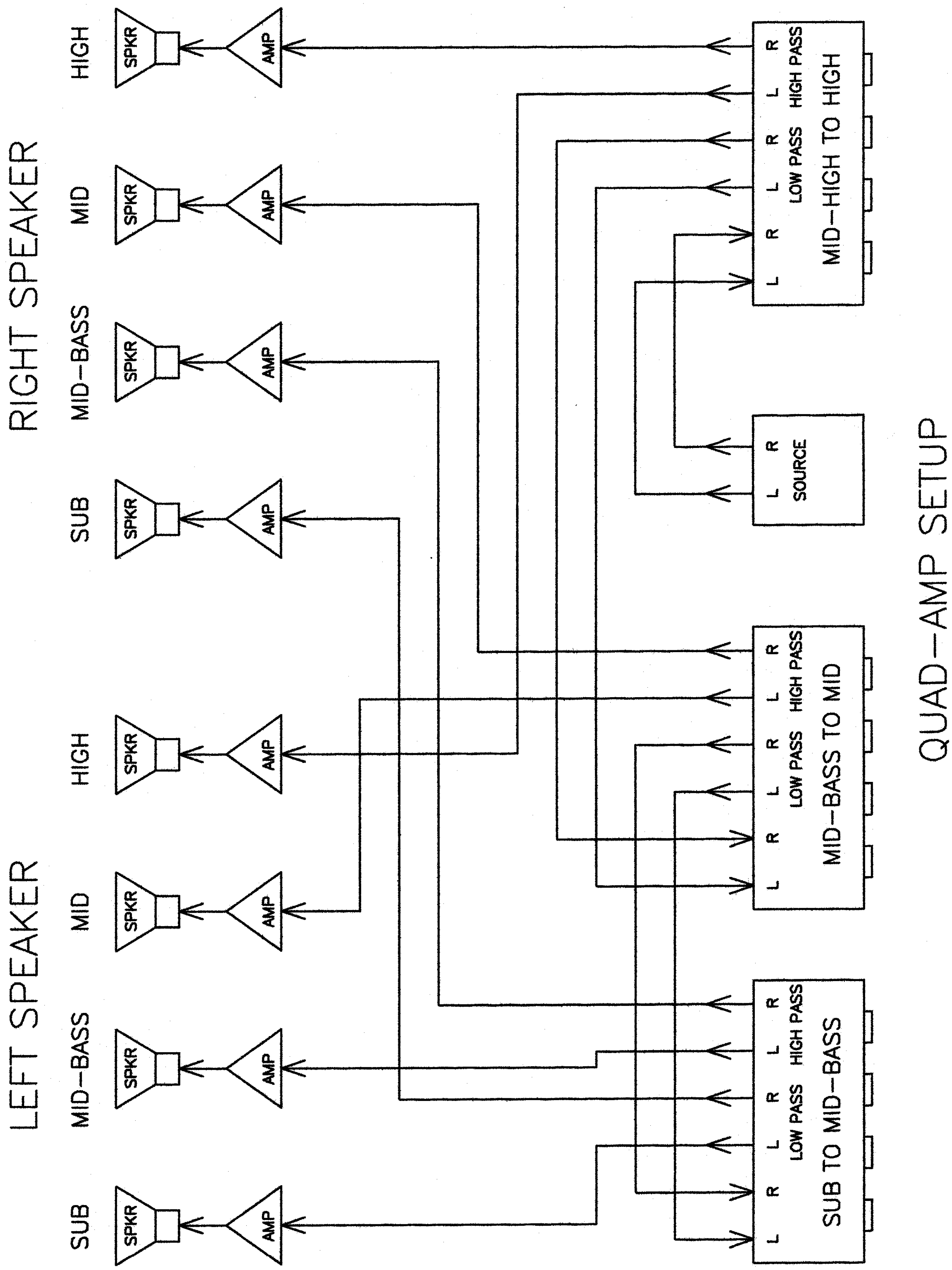


Tri-Amping

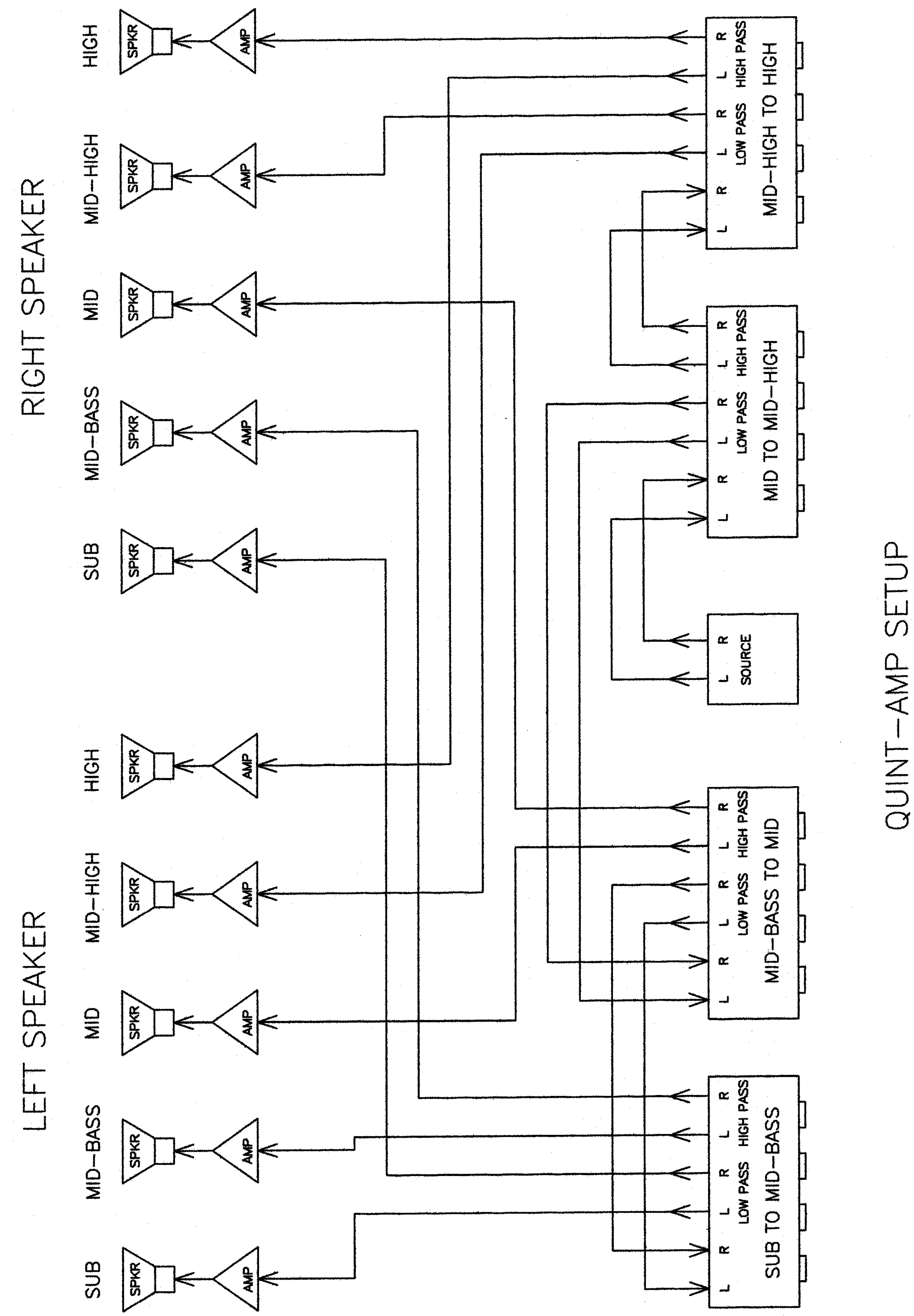


RIGHT SPEAKER
LEFT SPEAKER
BASS
MID
HIGH
SPKR
AMP
MID TO HIGH
LOW PASS
HIGH PASS
BASS TO MID
SOURCE
L
R
TRI—AMP SETUP

Quad-Amping


RIGHT SPEAKER
HIGH
MID
MID-BASS
SUB
LEFT SPEAKER
HIGH
MID
MID-BASS
SUB
SPKR
AMP
L R L R L R
LOW PASS HIGH PASS
MID-HIGH TO HIGH
L R
SOURCE
L R L R L R
LOW PASS HIGH PASS
MID-BASS TO MID
L R L R L R
LOW PASS HIGH PASS
SUB TO MID-BASS
QUAD-AMP SETUP

Quint-amping



SOME REAL TIPS

#1 Adjustment of crossover filters requires great peace of mind.

#2 Much of what you think you know about active crossovers is probably wrong. By this I mean that choosing textbook frequencies and slopes for loudspeaker drivers is probably not going to be the best solution. If loudspeakers had truly flat response and no phase variation, then a textbook solution such as “18 dB/oct at 1000 Hz” for both high and low pass filters might work perfectly. However, loudspeaker drivers do not have neutral characteristics, and if they did, we might not need a crossover in the first place.

Loudspeaker drivers bring lots of their own characteristics to the table, and the settings of the crossover must be adjusted to consider this. So use the textbook settings as a starting point, and don’t be surprised when it doesn’t work all that well. Be prepared to experiment, measure, listen, and experiment again.

#3 Acquire some means of measuring the response curve of your loudspeaker and learn how to use it. Measurements are not the last word in defining quality in a loudspeaker, but they are a big help.

#4 Unless the manufacturer recommends higher slopes for reliability reasons such as with horn drivers, start out with low slope and Q values and then progress to more complex filters as the need arises. All other things equal, low slope values such as 6 dB/oct tend to sound better due to lower phase shift. Even if the manufacturer recommends a steep slope on the high pass filter, feel free to try a more gentle slope at a lower volume level.

#5 Remember to try the response with the phase of the driver flipped. You do this by reversing the connections plus and minus at the driver. If this is a midrange driver, keep in mind that it has two crossover points, and you have altered the response of both of them.

SOME REAL PROJECTS

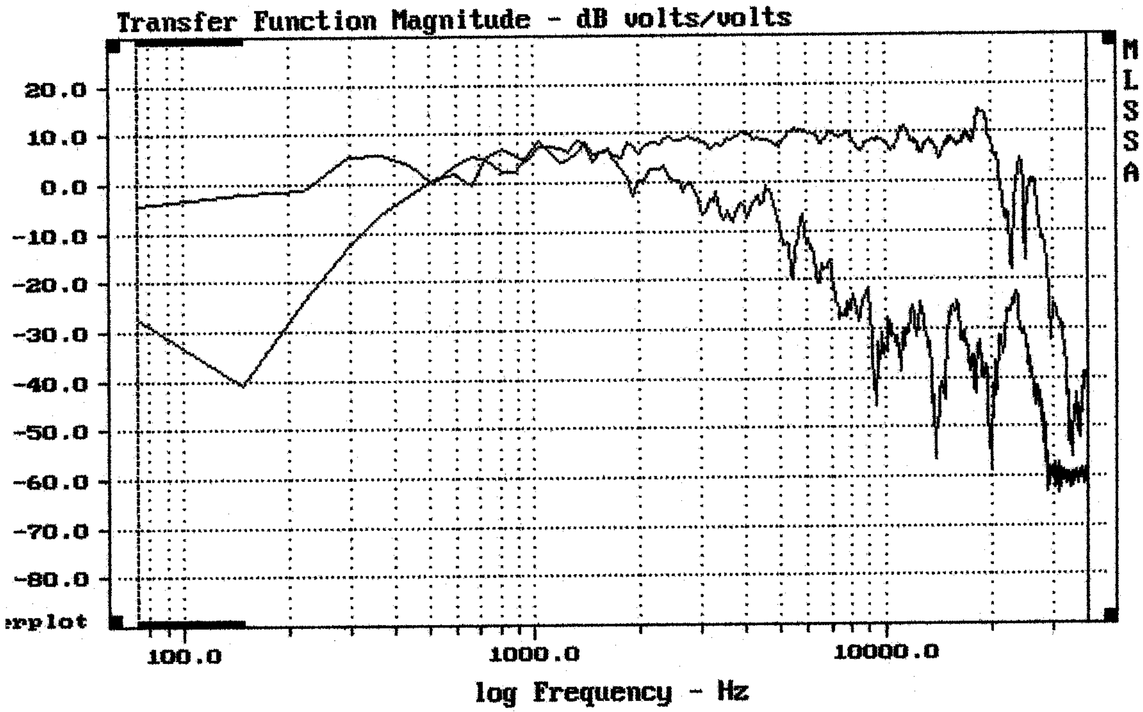
To show that real crossover networks often vary from textbook cases and to give you a flavor of how design often really proceeds, we worked up two real loudspeaker designs over the course of several evenings.

We started out measuring the drivers and trying on various slopes and frequencies to see what was likely to work. The procedure is somewhat haphazard, and the results you will see following are condensed, with the mis-steps removed. The approach was simply to get a result, which represented a reasonable approach, knowing the characters of the drivers, and also reasonably flat in frequency response. We generally start with the most gentle slopes, 6 dB/oct unless there is already some reason to use sharper slopes, as in the case of a horn loaded compression driver. If the gentle slopes don’t work, then we go to the higher slopes, usually 12 or 18 dB/oct. 24 dB/octave is used rarely in our experience, as the sharpness of the filter introduces other sonic effects that we don’t like as much.

The result is a fairly flat frequency response curve, suitable for listening tests. We then listen and adjust and re-measure over the course of several hours, several days, several weeks, several months, or even several years, until we get the best result.

Real Project: #1

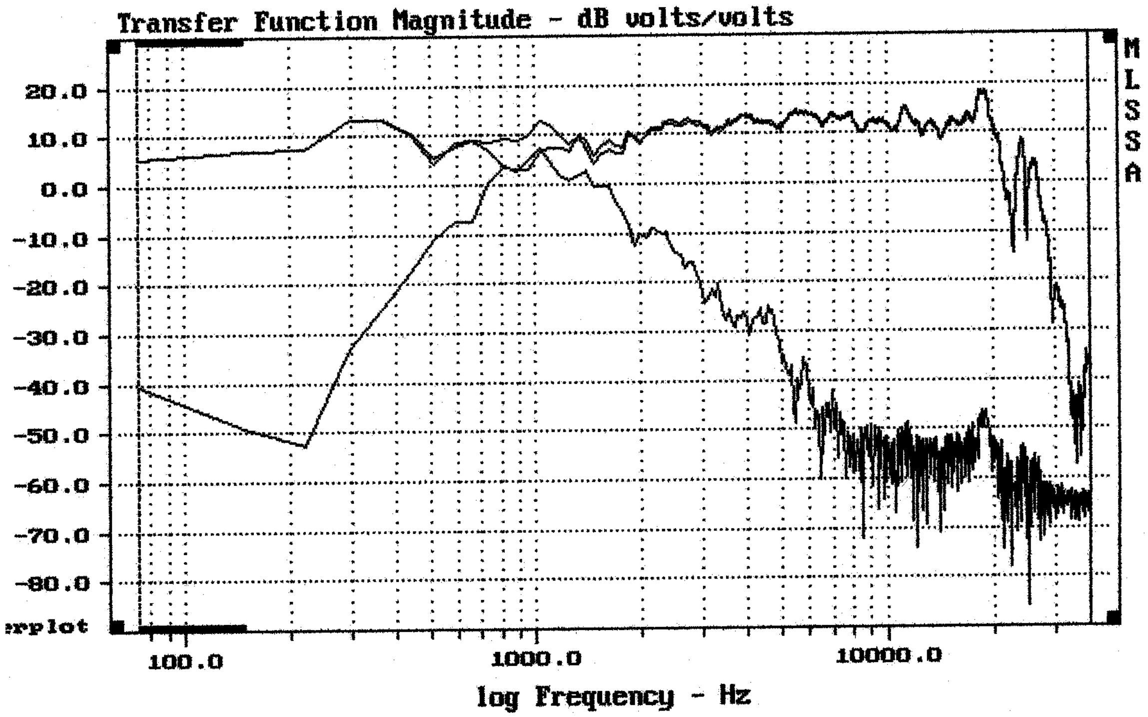
We took a Pioneer TAD 1101 woofer and mounted it in a four cubic foot enclosure and used a TAD 4001 compression driver with a Selenium exponential horn for a tweeter.



This is what the curves of the two drivers looked like run without a crossover filter, but with levels adjusted for roughly equal levels. We see that the 1101 has a bandwidth out to 3000 Hz and the horn goes down to about 500 Hz. Logically we will assume that the crossover point will occur somewhere between 500 Hz and 3000 Hz. We know from the literature of the TAD 4001 and the horn that it is not designed to operate below 800 Hz, and that they want a reasonably sharp cutoff to avoid overdriving the compression driver below the horn low frequency cutoff. To start, we chose 18 dB/oct (3 pole) at 880 Hz for the High pass filter. It turned out to be an excellent choice, and we did not find ourselves having to change it to improve the response.

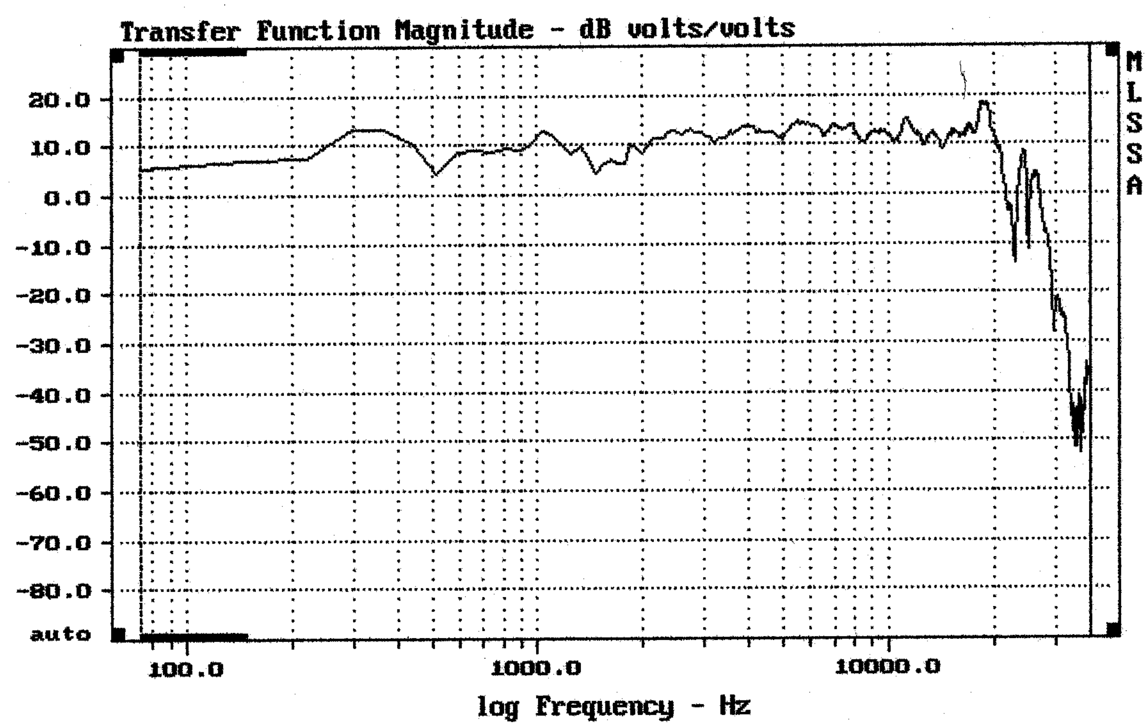
Then we tried a variety of Low pass filter characteristics for the woofer and looked at the result when operated with the horn. A variety of 6 dB/octave (1 pole) filters were tried, including flipping the phase of the tweeter for each, but we did not see a good looking curve, as the drivers interfered with each other too much in the 800 to 3000 Hz range. Then we tried 12 dB/oct filters (2 pole) on the Low pass with similar results. When we tried 18 dB/oct (3 pole), the curve became smooth with a 660 Hz setting. Flipping the phase of the tweeter gave us a dip, so we went back to both drivers in phase.

The following curves showed the final results: a reasonably flat, reasonably good sounding loudspeaker in about an hour's worth of fooling around. From this point it will be necessary to perform minor adjustments and evaluate the sound by listening over a longer period of time before making more decisions. Usually it takes several weeks to reach some final conclusion.



(Above) The curves of the two drivers measured separately, the woofer with 18 dB/oct (3 pole) Low pass filter at 660 Hz and the horn tweeter with 18 dB/oct filter High pass filter at 880 Hz.

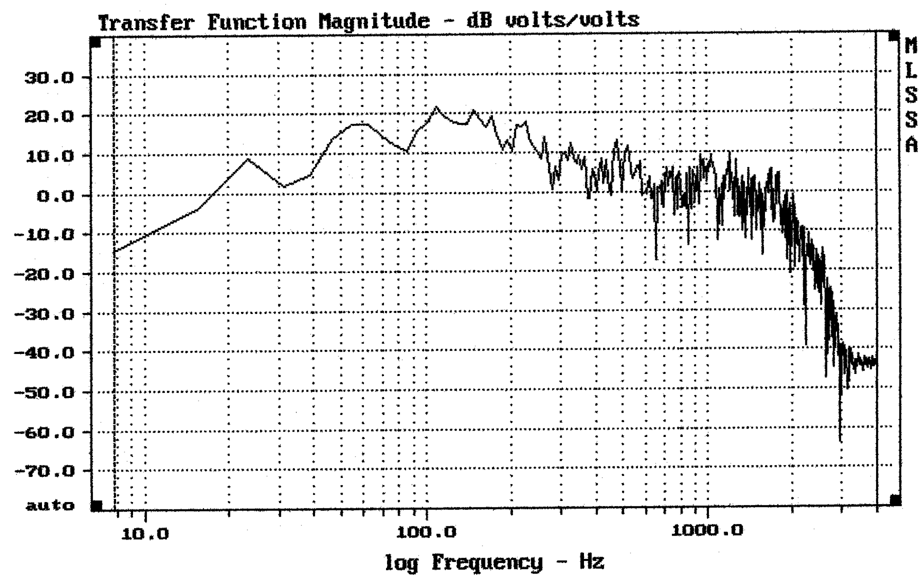
(Below) The curve of the speaker with both drivers measured simultaneously.



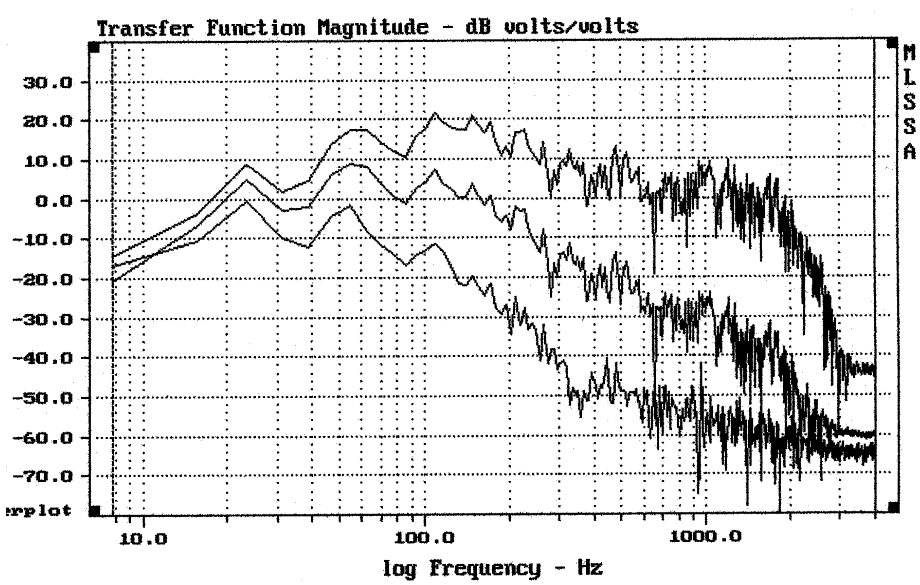
Real Project #2

This is a much more complex system. It has twin 21 inch subwoofers mounted in a 12 foot long transmission line, a 12 inch woofer for midbass, a 5 inch midrange, and a ribbon tweeter. This system will be quad-amped.

We start with the raw curve of the subwoofer:

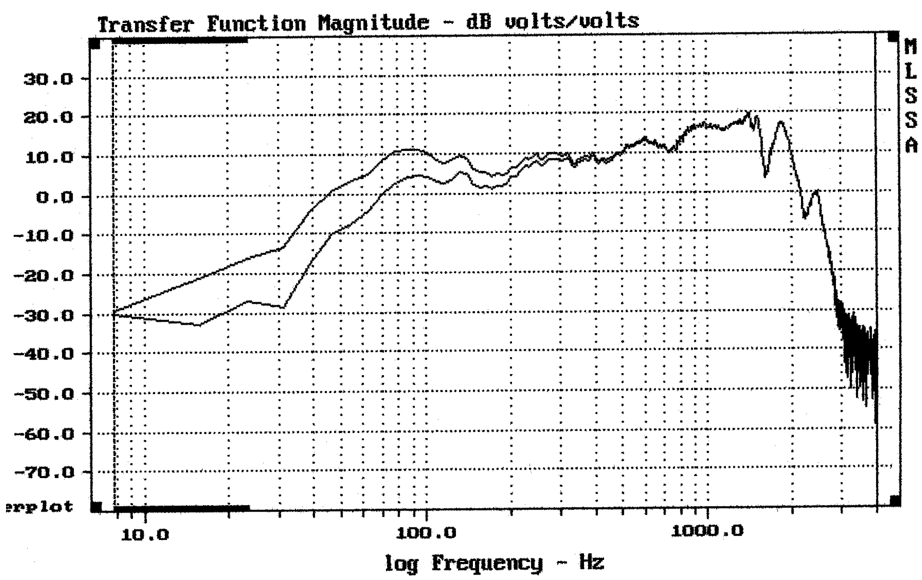


The response curve here shows some interaction with the room in the region below 100 Hz, but we see a clearly rising output as we go up toward 100 Hz, and we surmise that the woofer is going to need some equalization to be flat at 20 Hz. We try a Low pass filter at 6 dB/oct (1 pole) at 22 Hz, and at 12 dB/oct (2 pole) at 22 Hz with the following results:

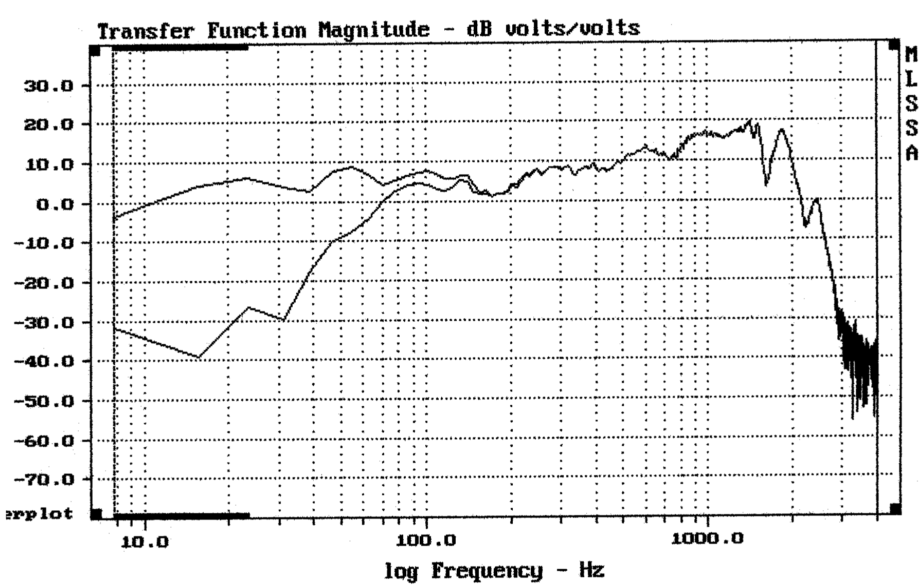


Either of the above curves could be attractive to us: the 6 dB/oct might serve suitably to mate this subwoofer to a mid-bass woofer at 200 Hz or so, and the 12 dB/oct filter might work for 100 Hz or so. It happens that our mid-bass woofer is perfectly happy down below 100 Hz, so we choose the 12 dB/oct as our starting point.

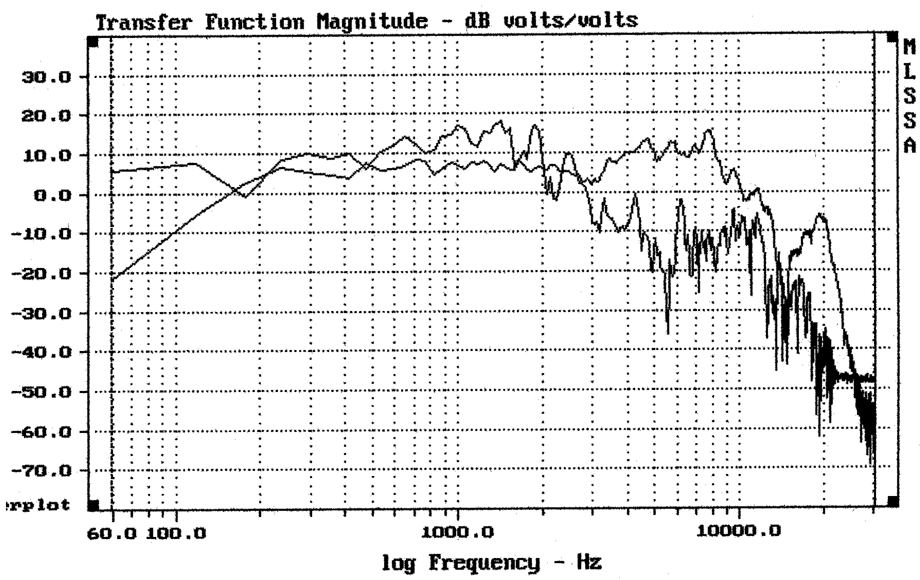
The mid-bass woofer has the curve shown below, which also shows its response with a 6 dB/octave High pass filter at 180 Hz. The higher crossover frequency was chosen to compensate for the bump in the curve at 90 Hz or so.



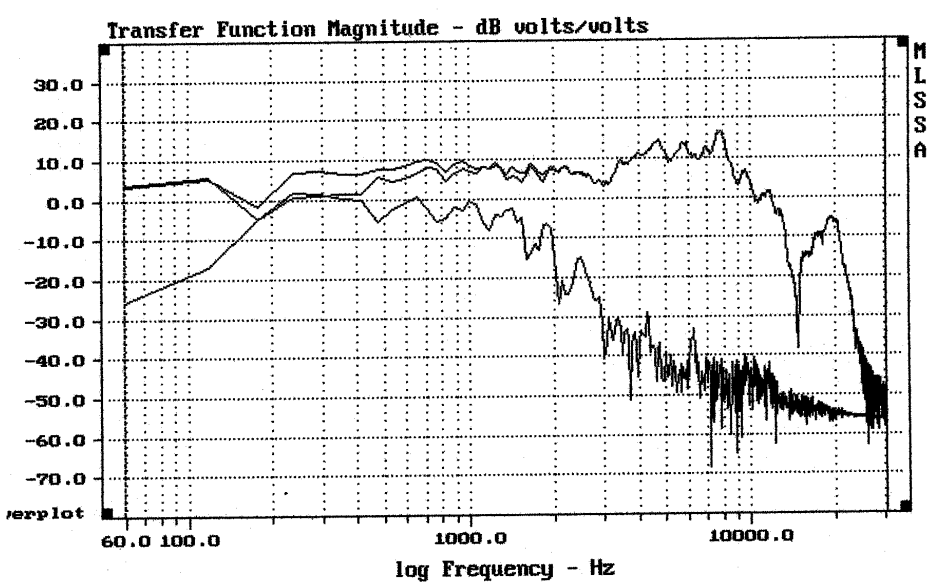
When we mate the subwoofer and the mid-bass driver with these filters, we get the curve below, which shows both the response of the mid-bass driver and both drivers together. If we flip the phase of the mid-bass driver, we get a big dip, so we leave the phase positive for both. That competes our initial setting of the first crossover point.



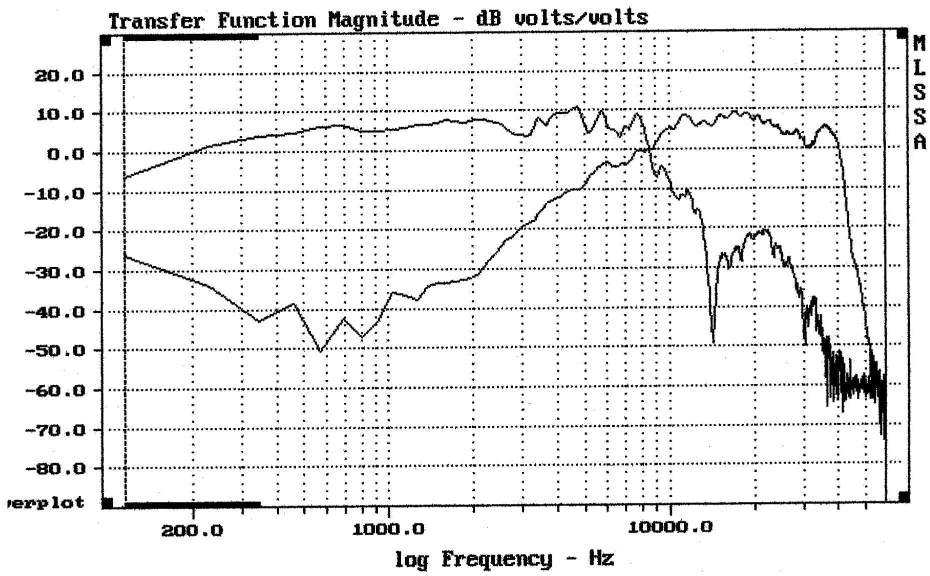
Now it is time to develop a crossover point between the mid-bass driver and the midrange driver. We will only be looking at these two drivers, and the subwoofer is not part of these curves. We see below the curve of the mid-bass driver and the midrange. The midrange is quite smooth from about 200 Hz to about 4000 Hz, where it starts to rise a bit. The mid-bass has a rising character into the midrange, and we will probably want to think about using a Low pass filter at a fairly low frequency to compensate.



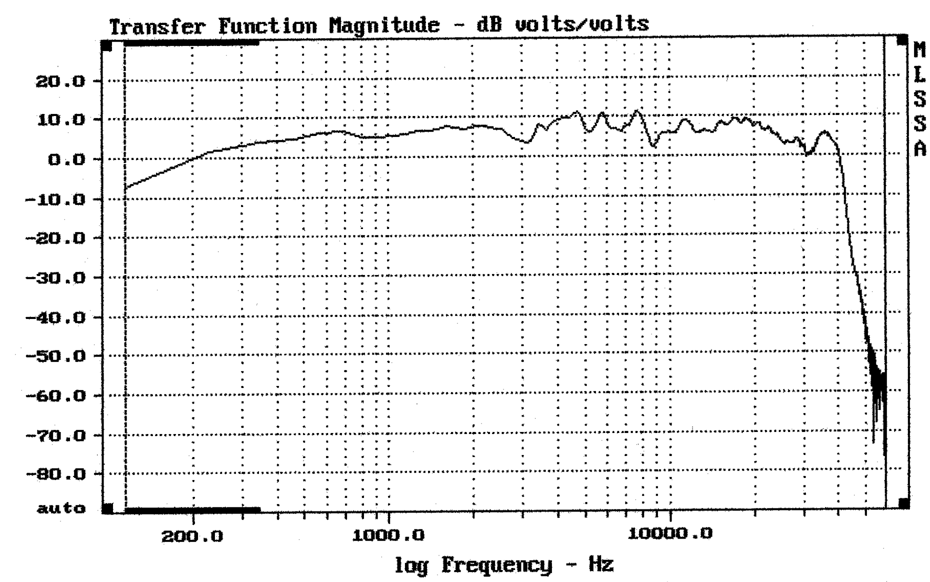
This particular midrange is not too happy being driven with power below 500 Hz, but a 6 dB/oct High pass filter will work well for it. The question is what Low pass frequency might bring these two drivers together happily, and with some experimentation we find that 6 dB/oct at 133 Hz gets us a fairly smooth curve over this region. Below you will see the two curves of the drivers separately and the smoother mix between the two. Once again, flipping the phase of the upper driver gives us a dip, and so we don't.



For the third and last crossover point, we want to make a smooth transition from the midrange driver to the ribbon tweeter. We experience that the ribbon will distort if operated at 6 dB/oct slopes below 10,000 Hz, but that it can go lower if a higher slope is applied. Playing around with it and various Low pass filters for the midrange, we conclude that we don't like the sound with a 24 dB/oct slope and we have to choose between 18 dB/oct at 5900 Hz or 12 dB/oct at 8800 Hz. After several days of listening we conclude that we prefer the High pass with a 12 DB/oct slope at 8800 Hz and a Low pass with a 6 dB/oct slope at 480 Hz. Below, you see the individual curves for the drivers with the filters applied:



The two curves combine to form the result below:

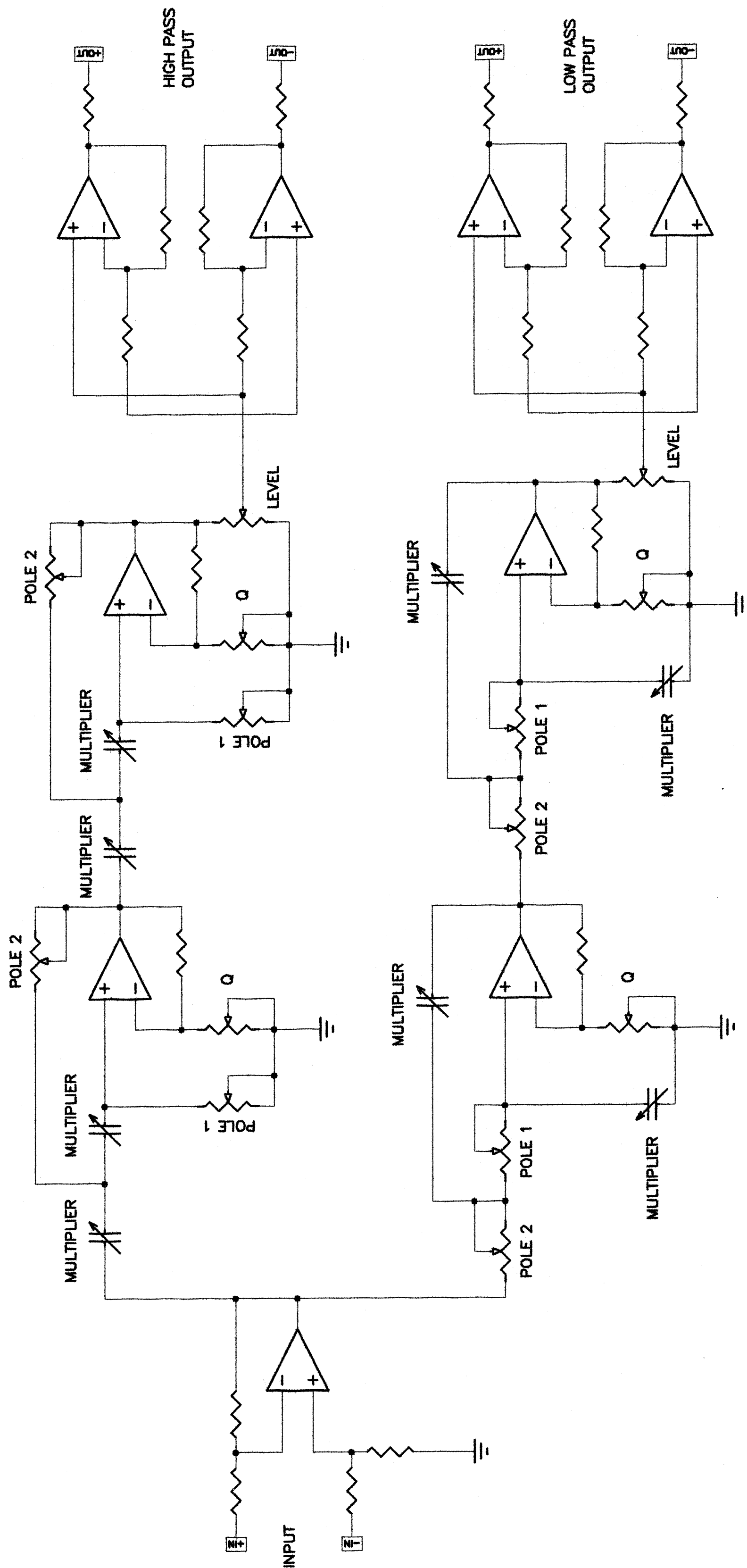


And there we have it, a quad-amped loudspeaker with a response +/-5 dB from about 18 Hz to 40,000 Hz. This of course is only the start of the listening tests during which more adjustments will be made.

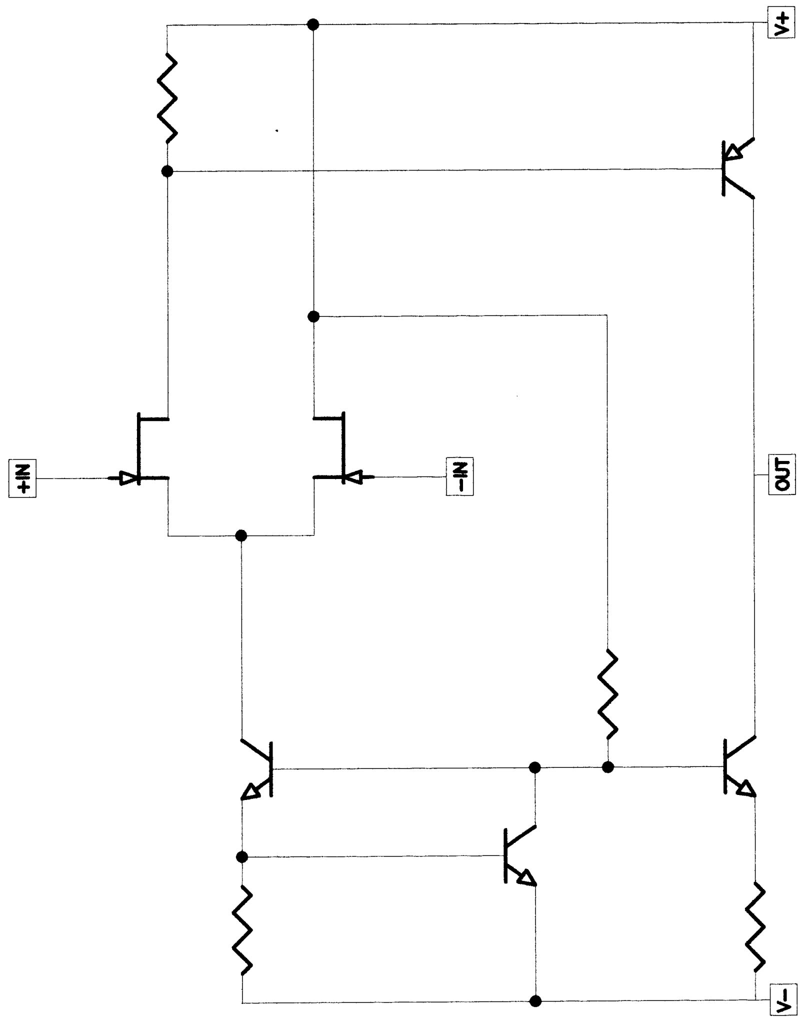
SOME PRODUCT SPECS

Tests conducted with 10 Kohm load on outputs, 50 ohm signal source, 120 VAC

AC current draw	.2 Amps, 24 watts
Ac voltage minimum	97 V
Input impedance	66 Kohm balanced differential, 44 Kohm single ended
Input CMRR	-60 dB @ 20 KHz
Crosstalk	-80 dB @ 20 KHz
Output impedance	200 ohm balanced differential, 100 ohm single ended
Gain, input to output	Low Q, XLR = 5.6 dB, RCA out = -.4 dB
	Med Q, 6/12 dB/oct, XLR = 8.6 dB, RCA out = 2.6 dB
	Med Q, 18/24 dB/oct, XLR = 13.4 dB, RCA out = 7.4 dB
	Hi Q, 6/12 dB/oct, XLR = 11.6 dB, RCA out = 5.6 dB
	Hi Q, 18/24 dB/oct, XLR = 17.6 dB, RCA out = 11.6 dB
All Pass Bandwidth	Low Pass: -0 @ 10 Hz, -0 @ 100,000 Hz
	High Pass: -1 @ 10 Hz, -0 @ 100,000 Hz
Maximum Output	30 V rms Balanced, 15 V rms single ended RCA
Maximum Input	30 V rms Balanced, 15 V rms single ended RCA
Distortion + Noise	.05%, .2 V to 30 V balanced, 20 Hz to 20 KHz
	.002%, 3V balanced, 1 KHz
Filter characteristic	High Pass: 6/12/18/24 dB/oct, 22 Hz to 18 KHz in 39 steps
	Low Pass: 6/12/18/24 dB/oct, 22 Hz to 18 KHz in 39 steps
Size	Two enclosures 3 by 17 by 11 inches
Weight	Shipping weight XX lbs.
Limited Warranty	Parts and labor, 3 years from date of manufacture. No warranty against consequential or collateral damage.



SIMPLIFIED SCHEMATIC – ONE CHANNEL

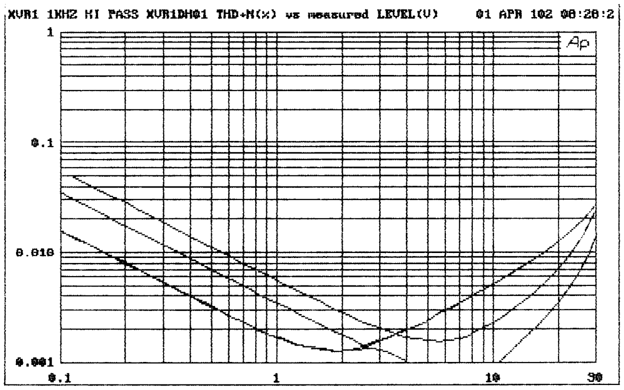


SIMPLIFIED GAIN STAGE

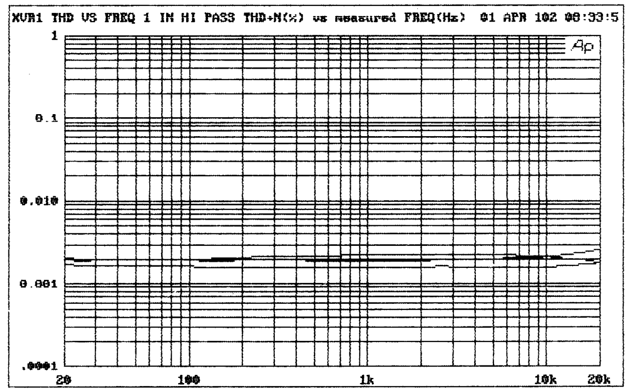
The basic circuitry is a very simple discrete single-ended Class A stage designed to be operated at low gain and feedback levels with high performance and stability. In the diagram above you see the matched JFET input devices. These drive a PNP bipolar gain transistor which is also a level-shifter. Both gain stages are driver by NPN bipolar current sources which are in turn regulated by an NPN bipolar voltage reference taking feedback from the first current source.

The distortion and noise imposed on a signal running through this circuit is typically .05% at 30 volts balanced output from 20 Hz to 20 KHz, and .002% at 3 volts output. The bandwidth is flat from DC to way beyond 100 KHz.

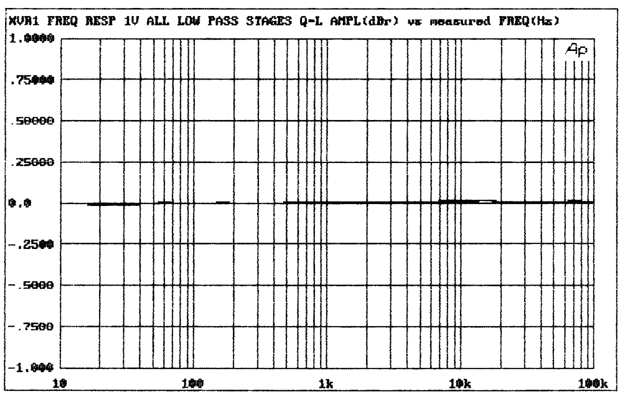
SOME MORE SPECS:



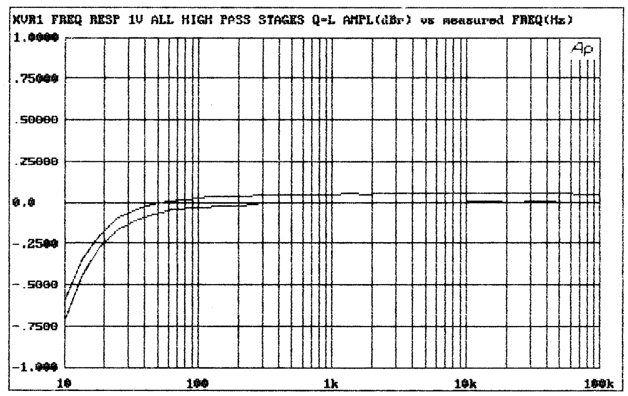
THD + NOISE, LOW/MED/HIGH Q



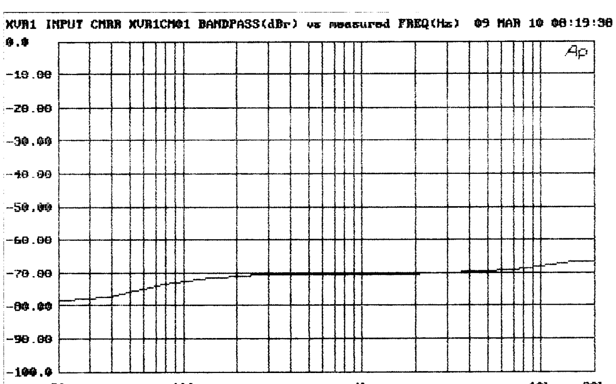
THD VS FREQUENCY



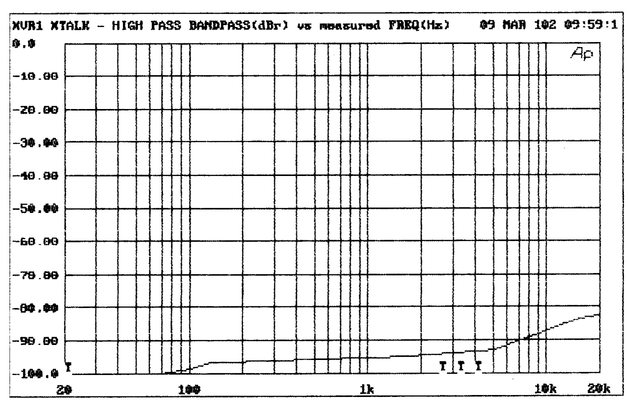
LOW PASS (OUT) FREQUENCY RESP



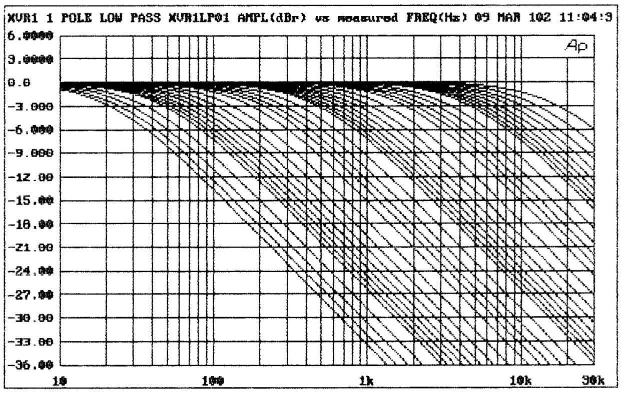
HI PASS (OUT) FREQUENCY RESP

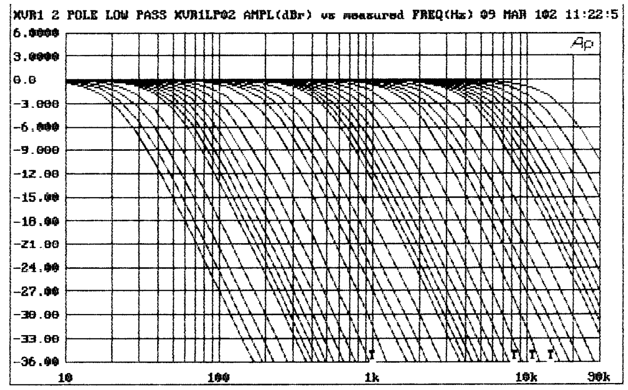


INPUT COMMON MODE REJECTION



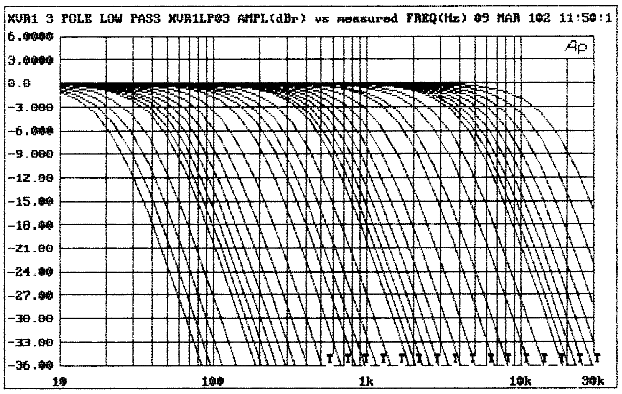
CROSSTALK

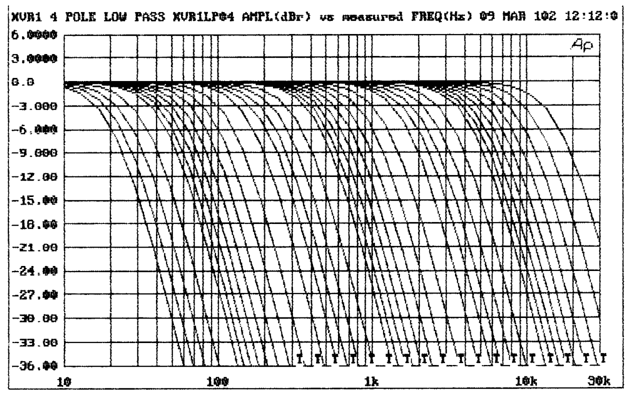




LOW PASS FAMILY – 6 DB/OCT

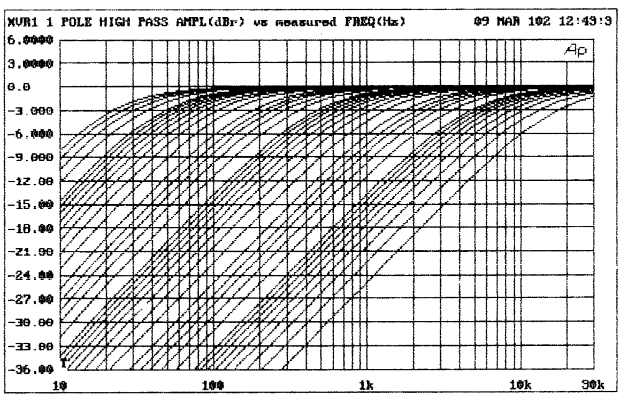
LOW PASS FAMILY – 12 DB/OCT

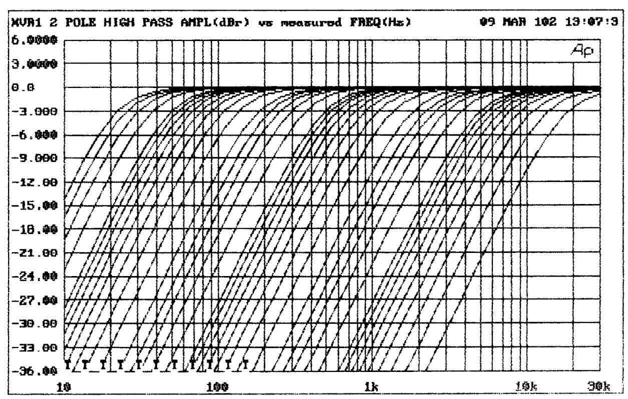




LOW PASS FAMILY – 18 DB/OCT

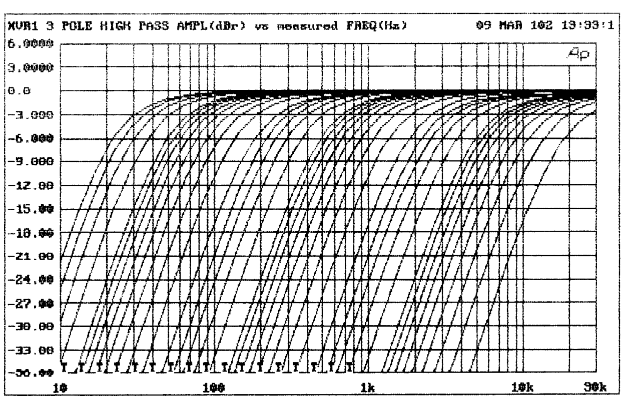
LOW PASS FAMILY – 24 DB/OCT

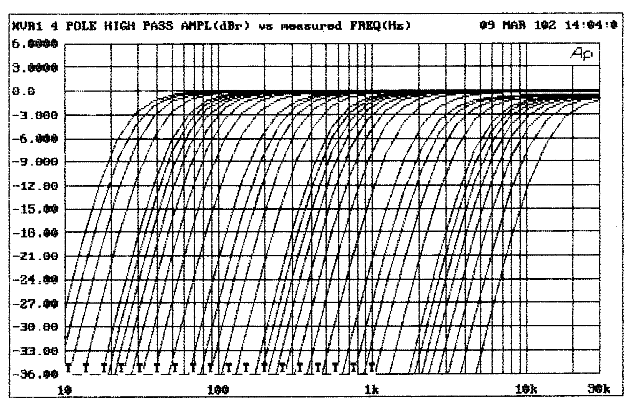




HIGH PASS FAMILY – 6 DB/OCT

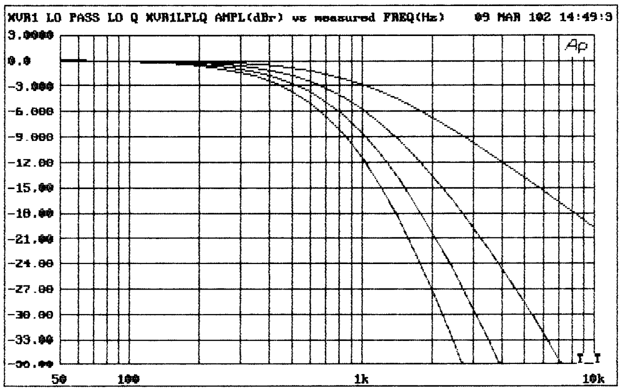
HIGH PASS FAMILY – 12 DB/OCT



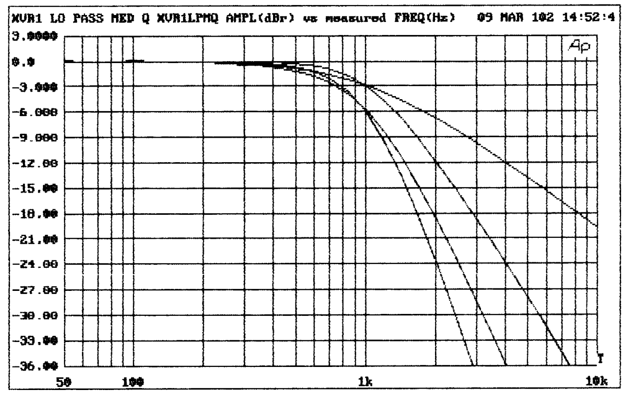


HIGH PASS FAMILY – 18 DB/OCT

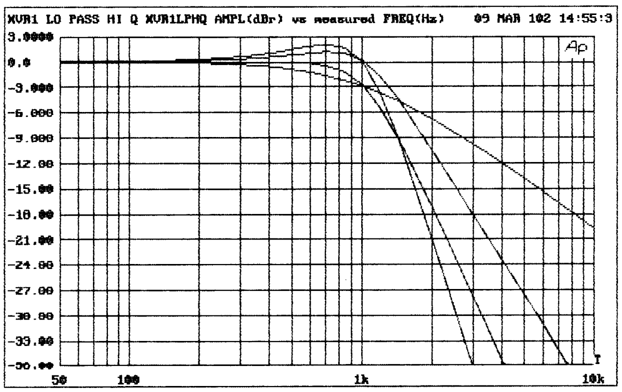
HIGH PASS FAMILY – 24 DB/OCT



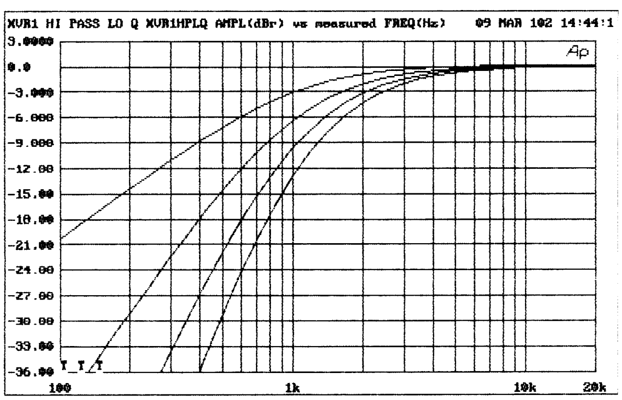
LOW PASS, LOW Q, 1060 HZ, 6/12/18/24



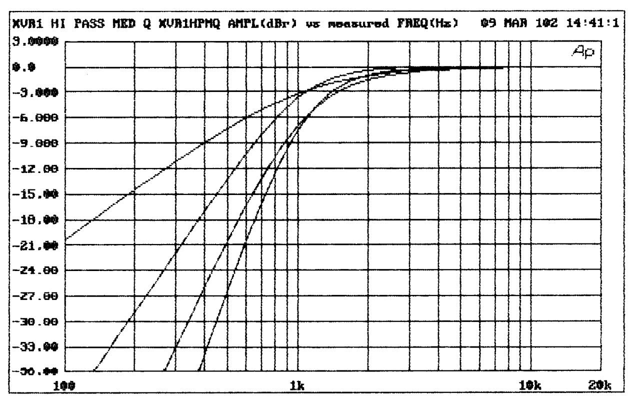
LOW PASS, MED Q, 1060 HZ, 6/12/18/24



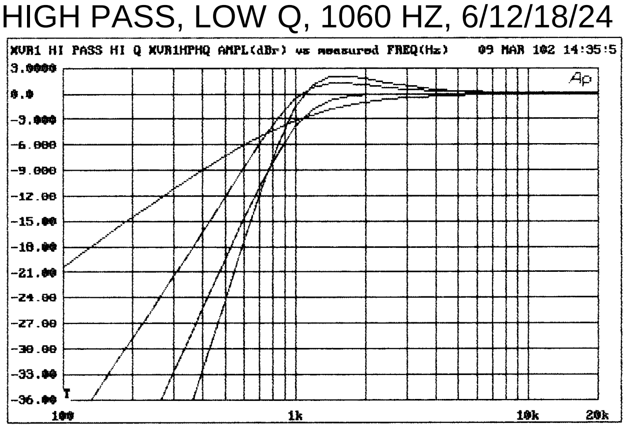
LOW PASS, HIGH Q, 1060 HZ, 6/12/18/24



HIGH PASS, LOW Q, 1060 HZ, 6/12/18/24



HIGH PASS, MED Q, 1060 HZ, 6/12/18/24



HIGH PASS, HIGH Q, 1060 HZ, 6/12/18/24