W7IUV Low Band Preamp

History:

Back around 1973, I began to experiment with receiving antennas for 160 meters. It soon became obvious that a preamp was necessary due to the low output level of some of those RX antennas . Over the years I tried building preamps with various active devices including tubes, Nuvistors, FET's, and MMIC's. None of them were very good, suffering from BCB IMD problems as well as instability and reliability issues. Around 1979, while searching for a good IF amp for a VHF project, I came across the basic feedback amplifier using a 2N5109. It looked good, so I built one up and tested it on 160. After a few component value adjustments, it turned out to be the best I had ever used for 160. Since then, I have made a number of "improvements" to the original circuit which were intended to optimize the preamp for my particular operating conditions. The circuit has been stable since 2001. It has been built by many hams worldwide and has been "pirated" by several vender's. This preamp appears in ON4UN's "Low Band DX'ing" 4th edition but some of the part values listed there are wrong. Be sure to use the values presented here. This web page is the only "official" source for correct information on this preamp.

Latest revision: 02mar09 (see text in USAGE section)

Licensing:

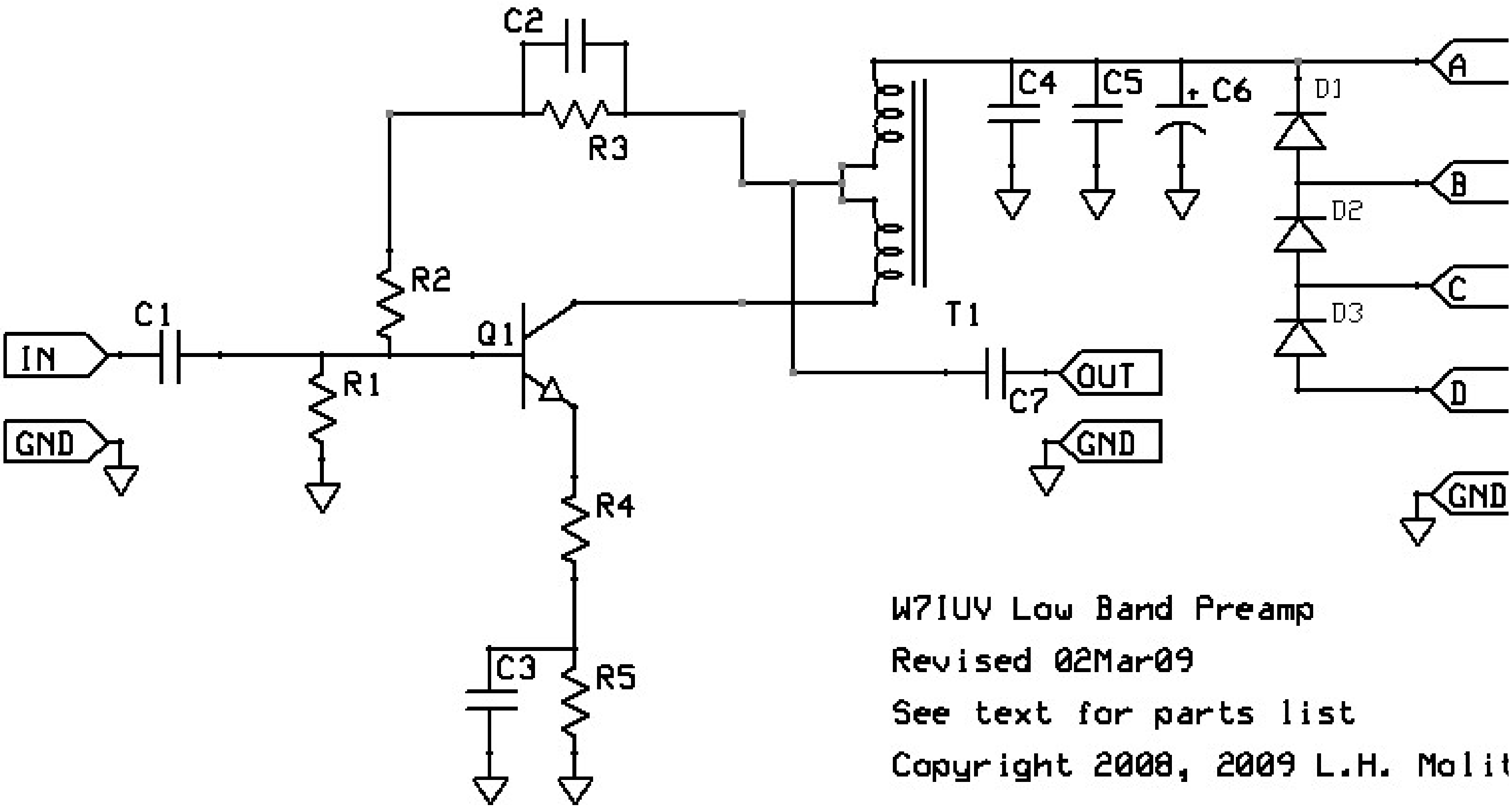
Amateur Radio Operators are both allowed and encouraged to duplicate this preamp for their personal amateur radio use. The circuit is copyrighted and no one has permission to use the circuit on a web page or publication without prior specific permission. Web links to this preamp design are encouraged but only if the link is directed to the main page. The reason for this is that the location of the preamp page will change from time to time but there will always be a link to it from the main page.

Specifications:

Performance has been measured in my lab with 12.0 volts power supply and 50 ohm source and termination impedance. (See revisions in RED for other voltages)

Gain = 19 dB +/- 1 dB
1 dB output compression level = +20 dBm +/- 1 dB
IP3 (output) = +39 dBm (typical)
Noise Figure = Unable to measure NF, but based on observed performance, it is likely less than 6 dB.
Usable frequency range = 100 kHz to 54 MHz

Schematic:



Parts List:

C1, C2, C3, and C7 0.01 uF disk ceramic This value is what I used in my application specific version. The 0.01 uF value provides a bit of low frequency roll off which helps reject AM BC interference. There ain't no free lunch, so the price you pay is a bit of gain loss at 1.8 MHz and an input impedance that is not 50 ohms at the low frequency end. Usually this is not an issue. However, if you have a high performance filter in front of the preamp, you may want to use 0.1 uF instead. This will provide a better termination for cranky filters and increase the gain by a small amount on 160. I've built and used both values in this circuit) DO NOT USE generic plastic encapsulated capacitors. Unless you know for sure that the generic caps have a low ESR and no odd resonances at frequencies up to 200 MHz, stay away from them. Disk ceramics are the safest in this application.

C4 0.01 uF disc ceramic

C5 0.1 uF disc ceramic

C6 4.7 uF/25 volt electrolytic

D1-D3 Silicon rectifier diode, 1N4001 or equivalent (used for dropping high power supply voltages, see text in USAGE section)

Q1 2N5109 preferred, 2N3866 usable. There are most likely many transistors that will work in this circuit. I

see no need to spend time and energy looking for them since the 2N5109 is readily available from a number of sources in the USA and Europe. This part is deliberately being run hot. It is operating Class A and needs to have a lot of current through it to provide the maximum IMD performance. It **NEEDS a heat sink. I use a snap-on heat sink with a surface area of about 1.5 square inches. See photos.**

R1 1.0 k ohm 1/4 watt (All the resistors are part of the bias/feedback system. Unless you have the ability to accurately measure the resistance, it is advisable to use 1% tolerance metal film or carbon film resistors.)

R2 560 Ohm 1/4 watt (1% film preferred)

R3 3.3 k ohm 1/4 watt (1% film preferred)

R4 This is a critical part. The optimum value for IMD performance using a 12.0 volt power supply is 4.7 ohms. Use a 1% film 1/4 watt resistor. I usually use two 10.0 Ohm resistors in parallel to give me 5.0 ohms. This will very slightly decrease the IMD performance but will also decrease the current through the transistor and the resulting dissipation. Under no circumstances should you use a value smaller than 4.7 Ohms. For those who do not need the maximum IMD performance and want to run the transistor at a lower temperature, use 10.0 ohms for this part.

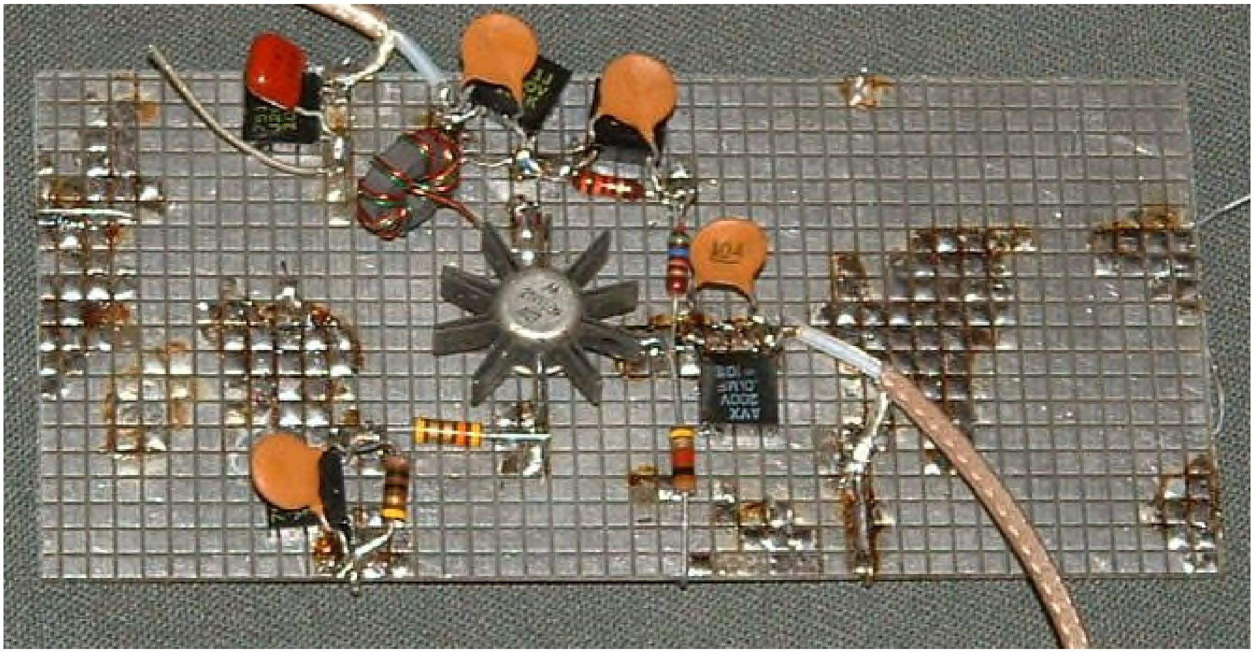
R5 10 Ohms 1/4 watt (1% film preferred)

T1 10 turns of #28 bifilar wound on a FT37-43 core and connected as an auto transformer. Do NOT twist the wires, wind them parallel and space evenly around core. If you don't know how to push wires through a hole, look in the ARRL handbook or equivalent for pictures. Other cores sizes may be substituted (I.E. FT50-43 and FT25-43) but be sure to use type 43 material or it's equivalent. Wire size is not important, you can use anything that fits in the hole.

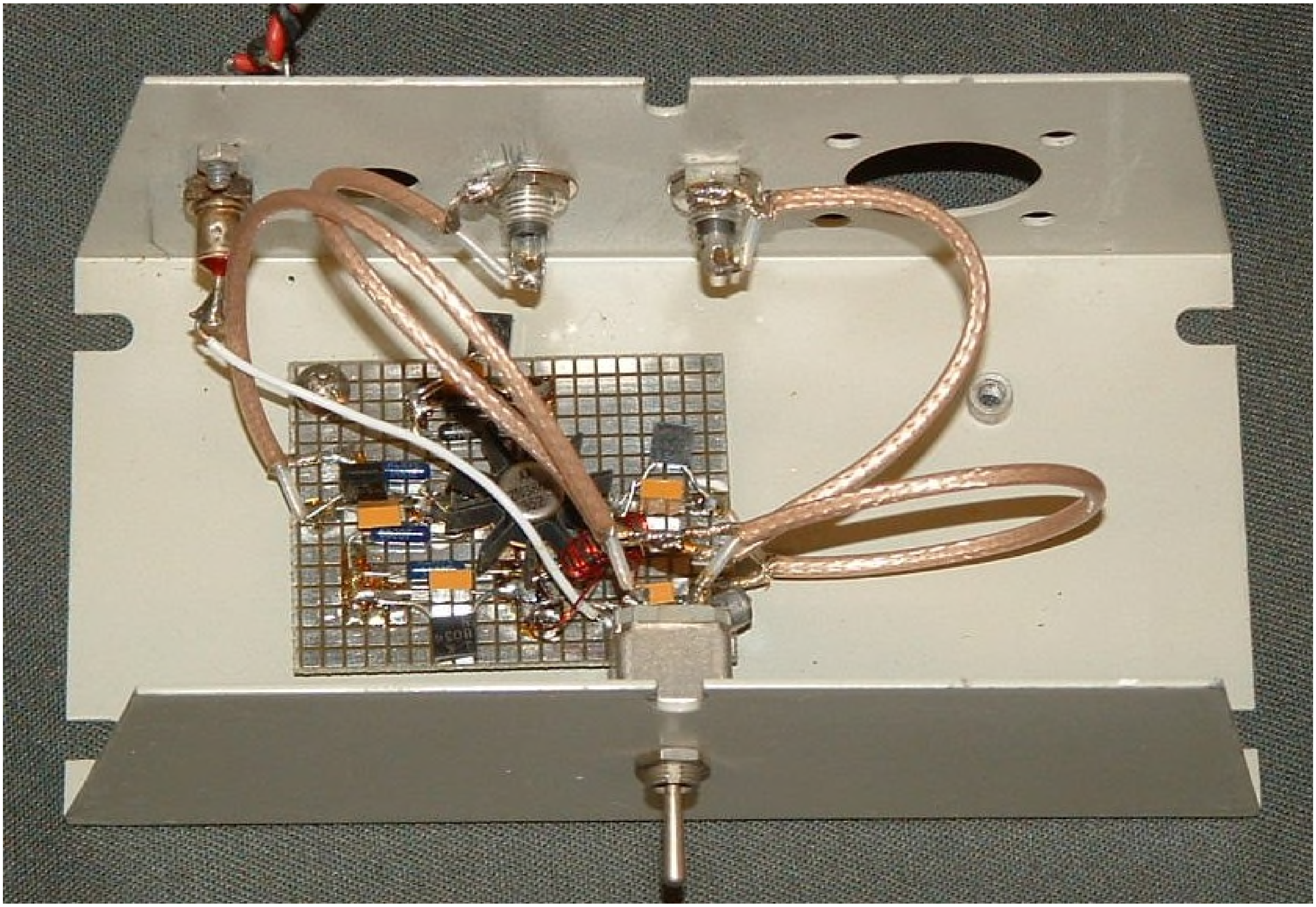
Construction:

Layout is not particularly critical. Use common sense and realize that this preamp has a bandwidth of 200 MHz or so. Build it like you would any 2 meter circuit and you can't go wrong. It is a good idea to put it in a metal box with well grounded connectors mounted on the box. The last thing you want is to pick up crap from computers and switching power supplies in the shack. A well "grounded" box will also help mitigate any potential "common mode" problems. Since I use this in so many application with physical requirements, I've never tried to make a PC board layout. Every one is different and I just use perf board or "checker board" and be careful about grounds. For my 160 station I have the preamp enclosed in a rather large box with a built in antenna selector switch, a switchable low pass filter and switchable attenuators. I have used phono type connectors, type F connectors, and BNC connectors for these preamps all with success.

This first image shows my "breadboard" preamp. This is my test bed for circuit changes and performance evaluations. It's pretty sloppy due to it having been built and re-built many times. Notice the black square capacitors. They are mil-spec ceramic types and are 0.01 uF. The tan colored disc ceramics are 0.1 uF and are tacked in parallel for test purposes. Note the emitter resistor shown is color coded as 4.3 ohms but being a carbon composition type, it's actual value is 4.70 ohms. Note the snap on heat sink.



This second image shows a preamp installed in reclaimed box along with a DPDT toggle switch that allows the preamp it be switched out of circuit. Note the feed through cap on the power lead. This unit also has the higher value capacitors tacked in parallel with the recommended 0.01 uF caps. This was done to allow use in the VLF beacon band. (100 kHz to 500 kHz)



This last image shows the preamp that I use everyday on the low bands. It has a built in selector switch that allows for ten different RX antennas. It has a high pass filter that can be switched in/out as needed. The preamp itself can be switched in/out as needed. There is a 6 dB and a 10 dB attenuator following the preamp that can be switched in/out as needed. There are also some switches that allow routing to different Receivers. I've been using this setup for more than 12 years and it has proven to be versatile enough to eliminate re-wiring the shack every time I want to use a different RX antenna or radio.

Troubleshooting:

Terminate the input and output with 50 ohms. Measure the current drawn from the 12.0 volt supply with an accurate digital meter. It should be 89 ma. +/- 5 ma. If it is higher than that, you did something wrong. Measure the gain with appropriate test equipment (not with your S-meter!). It should be 19 dB +/- 1 dB when measured at 1.9 MHz. If it's not, you did something wrong. Typical problems are mis-wired parts, solder shorts, and incorrect part values.

Use of an inappropriate layout or marginal components might result in out of band oscillation. These oscillations usually can not be detected without a spectrum analyzer or equivalent test equipment. Symptoms of out of band oscillation are spurious signals in band that cannot be otherwise accounted for and high current drain that otherwise cannot be accounted for.

This circuit, if built properly, is extremely robust. I do not disconnect it from the RX antennas when TX'ing or any other time for that matter and have never had a problem. The only way you can break it is if you don't heat sink it properly or if you manage to run full transmit power into either the input or output. Usually this happens because the operator is using a relay sequencer to switch the preamp in and out of the TX coax. Don't do that! Use a separate RX antenna input on your radio. If you radio does not have that feature either modify the radio so it does or buy a decent radio. Sooner or later if you use a relay sequencer, you will break the preamp.

Usage:

Run the preamp from a 12.0 volt supply. Make sure with an accurate voltmeter. If your supply puts out more than 12.0, drop it down with series resistors, series diodes, or a three terminal regulator. 12 volt wall wart transformers may work provided they are actually 12 volts. A switching type wall wart can be used if you are absolutely certain it has clean output with no spurs. It is counter productive to install a high performance preamp and then shoot crud down its throat. Remember any crud that appears on the power supply line will find its way into your receiver.

Revision 02mar09: From the feedback I get, it seems that ohms law is nearly as difficult as astrophysics for some folks. I revised the schematic to show diodes installed on the power supply line to provide adjustment for alternate power supply voltages. It is imperative that you accurately measure the voltage applied to the preamp. The optimum voltage for this design is 12.0 volts at point A in the schematic. Voltages as low as 10.0 can be used with a small reduction in performance. Under no circumstances should more than 12.0 volts appear at point A. If your power supply voltage measures between 10.0 and 12.0 volts, apply the power to point A in the schematic. If your measured power supply is between 11.9 and 12.7 volts, use the power input marked B in the schematic. If your measured power supply voltage is between 12.6 and 13.4 volts, use the power input marked C in the schematic. If your measured power supply is between 13.3 and 14.1 volts, use the power input marked D in the schematic. If you have more than 14.1 volts, you need to consider a different power supply or design a circuit to provide reasonable operating voltage for the preamp. This preamp circuit does NOT need a regulated power supply. As long as the voltage never exceeds 12.0 volts at point A in the schematic, it can wander around some. If you have 10.0 to 12.0 volts available, you can eliminate the three diodes.

This preamp is intended to be installed between a low output RX antenna and your radio. The fixed 20 dB or so of gain is optimum for RX antennas such as Flags and Pennants. Slightly less gain is optimum for K9AY

and EWE RX antennas that have a bit more output level. Decent Beverages have even more output and require less gain in the preamp. The proper way to reduce gain is to use fixed attenuators placed either at the input or the output of the preamp. Where they are placed depends on what kind of RX antenna you use. The lowest output type RX antennas will require the best Noise Figure and the least IMD performance so the attenuator should be placed on the output of the preamp as required. Higher level antennas such as a one wavelength Beverage should have the attenuator placed at the input of the preamp. Even though the system Noise Figure will be reduced it will be of no consequence and the IMD performance will be increased by the value of the attenuator. One last bit of info: the source impedance can vary wildly with no impact on the IMD performance of this preamp. However, the load impedance can have serious effects on the IMD performance. Receiver inputs are notoriously bad and can be almost anything except 50 ohms. Primarily for this reason I prefer to install any required attenuators at the output of the preamp.

This is a good place to talk about what the input level to you receiver should be. Modern receivers show approximately 20 dB difference between the minimum detectable signal level and the signal level which starts producing AGC action. As soon as the AGC circuit starts limiting gain, the RX performance is reduced. Old timers like to turn off the AGC and use the RF gain control. Since in a modern radio the RF gain control uses the same means of reducing gain as the AGC does it seems kinda dumb to do that. Over more than 50 years of weak signal operating, I've found that the maximum weak signal performance of any modern receiver occurs when the AGC is left on and the input level is adjusted so that background noise is just below the level at which the AGC starts operating. That means that normal band noise should NOT cause the S-meter to move off zero. If you use a combination of preamp and attenuators as described in the preceding paragraph to set the input level to this condition, you will be operating the radio at the maximum possible weak signal performance condition. You will find that the AGC will come into play when you tune across a very strong signal or a static crash and the speaker volume will be limited nicely. But, when you tune across a weak signal it will seem to jump up out of the noise. Once again, if your S-meter moves on background noise, you are not operating your receive system at it's maximum weak signal potential!

This preamp should be installed at the auxiliary RX antenna input on your radio. Do not use a relay scheme to put it in the TX coax. This preamp will function as a protection circuit for your RX in that the output is limited to a maximum value that is well under what it takes to break the radio. The transistor used is a power device and has a base-emitter structure that can handle far more than the input circuits in your radio. I never disconnect my preamp from the RX antenna. It's connected 24/7, during TX and lightning storms and anything else that fate sends its way. It will not break unless you take a direct lightning strike, transmit into it, or do something stupid. DO NOT put back to back diode on either the input or output thinking you will be protecting something. The only thing the diodes will do is generate IMD products from the strong BC stations, exactly what you are trying to avoid by building this high performance preamp!

The high IMD performance is "out of band", that is to say it is not the same as the "in band" performance so highly valued by hot shot contesters. "Out of band" IMD is caused by high level signals that are not in the ham bands such as AM broadcast. These out of band signals can cause problems that cannot be cured by magical roofing filters. If the preamp generates IMD products, there is nothing you can do in the radio to eliminate the resulting spurs. Thus the need for a high performance preamp in front of the radio. In some cases, usually when a low level RX antenna such as a Flag is used, you won't need a filter in front of the preamp if you didn't need one in front of the radio.

In extreme cases, especially when a high level RX antenna such as a long Beverage is used, a filter will be required ahead of the preamp. In many cases, the preamp doesn't need the filter but the radio does! In either case a filter should fix the problem. I don't recommend complex filters such as bandpass types or elliptic function types because component values are too critical and operating conditions such as input and output impedance are also critical. They seldom, in practice, provide the performance enhancements claimed for them. Simple high pass filters are easy to build with common parts, usually don't require any "alignment" to

function properly, and don't care much about exact input and output terminations. A 7th order Chebychev high pass, with a 0.1 to 1 dB passband ripple, will normally be all that's required to use with this preamp. (unless you operate on the same property as your local 50 KW BC station!)

Let me know if you find this circuit useful.

Enjoy!

73, Larry