Tube Phono Preamps
Several topologies & tricks
Part 2 of 2

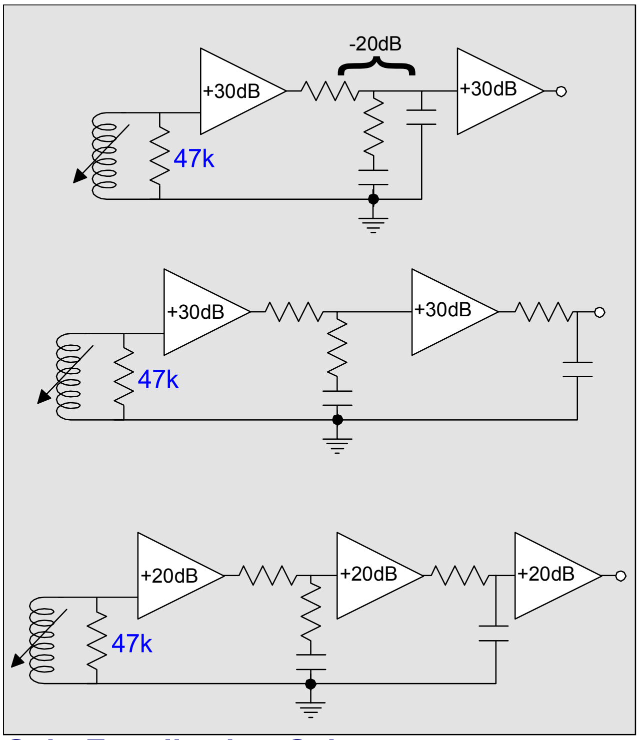
Part one of this article covered active RIAA equalization. *Active* means the frequency response is tailored to fit that of the RIAA curve by varying the amount of the feedback signal returned to the input (i.e. based on frequency). The problems arising from the use of feedback were covered—potential instability and the need for extra gain to power the feedback mechanism.

Passive Equalization

The alternative to active equalization is passive equalization. Passive RIAA equalization means brute force equalization: the frequency response is tailored to fit that of the RIAA curve by varying the amount of attenuation at different frequencies through a complex RC network. The advantages: no voltage overload, no feedback, no instability problems, and no high frequency gain limits. The disadvantages: no gain (in fact there is usually some slight insertion loss beyond the required frequency tailoring) and possible impedance matching problems.

We will examine the many forms that passive equalization can take:

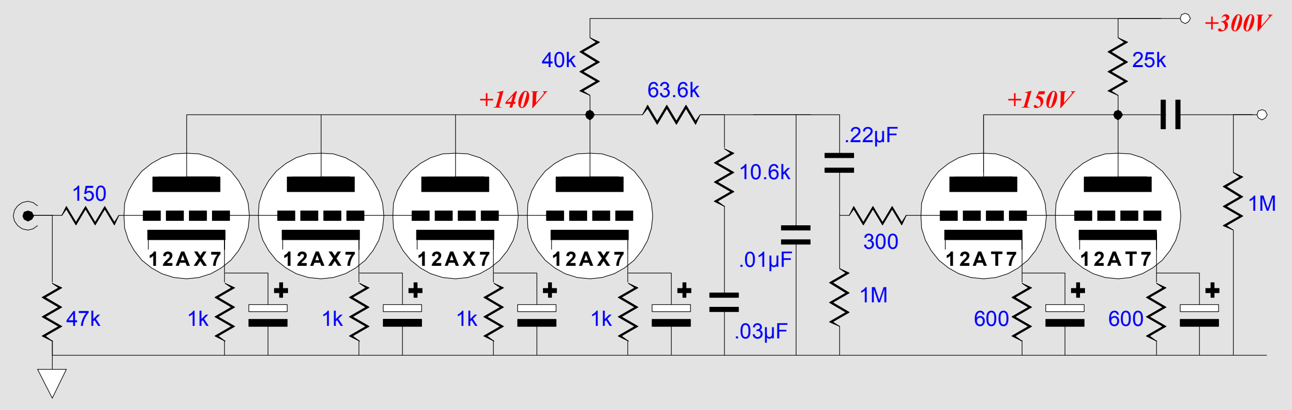
- two gain stages with one complete equalization network in between,
- two gain stages with one partial-equalization network in between and one partial equalization network following the last gain stage,
- or three gain stages with one partial-equalization network in between each gain stage.



Gain-Equalization-Gain

In the topmost circuit we see the approach of using two gain stages with one complete RIAA equalization network in between. One 6922 or 12AX7 or 6N1P per channel is all that is needed. If grounded-cathode amplifiers are used, a plate resistor and a bypassed cathode resistor, are all that is missing. Refinements might include eliminating the cathode resistors altogether by using batteries to bias the triodes. Further refinements might entail using a truly high-voltage power supply, say a 1000-volt B+ with a staggered turn-on; or maybe using a truly low high-voltage power supply, say 100 volts with solid-state constant current source loading of the triodes. Somewhat paradoxically, both of these approaches yield the same results: high gain and good power supply noise rejection.

Alternatively, the generic grounded-cathode amplifier topology can be retained, but the number of triodes in parallel can be increased to 2 or 4 or even 6 or 8. The following schematic illustrates this approach. The circuit is as straightforward as can be imagined, the only twist being the many triodes (four in the first stage and two in the last) used in parallel.



Parallel Tubes

The usual disadvantage of using many tubes in parallel is the greatly increased input capacitance, but in a phono preamp this capacitance works in our favor. Phono cartridges like to be loaded by capacitance, as the capacitor's declining impedance with increasing frequency helps to damp the cartridge's high frequency resonances. And the second gain stage's increased input capacitance only helps to complete the passive equalization network's own internal need for a final shunting capacitance.

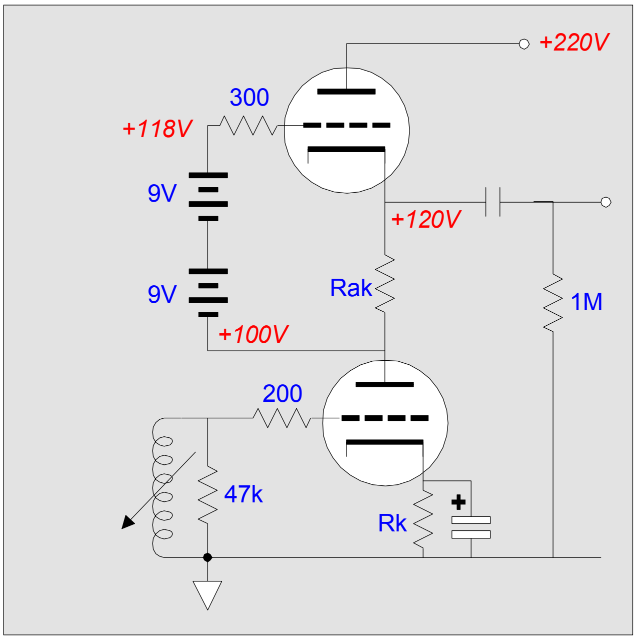
On the other hand, the usual *advantage* to many parallel tubes lies in the lower output impedance and lower noise figure, both being highly desirable in a phono preamp. Like many resistors held in parallel, many tubes held in parallel lower the effective resistance of the bundle. In other words, the effective rp of 6 12AX7s held in parallel is one sixth (about 10k) that of one 12AX7 (about 62k).

Furthermore, the triode's own r_p gives rise to a noise similar to the noise a high resistance resistor would bring to a circuit. And like the resistor, the lower the effective rp, the lower the resistance noise. In other words, six 12AX7s held in parallel are six times lower in *this type of noise* than a single 12AX7. Why not use three or five triodes in parallel? In other words, why should only an even number of triodes be used? If the triode you are using comes one to the envelope, then any number of triodes can be placed in parallel. But if the triode comes two to an envelope, such as the 6DJ8, 6N1P or 12AX7 does, then an even number is better. Why?

The logic is simple: particularly, in a phono stage, where millivolt signals are amplified, we do not want any interaction between the triodes in a tube envelope. With all the triodes in an envelope seeing the same input signal, the interaction is minimized.

The calculation of the equalization network's values requires taking into account the output impedance of the first stage and the input resistance and capacitance of the second gain stage. Assuming a bypassed cathode resistor, the output impedance is easily derived from taking the effective rp of the input tubes in parallel and placing this value in parallel with the plate resistor's value, which is added to the 63.6k resistor's value. The input capacitance, i.e. the Miller-effect capacitance, is derived from taking the cathode-to-plate capacitance and multiplying it by the gain of the second grounded-cathode amplifier and then adding this sum to the grid-to-cathode capacitance. This capacitance adds to the .01 µF capacitor's value, which brings the equalization network into the correct alignment.

Of course, a two-gain stage, passive equalization layout is not limited to grounded-cathode amplifiers. In fact, as long as there are two gain stages bridged by a passive equalization network, just about any tube amplifier circuit can be used: the SRPP, the cascode, the grounded-grid amplifier (with some tweaking), and the common-cathode amplifier. Other circuits that could be used are the constant-current-draw amplifier, the plate follower, and the two tube feedback pair.



Actively loaded (constant current source) grounded-cathode amplifier

Actively Loaded Grounded-Cathode

Let's move slowly through some of the possible candidates for the first gain stage. The simplest variation on the grounded-cathode amplifier we have already covered, entailing using more triodes in parallel. Moving up in complexity, the actively-loaded grounded-cathode amplifier finds its plate resistor replaced by another triode that functions as an active load. Depending on the size of its cathode resistor, the effective impedance this load presents to the bottom triode can easily be much larger than the plate resistor it replaces. The formula is a simple one:

$$Z = r_p + (\mu + 1)R_k,$$

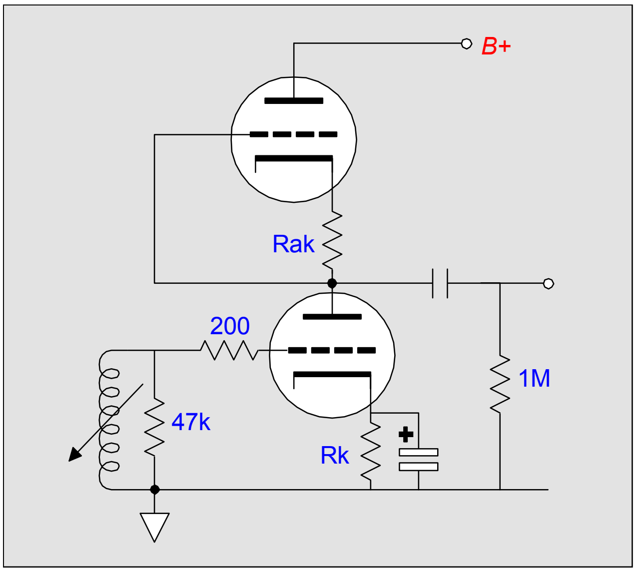
where, µ equals the triode's amplification factor (mu). For example, a 12AX7 with 20k cathode resistor would represent an impedance of

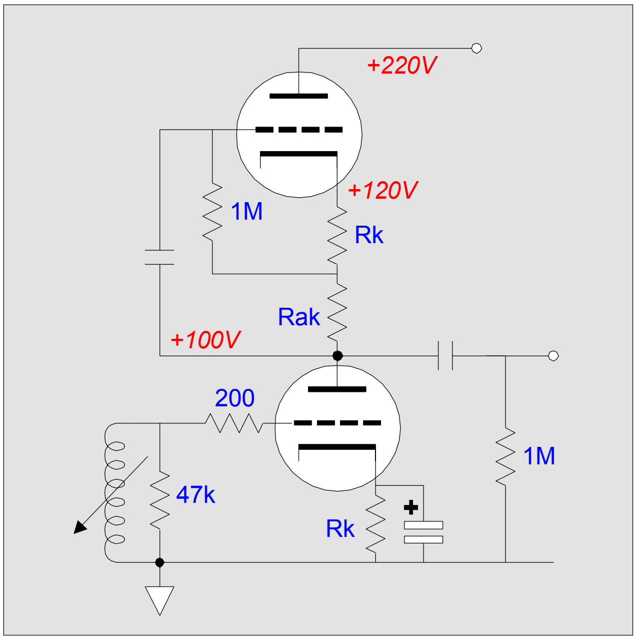
2,082,000 = 62k + (100 +1)20,000.

Just 1-mA against a resistor with this value would develop a voltage of 2,080-volts! Yet, both triodes could easily operate with a B+ voltage of only 300-volts. Unfortunately, using a 20k cathode resistor with a 12AX7 will require using an extra coupling capacitor, as a 20k resistor would bias the tube down to near cutoff.

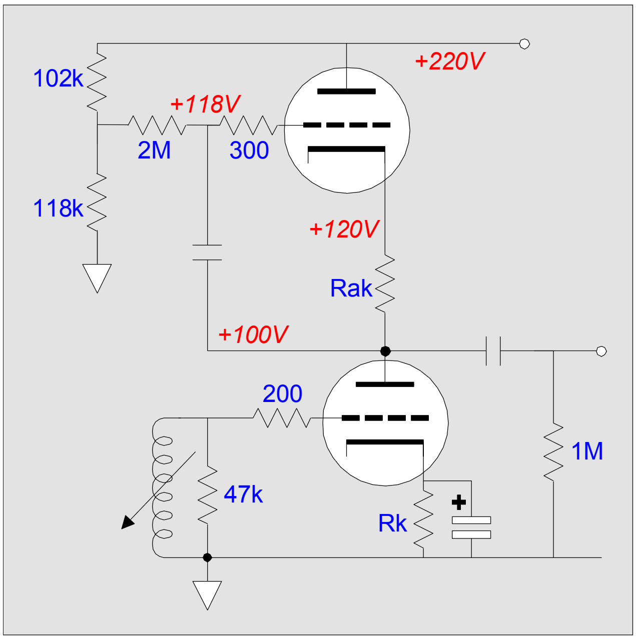
Here is a trivia question: How large a value of cathode resistor is needed to completely turn off the 12AX7? A trick question doubtless, for no cathode resistor can be large enough to turn off the tube, as the only way a negative bias voltage can develop across the resistor is when the tube conducts — which means it cannot be turned off. While we are on the topic of tricks, one strategy for increasing the effective load impedance of the active load without having to resort to an extra coupling capacitor is to run the triodes dissimilarly. Normally, Rak would equal Rk, but they can differ in value. Using different values means that the triodes will see different cathode-to-plate voltages, while seeing the same current. For example, equal resistor values would yield an equal voltage across each triode. Increasing Rak's value will increase the voltage across the top triode, but diminish the voltage across the bottom triode. Given a 200-volts B+ power supply, a good ratio might be 130-volts for the top tube and 70-volts for the bottom tube.

Thus, we have increased the value of Rak, and the effective impedance of the active load at the same time, without having resorted to adding an extra capacitor. However, if we desire the highest gain, the most linearity, and the lowest amount of power supply noise at the output, then a coupling capacitor must be added, as that is simply the price we pay for using a much larger value for the resistor Rak.





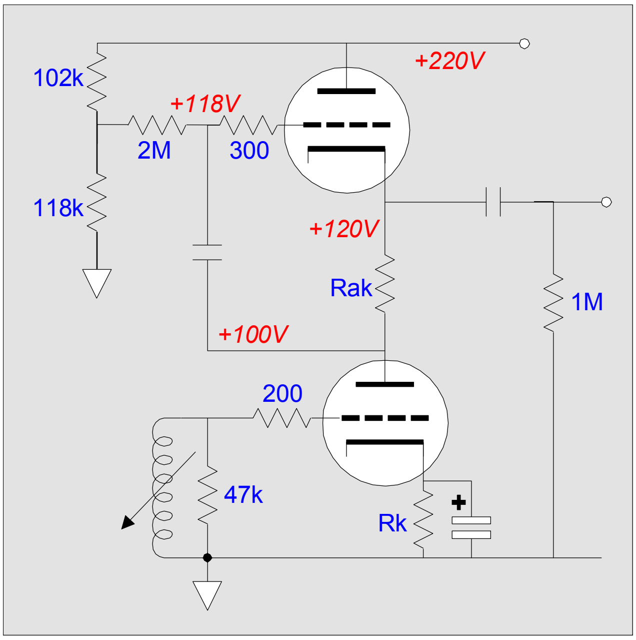
Two topological variations present themselves: the auto bias version, shown above and the fixed-bias version shown below.



The danger hidden in any multi-tube circuit that holds one tube atop the other is the chance of exceeding the maximum cathode-to-heater voltage of the tube, usually about 100 volts. The workaround is to use two heater power supplies, one referenced to ground (or a few tens of volts above ground) and the other referenced to some higher voltage, such as 120 volts.

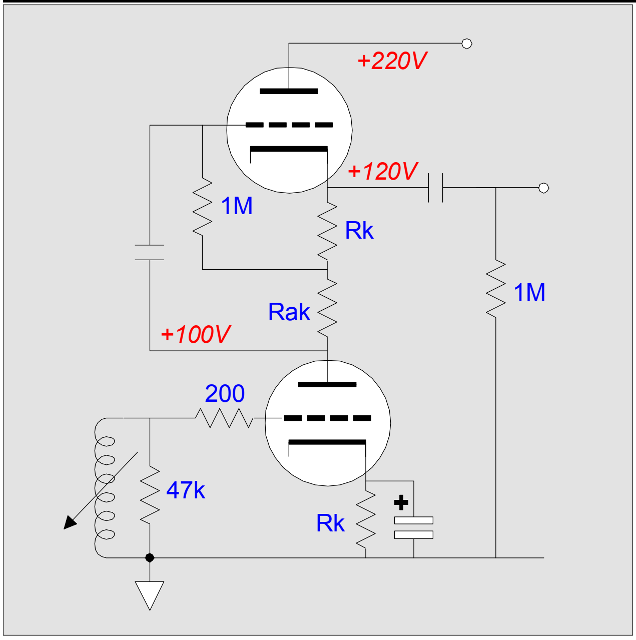
SRPP Amplifier

Moving the output from the bottom tube's plate to the top tube's cathode transforms the actively loaded grounded-cathode amplifier into the SRPP. Thus, all the same tricks and topological variations apply to this circuit as did to the actively loaded grounded-cathode amplifier. See *SRPP Deconstructed* or *SRPP Decoded* or *SRPP Once Again*. Understand that in a phono preamp, the SRPP functions more as a pure voltage amplifier and less as a power amplifier, so that much of the criticisms lodged at the SRPP do not apply in this application.)



Fixed-voltage referenced SRPP amplifier

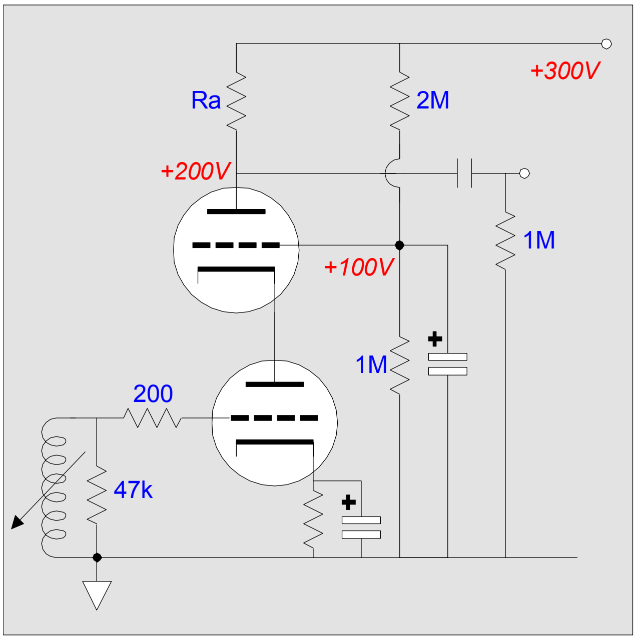
While the SRPP offers a much lower output impedance than the grounded-cathode amplifier, it is more sensitive to reactive loads. Consequently, the passive equalization's impedance values should be kept high (i.e. high resistor values and low capacitor values), which unfortunately will increase the noise from the equalization network. Possibly the best technique might be to preload the SRPP's output with a low-valued fixed resistance to shunt out much of the network's varying impedance, say 10k, or whatever value yields the lowest distortion.



Auto-bias SRPP amplifier

Cascode

The cascode offers more potential gain than any of the previous circuits, with the final gain often far exceeding the mu of the triode.



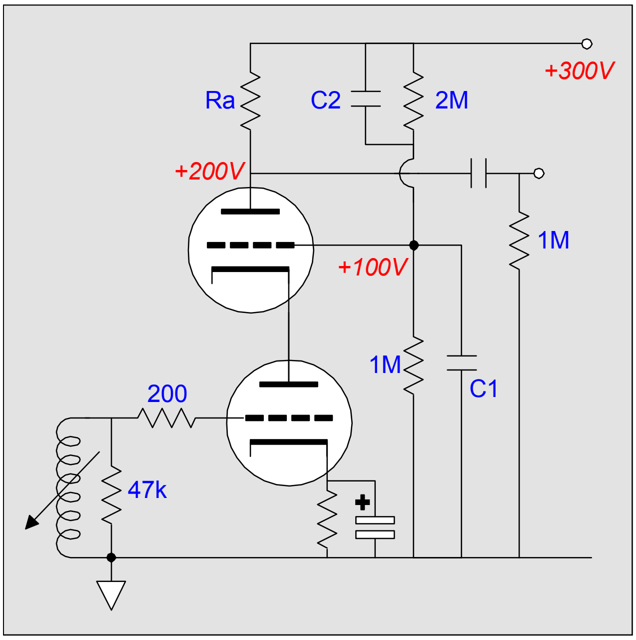
Cascode amplifier

The cascode's gain roughly equals the triode's Gm against Ra:

$$\text{Gain} = \frac{\mu R_a}{(R_a + R_p) / (\mu + 1) + r_p}$$

While the extra gain is welcome, the worst PSRR figure of any of the circuits under consideration is not. A workaround was presented in the *Tube CAD Journal's* first issue, March 1999, which offered a way to eliminate the power supply noise at the output. This technique works at reducing the power supply noise at the output by introducing a portion of the power supply noise to the top triode's grid, where it will be amplified in anti-phase to the noise at the B+ connection. (Many do not realize that the top triode is capable of gain, which is not the case with FETs or transistors in place of the triode.)

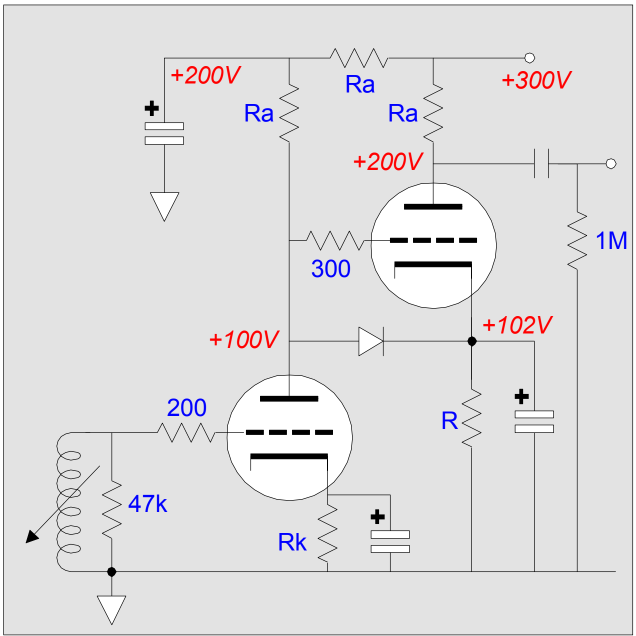
The triode's r_p makes the difference, as the bottom triode in effect becomes simply a large valued cathode resistor. Setting the ratio between capacitors, C2 and C1, to match the amplification plus one from the top triode will ensure that the noises cancel at the top triode's plate. For example, if the top triode realizes a gain of 3, then the ratio should be 2:1, as this would equal 3.



Noise-nulled cascode amplifier

DC-Cascaded Amplifier

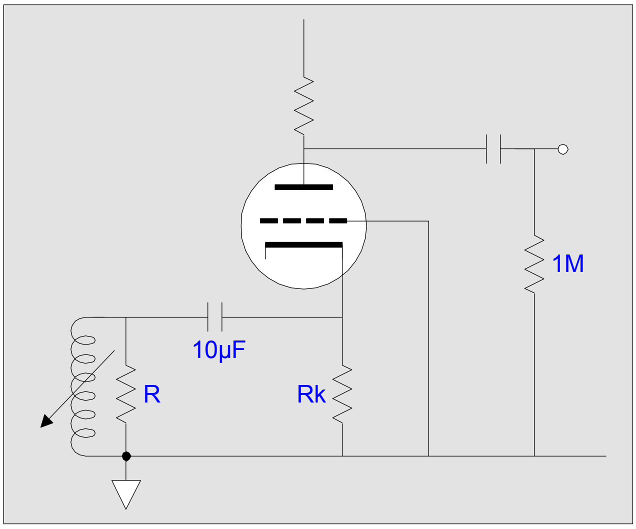
The next possible circuit for the first stage is the cascaded amplifier. Here one grounded-cathode amplifier cascades into another. In the schematic below, the connection is capacitor free, i.e. DC coupled. Each triode sees the same cathode-to-plate voltage, with resistor R taking up slack voltage. This circuit yields a huge gain that would be suitable for MC cartridge use.



Grounded-Grid Amplifier

The grounded-grid amplifier does not invert the signal's phase at its output and it offers a low input impedance, as the input is the cathode rather than the grid. A low input impedance (100-600 ohms) is great for MC cartridges, but not so great for MM cartridges, which prefer to see an impedance between 10k to 47k.

Since the cathode is the input of this circuit, DC coupling becomes difficult, as ground-level DC coupling would require using a negative power supply and a negative grid voltage to place the cathode at 0 volts. A DC servo loop would help, but the cartridge would still be susceptible to damage at turn on, when the tube just starts to conduct and the servo might be too slow to prevent a large DC offset at the cathode. Consequently, a coupling capacitor is the safer approach.



Grounded-grid amplifier

In the above circuit we see a grounded-grid amplifier cascading into a cathode follower. The coupling capacitor may seem too large in value, where in fact it is probably too small in value. The grounded-grid amplifier's input impedance is equal to the sum of the rp and the plate resistor divided by mu +1:

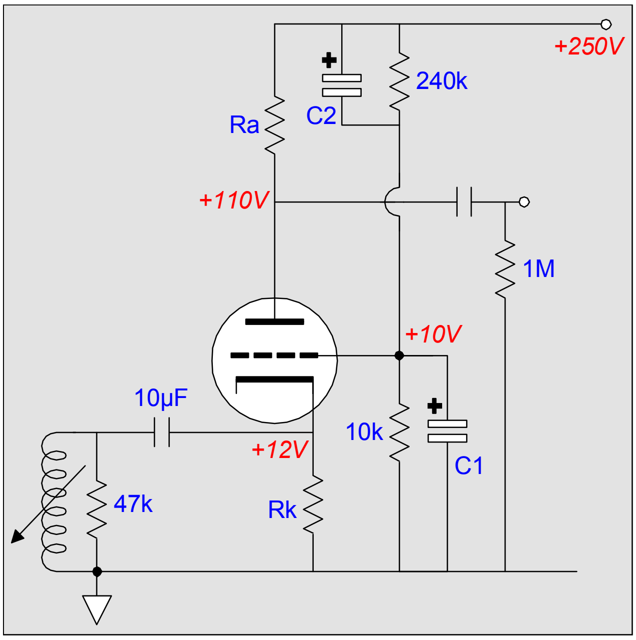
$$Z_{in} = (R_a + r_p) / (mu + 1)$$

Given a 6DJ8 as the tube, the input impedance equals 380 ohms in parallel with the cathode resistor's 200 ohms (about 130 ohms). The low frequency cutoff is found by the following formula:

$$F_{low} = 159155/(Z_{in} + Z_{cartridge})/C$$

So in this example, 50 µF equals a –3 dB cutoff frequency of about 25 Hz. Using a higher rp tube such as a 6072, 5751, or 12AX7 would increase the input impedance, but at the cost of more noise. (The usual compromise is to use an electrolytic capacitor in parallel with one or two high quality film caps.)

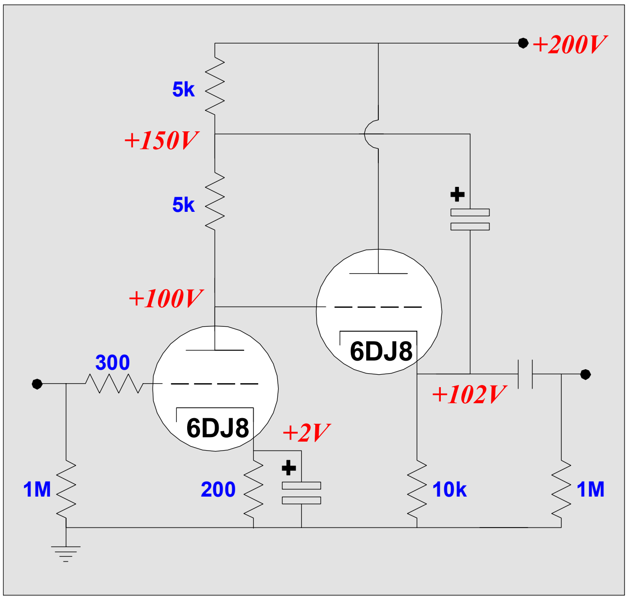
The grounded-grid amplifier allows an easy noise canceling trick, as a small quantity of power supply noise can be injected at its grid, causing an inverted noise signal to appear at its plate, which then mixes and cancels with the power supply noise there in much the same manner as it did in the cascode noise-nulled circuit.



Noise-nulled grounded-grid amplifier

Bootstrapped Compound Amplifier

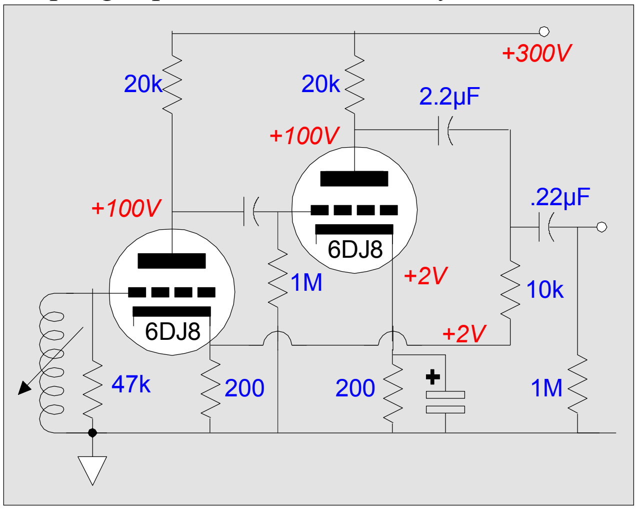
This sleeper of a circuit was described in length in the "SRPP Deconstructed" article from earlier this year. In a nutshell, this circuit works to magnify the first triode's plate resistor, making it effectively much larger, so that the gain from the first stage can nearly equal its mu. The tradeoff is that the second stage no longer has a low output impedance similar to a cathode follower. Still, this deserves a second look.



Bootstrapped compound amplifier

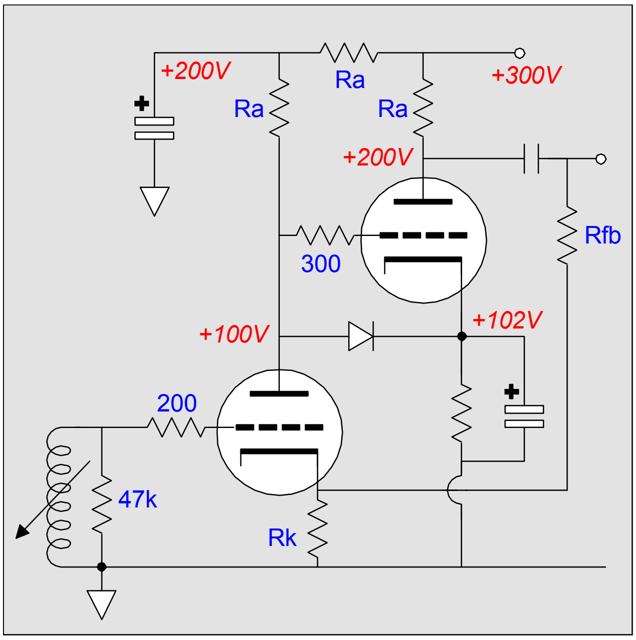
Two-tube-feedback pair

One possible measure of success might be a simple coupling capacitor count, with less being better than more. By this standard, the two-tube-feedback pair would seem a sure loser, with its internal coupling capacitor and its two output coupling capacitors...but then, maybe not.



DC-cascaded feedback pair amplifier

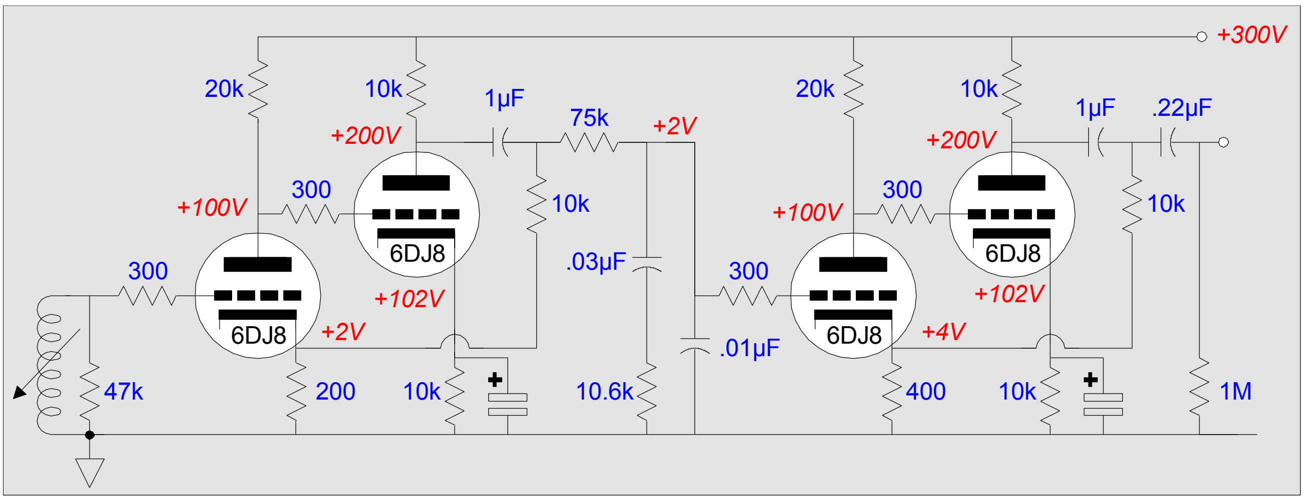
Why so many coupling capacitors? If we attach the feedback resistor directly to the second triode's plate, the first triode's cathode voltage and the second triode's plate voltage will be thrown off. Using a coupling capacitor between plate and feedback resistor isolates the feedback resistor from the plate, but not from the first triode's cathode, which will impose its DC offset on the resistor; thus the need for the secondary coupling capacitor.



Improved DC-cascaded feedback pair amplifier

Direct coupling between tubes eliminates the internal coupling capacitor and accepting the consequences of retaining the first triode's cathode voltage at the output eliminates the second coupling capacitor.

In the circuit below, we see a pair of two-tube feedback amplifiers being used in a way that only brings the count of coupling capacitor to three. This arrangement is possible because the second triode's cathode resistor is bypassed (which it would probably be even if the coupling capacitor had been retained), which allows us to specify the resistor's value arbitrarily.



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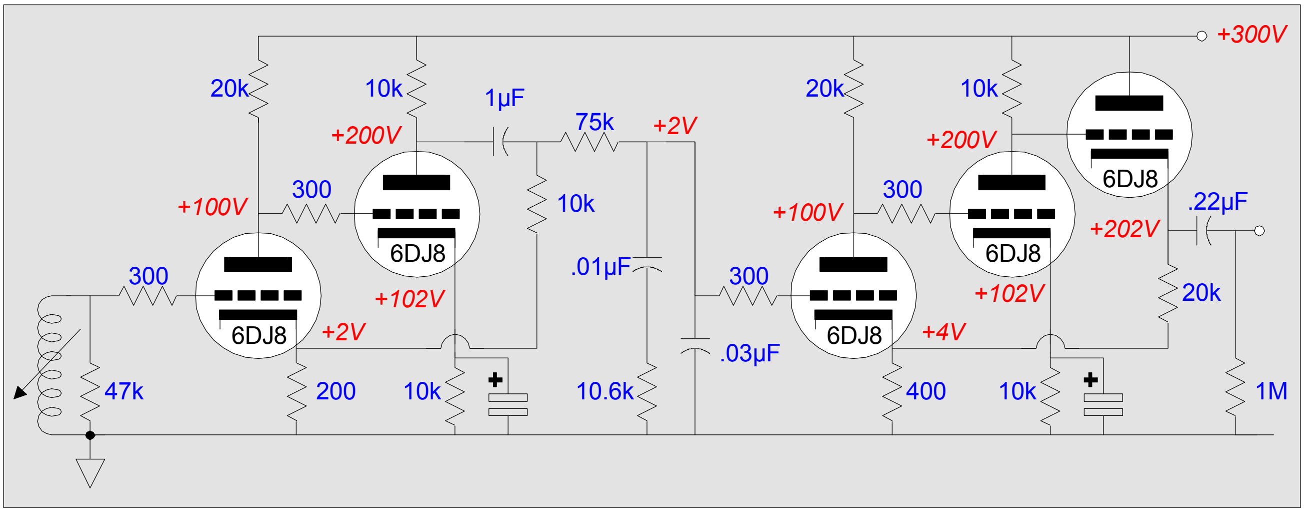


In other words, because the triode's cathode finds a low-impedance path to ground through the bypass capacitor, the triode doesn't see its cathode resistor's value in its AC operation; in its DC operation, however, the grid's DC voltage and the cathode resistor's value set the idle current through the triode.

The feedback loop encompasses the output coupling capacitor and purposely allows the DC voltage from the first triode's cathode resistor to be relayed to the other side of this capacitor. This small positive DC bias allows the use of a higher valued cathode resistor for the following gain stage's input tube, which helps us realize a lower gain from the second gain stage without having low-valued feedback resistor drag down the output too severely.

The last coupling capacitor is needed to shield the volume control and the line stage input from the DC voltage present on the feedback loop (potentiometers should never see a constant DC current flow through their scraper).

In the circuit above, we see that adding a cathode follower eliminates the need for the last coupling capacitor. The 20k feedback resistor is now is no longer in parallel with the plate resistor, which will result in higher gain from the that triode because its plate is sheltered by the cathode follower. Now the total coupling capacitor count has fallen to two and we have retained the feedback loops, while improving the stability of the amplifier. Not bad.

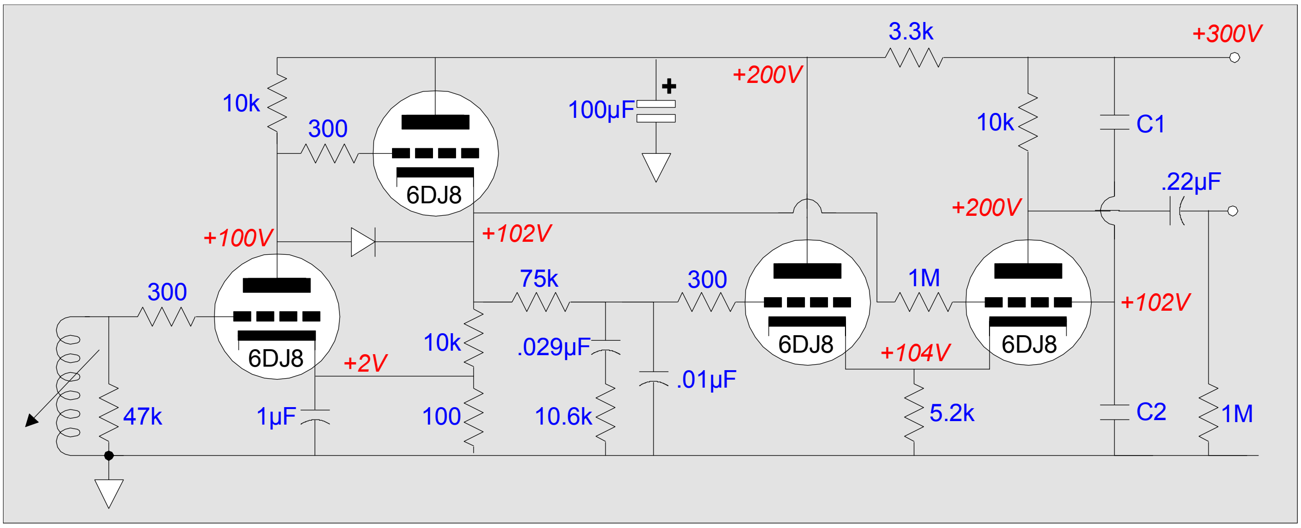
Fresh Topology

If fewer caps are better, is it possible to build a multi-tube passive phono preamp with only one coupling capacitor? In the circuit below we see a constant-current-draw amplifier feeding a passive equalization network, which then feeds a common-cathode amplifier, amazingly DC-coupled all the way to the output coupling capacitor. The 100-volt DC bias voltage on the network's output allows us to use a rather large valued common-cathode resistor (5200-ohms) without having to use a negative power supply.

The enemy of all preamplifiers is noise. Some noises are difficult if not impossible to counter, such as tube microphonics. One source of noise, however, can be reduced through an understanding and the careful applications of noise mulling techniques. The elaborate circuitry at the common-cathode's second triode's grid (the 1-meg resistor and the two capacitors in series) is there to allow canceling of the power supply's noise from its output by introducing a small amount of power supply noise at this grid by effectively voltage dividing the power supply' noise. Thus this portion of the power supply noise can be amplified and phase inverted at the output, where it will cancel with the power supply noise at the plate resistor. A single coupling capacitor is in itself a worthy enough goal, but by adding noise cancellation, we arrive at a truly desirable phono stage.

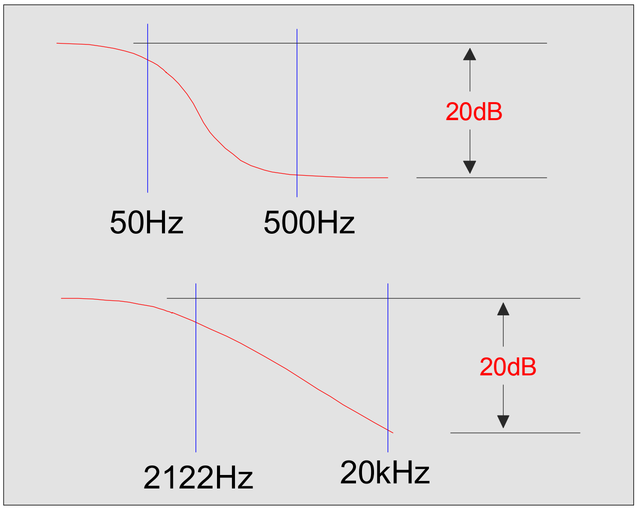
Notice how the 3.3k resistor in the power supply serves double duty by filtering the B+ voltage for the first stage and achieving a matched plate voltage for the second stage's triodes. A safe bet would be a floating heater power supply that was referenced to about 70 volts to prevent exceeding the triode's cathode-to-heater voltage limits.

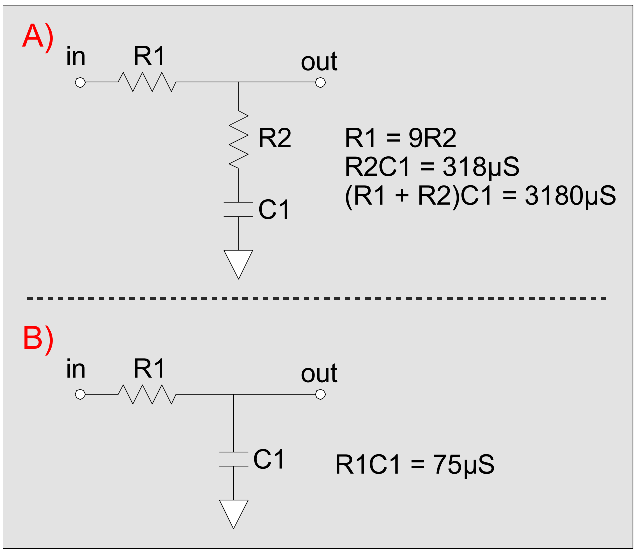
(Of course, my brief outlining of this circuit is not the correct tube-guru procedure to promoting a new design. The generally accepted guru approach would be to write a long article for a mainstream—or is minor-stream closer to the truth?—audio magazine, such as the late *Sound Practices*. The article would then go on to slam all other tube phono preamp designs and go on to explain how the preamp sounds far better than a friend's supremely-expensive-tube-name-brand preamp. The article would explain how the preamp must be made with both the carbon resistors and the capacitors culled from a 1961 RCA BW television; in fact, the preamp would be named the *RCA Uni-Cap* preamp, or better still, the *RCA-Unicorn* preamp. This circuit would then live and propagate, becoming user-group and chat-room fodder; finally, someone would use a different tube and claim to have invented a whole new topology or it might mutate into a simpler circuit, as few would understand how the noise cancellation works and what is not understood is not needed; right? Oh, what a tube-audio cynic I have become.)



Split Equalization Passive Preamps

Like the active alternative, the passive equalization network can be split into two sections, one covering the 50 to 500-Hz shelving function and another covering the 2122-Hz low-pass transition point.



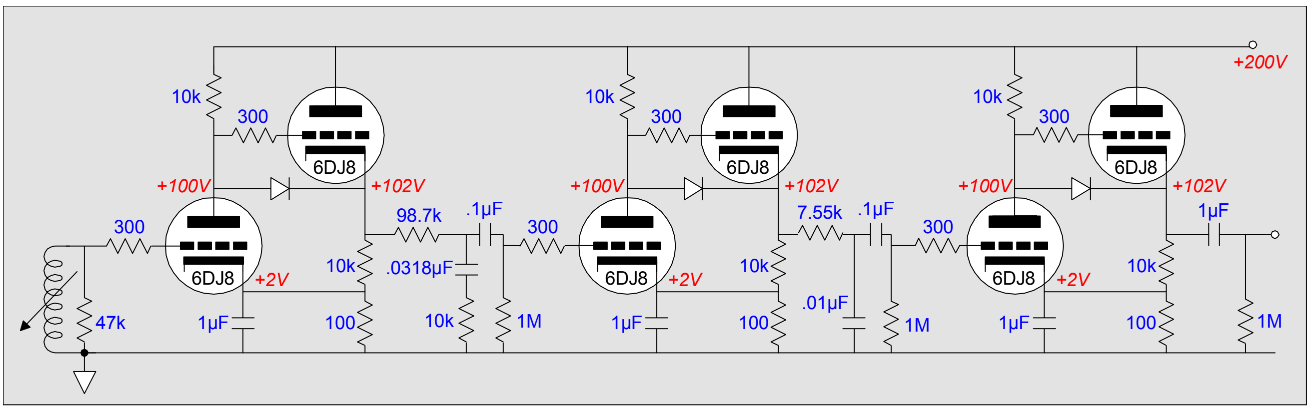


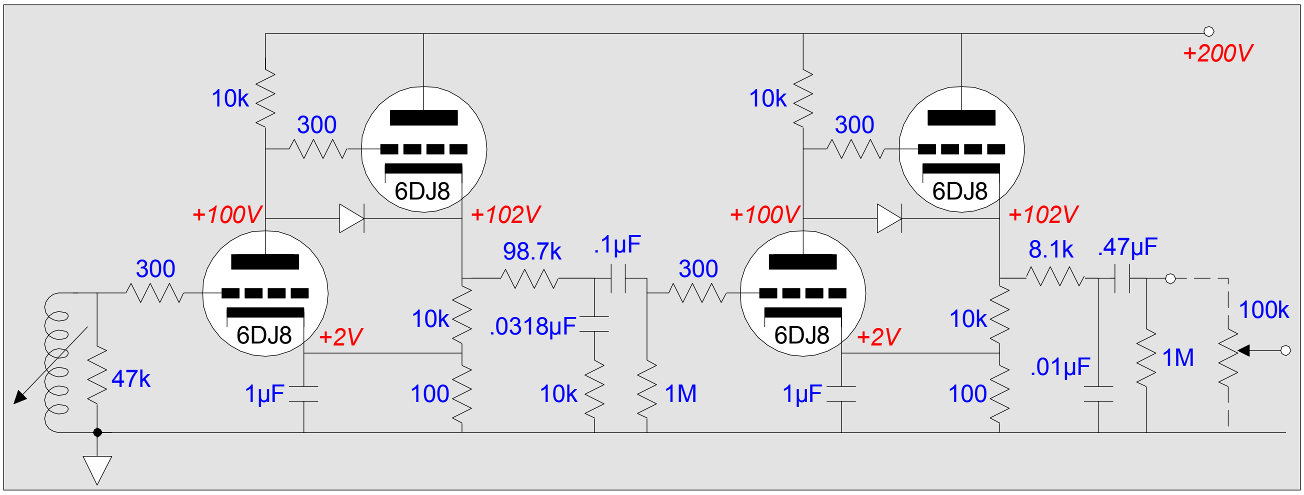
Two resistors and one capacitor are all that is needed to create a low-frequency shelving network. At low frequencies, the capacitor effectively isolates resistor R1 from resistor R2 and ground, so no attenuation occurs. At high frequencies, the capacitor effectively bridges resistors R1 and R2, creating a voltage divider and reducing the signal by the resistor ratio.

The usual approach is to use three gain stages separated by two passive equalization networks, for example, the circuit below. This scheme greatly reduces the gain requirement from each gain stage. For example, you would be hard pressed to find triodes that could realize a gain higher than 70 in the two gain stage scheme, which would yield only a final gain of 50 dB after equalization.

But that same 50 dB of gain could be had by cascading three stages with a gain of 15 times the input (23 dB). In the circuit below, each 6DJ8-based grounded-cathode amplifier achieves a gain of 25 (+28 dB) in this circuit, which brings the total gain to +64 dB after equalization!

If the values of the shelving network and the low-pass filter do not look correct, for example, 98.7k instead of 90k and 7.55k instead of 7.5k, the reason is that these values have been adjusted to compensate for the 1M grid resistors that follow and are effectively in parallel with the resistors. Thus, 1M in parallel with 100k yields 90k and 1M in parallel with 7.55k yields 7.5k. (Actually, we should also include each cathode follower's output impedance in the mix; be sure to read the last page)



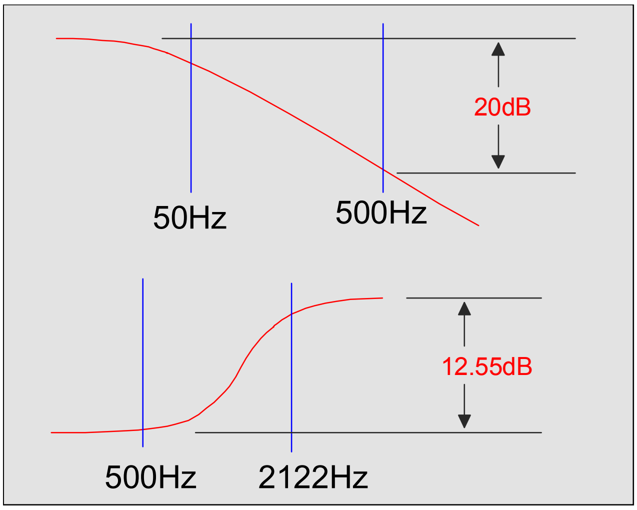


Another possible variation would be to use two gain stages, with the shelving half of the equalization network in between the two gain stages and the 2122-Hz RC low-pass filter following the output. This topology once again begs the irksome question of sufficient gain, as the 6DJ8-based gain stage would only realize a total phono preamp gain of +36 dB, which might be sufficient with some high-output moving magnet cartridges or with high-gain line stages. Still, this configuration would greatly reduce the preamp's output noise as it equalizes the signal, as whatever noise is present above 2122 Hz, no matter its cause, would also be attenuated by the final equalization network. (The output impedance of the final gain stage and the resistance of the volume control have been factored into the design of both equalization networks.)

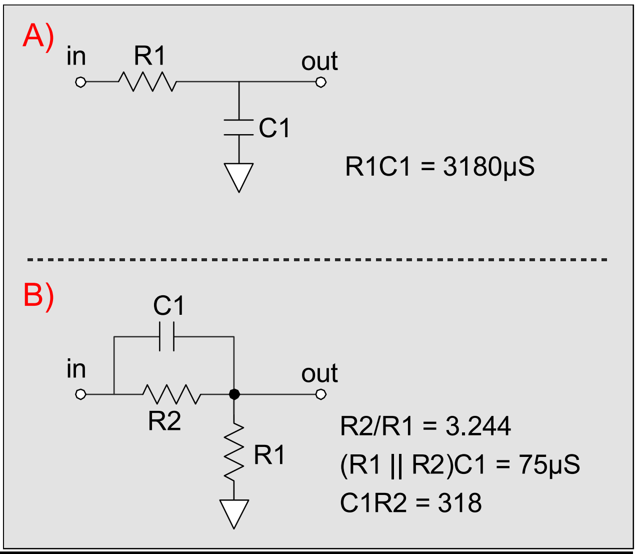
A Different Approach

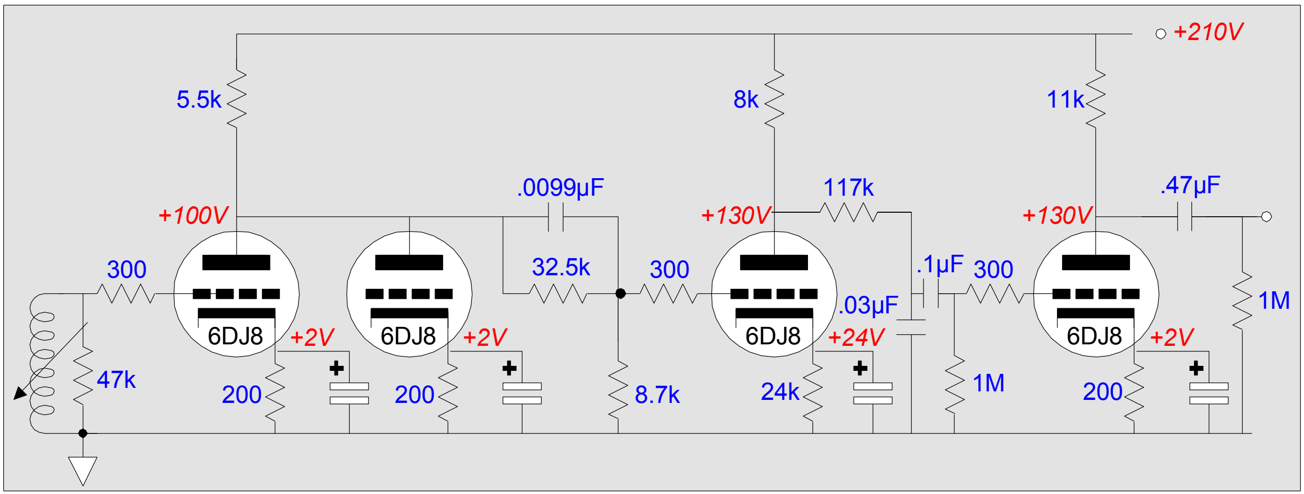
Notice how close the inverse RIAA equalization curve is to a 50 Hz low-pass filter, excepting the flattening at 1 KHz. (In fact, I believe that some cheap phono players back in the 60's used only a low-pass filter with a –3db point of 70 Hz or so.)

We can rearrange the sequence of the sub-networks so that the low-pass filter is tuned to 50 Hz and the shelving network applies to frequencies between 500 Hz and 2122 Hz, but this time the shelving boosts higher frequencies rather than attenuating them.

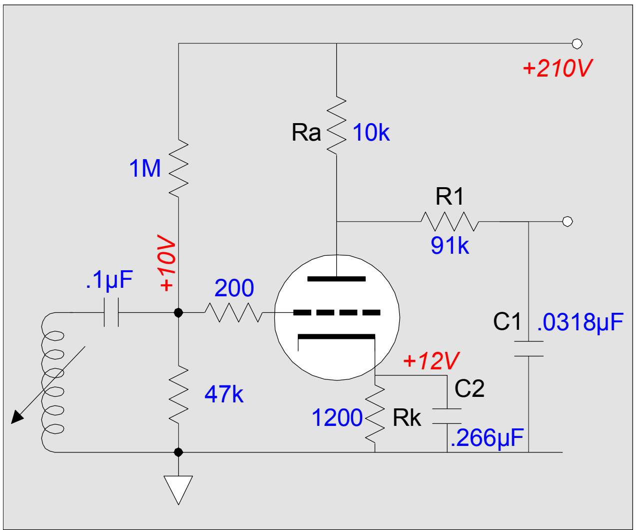


Below, circuit A defines the low-pass function, while circuit B defines the shelving function.





Cascading these two functions results in the same curve as the traditional two function combination creates. So, why bother with this alternate approach? Beyond the mental stretching, which is always for the good, this alternative approach engenders new phono preamp topologies, with some interesting benefits and one negative. The first benefit is that the 50Hz low-pass filter can filter more power supply noise away from the output signal than the 2122Hz can.



A single-triode phono preamp

Second, the 500Hz to 2122Hz shelving network can be implemented within one grounded–cathode amplifier, i.e. a single triode RIAA equalized preamp. Usually a cathode resistor is bypassed with a large valued capacitor, so as to ensure adequate low-frequency response. But if the bypass capacitor's value is reduced greatly, it introduces a shelving function, wherein the high-frequency gain is greater than the low-frequency gain, with the ratio being equal to the bypassed gain over the unbypassed gain or

$$\text{Ratio} = \frac{1}{1 + \dfrac{(mu + 1)R_k}{R_a + r_p}}$$

The transition frequencies are based on the capacitor's value and the time constants it forms with the triode's r_p and its plate and cathode resistor values:

$$R_kC_k = 75\mu S$$

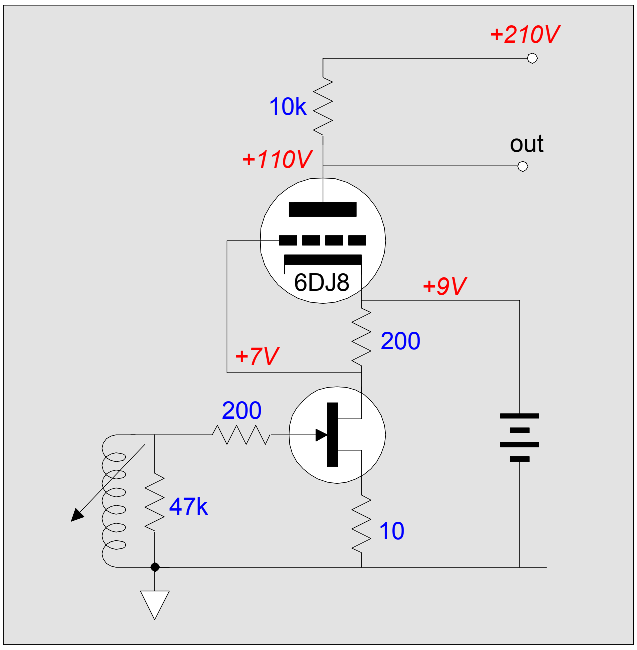
$$[(R_a + r_p)/(mu + 1) \,||\, R_k]C_k = 318\mu S$$

Of course, one triode is not going to provide enough gain in most cases, so additional gain stages will be needed.

The overarching liability of this different path to RIAA equalization is the –12dB insertion loss beyond the expected losses, which brings it 1kHz insertion loss down to –32dB. With this equalization network, the near DC and subsonic frequencies are reduced by –12dB, whereas the traditional path retained all of the gain at the bottom of range. Now, -12dB is just too much to pay in most two-gain-stage phono preamps, but it is almost nothing in a three-gain-stage preamp, where the problem is usually having too much gain. Still the advantage of using a portion of the equalization network in double duty either, as a pseudo coupling capacitor or a partial cathode-bypass capacitor, is tempting.

Hybrid Phono Circuits?

Hybrid circuits were mentioned in that distant first half of this article, but giving this topic a fair hearing would require more pages than I can write before we enter a new year. So what follows are a few schematics that offered as starting points for some new projects and articles.



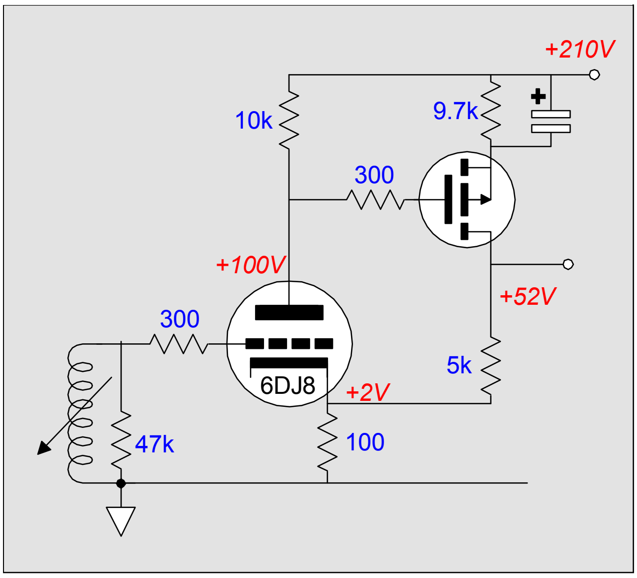
Hybrid Loftin-White first stage

FETs are marvelously quiet. The low noise from the best FETs make the quietest tube sound thunderous in comparison. I have always thought that the FET should first handle the delicate input signal from a phono cartridge and then give its amplified output to a tube, thus utilizing the best features of both technologies. But how to proceed? We can make a cascode with the FET receiving the input signal or we can cascade the FET into the tube in a Loftin-White like configuration, which may result in lower noise and a more tube-like sound.

Note the DC coupling between FET and triode and how the triode and bypass capacitor shield the FET from the power supply noise.

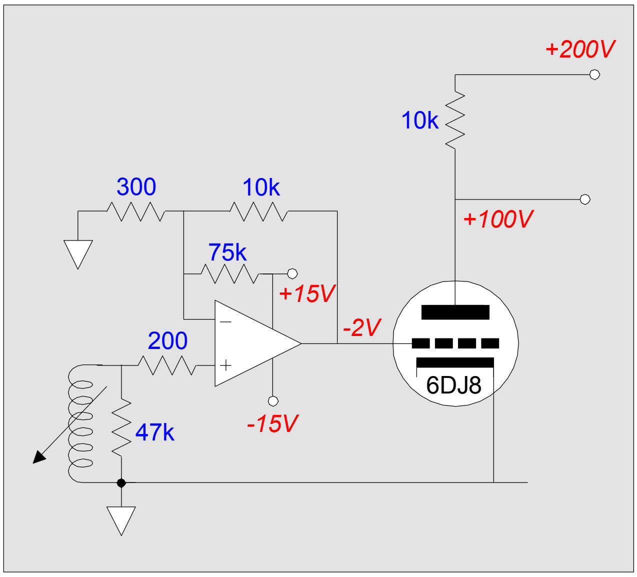
Another avenue I haven't had time to investigate is using a FET only in its triode region of operation, wherein it exhibits r_p!

MOSFETs can also be used, but not as the input to a hybrid circuit. A better place for the MOSFET might be as a grounded-source amplifier that an input triode could cascade into. If a P-channel MOSFET is used, the MOSFET can be DC coupled to the triode's plate resistor. The complete circuit will not invert the phase at the output. Thus, a feedback loop could be returned to the triode's cathode, which would give the triode control over the MOSFET's output.

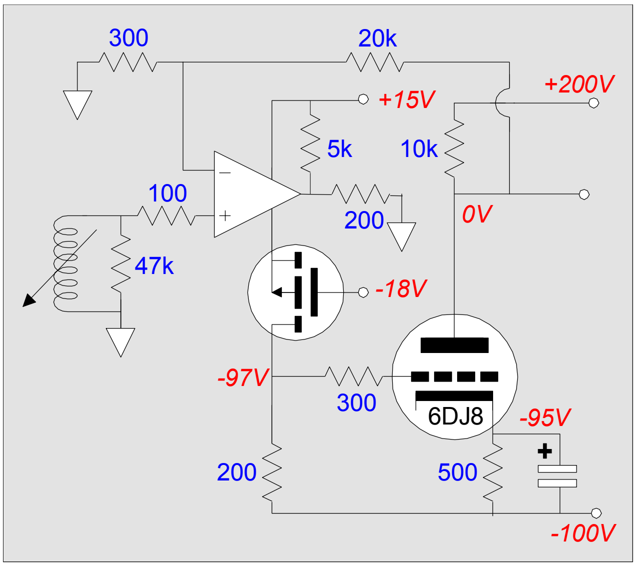


Hybrid triode-MOSFET first stage

Even the lowly IC Op-Amp could be used as the first stage of two-gain stage passive equalization preamp. The IC can be quiet and it allows DC coupling with the tube, if a small DC offset is put in place by using an additional resistor in the IC's feedback loop. This resistor applies a small amount of current from the IC's positive power supply rail, which will cause the Op-Amp's output to establish a negative DC offset at the output. Unfortunately, we cannot connect the resistor to the triode's plate, as this would create a positive feedback loop, not a negative feedback loop. (A second IC could be used to invert the DC signal from the plate, but this would complicate the circuit.) An AC feedback loop could wrap around the triode, but I would not want the Op-Amp's near infinite gain, and thus its near infinite potential feedback, to overwhelm the triode's output. The OP-37 and other Op-Amps are much quieter than the best triode... it's like receiving a large charitable contribution from a gangster: sure, you like the money, but at what hidden cost?



Well, why not carry the DC coupled theme a little further and run the Op-Amp in an inverted cascode circuit, shown below. As the Op-Amp delivers current into the 200–ohm resistor, the variation in current drawn through its negative power supply pin will be transmitted to the drain load resistor, which in turn will deliver the signal to the triode below.

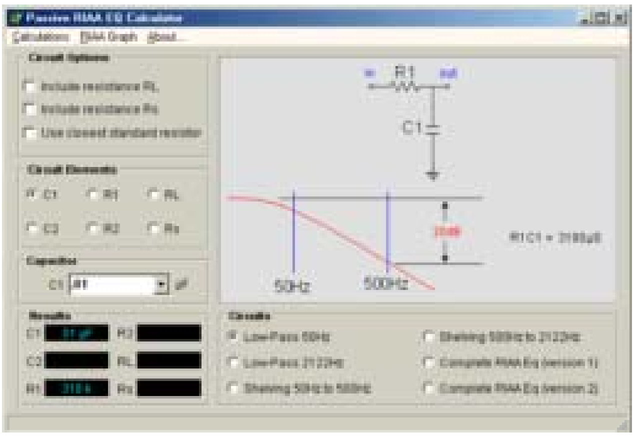


Hybrid inverted cascode amplifier

The triode then inverts the signal and a global feedback loop keeps the output's DC offset in line (no coupling capacitor!) and it offers all of the usual advantages to using feedback, lower distortion, wider bandwidth, and lower output impedance.

RIAA Program

If you have been wondering Where's the math? Here it is, in the form of a Windows program. *Passive RIAA EQ Calculator* quickly figures six basic RIAA equalization circuits.



This Windows program also displays the RIAA equalization curve and its inverse, while allowing specific frequency entry and mouse position readouts of amplitude and frequency. Added features include its ability to compensate for input impedance and load impedance in its calculations. The program is easy to use and if you have used any of the other GlassWare programs, you will have no difficulty getting results immediately from it.

How much does it cost? It's free, with one string attached: it's available at the Beige Bag Software website, www.beigebag.com where a short survey must be filled out first. (In order to make a better Spice program for the audio enthusiast, you, in other words, they need to know what you want, so it is really a win-win offer.)

//JRB

