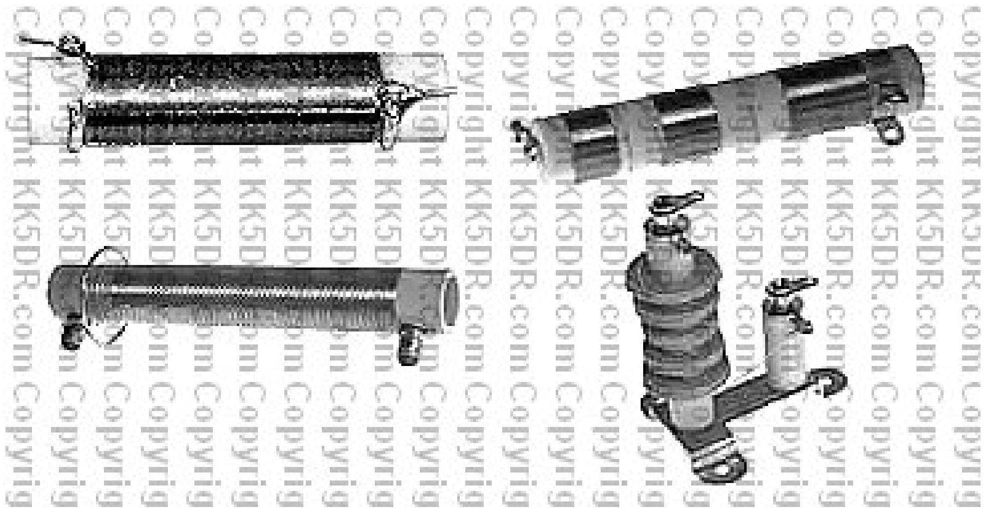
Plate choke design

By Matt Erickson, KK5DR. (Revised, 2012)



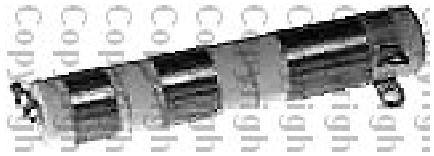
Traditional design:

The plate choke, as used in an HF tube type amplifier in this article. The plate choke is a device which serves the purpose of feeding the DC plate current back to the HV power supply, while blocking the passage of RF current. Since DC current only travels from negative to positive voltage potentials, the plate choke is in the return path for the current that has done the work of amplifying an RF signal inside the vacuum power tube. The choke must pass DC current, but block "ALL" RF currents. To do this, the choke has to have an inductance that is high enough to block "ALL" RF current on the lowest frequency the amplifier will be operated on. The high inductance presents a very high impedance to the RF signal. This all sounds straight forward, but it is more complex than it sounds. The choke has extreme levels of RF voltage forced against it. A small amount of RF current sometimes enters the choke, which can cause a problem if the frequency of the RF applied to the choke happens to be close to or on the series and or parallel resonant frequency of the choke.

The problem with traditional plate choke designs is that to get enough inductance to block ALL RF current on the lowest operating frequency, these chokes have a certain amount of distributed capacitance in the coil windings. Usually at some point the inductance and distributed capacitance act together to form an LC circuit, causing what is known as "series and or parallel resonance" in the choke. At a certain point in the choke windings the resonance will allow a large RF current and voltage to exist within the coils, many times, this will heat the wire to the point of melting, or arc to a near-by metal part. Either way, this is not a desirable condition, usually resulting in choke destruction.

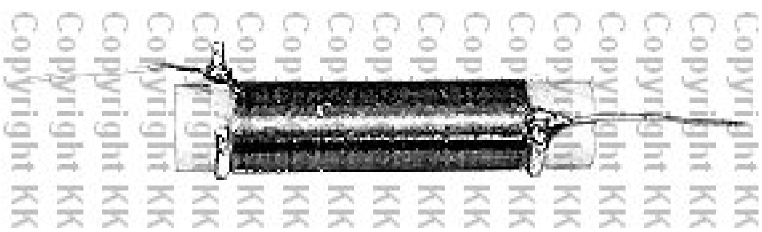
Most traditional plate chokes in amplifiers today have a range of frequencies that exhibit this series and or parallel resonance. The amplifier designer will often design a circuit that breaks up the distributed capacitance on the higher frequency bands where less inductance is needed, by switching in a capacitor to ground or jumping a section of the choke with a switch contact or relay.

Here are a few examples of chokes and the series resonate frequency;



This choke covers 1.5-30MHz (except 10.5-13MHz & 15-17MHz).

It will carry 1.5A of current.



This choke also covers 14-54MHz, but is resonate at about 96MHz.

This is a "Layer Pi" wound choke, but can't be used as a plate choke for high power amps.

All of these chokes are wound in what is known as a "solenoid" coil winding. The choke at the top is what is known as a "Pi" wound choke, with spaces between the windings. Pi-winding helps to breakup series resonance but does not always work at all HF frequencies applied to them.

The "layer Pi" choke is used in low power circuits or as a DC removing path in single-ended tank circuit. These typically have very high inductances, and also relatively high DC resistance. Layer winding type chokes are NOT suitable for high power plate choke applications, it is only shown here as an example of choke design.

All plate chokes have a certain value of DC resistance as well as inductance and distributed capacitance. The wire used in a plate choke must be able to carry continuously the full load DC plate current. Wire that is too small will heat up due to its higher resistance and likely ruin the choke. Wire that is too large will not have enough inductance to block ALL RF, at the lowest signal frequency. Typical wire sizes for traditional plate chokes are 20-28Ga. enameled/Formvar type wire.

To determine if and where a choke has resonance within the range of the amplifier, the choke can be tested with a grid-dip meter held near the choke while in the amplifier tank circuit, or out of the amplifier, shorted end-to-end or through a .001µF capacitor. Then the GDM is swept through the operating range of the amplifier. If the meter dips at any point in that range, it is highly likely that it is a series resonance. Hopefully, any dips found with this method are outside any amateur bands. If a dip is found on a band the amp should work on, do not operate the amp on that band until the choke it replaced with a choke that does not have any resonance points within or close to the bands it will operate on. This test can and should be performed on the choke when it is installed in the amp in it's final position. Special attention should be paid to dips on bands such as 12 and 10 meters. The amp should be set to the proper tune positions for the plate tune and load controls for each band, then a sweep made with the grid-dipper. If dips are found on or near the bands that the amp may be used on, it is a good idea to change out the choke to one that does not have such dips.

A NEW plate choke design:
I have developed a new type of plate choke. I can't say that this design is totally new, it did exist long ago, but was used only for very low power circuits.
I use common iron powder rods (such as Amidon R33-050-400) used for filament chokes about 0.5" outside and at least 4" long. I slip the rod into a hollow choke tube. Chokes that I have tested and used with this method go from about 90µH up to as much as 1200µH. But, the choke still has the distributed capacitance of the original lower inductance choke. Using a grid-dipper, I found that the choke now has a resonance that has dropped down to about 500kHz, due to the high inductance provided by the iron powder rod, and the low distributed capacitance which causes the resonance to be very low in frequency. This creates a very low Q resonate circuit, very little RF energy would ever be present in this circuit. The grid-dipper showed no dips anywhere in in the MF, HF range. I have used several of these in various amplifiers, and using various wire sizes and inductance levels, none of the chokes have ever had a series resonance problem. I don't wish to make it seem that very high inductance levels are the primary design goal. Levels of choke inductance above 200µH are completely unnecessary. The target inductance should be in the range of 100 to 200µH. This range will cover an amplifier range of 1.8-30MHz. Inductance levels that are far above this prescribed range can cause a problem, as resonance repeats on the harmonics of the fundamental resonance point. So, a loaded choke with a resonance point of 500KHz, would have another at 1MHz, then 2, and 4, and 8, etc. The one good thing about these harmonic points is that each has progressively less energy available to "kick" the resonance to a destructive level.

The iron powder rod MUST be insulated from the HV and RF, at least .062" of insulating material like the ceramic tube, fiberglass, Delrin, Teflon or other good tubular insulating material will do the job. The rod must also be secured inside the choke coils, if it moves, even a little, the inductance will change radically.

Ferrite materials are highly temperature sensitive, that is why I selected filament choke material iron powder rod like the Amidon R33-050-400, it being iron powder, it is less temperature sensitive. Filament chokes routinely run very warm, the iron powder rods are more tolerant of such heat than ferrite. If you use ferrite and it reaches a few hundred degrees F, the inductance may suddenly drop completely away, which can lead to RF entering the coils and causing even greater heating of the coils, and or arcing, and choke destruction. For ferrite materials, this temperature point is very critical, and varies from one mix type to another.
If the loaded choke has enough inductance to keep any RF current from entering the coils, the only source of heat should be the wire used. The use of iron powder rod will allow the builder to use much larger wire gauge, which will lower the resistance, and eliminate it as a significant heat source. Be careful when using ferrite. Use iron powder rods.

One might ask, " does the iron powder rod heat up?" Well, no, because there is no RF current flowing in the coils of the choke, nor is there and RF flux within the core of the rod, because RF current isn't entering the coils.
I have found that even at 1500 watts output, the choke simply does not heat up at all. This was proof to me that there is NO RF current in the choke, this is key to preventing series resonance, prevent RF from ever getting to start with. The high level of inductance effectively blocks ANY RF current from entering the choke.
One of my recent choke construction units was a 1" O.D. x 6" electrical-grade Delrin® rod (available from McMaster-Carr). I bored the rod out to a depth of 5" with an I.D. of 0.510", just over 0.500", this would hold a 4" long iron powder rod nicely with room to seal the open end with silicone rubber caulk. I wound it with 22Ga. Teflon® wire (don't ask me how many turns, I use the number required to hit my target inductance of 100-200). The wire is silver plated and stranded for good flexibility on the free ends.
Another question I have been asked; "How do you fix the ends of the windings?" Here is what I do; Just beyond the ends of the windings I use my dremal tool to cut a small notch into the the Delrin deep enough to allow me to cross drill a small hole in a tangent angle parallel to the center of the rod, in the direction of the coil windings at each end of the coils. The drilled hole is just big enough to slip the wire through it and secure it with a drop of Super glue.
The choke I made using this method is good for 1 amp of continuous plate current, with no heating noted. It covers 1.8-30MHz with no resonances within that range.
For plate current requirements above 1 amp, heavier wire gauges should be used, 18-16ga. should work fine.

How to build your own:

Use one of the following forms; A hollow ceramic tube at least 6" long with an ID of at least .5". An O.D. of 1" or more. The wall thickness should be not less than .062", more is better, but not thicker than .375". The same parameters apply to materials like electrical grade fiberglass, Delrin®, & Teflon®. The form used will have to handle some heat generated by the DC current flow in the wire used. Remember, the full input power of the amplifier will be flowing through this small wire. The use of the iron powder rod will allow the builder to increase the size of the wire, which will lower the resistance, which in-turn will reduce the heat generated. However, this will also lower the total inductance of the choke. Remember, the target inductance is 100-200µH. Use only the number of turns required to hit this target, regardless of wire size used.

Secure the rod inside the form with some hot glue, or silicone caulking rubber. The wire will need to be secured to the outside of the form as well. Use the cross-drilling on a tangent method mentioned in the above paragraph, or cut a notch into the coil form for the wire to lay in, and be secured with a drop or two of super glue.
Do NOT use heat-shrink tubing to cover the coils, as this will hold in any heat. Do NOT use varnish, shellac, or other doping agents to coat the coils.

The method of securing the choke in the amplifier near the tube and tank circuit is up to the builder. I prefer drilling and taping a hole in the bottom end of the form, which will allow it to be bolted to the chassis, standing up vertically or horizontally. I take care not to allow the mounting screw to touch the iron powder rod, this may provide a path to ground for an HV arc to follow. Should HV ever find its way to the iron powder rod (which is electrically conductive), it is less likely to happen if the path is of a very high resistance, on the order of several hundred Meg-Ohms or more. We are looking at very high voltages on the plate choke, so think insulate, isolate, and spacing. As a basic rule in high voltage circuits, I use a minimum of 1" spacing for voltages up to 5Kv, more spacing for higher voltages.

The wire size used will be determined by the DC current level it will need to handle. I have found that 22-24Ga, will work fine for up to 1A. Use larger wire for higher current levels. The wire must at least be insulated with enamel, but can be Teflon® insulated, but this will cause less turns to be used per inch. Used wire that will not overheat with sustained full current levels. You can test it with a variable DC power supply to send about 1A through it for 1 hour, then check how warm it has gotten with a thermometer. If it is under 100F, it should be OK for that current level, if it is warmer, step up a wire gauge size. Set the DC power supply for the current level your choke will have to handle.

The level of inductance you are aiming for is; 100-200µH. I have found that 30-100 turns on a 1" O.D. form will get you in the range needed. That many turns usually covers about 3-5" of the form. The goal is to get within this desired region with the least number of turns required to get there. Your results can vary widely, some experimentation may be required.
Use ferrite core material at your own risk. I have found it to be unreliable for this application. Use only iron powder, such as the type mentioned in the above paragraphs.

To make the job easier, you would need a grid-dip meter, and an LCR meter. These meters are highly valuable for amp building work, making the job much easier than without them. I purchased them years ago since I do so much of this type work.
Older grid-drip meters are abit difficult to find now-days, so an MFJ-259B with a grid-drip coil set will be an easier unit to find.

Good luck.

73 de Matt KK5DR