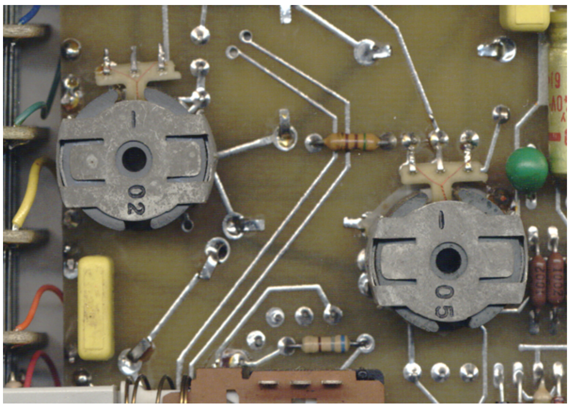
Why Toroids are Better Than Pot Core Inductors for Audio

One of the more common questions I'm asked is "why should I spend more on a toroid inductor when a pot core inductor will do the job?" To be fair it is true that both types will perform the same duty when properly used in a resonant filter circuit so there should be no reason to favor one over the other in that regard. The actual perceived sound of the inductor is not only subjective, it is also dependent on countless other factors imposed on it by the circuit the inductor is used in. In other words it's an apples to oranges comparison to compare the sound of a Pultec to the sound of a Sphere. The Pultec's use an MPP Toroid (mostly) and the Sphere's use pot cores for the inductors, however it is the rest of the circuit of each type of EQ that imposes most of the vintage "color" to the sound. By design the LCR resonant filter circuit is low distortion/minimal phase (read low color). That is it's greatest advantage over using a much cheaper IC based equalizer and why you still see inductors used in many if not most of the high end studio equalizers. For those reasons I'm leaving the "perceived sound" differences of the two inductor types out of this discussion.

With the above in mind you might be wondering if it's not sound what could be so important that corporate bean counters would allow the inductor cost differential to take a price point back seat? In my world it comes down to two things: accuracy, and, perhaps more importantly, stability. It is in these two areas that a toroid is in a different league from a lowly pot core. It is an important distinction to note that toroids are commonly available in both MPP and ferrite materials of varying permeabilities while pot cores are almost all ferrites.



Pot core inductors? They're cheap, efficient, easy to wind, they take up little pcb space. What's not to like? Accuracy for one! Pot core inductors were/are used in countless commercial LCR based EQ's and when I get an old Quad Eight or Sphere EQ on the bench I'm stunned over how much the inductor values have drifted. It is not uncommon for units to be 20 – 30% out of spec. Does this happen with toroids over time? No. Why does it happen with pot cores? Good question, I'm glad I asked it…. Pot core inductors are not wound around a core. The wire is wound on a circular bobbin and the bobbin is then placed between two ferrite cups (pots). In this arrangement the split between the two core halves acts as an air gap. What this means is that the final inductance value of the inductor is subject to the amount of pressure that is asserted on the two core halves, squeezing the air gap. There are several ways the core halves are closed during manufacture and they all affect the long term stability of the final inductor. The most reliable way to keep a pot core stable over time is to close the air gap with a non magnetic metal fastener like brass. Some manufacturers use nylon screws and nuts which is what I used for some time. Unfortunately nylon stretches, especially when it's warmed up so over time so the inductance values will drift. The most common way for a pot core inductor to be closed is when they are placed on the pcb. The standard method is to use non magnetic metal clamps for this purpose and this method is a tragedy for long term accuracy (short term for that matter). The pcb clamps are the reason Quad EQ's drift so horribly. Today some manufacturers are getting wise and finally potting the pot core inductors in epoxy. Potting does tend to change the values from what they were when originally wound and adjusted, however, a winding protocol can be initiated to accommodate the potting difference. Problem solved right? Not exactly. Ferrites are much more susceptible to changes in temperature than MPP cores. When assembling pot cores you can't handle them too much because even warming the cores up to hand temperature from room temperature will effect the values. I recall an episode of pulling what little hair I had have left out of my head trying to wind a ferrite toroid by hand years ago. I would wind to a specific value but when I would measure at a later time I would get a completely different value. I noticed it didn't happen when I wound on a machine. The answer was simple. When I wound by hand the core warmed up from my body heat. It was clear that even a 10 – 15 degree change in the core temperature had a sizeable affect on the inductance value. This temperature instability gets worse as the permeability of the core goes up. High permeability cores are needed for high inductances in order to keep the internal dc resistances low. In an LCR circuit the R affects the bandwidth. The lower the resistance the steeper the slope of the curve (narrow bell curve). This means you don't want to wind a ton of small diameter wire using a low perm. core to get a high inductance. The resulting bandwidth of the resonant curve would be too wide. Using a high perm core and less, larger diameter results in a much more manageable, tighter bandwidth. So in this scenario for high value inductances, say 1H or greater, the need for a high perm core means that the final values will drift even more with changes in temp. The permeability/temperature stability issue also affects MPP cores but not nearly as much as pot cores. So let's talk about MPP and toroids.

MPP Molypermalloy powder inductor cores were developed by Western Electric in the 1940's. MPP is a combination of Nickel (79%), Iron (17%) and Molybdenum (4%). It was developed specifically for use in resonant circuits. Resonant circuits can be used in a very broad range of applications but audio for communications was a priority and the MPP cores delivered exactly what they were engineered to do.

During the early to mid 20th century Western Electric supplied the entire world with communication equipment of all kinds. From radio to theater sound to television broadcasting WE had a piece of it all everywhere around the globe. When they installed a piece of equipment it could be at the North Pole or at the bottom of an ocean operating in the worst possible environment. It had to work and it had to be reliable. They used MPP core inductors and MICA caps when things absolutely, positively had to perform and maintain stability through high temperature and humidity swings.

There are several downsides to toroids. One big downsize is cost. MPP cores are expensive and if you need inductances over say 250 mH you need to start climbing up the MPP permeability cost ladder. The steps on that ladder get spaced farther apart as the ladder ascends. The cost of MPP cores gets exponentially more expensive as the permeability goes up. An Au125 core that costs $10.00 will cost $30.00 if you up the Au to 300 and much more for a Au 500 or 600 core. There are winding protocols that allow winding more wire on a low perm core which require time and skill to execute so for higher inductance values toroid ferrites are basically the only commercially viable option.

Another downside to toroids is that not only do they require different machines to wind them than standard lathe wound coils, they also require a different set of winding skills, especially when they are tapped. Then there are things like reverse winding and double reverse winding. Those are techniques to limit capacitive losses. Downside number three is the fact that the values tend to change a bit when the coils are vacuum potted. Those differences have to be compensated for during the winding process and that comes from experience. The upside, and this is a big one, is that once the values are established and finalized they will not change until the coating on the magnet wire inside deteriorates in perhaps 50 years or so. Even modern wire coatings will eventually flake off the wire and cause leakage or failure, potted or not. I'm currently seeing more and more transformers from the 50's and 60's come in for rewind that failed because the enamel has simply fallen off the magnet wire from age and temperature swings. Unfortunately that is a fact of life for any wire wound component.

By the nature of their physics toroids tend to concentrate and contain their magnetic field while at the same time fending off foreign signals which makes them quiet in an audio circuit. They maintain their intended values and are only affected by temperature. MPP cores are affected by temperature to a lesser degree than ferrite cores. Stability alone makes the toroid core the only choice for high end audio and they are an absolute must for solid stereo matching in my humble opinion. Seriously, until I obtained a schematic for a Sphere 900 pot core equalizer I couldn't tell what the inductor values were designed to be without doing the math. Every inductance value I measured channel to channel, frequency to frequency was so different I couldn't even get a consensus of what they were technically supposed to be. You don't have that with an inductor based Neve. When it comes to inductors you truly get what you pay for. CP