VINYL VS. CD – A RUNNING COMMENTARY – PARTS 1 – 5

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Vinyl is not on its way back. It has arrived and is thriving!!

Part 1: Introduction

When attending CES and Rocky Mountain Audio Fest over the past couple of years, I noticed that turntables are starting to be the majority of sources for exhibit rooms. We all have heard about the vinyl renaissance, but I just did not realize how strong it is. I mean, LPs are being played *everywhere* at hi-fi shows.

The feeling is that LPs still sound better than CDs, even SACDs, so I decided to run some experiments comparing the sound of LPs that were sourced from analog recordings, and CDs/SACDs also made from those analog tapes.

It is taking me more time than I realized it would, with some issues along the way that need to be solved, so rather than wait until it was all done, I thought I would share with you the results as I gather them, in a running commentary. This will also allow our readers to ask questions along the way, even suggest some tests that you might want me to run while I have all the test equipment connected.

Click HERE to go to Parts 6-9 (Part 6: In the Groove, Part 7: THD+N Test Results, Part 8: Phono Preamplifiers, and Part 9: A Few Bits About DACs).

The Participants

I contacted two companies (to begin with) that I greatly respect: McIntosh and Bryston. I asked McIntosh if they would be willing to send me their new MT10 turntable, and Bryston if they would send me another BP-26 preamplifier that I reviewed in the Fall of 2007. Both agreed with enthusiasm, knowing that I would be doing some in depth testing with my Audio Precision that probably has not been done before. Since the BP-26 could have either a DAC or phono stage (phono preamplifier)

installed, but not both, we decided to have the separate BP-1.5 phono stage to accompany the BP-26. That way, I could decode a CD bitstream in the BP-26, but then have the BP-1.5 handle the RIAA equalization from the phono cartridge, and all preamplification circuits would still be Bryston. A second reason I asked Bryston to participate, was the fact that my tests of the BP-26 revealed it to have astonishingly low distortion, and I obviously wanted the Audio Precision to be measuring distortion coming from the analog recording vs. the digital recording, rather than from the preamplifier.

Both the BP-26 and BP-1.5 are powered by the same power supply, which eliminates one more variable. Here is a photo of the trio installed on a shelf in the lab. As always, just click on the photos to see larger versions. The power supply is on the bottom, the preamp controller is in the middle, and the phono stage is on top.

The McIntosh MT10 is a new product from the big MC. They don't seem to have bothered trying to promote it much, because McIntosh fans have been snapping them up like crazy anyway. Below is shown a photo of the MT10 installed on a shelf in the lab.

The MT10 comes with the tonearm and a cartridge already installed. I needed only to add the counterbalance weight and the anti-skating weight (to be described below), plop (gently) the turntable on the spindle, and it was time to boogie.

Part 2: The Technology

The MT10 comes with what's called an MC cartridge. This means "Moving Coil", and that brings us to the stage of defining the terms (and there are lots of them to plow through).

Phono cartridges (the thumb-sized thing with the needle on it) come in basically two flavors. One is the Moving Magnet (MM) and the other is the Moving Coil (MC). Both work principally in the same way. The tip of the needle has a small diamond, called the "Stylus", that is shaped like the groove of the LP. It is attached to the cantilever which is a long thin – and very light – rod. It is really not much wider than the diamond stylus. It is attached at the rear of the cartridge, and it goes up and down in the LP groove as the LP is spinning.

When the stylus is moving, the interaction between a magnet and nearby coils of wire creates a very small signal (millivolts) in the coil, and that is sent to the phono stage.

So, here is the difference. With a moving magnet cartridge, a magnet is attached to the cantilever, while the nearby coils are stationary. With the moving coil cartridge, coils of wire are attached to the cantilever, and a magnet nearby is stationary. There are advantages and disadvantages to both types, and that is why they both still exist. For MM, the cantilever with its magnet has more mass, and thus, is a bit more sluggish to respond in the groove. Therefore, it tends to have slightly less detail in the sound. However, because the coils can be large, the resulting voltage is high, e.g., 4 millivolts (mV). This is important, because the lower the output voltage, the more likely the signal is to be swamped by electrical noise and hum. Remember, the output of a CD player's analog jacks is on the order of 2 volts. That is 500 times higher than the output of even the MM cartridge.

The MC cartridge has tiny coils of wire attached to the cantilever, often just a few turns of very fine wire. The magnets are stationary, nearby. Because the cantilever has a very low mass, it responds to even the smallest detail in the LP groove. The result: better fine detail in the music. However, its output is usually less than 1 millivolt (mV). The MT10 cartridge, for example, made by Clearaudio for McIntosh, outputs only 0.75 mV. Talk about having to be very careful about where you put the interconnects – Wow!

MM cartridges have high voltage, low current output, while MC cartridges have low voltage, high current output.

Phono preamplifiers need to have an extra gain stage for use with MC cartridges, and for example, the BP-1.5 uses a transformer to boost the voltage from an MC cartridge to the same level of an MM cartridge output, and then it is fed to the same gain stage circuits for both types of cartridges.
One rare variation is the Moving Iron cartridge, where the cantilever has a small piece of non-magnetized steel on it, and when it moves, this disturbs the magnetic field set up between stationary magnets and coils, generating the signal voltage. This type is generally not available now.

Lastly, there are ceramic cartridges that were used in children's record players, and are still available as replacement parts. They can put out several volts, so a preamplifier is not really even needed. Unlike CDs where you just pop the disc in the player and press the Play button, there are a bunch of other things you have to be concerned about with a modern turntable, and the LP itself, in order to get the best out of it (them).

One of these is that once you have decided on using either an MM or MC cartridge, you can't just use any old tonearm on the turntable. It has to balance what is called the "Compliance" of the cartridge. Ready for another definition? Here we go.

Think of the stylus dragging the cantilever as it wiggles through all the grooves on the LP. And, think of the cantilever dragging the cartridge. OK, now imagine you are holding the end of a 10 foot rope that is attached at the other end to a wall about waist height. You begin moving your end up and down, faster and faster. At some frequency, the up and down force you are applying to your end of the rope will match the mass of the rope, and it will move in a wavelike form, with a peak in the exact middle of the rope. This is the resonant frequency of the rope and the force you are applying. It's the same with the stylus, cantilever, and cartridge. At some frequency – the resonant frequency – the force of the stylus to cantilever to cartridge will be "just right" so that the entire mechanism is swinging back and forth with the movement of the stylus in the groove. That resonant frequency depends on the "compliance" value of the cartridge and is specified in centimeters per dyne, which refers to how far it will move with a specific value of force applied.

The range of compliance values is from about 5×10^{-6} cm/dyne up to 25×10^{-6} cm/dyne. If the value is less than 12, it is considered a low-compliance cartridge, 13-18 is mid-level, and above 18 is high compliance.

Now, the reason this is worth paying attention to, is that when selecting a cartridge, you want to know the "mass" of the tonearm – in grams – to which it will be attached. And, the idea is that you match a low compliance cartridge to a mid or high mass tonearm, and a high compliance cartridge to a mid or low mass tonearm. A mass value of 10 grams or less for the tonearm is considered low, 11-15 grams mid, and above 15 grams, a high mass. These numbers and categories are not engraved in stone, but just a general guide.

The combination of cartridge compliance and tonearm mass will result in a system resonant frequency, and you want that frequency to be between 10 Hz and about 18 Hz. If it is above 20 Hz, you will get too much audible deep bass. If it is lower than 10 Hz, this will make the rumble (the motor and platter make very low frequency noises of their own) audible.

Part 3: Turntables, Tonearms, and Cartridges

When CDs supplanted LPs about 20 years ago, there was less and less availability of "record players". However, there were still plenty of aficionados out there who wanted to maintain and expand

their LP library, and some of them were clever engineers who simply decided to build their own turntables. And, the ones they built were a far cry from the $100 jobs that we used to buy at Radio Shack. Along the way, they said, “You know, I could probably sell these things and make back my investment.” Thus was born the high-end turntable market.

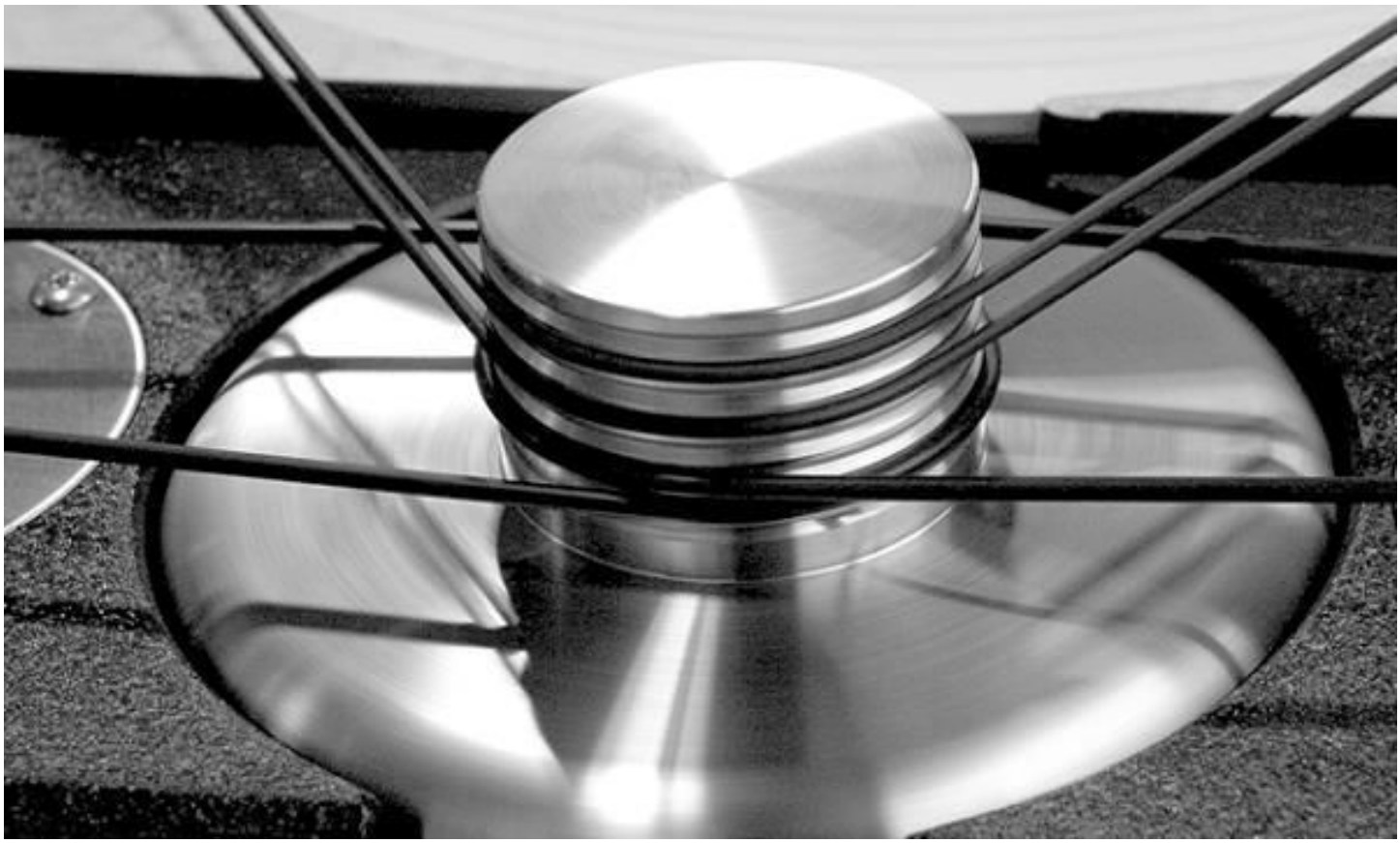
Of course, high-end tonearms had to be designed too, and the cartridges.

These days, you can spend $100,000 on a turntable, $15,000 on a tonearm, and $10,000 on a cartridge. That’s a lot of trips to Starbucks.

Besides being built in extremely limited quantities, they are all hand made products. No mass production on an assembly line for these things.

Here is one example, the VPI HR-X turntable and JMW-12.7 tonearm. The current price (2013) is $13,000. Notice that the platter is driven by a belt that is attached to a flywheel on the left, and that flywheel is driven by two motors using another belt. This totally decouples the platter from the motor and eliminates rumble that would otherwise be transmitted to the platter from the motor. This particular tonearm is described as low mass, although a specific number is not given. If you are anal, as just about any hard core audiophile probably is, you will ferret out the info about tonearm mass before you purchase one.

Here is a close-up of the flywheel and attached belts.



(Turntable photos copyright VPI)
Of course, you don't have to spend $12,000 on a turntable and tonearm. There are plenty of nice products out there in the less than $1,000 range.

So, you have a turntable, and now you pick the cartridge.

Depending on how careful you think you can be setting it all up, you need to choose MM or MC. The Moving Coil (MC) will give the best detail, but will be the most vulnerable to noise because the output is very low. The more expensive they are, the more they seem to have lower and lower output, probably because just a few hand wound turns of wire are on the cantilever.

Here is the Koetsu Onyx Platinum MC cartridge. It is priced at $8,000. The output is only 0.2 mV. Keep in mind that is 2/10 of one thousandth of one volt. So, the interconnects from the turntable will be carrying less than a thousandth of a volt, and the interconnects from your CD player will be carrying about 1.5 volts. That is a factor difference of 7,500 to 1. Remember how careful I said you would need to be in connecting the turntable to your preamplifier? Very careful. A flatulent mouse standing two inches from the interconnects would probably cause some audible noise in the cables. Get the picture?

(Photo copyright Koetsu)

The one cartridge that does not fit the usual mold is the Sumiko Blackbird, which is an MC product, outputs 2.5 mV, and has a compliance of 12 x 10^{-6} cm/dyne. It's priced at $1,249, and we will talk about this cartridge a bit later.

(Photo copyright Sumiko)

Part 4: The RIAA Curve

When commercial phonograph recordings were being produced in the early twentieth century – on wax cylinders at that time – they realized that the grooves for low frequencies were so wide, they took up a lot of space and reduced the recording time. And, as the frequency response technology improved, they started worrying about the hum and hiss from the electronics, as well as surface noise from initial plastics (which were not very good).

Then they got a bright idea. They realized that all of these problems could be addressed by using "Pre-emphasis" in the recording, which means altering the recording level of different regions of the audible frequency band, i.e., EQ.

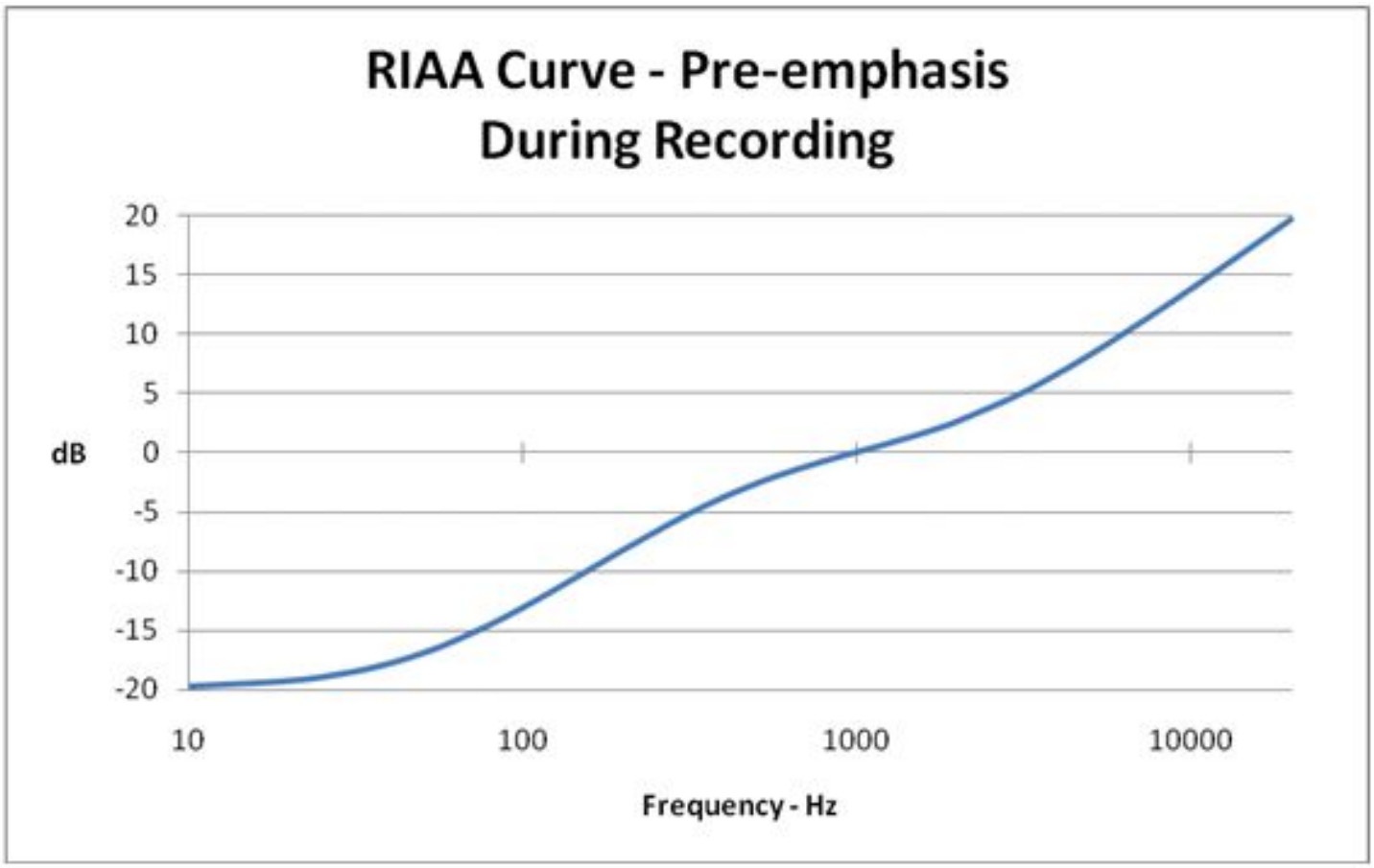
However, no standards for doing this had been set up, so various recording companies added the EQ in whatever way they felt was best for them. Of course, this meant that playing back a recording could

produce all kinds of tonalities, because the playback mechanism had its own tonality, engraved in stone.

Amazingly, it was not until 1954 that such a standard was realized, called the RIAA curve (Recording Industry Association of America). It took into account the need for increasing the recording time by reducing the recorded level of deep frequencies, and reducing surface noise and hiss by emphasizing the recording level of high frequencies, and then applying the inverse RIAA curve during playback. They also decided to manipulate the region between 1 kHz and 10 kHz to bring forward the sibilance of the music and voices.

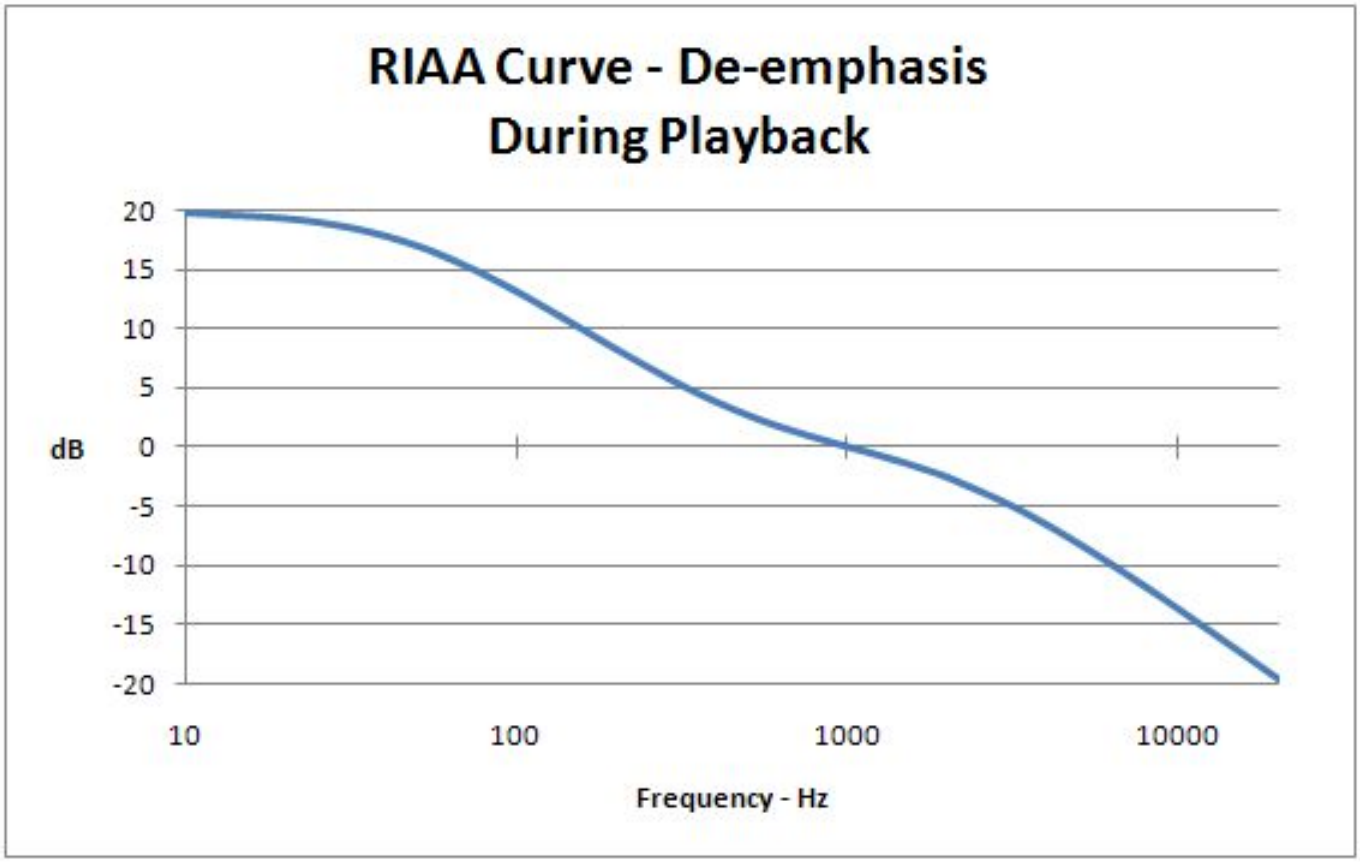
So, there was an RIAA pre-emphasic curve and an RIAA de-emphasis curve.

Here is the pre-emphasis curve which is applied in the electronics during the process of cutting the master disc. Setting 1 kHz to 0 dB, you can see that at 10 Hz, the pre-emphasis is basically a 20 dB attenuation, and at 20 kHz, there is a 20 dB boost. Bottom line: 40 dB variance between the EQ for low frequencies vs. high frequencies.



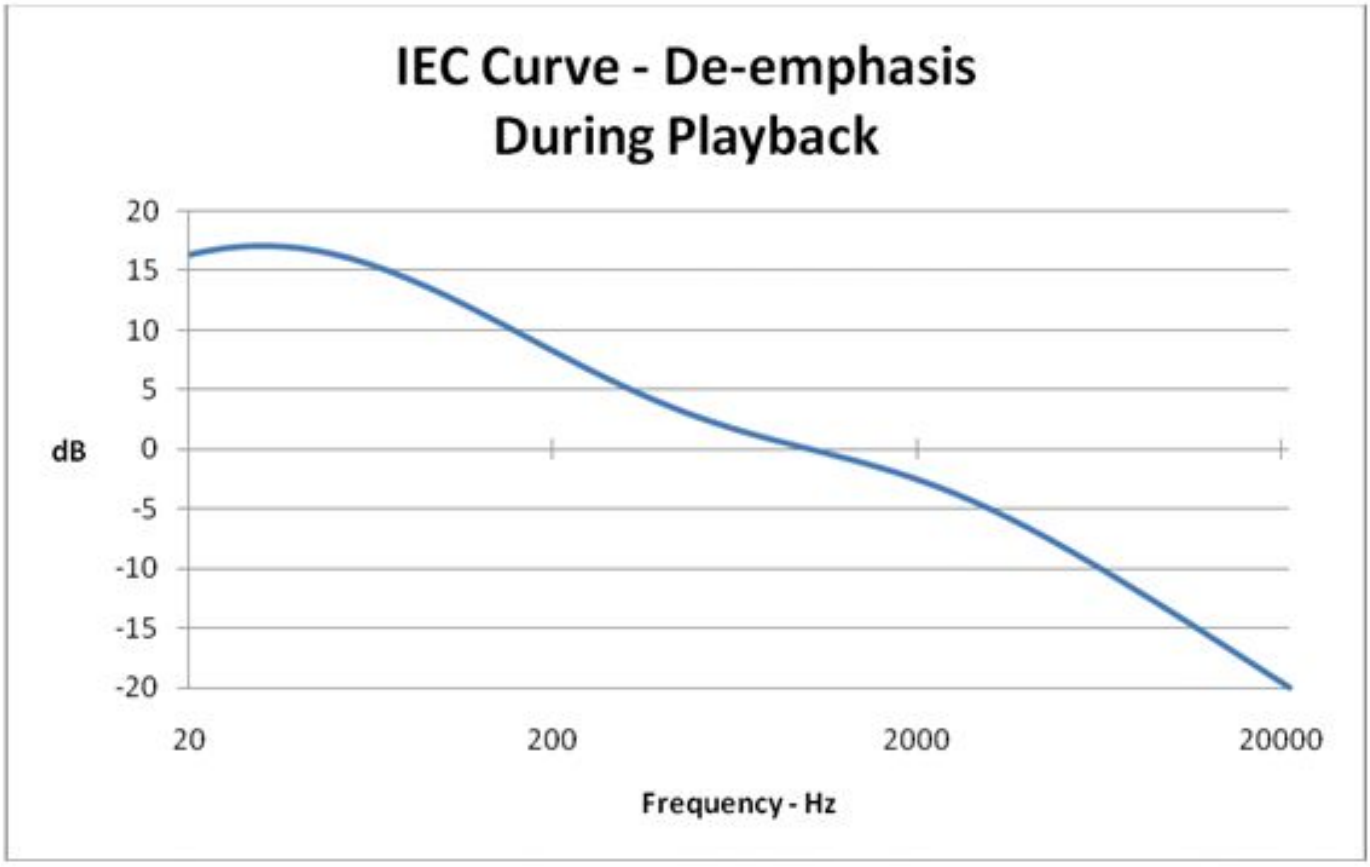
You can see that it is obviously not a straight line. It took into account everyone's wishes to reduce this or emphasize that. The curve actually goes out to 50 kHz, which says something about the wide bandwidth that LPs have in comparison to CDs.

So, when you play the LP at home, the de-emphasis curve is built into the phono stage in your preamplifier or receiver. Here is what it looks like:



It is the opposite of the pre-emphasis curve, and the idea is to make the final frequency response flat, but get rid of hum, hiss, surface noise, and extend the recording time that will fit on the LP disc.

It works well, but like all “standards” engineers were always thinking of ways to improve it. Something called the IEC curve arose in the 1970’s, and the de-emphasis curve is shown below.



The biggest difference seems to be in the 50 Hz region.

The IEC curve did not take off, and maybe that is fortunate, because then what would we do with all the other recordings we had that were EQ'd with the RIAA curve?

Application of RIAA to the Phono Stage

Applying the RIAA curve in a phono stage is not as easy as you might imagine (on the other hand, maybe you imagine it is hard). It's not just a crossover point. It is a continued scale of EQ all the way through the audible band.

There are basically two ways to do this. One is the passive method, using a variety of filters. The other way is the active method, which uses op amps and feedback in different amounts throughout the audible band.

The purists will say that the active method is not good, because it uses all those op amps that have voltage limitations and negative feedback which causes lots of distortion.

But, with either method, there is one big issue, namely, phase shift. Remember the discussion of phase shift problems that you have at the crossover point in speaker crossover networks. Well, since the response in the RIAA curve is basically one big alteration throughout, you have phase shift all over the place. It is defined by a complex set of mathematical equations.

Now, when the RIAA pre-emphasis curve is applied at recording, and then the de-emphasis curve is applied at playback, the phase shift should cancel out and you end up with a proper phase relationship throughout the audible spectrum. Right? Well, that would be fine if all the recording systems applied the RIAA pre-emphasis curve perfectly, and all our phono stages applied the RIAA de-emphasis curve perfectly.

Guess what? Nothing is perfect out there.

So, we end up with LPs and phono stages that deliver a sound with varying amounts of phase shift in all areas of the audible spectrum, and I feel that this is one of the defining characteristics of the analog LP sound. It delivers a soundstage that is *much* different than what you would hear from a CD where such EQ curves are not applied.

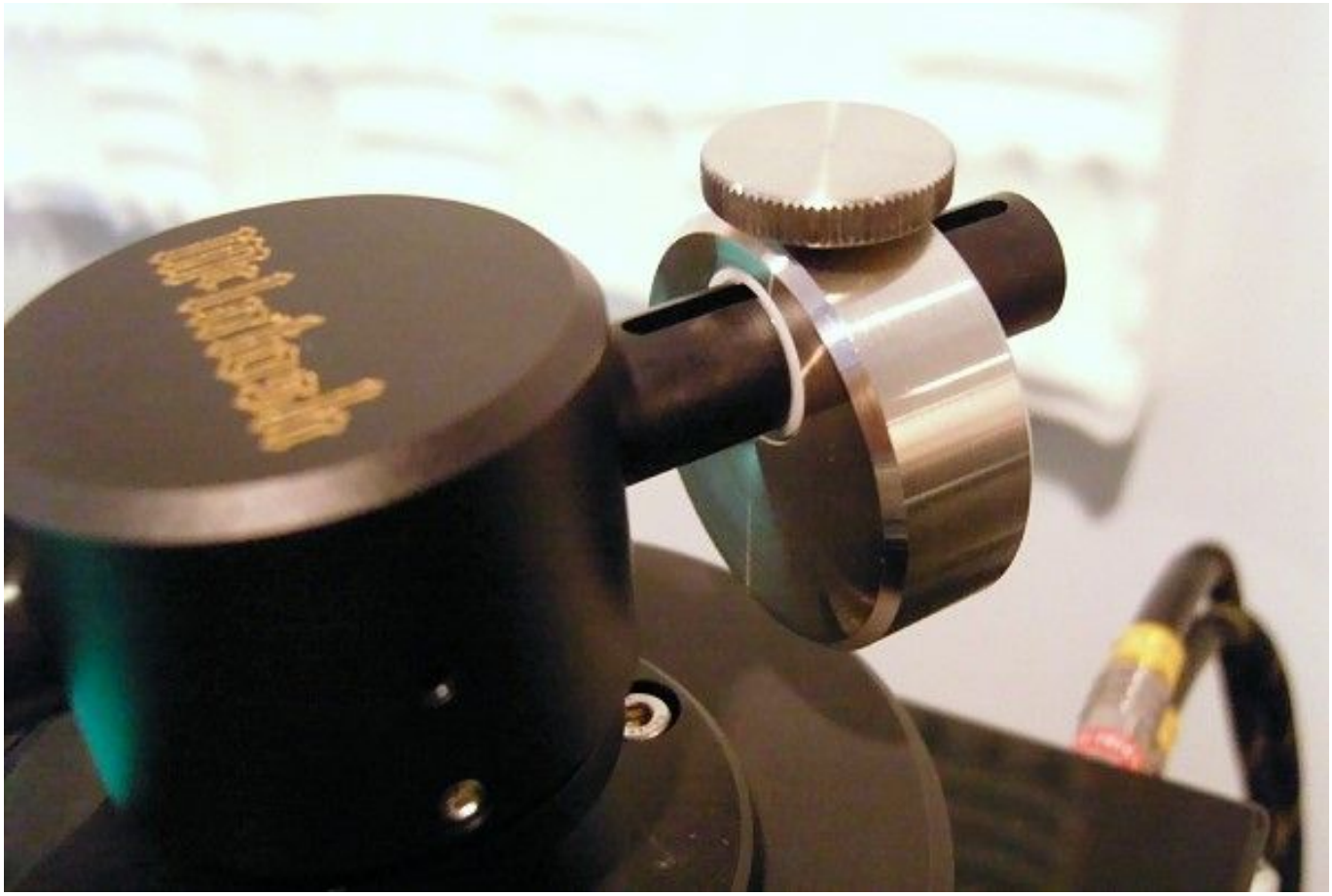
And, it's *very* appealing.

Part 5: Setting Up the Turntable

I have seen a couple of turntables out there that come with the table, the tonearm, the cartridge, and a USB connection for your computer that will let you turn your LPs into MP3s. The cost of the entire package is $149. Those things may not need to be "set up", but if you have a good turntable and an LP collection, and you want everything to last, it is important that the turntable be properly dealt with before you plop the discs on the platter.

There are several things to do in setting up the turntable: (1) Tracking Force (TF); (2) Vertical Tracking Angle (VTA); (3) Lateral Tracking Angle (LTA); (4) Azimuth; and (5) Anti-skate Control (ASC). Let's go through them one by one.

The ***Tracking Force (TF)*** is the amount of weight, in grams, that holds the stylus in the LP groove. A typical TF would be 2.5 grams, such as for the cartridge that came with the McIntosh MT10. The adjustment is made by moving a counterweight at the rear end of the tonearm forward or backward. Here is a photo of the counterweight on the McIntosh MT10. You loosen the knurled knob on top, slide the weight forward or backward, then tighten the knob. The TF should be adjusted before the others, as this insures that you are not putting too much weight on the stylus at any time.

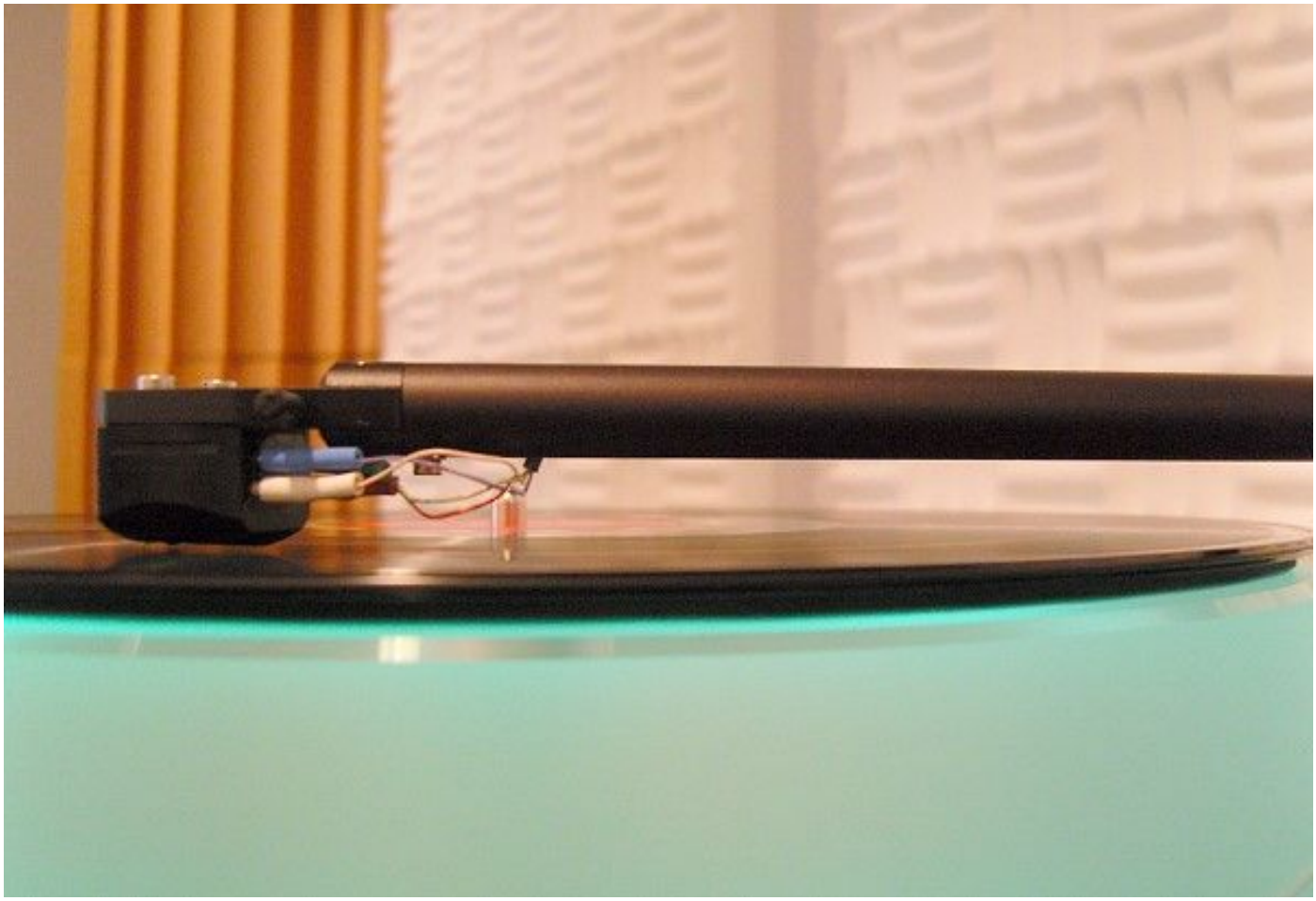


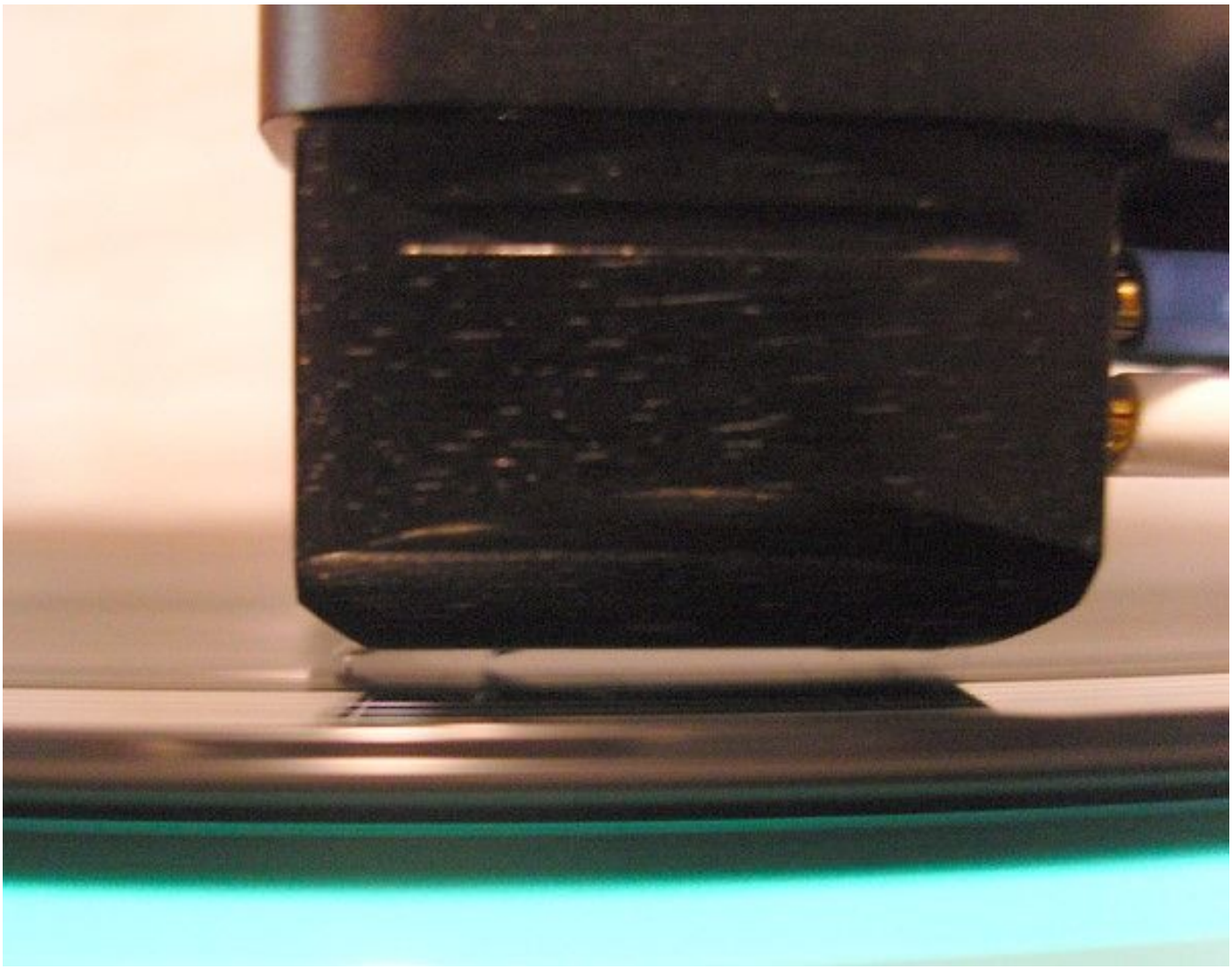
Of course, you need a way of determining what the TF is while adjusting the counterweight. There are several products out there for this. The least expensive ones let you put the stylus on one end of a small strip, with a pivot in the middle, and tiny weights on the other end. When the weights balance the cartridge, you have your measurement. The other kind is the digital balance, which is what I am using here ($129). You turn on the unit (powered by a small battery), press the “Tare” button which sets the balance to zero. Then you carefully set the stylus on the “pan”. Here is a photo. In this case, the TF was 2.7 grams, and I needed it to be 2.5 grams. So, I moved the counterweight on the tonearm just a bit to the rear, and it came out to 2.518 grams (second photo).


ON/OFF
TARE
LIGHT


25.18
ON/OFF
TARE
LIGHT

The ***Vertical Tracking Angle (VTA)*** is the angle of tilt, nose down or nose up, that the cartridge has when the stylus is in the record groove. Here are a couple of photos. In the first one, see how the space between the tonearm and the LP is the same from front to back. In the second photo, you can see that the bottom of the cartridge is horizontal to the LP surface.



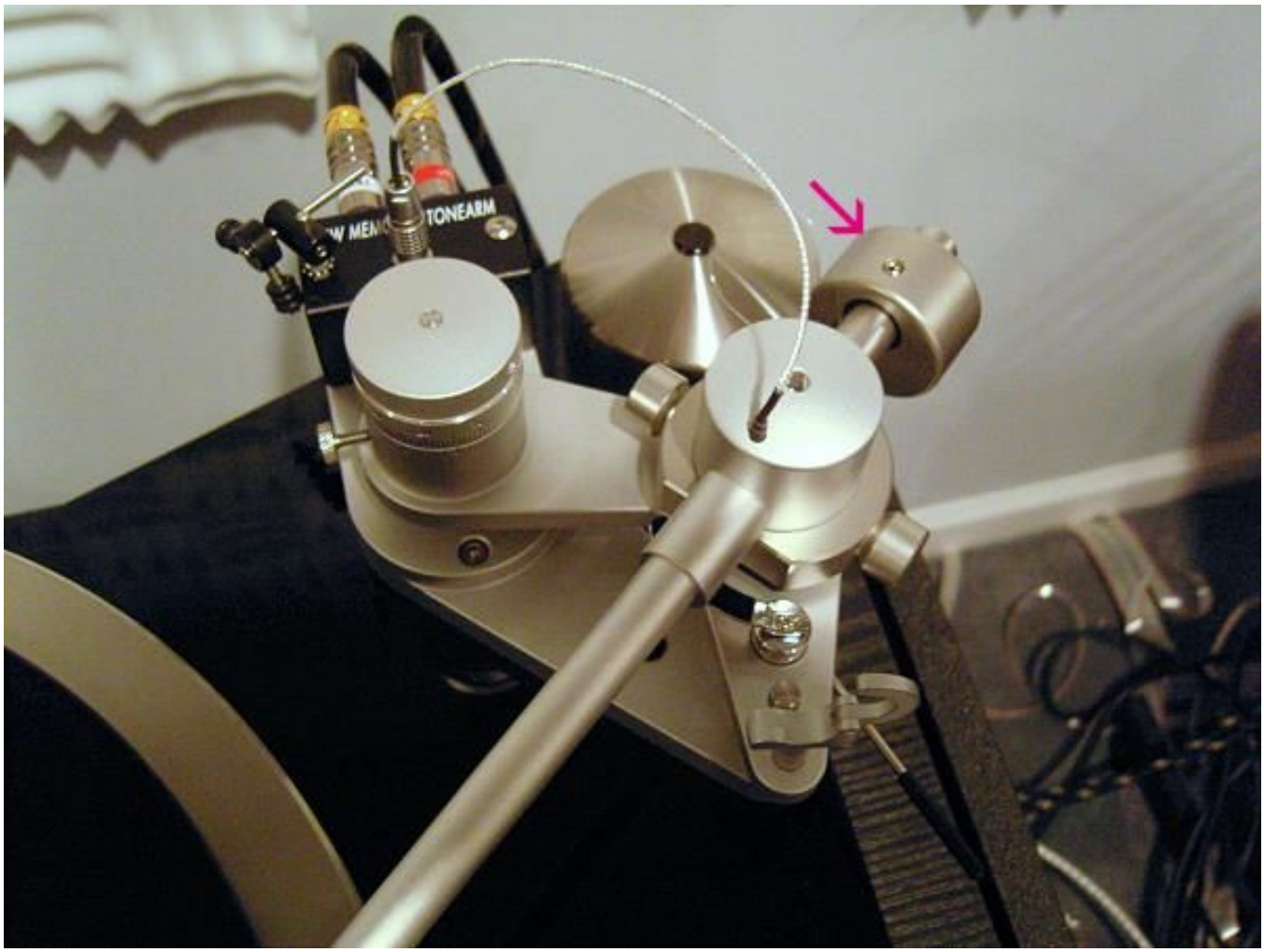


Adjusting the vertical tracking angle to be horizontal is where you start, and it is accomplished by making sure that the cartridge is mounted flat across the bottom of the head shell and then adjusting the tonearm height so that when the stylus is in the groove, the cartridge and tonearm are horizontal. Once everything is set up and you are playing LPs, you can go back and fine tune the VTA, knowing that adjusting the VTA so that the cartridge is nose down will increase the high frequencies and decrease the low frequencies, while adjusting the cartridge nose up will reduce the high frequencies and increase the low frequencies.

The ***Azimuth*** refers to having the cartridge not tilted to the left or right, i.e., when looking at the front of the cartridge, not having the left side closer or farther from the surface of the LP than the right side. Besides the McIntosh MT10 turntable, we now have a VPI HR-X (photo below) so that we can compare cartridges. The cartridge that I chose to use with the VPI HR-X was the Sumiko Blackbird, mentioned in Part 3, above.

Here is a photo of the VPI HR-X tonearm when I first mounted it. If you look at the rear of the tonearm, you can see that the left side is down and the right side is up, with respect to the base, rather than being level. In other words, it was leaning over on one side.

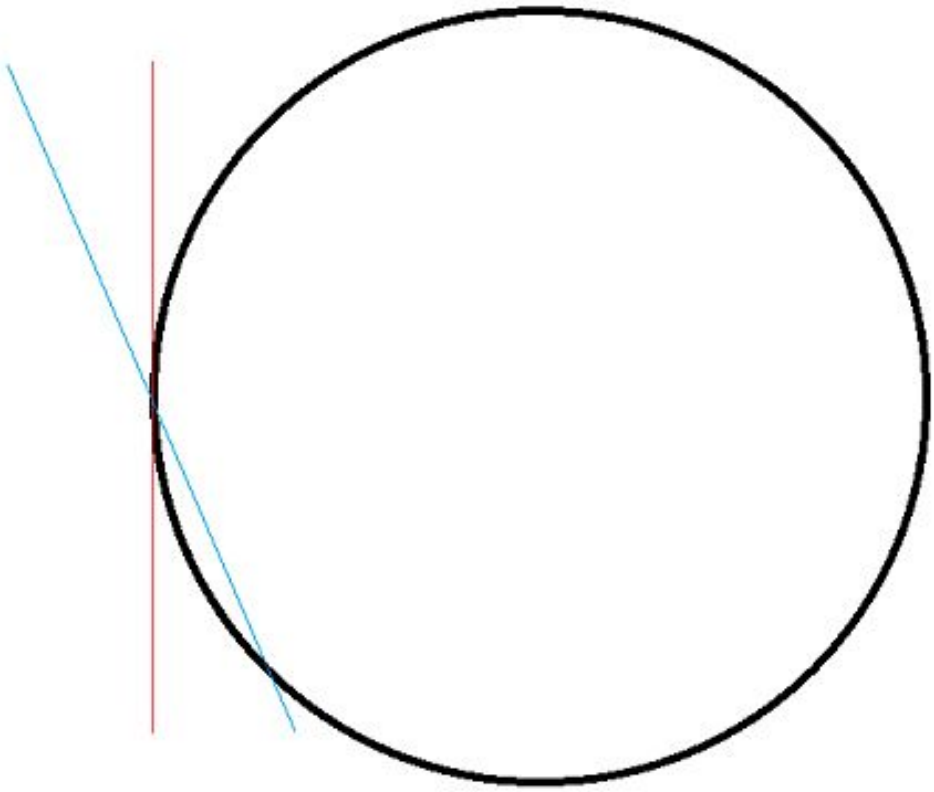
So, I rotated the tonearm counterweight at the rear (red arrow) such that the tonearm moved back into a level position. The counterweight is oval shaped, so rotating it places more weight on the left or right side of the tonearm.



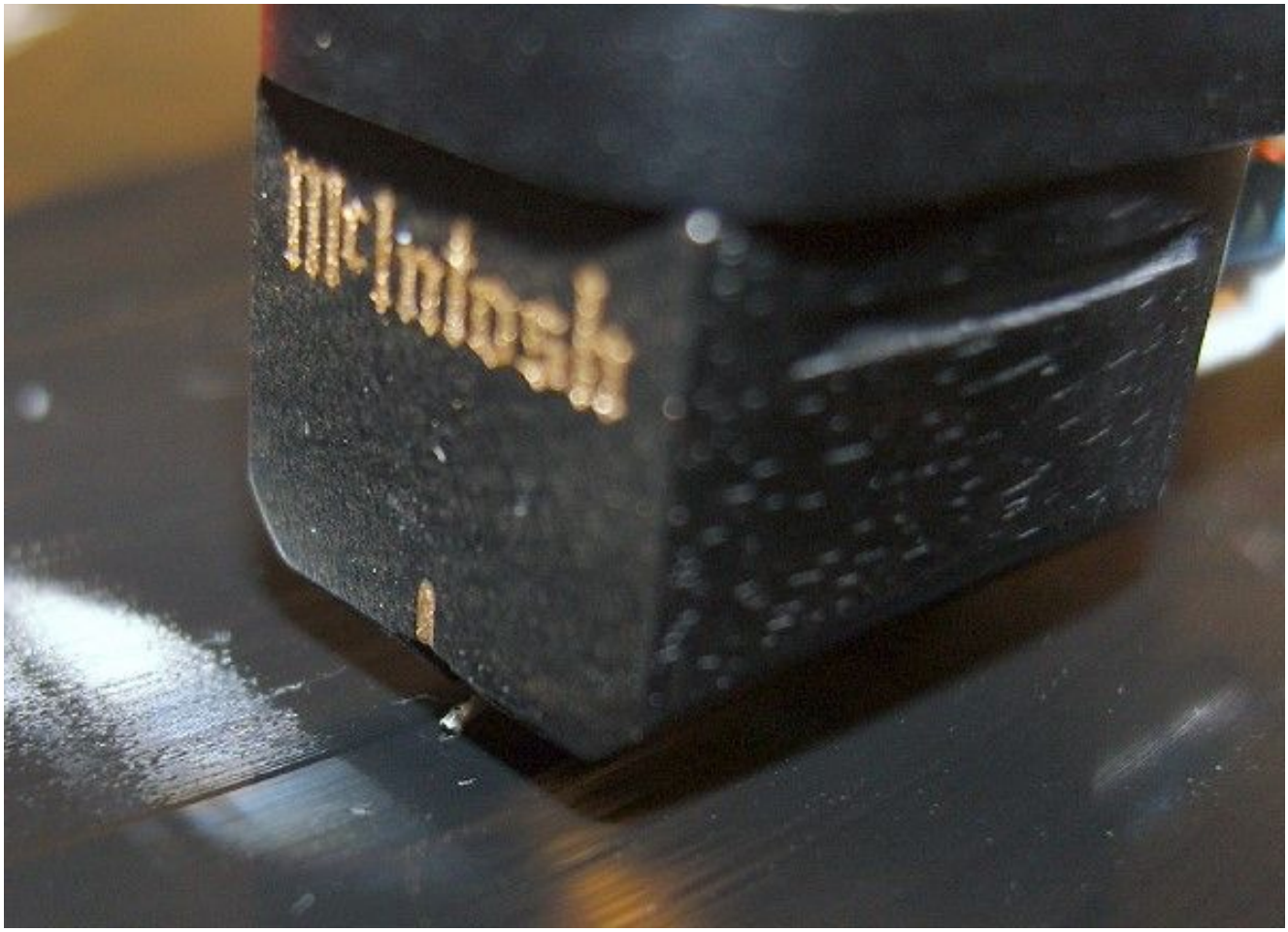
Now the cartridge was level (horizontal) in relation to the LP surface, as shown below.

The ***Horizontal Tracking Angle (HTA)*** is the angle between a line drawn from the center hole of the LP to the outside edge, and a line drawn through the cantilever as the stylus is in the groove. What you want is for the cantilever to be perpendicular to the line from the hole to the outside edge and tangential to the LP groove. The adjustment is made by loosening the screws that hold the cartridge in the headshell on the arm, shown in the photo below (beneath the diagram), and then turning the cartridge until the cantilever lines up with the record grooves at 4-23/32″ from the center of the LP spindle hole. Then you tighten the screws.

In the diagram shown below, the red line indicates proper alignment of the cartridge in the LP groove, at the distance from the center hole in the LP mentioned above, with the line being the front-to-rear axis of the cartridge, tangential to the LP groove, and directly in-line with the cantelever, at the end of which is the stylus. The two stereo channels, located at opposite 45 degree angles beneath the horizontal plane of the LP, would be tracked correctly by the cartridge stylus. The blue line indicates improper cartridge alignment (improper HTA), and is non-tangential to the LP groove. In this case, the stylus would not be tracking the two stereo channels correctly. Tangential means that if a line intersects a circle, and if extended at both ends, it will not intersect the circle again. You can see that the red line, which is tangential, only would intersect the circle one time, while the blue line intersects the circle a second time.

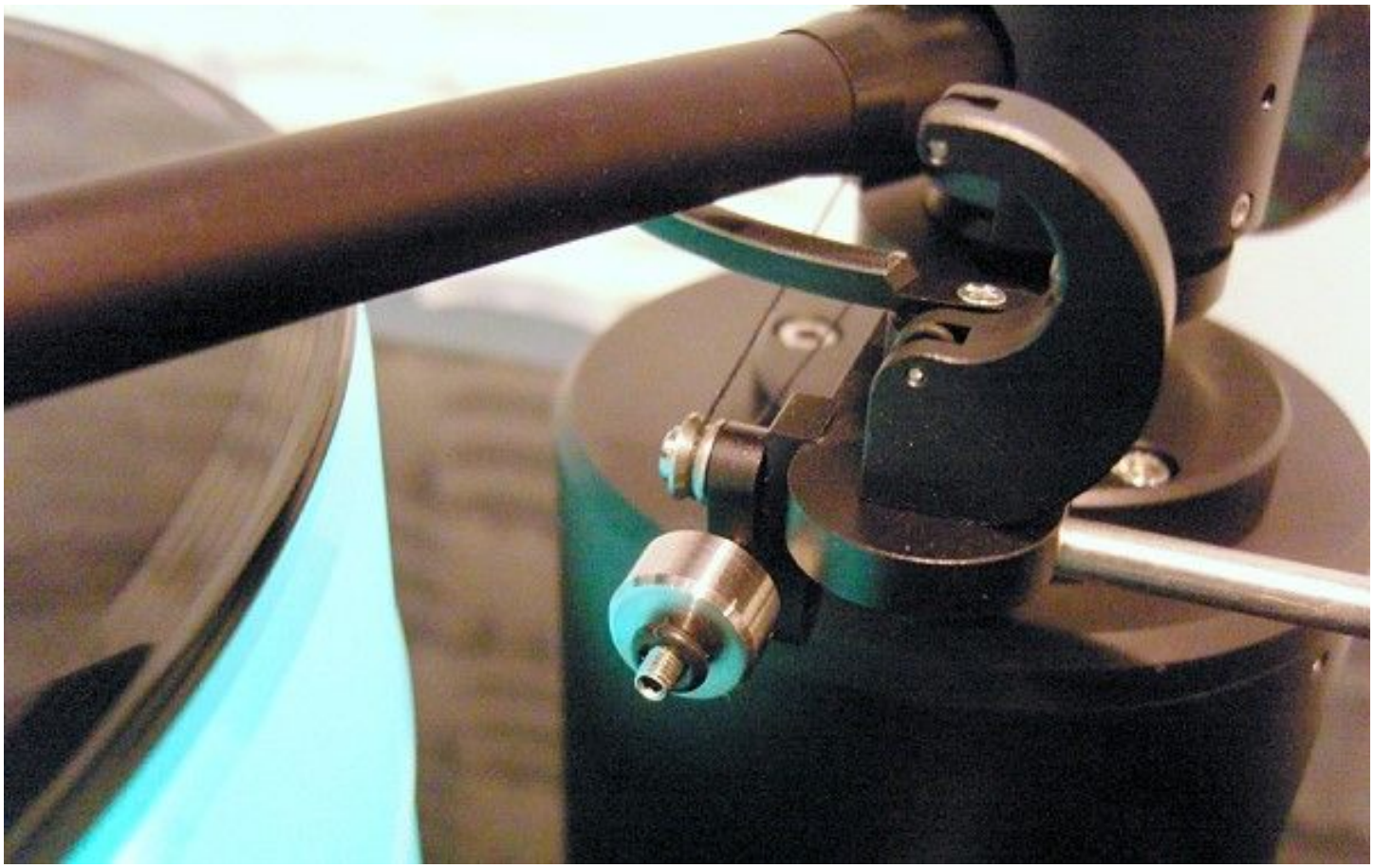


Because the cartridge moves in an arc, the best that can be done is to have it exactly line up in two points across that arc. The rest of the time, it will be just a bit off. The reason this is important is that with the right channel on the outside edge of the groove and the left channel on the inside edge, if the cantilever is not tangential to the LP groove, the stylus will bleed information between the channels. Increased distortion also results. The second photo shows a close-up, and you should notice all the dust on the LP surface. I will talk about how to get rid of this in a later chapter.


McIntosh

The ***Anti-skate Control (ASC)*** is used to counteract the tendency for the stylus to move towards the center of the LP (this is called “centripetal” force), as the music is playing. This results from the fact that the groove is one big inward spiral, and the stylus “seeks” the inward grooves because they have lower linear velocity. Because the stylus tends to move towards the center of the LP, the force against one side of the groove is greater than the other side. The anti-skate adjustment fixes this by applying an equal force to move the stylus towards the outside edge of the LP.

Here is a photo of the ASC on the McIntosh MT10. It is the small thread attached to the pulleys with the round weight at the end. As the tonearm becomes longer (there are 9″, 11″, and 12″ tonearms), anti-skate becomes less important. Also, note that there are forces (other than anti-skate) acting to pull the arm towards the center – particularly if the tonearm is “S” shaped, and forces pulling it towards the outside edge of the LP. The inward force is larger than the outward force, so anti-skate is a force applied to bring the tonearm back towards the outside edge of the disc.



Click HERE to go to Parts 6-9.