ΩMA

NOTES ON THE DESIGN, DEVELOPMENT, CONSTRUCTION AND GOALS FOR THE OMA K3 TURNTABLE PROJECT

BACKGROUND

Since its inception in 2006 OMA has made customized direct drive and idler drive turntables for our clientele. These decks were made from massive slabs of Pennsylvania slate, a very heavy and well damped material. We began using Technics SP10 MK2 turntables in slate more than 15 years ago and modified those decks to use only their motor and control system (OMA Tour- maline) something done today by manufacturer's charging over $200,000 for a Technics SP10 motor driven deck. For K3 we were not content with hot rodding other companies' technology, we developed everything in house, from the ground up. Our motor and electronic motor control technology are completely original, proprietary, and state of the art designs which took well over 1000 hours to create. K3's chassis or plinth is constructed from materials and engineering never used before on a turntable, with a similarly revolutionary tonearm design using entirely new principles and construction for such arms, made by Frank Schroder in Berlin.

INSPIRATION

Inspiration for the K3 turntable project came from the vintage record cutting lathes that created the master dies for all records pressed over the last century. From Western Electric and Universal to Scully and Neumann, these lathes were created to solve the problem of how best to inscribe the musical signal onto an analogue flat disc- the record. They possess an inherent beauty in design often found in objects which were made first and foremost for a function, a task, and not to please a mass consumer audience. They were designed as very expensive tools, built on the level of extreme precision scientific, laboratory instruments. We wanted to create a turntable in the same vein, and with a similar aesthetic and choice of materials. The analogy would be to making a scanning electron microscope, but in reverse. Instead of a device designed to take images at the sub-micron level, our device needs to actually physically trace modulations in a vinyl groove to the order of .005 microns. That's the scale of a large organic molecule. Any vibration or jitter in the microscope results in a blurred image, the same goes for the arm, mount and plinth of a turntable- any movement results in distortion, a loss of signal or addition of noise to the system and degradation of sound quality. Because a turntable has a powerful motor that spins a large platter, any movement of the tonearm components relative to the platter results in an apparent platter speed change, something we don't want. Speed stability is not only how accurately the platter rotates, it is also how accurately we maintain the position of the arm relative to the platter in real dynamic conditions. If any part of the loop moves other than rotation of the platter, we are seeing a change in speed.

We found that dynamic speed stability is incredibly important at the upper echelon of vinyl play- back technology, something ignored in favor of average speed which is far less important to your ears.

All cutting lathes were made from cast and machined iron, because they require great mass and rigidity to properly control the cutting head and the disc being cut on the platter. The requirements of a turntable as a playback system share the basic needs of isolation from vibrations, both from within the drive system and externally, and great rigidity of the moving elements to ensure their proper registration and/or complementary function. There are many ways to damp a turntable system, such as using very high mass in the materials, floating elements on air, magnetically or using liquids, using dissimilar materials in a CLD or Constrained Layer Damping fashion to make use of the boundary effects as vibrations move through the layers, but what is rarely discussed is the concept of Critical Damping, which was extensively employed with the K3 project. Critical Damping refers to getting rid of the vibrations in a system without overkill (or underkill)- a targeted approach to get things quiet but not dead sounding. To achieve this goal we did a few things similar to the ultimate cutting lathes ever made, such as those from Neumann. We used a massive plinth structure cast from hypo eutectic gray iron, with a very high graphite content, typically used on photolithography (chip making) machine bases, for example. Aided by FEA (Finite Element Analysis) and the Departments of Engineering and Physics at Bucknell University, we designed a plinth and a platter with internal chambers filled with a mixture of a special oil and particulate matter to deaden vibration and resonances. Vibrational energy enters this system, encounters these pools of oil and sand like material, and dissipates as heat. To cast these parts required ultra sophisticated 3D printed sand molds, and many iterations of casting and machining to arrive at the final K3 design, an extremely expensive process that took several years. K3 truly pushes the boundaries of what can be made today using 5 axis CNC machining at aerospace mil spec level, and metal casting that simply could not be done with prior technology even ten or fifteen years ago. (Bucknell University gave OMA their 2019 Award for Most Innovative Product for K3.)

Returning to record cutting lathes, virtually all records made today are cut on either Neumann or Scully machines the last of which are now 40 years old. Many machines are nearing 60 years plus and most of the motors (Lyrec) are old fashioned synchronous drive units using gears in an oil bath. Because our motor technology is state of the art we hope to offer cutting/mastering engineers a new alternative motor to replace their worn Lyrecs, which will be far higher torque (better even than the later Panasonic Technics SP02 direct drive motor) and much quieter. This in turn would enable the industry to cut better sounding, quieter and more dynamic records, and improve the state of the art for everyone listening to new records.

SPEED AND DRIVE TECHNOLOGY

While the rest of the audiophile industry relies on belt drive technology, we recognized from the outset that only direct drive and idler drive provide the degree of timing we deem necessary. Our engineering team led by Richard Krebs took a complete review on the concept of direct drive.

This decision to use outlier technology in terms of drive mechanism and materials was driven by our experience that even the best belt drive turntables lack the ability to track and reproduce a record with sufficient accuracy. Even the most expensive belt drive turntables, typically featuring extremely massive platter systems with high moment of inertia, fail to correct for the speed perturbations exerted on the system while playing a record. This is due to the compliant nature of the drive mechanism, which acts like a spring in a belt drive system. By the time a belt drive system's platter notices slowing due to the modulations encountered by the stylus on a record's grooves, whether that be through sensors located on the platter itself or electronically through measuring the motor parameters, any speed change effected is, shall we say, past due. Nor can even the heaviest platters which rely on their momentum (moment of inertia) and using however sophisticated bearings (air, etc) come back up to speed accurately or quickly enough with a belt to properly reproduce the transients found in music on records. A good analogy would be a 1000 ton freight train, racing down the tracks. If we hit the train with just a one kilo brick at speed head on it will in fact change the speed of the train. It's just Physics 101 (Law of Conservation of Energy.) It may not be a big change in speed, but it is a change, and if you compare even the best, most expensive belt drive decks to K3, that change becomes obvious, because you can hear it.

Such speed anomalies are registered by the human ear as softness, smearing or simply a lack of natural, life-like flow to music. Scientific studies in recent years have revised assumptions on the limits of human hearing vastly upwards, showing that we can detect incredibly tiny changes in time much better than had ever been thought. In the process of developing K3 our team encountered truly surprising results again and again while refining the speed control technology we developed, to a point where we even have a hard time understanding how the human ear and brain can resolve such incredibly tiny changes in time. While much of turntable engineering has concentrated on speed accuracy as an average, it turns out that accuracy moment to moment is what really matters when it comes to listening to music.

DEVELOPMENT OF K3'S SPEED CONTROL

At the core of the K3 turntable is a uniquely powerful, ultra high torque motor. This 18 pole, coreless-slotless design with large neodymium (not ceramic, as with Technics) magnets is by far the most powerful motor ever

used on any turntable. It is significantly more powerful than the motor used on the legendary Technics SP-10MK3 turntable, and is more powerful than the Lyrec motor on the Neumann cutting lathes used to make master records. We have in fact developed a kindred motor which is yet more powerful than the incredibly exotic Technics SP02 motor created to replace the Lyrec on Neumann decks, especially those outfitted to cut direct copper discs (DMM-Direct Metal Mastering.) Our motor can be found on such devices as anti ballistic missile defense systems, enormous deep space telescopes, nano and photolithography ma- chines used to make semiconductors; instruments that require ultra precise control and speed, with cost being no object (besides K3, the least expensive thing using our motor costs around
$80 million.)

We chose this motor (and we went through several contenders in the process) for one reason- ultra tight control of our turntable platter's speed. Modulations in the groove due to changes in the musical signal exert changes on the speed of the platter, these must be resisted- actively (by the motor and controller turning the platter) or passively (by a massive platter whose moment of inertia hopefully mitigates changes to the speed, while never actually correcting them in time.)

Let's talk a little about how our approach to the speed issue was actually done.

First there's the platter. Direct drive professional turntables and cutting lathes have used various approaches, from the ultra lightweight strategy of EMT's 950 (a plexiglass platter weighing only ounces, which could be controlled easily and quickly by a relatively low torque motor) to the very heavy platters found on cutting lathes (which are not playing back a record, but cutting a groove in the first place). With K3 our team created a platter (the design and construction of which will be addressed separately) of middle weight (14 kilos) calculated to provide the correct load for the motor and bearing system such that any stylus induced speed variation could be rapidly overcome, if not ignored, by the system. Remember that with a direct drive turntable the motor is actually part of the platter; each time the motor makes a revolution so does the platter. Inside this motor bearing K3 has an ingenious mechanism that keeps a column of special, viscous oil in a pressurized column within the height of the bearing that acts as a pre-drag or load on the system even before a record is played. This renders changes in speed less "noticeable" to the system than if a low drag bearing, like an air bearing, were used.

Imagine a big revolving wheel in a very powerful machine- you grab it and try to slow it down but it resists your efforts. The degree to which you are successful in changing it's speed depends on you (how strong you are) how powerful the motor is and what controls it (how does it sense what you are doing and respond to it?) Direct drive motors have been the most powerful motors used in turntables, and controlling their speed has easily been the most difficult engineering problem yet encountered. That's because as the motor become more powerful, with greater torque, the way it responds to commands for correcting anomalies in speed also create greater audible problems, aberrations in time that are clearly audible and often objectionable. Its the classic double edged sword dilemma and the high end turntable industry (if you can call it that now) has responded by ducking the issue (using belts, which are easy to work with, but inherently inaccurate.) In short, using a very powerful motor can give you better sound but it can also create serious problems with sound-speed control artifacts you might call them.

We can envision this problem by way of a clock with two second hands -one represents the rotating field in the stator, the second represents the rotor. These two hands are connected by a rubber band and they are separated by a few seconds. The field or stator hand pulls the rotor hand. As the load changes (stylus drag) the rubber band stretches or contracts, changing the gap but they never overlap. This causes micro speed changes The relationship between the load and the gap is not linear. A doubling of the load does not result in a doubling of the gap. The change is less than double and a stiff motor will result in a smaller change in the gap. The motor in K3 is exceptionally stiff. As you can see, even though there are micro speed changes taking place, both hands take an AVERAGE of one minute to complete a full circle, however it is these micro changes that cause audible distortions in the resulting music. It is these tiny speed changes that we concentrated on eliminating during the protracted programming phase.

With its powerful neodymium magnets and optimized stator coil configuration, the motor in K3 is very tightly coupled between the rotor and the stator field. This produces higher torque for a given input (higher torque constant) and it is very stiff- the two hands do not deviate from each other much. This is very difficult to accomplish and control. Other turntables, even professional direct drive decks like the Technics SP10 have historically used less powerful motors, with ceramic magnets for example, creating a less stiff system, a softer control that can be addressed in a number of ways. The designer can increase the intensity of the feedback controlling the motor, but this can have a negative impact on the sound. That's because the feedback is trying to correct an error via a compliant drive (the rubber band) so it is more active. It has more correction work to do. Or the designer can apply less feedback and leave the drive system to react to correction commands more slowly. Either way, a softness to the sound and rounding of transients is the outcome. This is something we can hear.

When a turntable manufacturer publishes speed accuracy specs for their product, it's based upon average speed, which is pretty much irrelevant to our ears. What we listen for with a turntable is the dynamic speed stability, how the system is reacting under real life conditions- playing back a record. The controller we have chosen is literally state of the art and has thou- sands of parameters for selecting proper speed under a multitude of conditions. Many of these parameters interact with each other further complicating choices for controlling speed. Beyond pretty basic measurement of static conditions for programming the speed controller, there exists no easy nor automatic, computerized way to do this work. You have to listen, make changes, and then listen again. This process took our engineering team over 1000 hours of work to pro- gram the speed control on K3. This process entailed making smaller and smaller changes to the point where they were impacting how the platter moved down to several arc second increments. One arc second is 1/1,296,000 of a circle. To our team's astonishment they could hear these changes. This process was done double blind, btw.

PLATTER AND BEARING

Vacuum hold down is a necessity in record cutting lathes due to the forces at work with a cutting head on a lacquer master but unnecessary on a turntable for playback. Such vacuum systems add a great deal of complexity and user interaction that are problematic. We dispensed with this by using a sufficiently critically damped platter, and with the assistance of Bucknell University's Engineering Department, we created a platter which is filled with chambers of an oil and particle mixture which is extremely well damped. The underside of the ultra precision machined platter is CLD damped with a sub platter of marine brass and elastomers. A special clamp was created for K3 which itself is damped internally with the same oil and particle mixture and forcibly holds the record tight to the platter. The bearing is of inverted type with an extremely large diameter 25mm shaft of a hardened stainless steel alloy, the bearing sleeve using an ultra high tech lining material that requires no lubrication, being designed for advanced weapons. We nonetheless use a special high viscosity oil in a pressurized column not to lubricate the bearing, but to add pre drag to the system which mitigates any changes due to the stylus. The bearing is also much longer than previously used on direct drive turntables, which has the advantage of placing the powerful motor magnetics (located at the bottom of the platter/bearing assembly) much further away from the cartridge to avoid any EMI.

Because the motor is in fact part of any direct drive turntable's platter and bearing system (the motor makes one rotation, the platter does too) it is imperative that the motor have a very solid, rigid mounting. With K3 the stator of the motor (the part which does not rotate but creates the energetic field to propel the rotor, the moving part) is bolted directly and completely to the cast iron plinth. While other direct drive designers have used PCB's to mount their stators, or three point fasteners, these approaches invite problems due to insufficient rigidity or multiple, uneven paths to dissipate energy.

HOW ENERGY MOVES IN THE K3 DESIGN

K3 as a turntable and tonearm integrated system uses a very sophisticated approach to dissipating the energy found in all turntable systems. We've used very heavy, well damped materials (grey cast iron) with liquid/solid internal chambers, but just as importantly, our design features very few joints/junctures and material dissimilarities, because we want the energy that could create noise to simply leave. As quickly and easily as possible. To do that we use materials with similar propagation velocities and a simple path to a mechanical ground (three feet, one with high propagation velocity to act as a mechanical "drain." The truly unique tonearm created for K3 (and only available as part of the system) by Frank Schroder continues this design philosophy by using a girder like arm structure that is both extraordinarily rigid and well damped and a levered counter-weight on a special bearing that is designed specifically to not store energy, as the counterweights do in all other arms. How energy is stored in turntable playback systems became a crucial factor in the overall design of K3.

K3 POWER SUPPLY, A LESSON

K3 took so long to create- a full 6 years from conception to market with no hiatus, we were able to discover some valuable insights into what actually matters (sonically) in turntable design which we might have missed trying to rush a product through to sale. Many of these insights came as big surprises. We're all still rather shocked by just how tiny changes in speed control can be readily discerned. But the biggest overall takeaway is that literally every little thing, every change, has resulted in a sonic difference, and a great example is the 24v DC power supply which runs K3.

A DC motor requires (no surprise) direct current, and that's very easy to do. Your wall warts make DC for your appliances and electronics, and we could run the K3 off a wall wart if we wanted to. The 24v DC we need does not run the motor directly, it goes through an astronomically complicated digital motor controller, which itself modifies the power. So any high quality DC supply should theoretically sound the same. On a product of this quality, a cheaper switching DC supply was never considered, and we started with a very expensive lab grade scientific quality regulated linear supply. For due diligence we then began making our own supplies, trying such things as batteries, saturable reactor supplies (used in studio applications by RCA) choke input unregulated supplies, and finally landing on a truly old fashioned idea- a tube regulated supply using a Xenon rectifier. Tubes were used to rectify AC to DC in the early part of the 20th Century when devices such as selenium rectifiers and then diodes hadn't been invented. There is no simple explanation for why a tube rectified DC supply should sound so much better than anything else, but it does. Which is why we use it, and also why we made all the other decisions involved in creating K3. Sometimes you just have to go back, to the future.

THE INDUSTRIAL DESIGN

K3's appearance is a collaboration with designer Ana Gugic of Rome, whose work includes the architecture of the Shenzhen International Airport with Massimiliano Fuksas, and the Armani Boutiques in NYC and Tokyo. Ana brought a refined, architectural aesthetic to turntable design.

Jonathan Weiss CEO/Founder