Teres Micro-Precise Speed Technology

Teres Audio Inc.
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Abstract
Years of experimenting with turntable drive mechanisms (often with unexpected results) revealed many of the pitfalls and problems of turntable drive mechanisms. From this experimentation it became clear that current drive methods were in all cases, less than ideal. At Teres Audio we made a decision to stop pursuing incremental improvements of existing technologies. It was time to examine and experiment with new approaches. Only with new, fresh ideas could we expect to achieve the levels of performance we were looking for. This effort lead to the development of new technologies that deliver what we call *Micro-Precise speed.*

This article describes in some detail the design challenges for a high quality turntable drive mechanism. Each of the issues are discussed along with details of how these are addressed by Teres Audio technology.

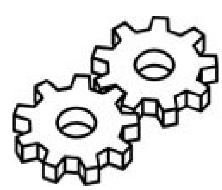
1.0. Driving the Platter, a Difficult Challenge

One of the most critical components in any turntable design is the drive mechanism. At first glance it appears to be a simple task to turn the platter at a constant 33-1/3 or 45 RPM. In practice it is extremely challenging to produce rotational speed that is sufficiently stable to prevent audible degradation of reproduced sound. Close examination of speed stability reveals a host of problems. Micro (short duration) speed variations are responsible for audible problems that most audiophiles would not attribute to the turntable drive mechanism. Harshness, muddiness and smearing are the classic symptoms of micro speed variations. In addition problems with a slow, dull presentation can often be traced to deficits in the turntable's drive mechanism.

Human hearing is remarkably sensitive to infinitesimally small errors in the time domain. This has been well documented in digital audio where timing errors (jitter) as small as ten trillionths of a second, have been shown to be detrimental to quality sound reproduction.

Our experience has shown that timing errors are no less significant in the world of analog audio. Our experience with turntable design reveals that, very subtle changes in any portion of the drive system are surprisingly audible to the listener. An excellent example is an evaluation that was conducted comparing the use of a Cerafine vs. Black Gate capacitor installed upstream from a very high quality regulator circuit. In blind evaluations listeners consistently preferred the motor controller with the Black Gate capacitor. Similarly we have found that drive belts, pulleys and even the motor housing itself all have a clearly audible effect on sound quality.

1.1. Cogging, Enemy Number One



The motor itself is in many cases the most significant contributer to micro speed variations. All motors exhibit some amount of cogging. When we observe a rotating motor it appears that the rotation is constant. However, upon closer examination we find that the rotation is not constant but rather cycles of pushing and then coasting. Cogging is measured as torque ripple. Commonly used single-phase AC turntable motors exhibit nearly 100% torque ripple. So as the motor rotates the torque developed by the motor varies between zero and maximum torque. This characteristic is obviously not desirable for producing constant speed. Motor cogging is one of the primary causes of micro speed variations.

1.2. DC Motors, Better, but...

DC motors typically have a far more desirable torque ripple of 10% to 20%. A dramatic improvement over a single phase AC motor, but there is a downside. The speed of a DC motor is determined by a combination of load and voltage. Since there are always subtle changes in the load during operation the speed always drifts. Our experiments have shown that without a servo circuit the speed will drift 2 to 3% in the time it takes to play an album side. A servo control mechanism is required to keep the speed reasonably accurate. But servo circuits must first sense the speed error and then apply correction. This delay between sense and correction, no matter how slight, is the Achilles heel of DC motors. A servo circuit with a fast correction algorithm will maintain precise absolute speed but does so at the expense of sound quality. A fast servo circuit makes many small and abrupt changes (referred to as "hunting") to maintain the correct average speed. These small rapid variations are exactly what we are trying to avoid and are detrimental to quality sound. Hunting may be avoided by using a very slow time constant that only allows small and infrequent speed corrections. The result is more constant speed (better sound) but at the cost of less accuracy in absolute speed. A proper DC motor servo will by design not be able to compensate for rapid speed changes from stylus drag due to the slow correction algorithm. In spite of these drawbacks the low cogging characteristic of DC motors makes them a highly desirable compromise that is generally preferred over AC motors. However, a proper implementation of a DC motor is difficult to design and also more expensive.

1.3. Isolate or Couple, the Question

The most common method for dealing with cogging is to isolate the motor by connecting it to the platter via a compliant medium. In most cases this is a rubber belt that stretches and contracts to filter much of the cogging before it reaches the platter. However, adding any amount of compliance between the motor and platter has deleterious effects. First, compliance is an incomplete solution because it only diminishes cogging effects and can not eliminate them. Second, and most important isolation limits the motors ability to control the platters speed. If the platter decelerates slightly the motor applies more torque to compensate. But with a rubber belt the belt simply stretches a little more. The energy ends up being stored in the belt causing a delay before it affects the platter speed. Lastly the introduction of compliance creates an opportunity for resonance and unpredictable behavior.

Well implemented drive mechanisms strike a balance between eliminating cogging effects and the negative effects of isolation. For a given platter and motor there will be an optimum amount isolation that will deliver the best sound. Personal preferences will to some extent affect this compromise. So ideal the amount of motor isolation is dependent on not only motor and platter characteristics but also individual tastes. The effects of cogging and isolation are both detrimental, but different musical priorities will dictate which form of degradation is deemed least objectionable.

Single phase AC motors have a lot of cogging and require a great deal of isolation. So they are almost always used with a compliant, stretchy belt. DC motors on the other hand have less cogging and will often sound best with more direct coupling. A DC motor allows for a more desirable coupling/isolation compromise at the cost of greater complexity.

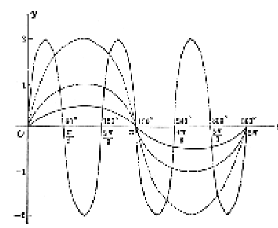
High mass platters are also useful in reducing cogging effects. However, as in the case of using compliant coupling, a heavy platter will reduce cogging effects but cannot eliminate them. Even with a 70-pound platter subtle changes in cogging are clearly audible.

1.4. Stylus Drag, Tiny but Ferocious

Dealing with stylus drag is another important aspect of a quality turntable drive system. It would seem that the tiny forces exerted by the stylus would fade into insignificance. However, given our extraordinary sensitivity to micro speed variations, the uneven force from stylus drag is audible and degrades sound reproduction. With a microscopic view, loud passages slightly slow the platters rotation. Contrary to popular beliefs platter mass changes how stylus drag affects speed but does not counteract the effects of stylus drag. A massive platter will reduce the magnitude of the variation but extends it over a longer period of time. A light platter will conversely allow a larger speed variation but it enables more rapid recovery. Heavy vs. light platters exhibit quite different sounding degradations but they are still degradations. We find the longer shallower variations that result from a heavy platter to be more benign. However, there are others that prefer the degradations from a light platter. The point is that stylus drag causes degradations that are changed but not eliminated by platter mass.

The only effective mechanism for truly reducing stylus drag effects is application of torque from the motor. Increasing the available motor torque makes stylus drag proportionately smaller and therefore will result in a net reduction in the effects of stylus drag. However, increasing torque usually will at the same time increase cogging. Once again we are back to the need of finding a balance between two competing objectives. To further complicate the situation a compliant coupling between the motor and platter reduces the motors ability to control platter speed. Any compliance between the motor and platter causes a delay in the delivery of torque. When a rubber belt is used additional torque from the motor will cause the belt to stretch. This energy will eventually be delivered to the platter but only after a time delay making it impossible for the motor to compensate for short term effects of stylus drag.

2.0. Multi-Phase Synchronous Motor, a Solid Foundation



Our drive technology begins with a unique motor topology (permanent magnet, multi-phase synchronous) that exhibits extraordinarily low torque ripple (less than 1%). This is at least an order of magnitude less torque ripple than that of a quality DC motor. We further decrease the inherently low torque ripple of the multi-phase motor by driving it with carefully optimized waveforms that compensate for small motor imperfections.

Another important feature of our multi-phase motor is it's purely synchronous mode of operation. This means that the rotational speed is precisely controlled by the drive signal frequency. The speed of a synchronous motor is completely independent of load. Probably the most important characteristic of a synchronous motor is how torque is applied. As the load is increased a synchronous motor instantly applies additional torque to compensate. If the motor is intimately coupled to the platter this characteristic allows for ideal compensation for stylus drag or any other variable forces that may be exerted on the platter.

The most common AC motor used in turntables are induction motors that are only partially locked to the drive frequency and the speed varies somewhat with load. These motors are often referred to as synchronous but this is not technically correct. True synchronous motors are rarely used because complex drive circuitry is required for starting. However, once the starting issue is resolved a true synchronous motor offers superior speed accuracy that is rigidly controlled.

The Teres multi-phase motors are absolutely silent and turn so smoothly that no isolation is needed nor is it beneficial. Because of the true synchronous nature of our motor the speed is rigidly controlled. This eliminates the complexity and compromises of DC motors. No sensors or servo circuits are needed. Both the absolute speed and speed constancy are tightly controlled. For the Certus motor the speed at 33-1/3 RPM is established at -0.011% +- 0.003% and +0.006% +-0.003% at 45 RPM. The Verus motor allows for precise speed adjustment steps of 0.16%. The speed remains locked and does not drift over time or require re-adjustment.

2.1. Direct Drive, No Compromise

Since our multi-phase motor requires no isolation, direct drive was selected as the drive mechanism for our Certus line. Direct drive provides perfect coupling of the platter and motor and avoids the pitfalls and compromises inherent in all belt and idler wheel drive systems. In addition there are no moving parts (other than the platter) to resonate, create noise or wear out. Since a brush less motor is used the platter bearing provides the only physical contact with the platter. Direct drive is the only drive mechanism that when properly implemented is completely free from compromises. However, the lack of motor isolation makes direct drive brutally unforgiving of even the most minor flaws in the motor and it's driving circuitry. Therefore proper implementation of a high quality direct drive system is both daunting and expensive.

2.2. Magnetic Damping, Icing on the Cake

To further stabilize platter speed the Certus drive system employs a powerful eddy current brake to provide magnetic damping. The eddy current brake applies a very large and perfectly uniform braking force. This uniform force is vastly greater than the highly variable force of stylus drag. By applying large and constant forces from the low cogging motor and the eddy current brake the proportional size of the force from stylus drag is dramatically reduced. This technique requires a massive amount of torque from the drive motor. The Certus motor is capable of generating an unprecedented amount of torque (more than 150 times as much torque as our Signature DC motor).

2.3. Certus Results

Certus technology results in a drive system that from a technical perspective eliminates or greatly reduces the major problems and compromises of current turntable drive mechanisms. The Certus drive system provides state of the art Micro-Precise speed both in terms of absolute speed and also consistency.

But what matters most of course is the sound. While the Certus drive system design effort was mostly a technical pursuit, all aspects of the design have been carefully optimized by tuning with the most sensitive instruments available to us, our ears.

Eliminating micro speed errors has a dramatic effect on the listening experience. The improvements in clarity and inner detail are not subtle. The presentation is more relaxed and effortless. Perhaps most significant is that the rhythm and drive of the original performance is fully preserved. Certus drive technology is the most musically significant development to date from Teres Audio.

3.0. Enter Verus

The Certus direct drive system, while a technical success, is an expensive solution that is out of reach for many Vinyl enthusiasts. The Verus motor is the result of our effort to make the Certus *Micro-Precise* technology available at a lower price point. While the implementation is quite different the core principles are the same. Like Certus, Verus uses a very low cogging true synchronous motor coupled to the platter as intimately as possible.

3.1. Direct Coupled Drive

Verus introduces a new, simple and effective drive methodology we call *Direct Coupled.* The *Direct Coupled* topology utilizes a large diameter pulley, an o-ring and gravity to directly couple the motor and platter. With the Verus motor there is no intermediate media between the motor and platter. An idler wheel or belt, regardless of it's type or construction results increased isolation between the motor and platter. As noted above, isolation brings both problems and benefits. Since the Verus motor has vanishingly low torque ripple it does not benefit from isolation. Because no isolation is needed the degradations introduced by belts and idler wheels are eliminated. The Verus motor utilizes a novel method for providing constant drive wheel pressure that is critical for precise speed stability. All platters have a finite amount of error in concentricity. If the motor and drive wheel are in a fixed position drive pressure will vary as the platter rotates causing speed variations. Even a thousandth of an inch of concentricity error will have a deleterious effect. To avoid this the motor must be allowed to move, following the contour of the platter. Springs, pivots, sliders and such could be used to provide this functionality. However, these mechanical attachments would need to be designed to not resonate and to be free from friction and would potentially introduce problems. The Verus Direct Coupled approach dispenses with these complexities and uses a simple pivot and gravity to provide constant drive pressure. The Verus motor pod has two small feet that are offset from the center of gravity. The motor pod is simply placed next to the platter so that the drive wheel rests against the side of the platter. The motor pod stands vertical and leans against the platter applying constant pressure supplied by gravity. In spite of it's obvious simplicity this method is an ideal solution. It provides excellent uniformity in drive pressure without resonance or friction issues.

3.2. Flexibility

One of the important design goals for Verus was flexibility. The Verus motor may be used with any turntable without modification if the motor pod can be placed properly. The motor pod just needs to be placed so that the drive wheel contacts the outside edge of the platter. The Verus motor is available in two heights placing the center of the drive mechanism at 4.3 or at 6.1 inches. The drive wheel extends up to 0.8” beyond the motor pod.

3.3. Verus Results

As may be expected the Verus motor shares many of the musical virtues that are uniquely encountered with Certus. The list of virtues, clarity, detail, pace, etc. are all there but not in the same abundance. While Certus takes he most musical Teres Audio development honors, Verus is likely to be the most important value proposition to date.