

A Short Study on Turntable Drives

Postulation: The ideal turntable platter would turn by itself to prevent audible distortion induced by the drive mechanism. Platter movement should also be even, quiet and steady and also be completely independent of the tracking of the LP.

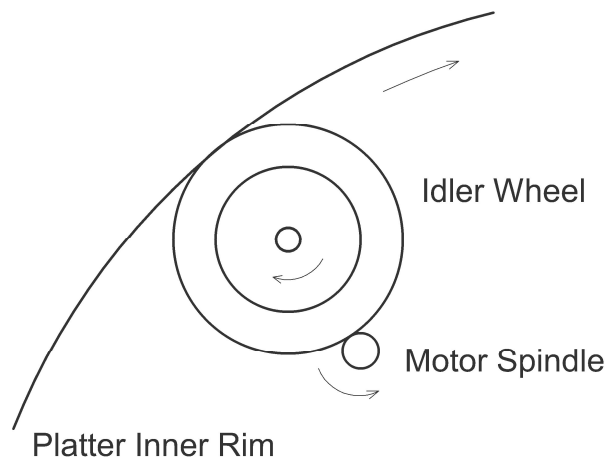
What follows is a brief but detailed study of the different concepts that turntable-drive designers have employed in their attempts to achieve this ideal.

Rim Drive

Rim drives can be found in the first turntables that were built for the modern LP. 50 years ago a small, portable Telefunken turntable used a platter driven by this rather complex drive mechanism. Today they're mostly found in vintage turntables, and rarely seen in current production. Vintage rim drives are still popular and in use due to their unique musical qualities.

Most "classic" rim-drive mechanisms use a fast-turning motor wheel, which drives a rubber wheel that in turn drives the platter on its inner rim.

It has the same basic structure as a gear mechanism; if the motor wheel and the rubber wheel had cogs it would work like a transmission gear, and the inner rim of the platter would be a cogwheel too.

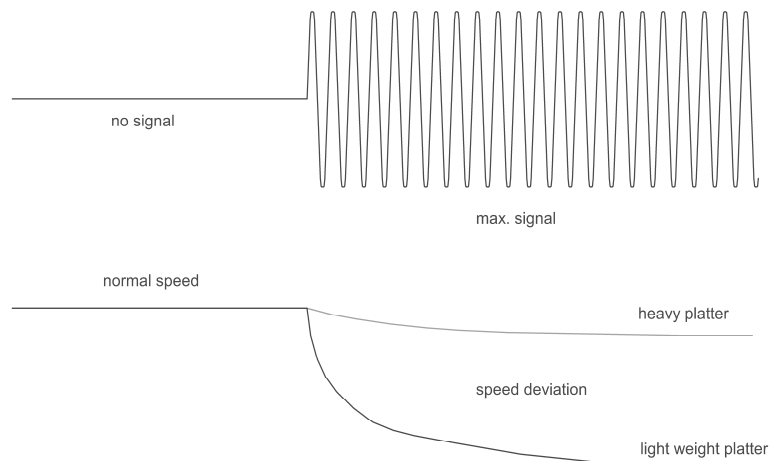


Since a drive mechanism with gear wheels would cause noise, the intermediate wheel has a rubber coating and initiates movement by friction. Contrary to the close coupling between motor and platter that would be possible with cogwheels, a rubber wheel has a certain amount of slippage. However, the slippage is minimal once the platter is on speed because it takes very little power to keep it running on speed.

Most rim-drive turntables use a spring mechanism to pull the rubber wheel in between the motor wheel and the platter rim. The momentum of the motor wheel and the platter turning pulls the rubber wheel in tighter and ensures maximum contact with the in-between wheel initiating the motion. Therefore the speed-reduced driving force on the platter has maximum contact and stability. The slippage, even when starting the platter, is almost eliminated, but the wear on the rubber wheel is quite high.

The special musical quality of the rim drive is in the direct mechanical coupling of motor and platter. Even though the platter mass is relatively low - usually 1...3kg - the drive sounds as though it “pushes” the music forward. While tracking the groove of an LP can cause a “braking torque” that is clearly perceptible in simpler belt drives without electronic control, groove-tracking forces don’t affect the speed stability of rim drives because such a gear mechanism is almost impervious to this reverse friction on the platter.

This calls for a short explanation of the influence that the modulation on the LP has on the speed stability of the platter: a quite common occurrence is a groove that runs quiet, with little or no modulation, and then suddenly runs into a musically complex crescendo at full amplitude. The strong modulation in this area of the groove puts reverse friction, or a braking torque on the platter. This is undeniably small, but with the sudden start of a crescendo braking torque’s effect on speed stability becomes audible. There might be a loss of dynamic power in the crescendo, or the pitch of the instruments might be altered noticeably.



The LP cutting process could theoretically include minor speed changes on the record to compensate for such passages, but due to the solid construction of cutting lathes that almost never happens.

Cutting lathes usually have AC synchronous motors, and their speed is strictly dependent on the frequency of the incoming AC power’s alternating current. These motors run at a very low speed because they work with high numbers of poles, so they drive the platter directly. Some of them have a viscous coupling similar to the one that can be found in an automatic gear mechanism. The very strong motor – cutting of course demands a lot more power than tracking – and the high platter mass effectively rule out any speed variations or at least minimize them substantially. A cutting lathe usually has a very high-mass platter with a larger diameter than the LP has, so it relies on the flywheel effect for speed stability.

The flywheel effect is perfect at preventing braking torque since the platter doesn’t slow down suddenly, but rather slowly and steadily, which in turn is prevented by motor regulation. The platter speed is being controlled and if needed will be supplied by more power or higher-frequency AC to keep the speed stable. In short, the combination of high platter mass (which supplies the flywheel effect) and motor regulation prevents speed variations during the cutting process.

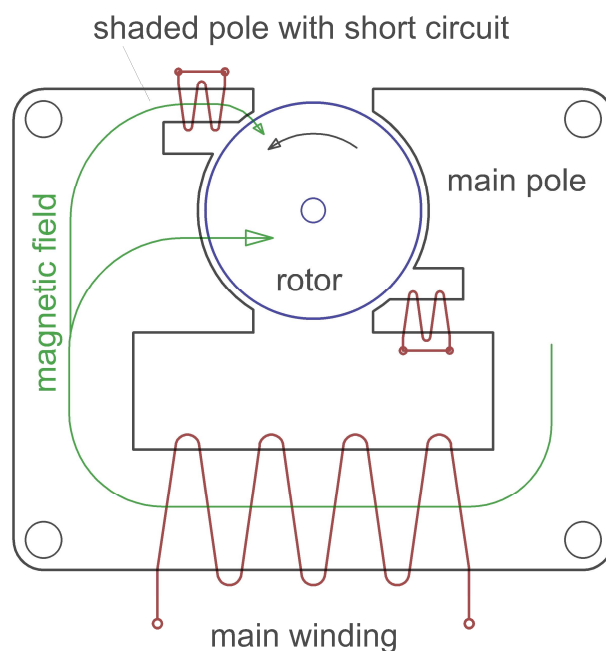
How does this relate to our discussion of rim drives? Rim drives have the strong coupling between motor and platter required to prevent speed variations, but how stable is the motor regulation?

Earlier rim drives mainly used asynchronous motors. This motor concept is very simple, using a direct connection to the incoming AC power, which doesn't require any additional regulation. But rim drives are not synchronized to the AC power's frequency; they have a certain load-dependent deviation (load in this instance means that the motor has to give more power to reduce the speed in the same manner). Usually they have two poles and therefore run very fast, typically 1400-1450 RPM or faster. Consequently the diameter of the motor spindle is small, which again might cause slippage between the motor wheel and the rubber wheel.

At 33 RPM, the speed reduction between motor and platter is approximately 43:1. Asynchronous motors are relatively strong, around 10W, and due to the speed reduction they have a significant impact on the platter. Since the speed stability is load sensitive, the aging process of the mechanical parts (e.g. the bearing running less free) can change the platter speed. Therefore rim drives require speed regulation, an adjustable brake, and in most cases an eddy-current brake to allow fine adjustment of the platter speed. This feature maintains a stable power query for the motor, and the reverse braking through the gear mechanism has no impact on speed stability. The speed stabilizes at a certain adjustable speed.

The result of all these measures is the apparent "pushing forward" quality of the music mentioned earlier.

While all of this makes rim drive look like the perfect turntable drive, there are downsides to this design too. The asynchronous motor causes strong vibrations that are transferred to the platter and to the chassis through the close coupling of the wheels. Most chassis have a complex suspension with springs to reduce these vibrations, but that's not enough to eliminate them fully. Using a belt between the motor wheel and rubber wheel is another attempt to suppress vibrations, but this doesn't eliminate the problem entirely either and of course reduces the direct coupling and thus the "pushing forward" quality. Asynchronous motors have good performance with regard to cogging, but the rim-drive mechanism has no means to suppress cogging. There are three bearings involved: the motor wheel, the rubber wheel and the platter all have a spindle running in a bushing, and due to the strong



Shaded Pole Motor

horizontal forces they don't run silently. The wear induced on the rubber wheel results in an uneven surface, which can be heard as "rumble."

Consequently we have a turntable drive concept with obviously positive musical qualities, but with disadvantages that can be described as unacceptable in modern music systems with good resolution.

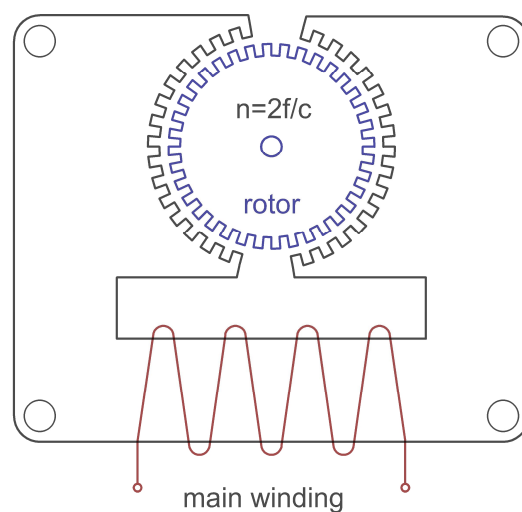
Due to the rim drive's inevitable noise and distortion, and its very complex mechanical construction (each different speed, 33/45/78 RPM, had to be adjusted independently despite a motor that was always running at the same speed), alternative turntable drive designs soon followed.

Belt Drive

Belt drives can be constructed very simply. A simple synchronous motor and a rubber belt around the platter is all that's needed. In its basest form, it's impossible to build a simpler or cheaper turntable drive mechanism. This is probably the main reason that the belt drive still has dominant market share today.

A synchronous motor runs continuously, corresponding to the supplied AC-power frequency. Basically it's a step motor using alternating current. A star-shaped rotor corresponds with a stator that has the same number of poles. When the stator generates magnetic energy with the supplied alternating current, it attracts the jag of the star-shaped rotor to the counter pole of the stator. Since this alone wouldn't instigate movement, a second motor of the same type is installed exactly halfway between the original poles on the same spindle. This second motor receives its alternating current from a phase shifter (capacitor). This means that when the first motor is at the zero position of the alternating current, and therefore can't induce movement, the second motor with its phase-shifted position can move the motor half a pole and then give over to the first motor again for half a pole while going into zero position itself.

The speed in RPMs of the synchronous motor is the AC power frequency divided by the number of poles. If there are enough poles they can run as slow as 100 RPM, and since they run synchronized to the AC frequency there are no speed variations. The only thing required is a supplied voltage that is strong enough to keep the motor running with platter mass. If a strong braking torque is working on the motor, it stops abruptly. This can lead to problems when driving high platter masses since the motor might not start to move when the mass is too high. A viscous or magnetic clutch that only grips when the platter is on speed is often used to prevent this. Sometimes the user is requested to give the platter a gentle push.



Synchronous Motor

These motors are also not free of vibrations. The “stepping” movement causes cogging because the movement of the motor bearing isn’t uniform; it consists of alternating acceleration and braking forces. The belt can reduce some of the impact on the platter’s speed stability, but speed variations are still perceptible.

One way to improve this is a soft suspension for the motor, which allows the motor to swing back and forth to compensate for the stepping movement of every acceleration. This also ensures the full vibrations from the motor are not transferred to the chassis. These kind of suspensions can be very simple. Sometimes ordinary rubber rings are used, which are easily exchangeable when they get brittle.

Obviously there is no direct coupling between motor and platter, so accordingly some simple belt-drive designs have dynamics that are somewhat restrained.

Dynamics with a belt-drive turntable can be improved, however, with a high platter mass that approximates the greater weight of cutting-lathe platters. As mentioned before, the best way to prevent braking torque is the flywheel effect of a heavy platter. Since synchronous motors have issues starting up heavy masses, there are special motors for these designs which start up with asynchronous mode and switch to synchronous mode when they reach correct speed. These motors are still very common in belt-drive turntables. The downside is that they run fast, so the motor pulley is proportionately small and the result is increased slippage. Several parallel belts can be used to reduce slippage, but that reduces the damping of the cogging. A typical vicious circle.

As soon as the technology was advanced enough, electronically-controlled motors became more common. Here the motor control is matched with the platter mass and the flexibility of the belt to prevent an oscillating effect between motor and platter caused by the different time constants of belt flexibility and motor steps. These motors can run slow enough to work with a bigger motor pulley and consequently prevent slippage. Different platter speeds can be switched electronically, so no complex mechanical construction such as we saw with the rim-drive designs is needed.

This would describe the optimal belt-drive turntable design: a heavy platter to guarantee strong dynamic qualities, and a cogging- and vibration-free electronically-controlled motor to ensure a steady platter speed.

Some users prefer a non-flexible belt, e.g. from tape material, as better sounding. This allows for a more direct coupling between motor and platter and consequently improved dynamic attack.

Let’s return to the fact that with belt drives the braking-torque impact on the platter is unavoidable, which means the flexibility of the belt and the suspended motor can’t prevent it completely. The only useful countermeasure is the flywheel effect of the platter.

Experiments have shown that a platter mass of 20kg with at least 30cm diameter can compensate all braking torque down to 50Hz. Given of course that the music swells and subsides and no constant, strong braking torque slows the motor down.

This can be explained using the discharge of a capacitor as an analogy. Connecting a resistor, the capacitor discharges in relation to the amount of resistance used. A larger capacitor (like a heavier platter) stores the charge longer than a small one.

An electronically-controlled motor can compensate for small speed variations and prevent problems with oscillation through the flexible belt.

Belt-drive turntables work with low distortion and stable dynamics, but still use two bearings, one (platter bearing) turning slow and the other one (motor bearing) turning fast. The motor bearing needs to be highest possible quality to prevent audible noise.

Direct Drive

For a while, direct drives, in which tight motor regulation is used to reduce wow and flutter, were popular and almost achieved a commanding position in the market.

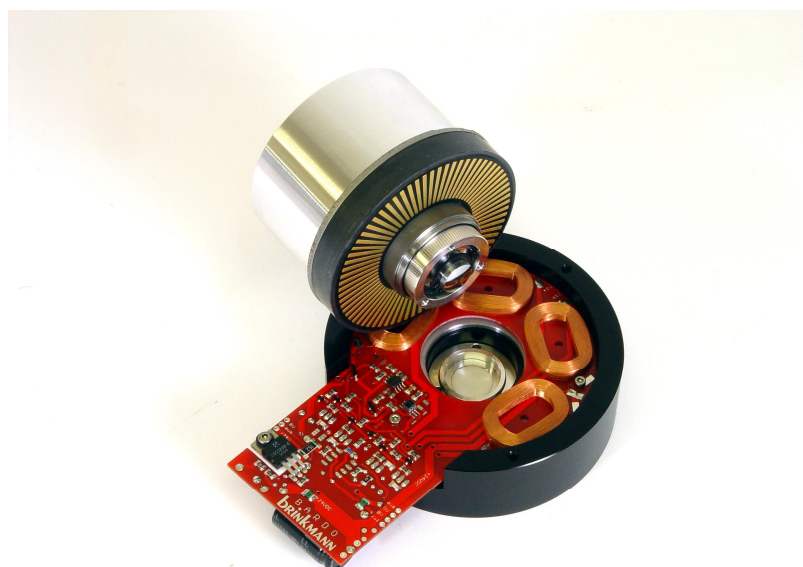
The direct-drive mechanism is basically built into the bearing of the platter; the motor bearing and platter bearing are the same and consequently direct-drive designs don't require a belt or intermediate wheel. These motors need to run at very slow and very stable speeds – 33 or 45 RPM – to drive the platter. The position of the motor inside and the main platter mass outside are ideal to compensate for any speed variations of the motor.

Strong synchronous motors and light platters are often used to electronically reduce wow and flutter to very low numbers. Tight electronic regulation measures the speed at every single step of the motor and readjusts the speed instantly. This way, the strong motor “forces” the light platter to a stable speed. With this drive mechanism, braking torque induced by tracking or low-quality bearings can't influence the platter speed.

Observationally it's obvious that direct drives represent a change from a purely mechanical turntable to a more electronic design concept. The more expensive mechanical aspects are reduced to an absolute minimum and all accompanying problems are solved electronically.

Unfortunately, too often this results in a discordant, jagged sound, as the constant motor regulation is clearly audible. There is continuous change in the mode of operation as the motor either accelerates against a slowing force or slows against an accelerating force. These disturbances are minimal, and therefore direct drives produce good measured wow and flutter numbers. But these distortions are clearly perceptible to the human ear. It is these constant speed regulations, which cause the jagged sound that eventually resulted in the failure of the direct-drive concept in the high-end market.

However, a better direct-drive concept is to use a heavier platter and a softer motor regulation to just



stabilize the overall speed. The major part of the braking torque is being compensated for by the platter mass and the flywheel effect. The motor only needs to maintain the correct speed and therefore doesn't need tight regulation.

The big advantages of the direct drive are the elimination of fast-running bearings and noise from rubber wheels, in addition to the fact that the revolutions are very slow. With 33 RPM, the bearing performs approx. one revolution every two seconds. Any noise coming from the bearing is at a very low frequency, below the audible spectrum, and soft magnetic fields ensure speed stability.

However, this is also representative of the technical "problem" of the direct drive: the power transferred to the platter by the motor is minimal. Similar to the flexible rubber belt used in belt drives, the magnetic field is "soft," so the transferred force is not very strong. This requires a high-mass platter to compensate for the braking torque. The motor needs to supply a high start-up power to get the heavy platter up to speed against the flywheel effect. Once running, there is next to no power required for speed stability, but the regulation still needs to be accurate which is not always the case with strong motors. This requires precise electronic regulation, adjusted for the greatest accuracy.

Conclusion

All turntable drive concepts can supply high-fidelity sound when the design and construction are carefully thought through.

The weak points of the rim drive are the distortion elements caused by the bearing and the rubber wheel. Vibration-free motors, electronically adjustable speed and careful execution can compensate for most of that.

The belt drive provides excellent results when a high-mass platter is used to compensate for the weak coupling between motor and platter. The fast-running motor pinion and the belt can cause instability, which must be addressed by using an electronically controlled motor that is free of cogging and vibration to ensure steady platter speed and very high-quality, low-noise bearings for the platter and motor.

Direct drives cause the least distortion because all motor regulation happens very slowly. High performance is achieved with direct drives so long as the platter mass is high enough and the electronic speed regulation accurate enough. If these requirements are met the direct drive in many respects comes closest to the ideal of a platter that simply turns by itself.