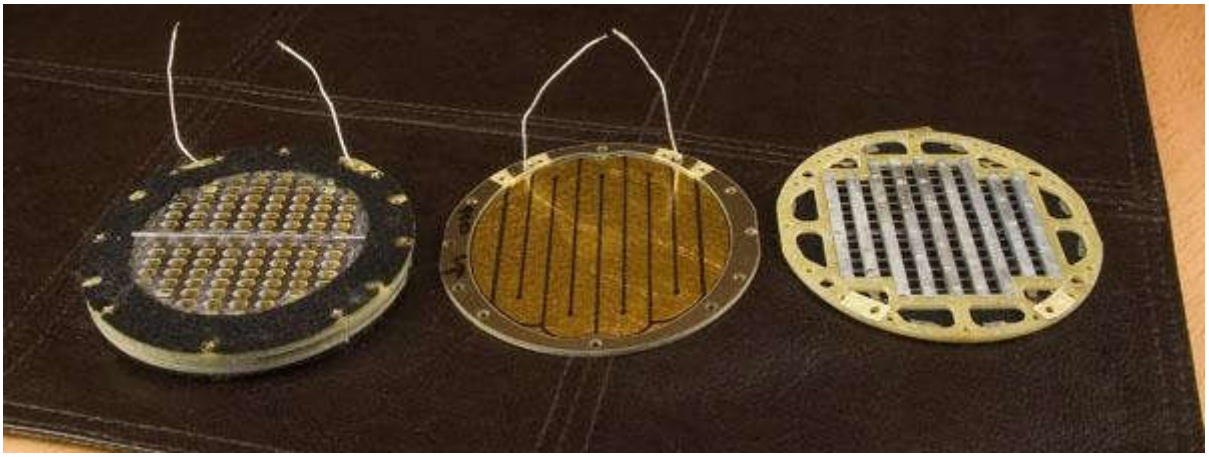
HEADPHONE 101

How Planar Magnetic Headphone Drivers Work

By Tyll Hertsens • Posted: Oct 6, 2014



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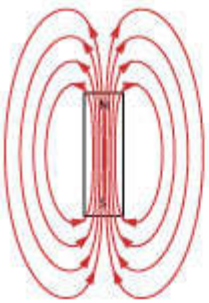
Like dynamic headphone drivers, planar magnetic headphone drivers use the electromagnetic interaction of a conductor with an audio signal on it immersed in the magnetic field of permanent magnets. But in this case, the conductors are not in a voice coil, but rather attached to the surface of a thin film diaphragm.

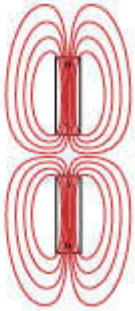
Planar-magnetic headphones have experienced a resurgence in popularity since about 2009 with offerings from companies like HiFiMANand Audeze initially, and later Mr. Speakers, OPPO digital, Abyss, Fostex, and others. But planar magnetic drivers in both headphones and speakers have been around for a long time.

Many will be aware of Magnepan and their speakers, for which they've coined and registered the name "Magneplanar" referring to their planar magnetic operating principle. Most won't know, however, that Yamaha similarly branded their planar magnetic headphones as "Orthodynamic" headphones, with a U.S. introduction in 1976. Just like with planar magnetic speakers, Yamaha's Orthodynamic headphones (and those by Fostex, MB Quart, and others) never gathered a wide following, but both have gathered cults of rabid fans...with good reason, as it turns out.

Terminology!

The correct term to refer to this type of headphone is *planar magnetic*. Unfortunately, all of Headphonedom calls them *Orthodynamic*, a Yamaha marketing term. Well, I call a facial tissue a Kleenex, so no big deal I suppose, but it's not technically correct. Likewise *Magneplanar* (not often used) is a registered mark of Magnepan.





force," and refers to the zones of evenly distributed magnetic force in the driver within which the electrical conductors are immersed. Isodynamic magnetic systems exist in numerous types of devices. For example, isodynamic separators can sort streams of powders of mixed materials having differing magnetic permeability.

So, in the world of headphones, Orthodynamic, isodynamic, and planar magnetic all mean the same thing. I'll probably use them somewhat interchangeably here to be sure people Googling for the terms will find the info...but planar magnetic is the correct term.

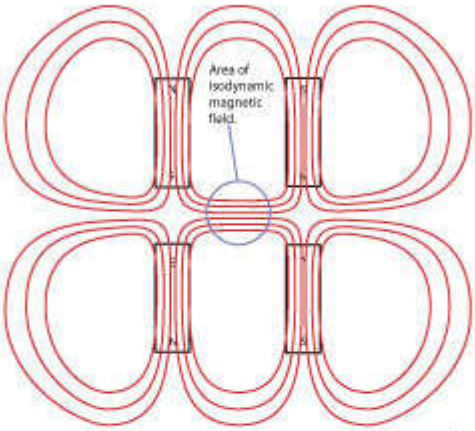
The Planar Magnetic Operating Principle

You can think of planar magnetic drivers as a sort of cross-breed between dynamic and electrostatic drivers. Like a standard dynamic headphone, planar magnetic headphones use the magnetic field around a conductor that has electrical current flowing through it to drive the diaphragm. Like an electrostatic driver, the diaphragm of a planar magnetic speaker is a thin sheet of flexible transparent film, but unlike an electrostat, the film has very thin, flat electrical conductors (wires ... but very flat ones) in it.

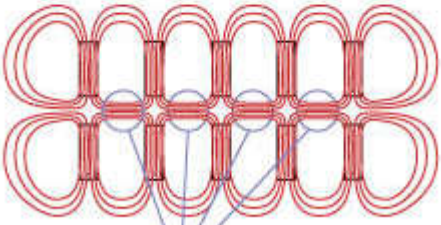
An array of magnets is placed in front of and behind the diaphragm such that the conductors are immersed in a very even field of magnetic flux (isodynamic magnetic field). When current is passed through the conductors, the magnetic field created by the current flow interacts with the isodynamic field created by permanent magnets, causing the conductors, and therefore the diaphragm, to move. The importance of the isodynamic field is to ensure that the relationship of current flow to force exerted on the diaphragm is constant regardless of the position of the conductor in its excursions through the field. The quality of the isodynamic field partly determines the linearity, and therefore contributes to the harmonic distortion content of the reproduced sound.

Other Magnetic Circuit Topologies

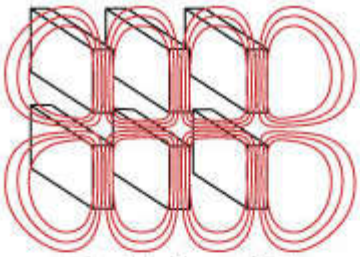
together.



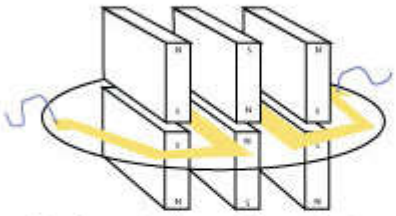
Proper magnet geometry creates an area of evenly distributed force: an isodynamic field.



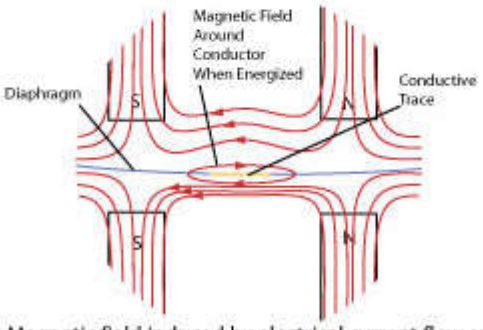
Arrays of magnets form multiple regions of isodynamic magnetic field.



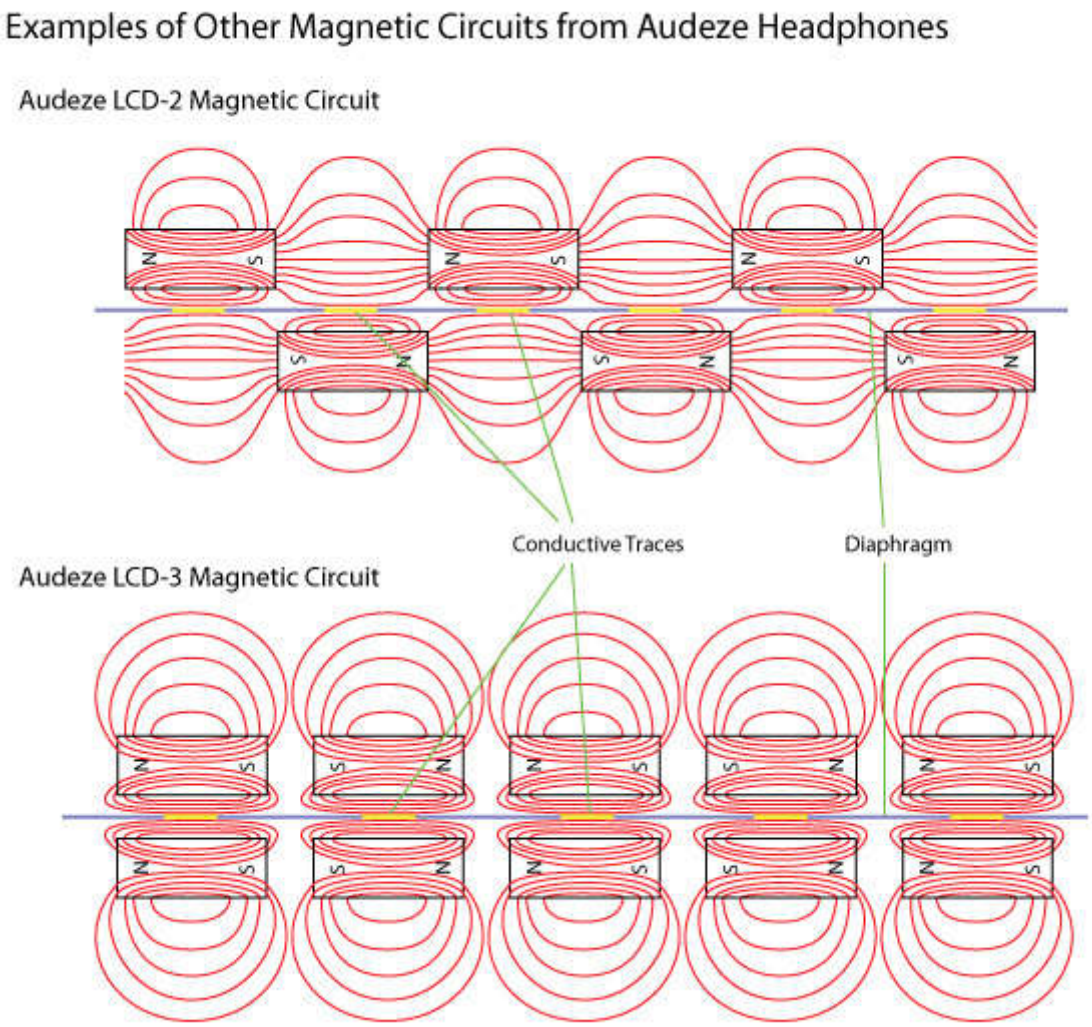
Extend isodynamic fields with long bar magnets



Diaphragm in place with conductive trace (yellow) immersed in areas of isodynamic field.

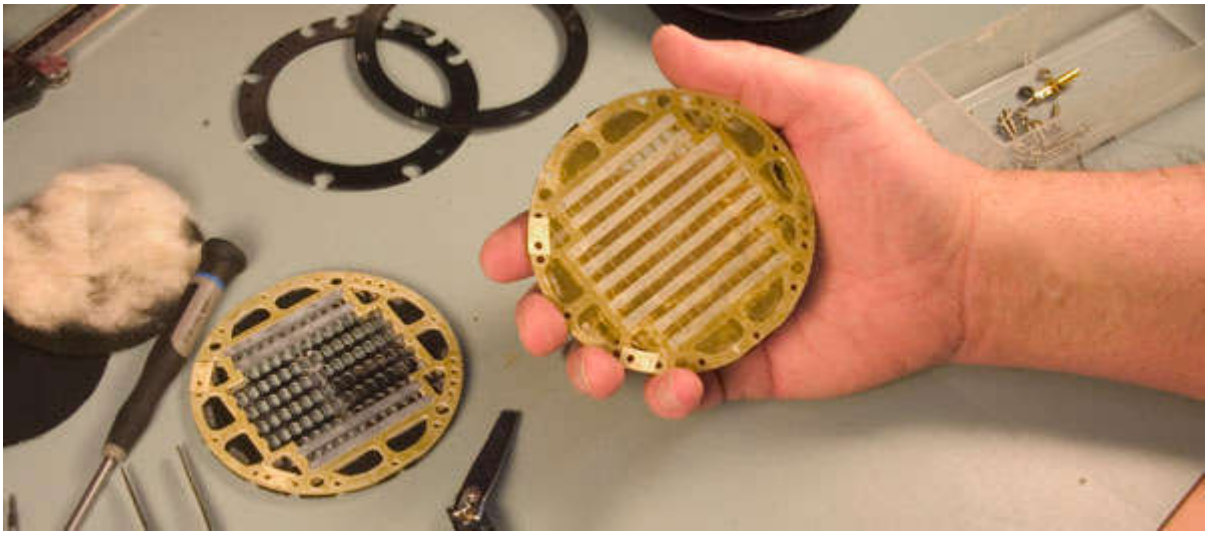


Magnetic field induced by electrical current flow around conductive trace pushes diaphragm away where magnetic flux arrows are opposed; pulls where arrows align.



Engineers are pretty good at finding a variety of solutions to a probem, so there are also numerous other configurations of magnetic circuits in planar-magnetic headphones.

The first diagram on the page shows how some of the older HiFiMAN headphones are configured; the diagram immediately above shows two alternatives that are used in the Audeze LCD-2 and LCD-3 headphones. In addition a number of planar-magnetic headphones use single-sided magnetic structures in order to reduce reflections around the diaphragm and reduce the weight of the headphones. Single-sided designs are used in the JPS Labs Abyss AB-1266 and HiFiMAN HE-560 and HE-400.



Advantages of Planar Magnetic Drivers There are so many advantages to this type of driver in a headphone that I'm surprised it hasn't caught on more. Let's work our way down the list.

Planar Sound Wavefront --- In my opinion, this may be the most important characteristic advantage of Orthodynamic headphones. Standard dynamic drivers are fairly small and

essentially operate as a point source of sound radiating a spherical section wavefront. When a spherical wavefront hits your ears it reflects on the outer ear in a geometrically different way than a planar wavefront. This causes the focusing of sound entering your ear to behave somewhat differently than it would normally. It is surmised that this disturbance of the reflective characteristics of your ear may inhibit normal localization of sound, and therefore disturb the audio image heard.

Headphones like the Stax electrostatics, AKG K1000 earspeakers, and Sennheiser HD 800 with it's large ring-radiator, are known for their excellent audio imaging likely due to the more planar wavefront they present the ear. I find the imaging (such as it is on headphones) to be quite good on the latest crop of planar magnetic headphones, though possibly not quite as good as those mentioned above.

It seems to me generally that getting the sound out of the large magnetic structure is problematic and causes some additional features in the time domain response of the headphones (additional second peak on the 300Hz square wave, for example). Good examples of attempts to mitigate this problem include the Audeze Fazor and single-sided magnetic structure designs like that found in the Abyss AB-1266.

Low Distortion --- Unlike dynamic drivers that are driven from the point at which the voice coil is attached (usually near the center), planar magnetic drivers are forced to move over their entire surface. This means they don't suffer from modal break-up found on traditional drivers when the cone surface starts wobbling in undesirable ways at higher frequencies.

Large and Powerful Diaphragm --- Getting powerful, tight bass response is difficult for most dynamic headphones as the driver surface area is relatively small and would have to make large excursions to move the volume of air that good bass response requires. The force used in electrostatic drivers (the static force the makes your socks cling together out of the drier) is relatively weak compared to the electro-magnetic force in planar magnetic drivers. Electrostatic drivers have trouble delivering the horsepower needed for big bass notes. The large surface area of the planar magnetic driver coupled with the powerful drive of the electromagnetic force permits large amounts of air to be moved with authority. My experience with planar magnetic cans is that they offer the best bass response of any type of headphone.

Responsiveness --- The diaphragm in an Orthodynamic headphone is very light, and the electromagnetic force is very strong, so the ability for the signal to accelerate the diaphragm is very, very good. Like electrostatic speakers, planar magnetic headphones tend to sound very coherent.

Easy on the Amplifier --- Unlike the coiled winding of a dynamic driver, which creates inductive peaks in the impedance characteristics of the headphone, current planar magnetic headphones use a serpentine pattern for their voice coil, which makes their impedance characteristics almost purely resistive. Though they sometimes need quite a bit of voltage to drive them, they are not difficult loads to drive at all.

The Disadvantages of Planar Magnetic Headphones

Damping --- With electostatic drivers, the charge carrying stators on either side of the diaphragm can be very thin and sonically transparent. Planar magnetic driver diaphragms are surrounded on either side by relatively large structures. The magnets are fairly large, and the opposing force they exert on each other is significant, so sturdy metal structures hold the magnets in place. There is a significant amount of trapped air in volumes of various sizes that must be moved before sound is radiated out of the driver. The springiness and resonances that may exist in this trapped air volume can cause problems. Quite a bit of the design effort with planar magnetic headphones seems to be spent on getting just the right damping. The vintage Orthodynamic headphone scene is filled with various damping modifications done by enthusiasts.

Weight --- As really cool as neodymium magnets are, they're still heavy. The weight and size of a planar magnetic headphone driver makes these headphones potentially uncomfortable.

Summary

Planar-magnetic headphones use a thin diaphragm with electrically conductive traces on it immersed in a magnetic field. Some claim that because of the large, thin diaphragm, sound wave approach your ears with a flatter wavefront more similar to the arrival of real sound than dynamic driver headphones.

Planar-magnetic headphones tend to have powerful bass punch, and tend to be somewhat immune to driver break-up. Though they sometimes need a relatively high voltage to drive them, planar-magnetic cans usually have a very flat impedance response and will generally deliver consistant tonal characteristics on a variety of amplifiers.

On the other hand, planar-magnetic headphones tend to be heavy due to their bulky magnetic structure, and sonic performance can be difficult to achieve due to interference from the large magnets.

Resources

A very well written introduction to the technology from planar magnetic speaker maker Wisdom Audio.
A great source for information on rare headphones including the Yamaha Orthodynamic line is Wikiphonia.
Home pages for planar magnetic headphone makers HiFiMAN, Audeze, Mr. Speakers, OPPO digital, Abyss, and Fostex.