Afterword 14
Bridge-based phono preamplifier

Introduction

When a phonograph record is played, the movements of the stylus are communicated via the cantilever to move a coil and a magnet relative to one another, thereby generating a small electric current in the coil according to Faraday's law. Either the cantilever moves a small magnet near a large coil, in which case the cartridge is termed a *moving-magnet* type: or very small coils are contrived to move in a powerful magnetic field, in which case the cartridge is called a *moving-coil* type. Most vinyl-record enthusiasts share a belief – enthusiastically underwritten by cartridge manufacturers – that the more expensive, and more profitable, moving-coil type cartridges outperform the moving-magnet type. This is a simplification bordering on misrepresentation.

It is easy to demonstrate that the electrical characteristics of the moving-magnet cartridge set a lower bound on noise and variability of frequency and phase response due to the internal impedance of the electrical generator interacting with the reactance of the cables and preamplifier (see chapter four). The moving-coil cartridge is unarguably the better electrical generator. This type is less affected by interface impedances.

But, as explained back in chapter four of the **Needle-drop Handbook**, the performance of any phonograph cartridge ultimately relies on the stylus' ability to remain in contact with the walls of the groove, which is referred to as the cartridge's ability to *track the groove*. The greater part of this accomplishment lies in the design of the moving part of the cartridge which must be made as light as possible – especially its inertial effect at the stylus point. Good tracking performance is a prerequisite, not only for good reproduction, but for the responsible care of records too, because the result of poor tracking is, not only information loss, but quite possibly, permanent damage to the medium.

Vinylistas' dilemma

The vinylista is faced with a dilemma because the moving-coil cartridge type, with its better electrical performance, does not offer superior tracking performance due to the typically greater mass of the moving armature. To support this assertion, we gave the results of our own tests and the study of the data from *Hi-Fi World* magazine technical reviews in chapter four, which confirmed that moving-coil cartridges do not (generally) outperform moving-magnet types in terms of tracking. Serious archivists have known for many years the moving-magnet cartridge type is superior in terms of its tracking ability.[1]

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[1] Shure Brothers Inc. made an unparalleled contribution to the understanding of the importance of tracking ability (see chapter 4). The sound archivists for the American Library of Congress considered

PHLUX active cartridges

Pspatial Audio and our partners Phædrus Audio developed the active **PHLUX** cartridges to address the electrical limitations of the moving-magnet cartridge, which we can catalogue as:

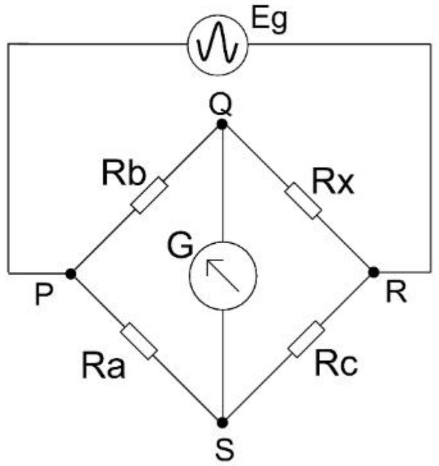
- Frequency response distortion due to the uncontrolled cable impedance
- Electronic noise in the high impedance interface
- Limited bandwidth
- Left-right crosstalk in the tiny, unscreened cables in the tonearm

The design of these cartridges is fully covered in chapter four of the **Needle-drop Handbook**.

The **PHLUX** cartridges address these problems very successfully. But some customers asked us for a solution so that they could use existing (non-active) moving-magnet cartridges – especially those historical models known and admired for archive work.

For those customers, we developed the bridge-based preamplifier.[2] The technique secures all the advantages of the **PHLUX** cartridges without active electronics in the cartridge or headshell. The commercial bridge-based preamplifier compensates for all the electrical shortcomings of the standard moving-magnet arrangement. This afterword outlines the operating principle of this new preamplifier design.

Wheatstone's bridge



In about 1843, Sir Charles Wheatstone designed a circuit called a *bridge* which gave an accurate method for measuring *resistance*. The circuit is given left. In this circuit, resistors ***Ra, Rb, Rc,*** are all known values. ***Rx*** is the unknown resistance.

The full explanation of this circuit is in almost every textbook on electricity, so we won't repeat that here. The important feature to appreciate is that when the bridge is said to be *balanced*, current through the galvanometer ***G*** falls to zero, which occurs in the condition,

$$Ra / Rb = Rc / Rx$$

At the time, this relation was important because from this it was possible to deduce the resistance of ***Rx*** according to the formula,

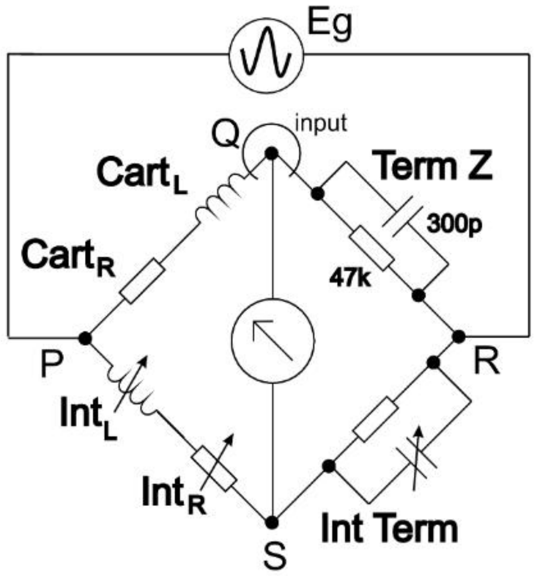
$$Rx = (Rb / Ra) \times Rc$$

the tracking performance of Shure's V15 moving-magnet cartridge so highly that they purchased all remaining stock of the V15 line from Shure in 2009.

[2] Phædrus Audio refer to this as their *active interface* preamplifier, the **PHLUX-AI**.

Maxwell's bridge

Maxwell's bridge is a development of the Wheatstone bridge, named after James Clerk Maxwell, who first described it in 1873. Maxwell's bridge extends the use of Wheatstone's bridge to measure reactive (not simply resistive) circuit elements.[3] An example is illustrated below. This bridge circuit relates directly to the application in which a moving-magnet electrodynamic phono pickup is driving a conventional high-impedance (47kΩ) preamplifier input.



$Cart_R$ and ***$Cart_L$*** represent the resistive and inductive components of the cartridge generator impedance which together we call **$Cart_Z$.** The termination impedance (***$Term_Z$***) is made up of the resistance (typically 47kΩ) in shunt with the cable capacitance – here shown as 300pF, a typical figure. Note that point ***Q*** is the coäxial cable input to the preamplifier. Just like the Wheatstone bridge, provided the impedances ***$Cart_Z$*** and ***Int_{Term}*** are balanced with respect to the external impedances, the galvanometer will indicate zero current.

Now, this is of little use practically because point ***P*** doesn't exist in reality. The generator voltage ***Eg*** is developed across ***$Cart_Z$*** and is not independent. And, even if it was, there would be no way to access point ***P***. Nevertheless, the Maxwell bridge indicates the concept that – provided we balance the impedances of the cartridge and the cable, it ought to be possible to recover the "pure" generator EMF (***Eg***).

"Take it to the Bridge"

In the case of the **PHLUX** active cartridges, recovering ***Eg*** is accomplished by the "belt-and-braces" technique of buffering the generator signal, thereby eliminating the effects of the cartridge impedance, the cable, and their mutual interaction.

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[3] It is often said that Maxwell's bridge is for the measurement of *inductance* and that was indeed Maxwell's original intention. However, it may be said to be a bridge of general reactance – capacitive as well as inductive.

The necessary step in realising a practical preamplifier which avoids the need for active electronics in (or very near) the cartridge involves an appreciation that, when the bridge is balanced, point ***S*** and point ***Q*** are at the same potential. They must be for there to be no current through the galvanometer.

Now consider the following circuit in which a high-gain operational amplifier has its two inputs connected to points ***Q*** and ***S***: the non-inverting input fed from point ***Q***, and the inverting input from point ***S***.