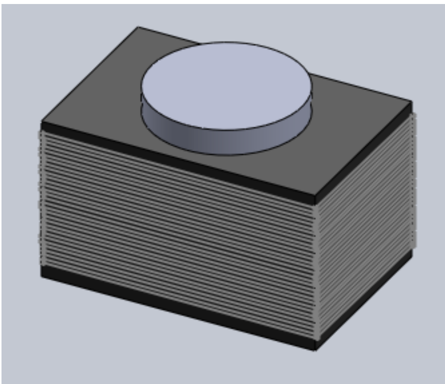
Geometry of the Pickup

Three different geometries for the pickup were considered. Initially a cylinder, then an elliptical cylinder, and now the current theory is a rectangular block. This solution was arrived at with the goal of increasing the isolation of the pickup to target string above it. The idea is to maximize the proportion of the cross sectional area of the pickup underneath the target string, keeping it further away from the pickups on adjacent strings, while also keeping the area of the inductive coil large enough to obtain a sufficient signal. A circular cross section has the greatest area to perimeter ratio, but it would locate portions of the inductive area closer to adjacent strings. This would require the pickups on adjacent strings to be placed further apart. To allow 6 of these pickups to fit compactly on a single instrument, the inductive area should align with the length of the string. An elliptical or rectangular cross section accomplishes this.

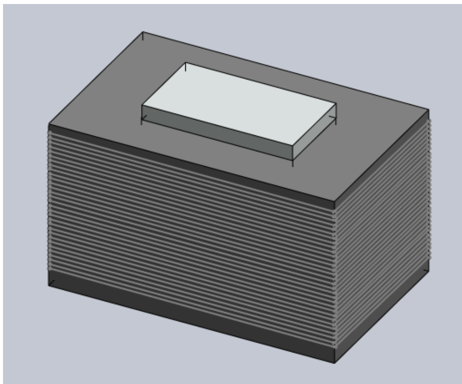
Geometry of the Magnet

A secondary consideration is the geometry of the magnet. Magnets are most commonly sold as either cylinders or blocks. A particularly shaped block magnet is predicted to be best suited to the design. Consider the cross section whose normal is the magnetization direction. The block magnet can be long in one dimension and short in the other, so that its cross section more closely matches the string immediately above it. Its long edge should be positioned parallel to the string, facilitating a greater ratio of the magnet's area placed under the string, and an overall greater induced dipole. Alternatively, a cylindrical magnet provides an advantage in that with block magnets, magnetic potential tends to accumulate on sharp edges and corners (this is a common phenomenon observed with electric potentials in other applications). While both shapes have a degree of sharpness to their outer edges, the cylinder does not have sharp corners, and so the magnetic field tends to be directed more upward from the outer face—directly to the string above it. With block magnets, especially those with non-square cross sections, the magnetic field tends to be stronger at the corners. It behaves less like an ideal dipole, so the string above it will experience a weaker magnetization force.

Note: the magnet's thickness (length in the magnetization direction) is the primary contributor to the strength of the magnet.



Rectangular Pickup with Cylindrical Magnet



Rectangular Pickup with Block Magnet

Components

Magnet

The magnet is a ¼” x $^1/_8$” x ¼” (6.5 x 3.25 x 6.5 mm) block of nickel-coated 42-grade NdFeB (neodymium). It is magnetized in the direction of one of the longer ¼ length dimensions. A neodymium magnet was chosen over an AlNiCo magnet because it generates a much stronger magnetic field at the small size needed for a single-string pickup. A cylindrically-shaped alternative is a ¼ ” dimeter ¼” thick (5.1 mm x 6.5 mm) nickel coated 42-grade NdFeB.

Magnetically Permeable Core

The core material is either a silicon-steel or ferrite with a high saturation point. The high saturation point is necessary so that the nearby placement of the magnet does not saturate the material so that its permeability drastically decreases. Otherwise, air would be preferred to fill the core. Silicon or “electrical” steel is often used in transformers because it is highly permeable, has high a saturation point, low hysteresis loss, and high resistivity (to reduce eddy currents). In transformers, it is rarely implemented as a single block, but instead layers of insulated sheets to increase the electrical resistance or the core. For the purposes of the pickup, these will not be needed. Electrical steel is often sold as “grain oriented”. This means that the grains are oriented in the rolling direction so that the microscopic dipoles more easily align with the assumed direction of the magnetic field[*]. Unless the rolling direction is already suited for the pickup, “non-grain oriented” would be preferred. The shape of the core is a 14mm x 8mm x 7mm block with a rectangular hole to fit the magnet. The corners of the block can be smoothed to better facilitate the winding of thin and delicate copper wire.

Air Core

A simpler alternative to a solid core is an air-filled core. This avoids the complication of avoiding saturation of the ferromagnetic core by the magnet. In this case, a thin wood or plastic frame can be designed for the wire to wrap around. The magnet would be attached to a wood or plastic base plate.

Insulated Wire

42 gauge insulated copper (“magnet wire”) is wound around the core, acting as a high-inductance high-capacitance antenna. Several hundred turns may be necessary to generate a sufficient voltage.

Magnetic Shielding

The shielding is a rectangular case (matching the pickup geometry) of thin mu-metal or permalloy. Both are nickel-iron alloys, near 20% nickel and 80% iron composition. The process of annealing and manufacturing magnetic shielding materials, especially permalloy, contributes to its high cost. Mu-metal is cheaper and more malleable than permalloy, but has much lower permability and is therefore not as effective at shielding. Note the confusion of words here: permeable is usually used to indicate that something can pass through. In the case of magnetic fields, a permeable material “directs” the magnetic field through the body of the specimen, so a permeable case directs magnetic field (coming from the sides of the pickup) through the inside of the case, around the interior. The shield does not block communication with the target string because it is open at the top. It is also open at the bottom to allow for wiring to the exterior.