The WoodBug: A Semiautomatic Morse Key

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Abstract

A new semiautomatic Morse key has been fabricated almost entirely of wood. Its primary design feature is a very low inertia mechanism that permits exceptionally sensitive operation similar to high-performance iambic paddles. Magnets, used in attraction mode, are used in lieu of springs and provide crisp action. Lever force adjustments are made via a novel rotary adjuster. A magnetic reed switch is the dot contact, and dot weighting is precisely adjustable while operating. No lock nuts are used for any adjustments; 56 TPI threads with an interference fit provide high-resolution positioning and are vibration resistant. Overall form factor is a compact 6 by 3 by 1.8 inches and it weighs 2.0 lb.

Introduction

Semiautomatic Morse keys, otherwise known as speed keys or bugs, have been useful tools for telegraphers for over 100 years and are still popular among amateur radio operators. A few commercial manufacturers still exist, but more interestingly, numerous home craftsman are still innovating in this area (e.g. WB9LPU, WA9TGT), creating novel and beautiful bugs. I am a member of the latter category.

One thing all these designs have in common is that they are made entirely of metal—most commonly brass—though the base is sometimes made from other materials. For some reason, wood has been overlooked. Being an experienced woodworker and having previously built a Morse hand key that worked out well (Figure 1), this felt like an opportunity to me. I started experimenting with various bug components and doing some engineering calculations and soon realized that a wooden semiautomatic key was not only feasible, but may offer some advantages over conventional metal construction. This report will cover the background and construction details of my *WoodBug*.

Figure 1. Morse hand key, made by the author in 2008. Cocbolo.

Bugs are like musical instruments in that they are subject to much personal preference regarding their mystical “feel” as well as overall performance, reliability, ease of adjustment, and aesthetics. My goal in this project was to design a bug with lower inertia and the possibility of a lighter touch that more closely emulates state-of-the art iambic paddles. Also, I wanted to simplify some of the adjustments, in particular eliminating locknuts and also improving adjustment resolution.

Why Wood?

Wood is among the oldest engineering material but is too often overlooked outside its common applications such as construction and furniture. Like many natural substances, it has some exceptional properties and is of course beautiful, but does require care in selection due to variations among species and even within a single sample.

An old saying is, “pound for pound, wood is stronger than metal.” Table 1 shows that wood is certainly competitive, at least in one parameter: Specific stiffness, which is the ratio of the modulus of elasticity to mass. This parameter is of particular interest in a mechanical structure where we seek a compact, light, yet stiff assembly. If a very stiff structure is desired, one can also adjust the dimensions to optimize section modulus, perhaps in a particular direction. Where low mass is needed but without high strength, you can turn to much lower-density species such as Balsa and Basswood.

Table 1. Properties of Selected Species of Wood and Some Metals

Material	Modulus of Elasticity, MPa	Density, g/cc	Specific Stiffness
Steel (1050)	210	7.85	26.7
Brass (C36000)	97	8.5	11.4
Aluminum (6061-T6)	70	2.7	25.9
Maple, Sugar	12.6	0.67	18.7
Cocobolo	19	1.1	17.3
Ebony, Gabon	17	0.96	17.7

Wood is highly machinable and tool life is very long except with certain exotic species that may contain mineral deposits. Holding tolerances better than 1 mil is not a problem especially in dense, diffuse-porous species.

The main problem with wood is its expansion across the grain in response to humidity, which can be significant. This will be the major source of "drift" in a precision instrument such as a bug. Temperature coefficient of expansion is not much of a concern, especially in small assemblies. Long-term warping of larger pieces, for instance the base of the bug, could also affect alignment to some degree, but this is a very slow process.

Tooling for Wood

If you are a more of a machinist than a woodworker, treat wood like plastic. Use high positive rake, very sharp HSS cutters, 2-flute endmills, and high surface speeds. Saws of all types are great for roughing; slitting saws work great and last forever. Files are very effective for detailing and breaking sharp corners. Precision holes can be reamed, holding tolerances of a few tenths of a mil without problem. Don't worry too much about the dust on the ways of machine tools; it's not abrasive and simply wipes away. Infinitely better than machining cast iron!

If you are a skilled woodworker and wish to build something on the scale of this WoodBug and with suitable precision, it may be difficult to do so without access to a lathe and mill. That being said, most of the special operations can probably be done with nothing more than a drill press and a few special cutters. For instance, the finest X-Acto razor saw works just about as well as a slitting saw, and leaves a kerf around .013 inches. Very careful layout, knife-marking, and centering of holes is mandatory.

Development Process

Many experiments were performed on candidate materials, components, and fabrication methods over the four-month duration of this project. These elements were integrated into mechanical testbeds so that I could do some operational evaluations. For once, the term *breadboard* may be used literally!

Cocobolo was chosen as the primary timber due to its density, high strength, good machinability, and spectacular grain. The weight arm is ebony, which is extremely hard and smooth. The fingerpiece is carved from basswood to reduce weight in this large component. I shaped it to fit my particular finger position, matching height and spacing of my favorite paddle. Final finish is Watco oil and wax, except for the fingerpiece which is black enamel.

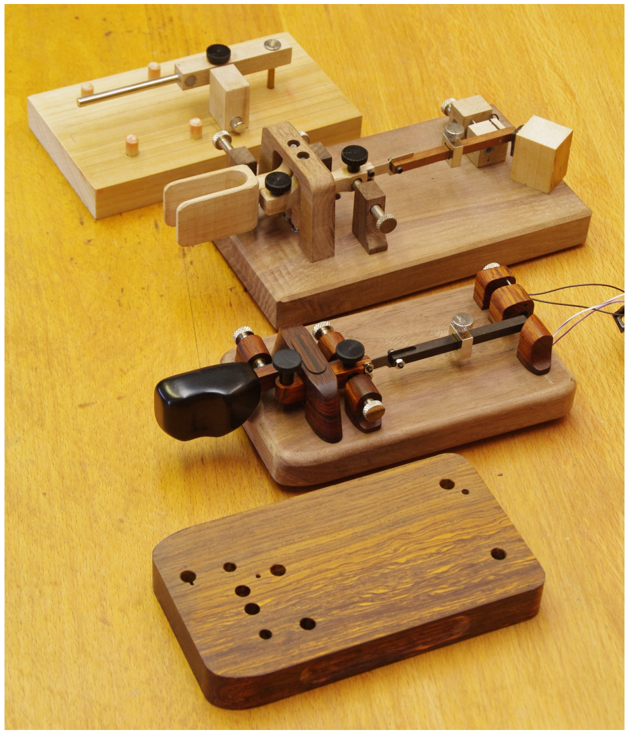

Figure 2. Development proceeded from breadboards to the final article

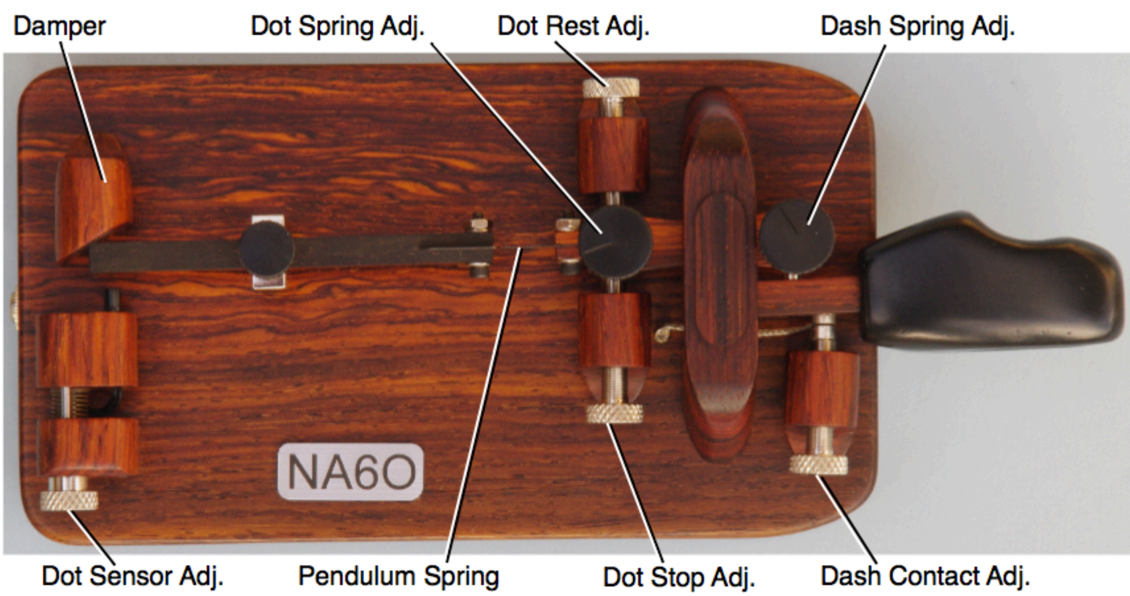

Figure 3. Top view of the Woodbug showing its main features.

Magnetic Force Adjusters

Instead of springs, this bug uses magnets in attraction mode to provide return forces on the dash and dot levers. One of the novel mechanisms in the Woodbug is a rotatable magnet assembly that allows you to vary the force without the need for linear displacement of one of the magnets

(Figure 4). The assembly is very compact and quite sensitive. I chose to use attraction rather than repulsion because it yields a “snappy” feel when actuated.

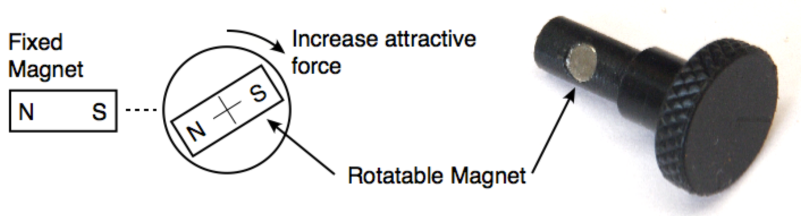

Figure 4. A rotatable magnet allows adjustment of return force.

Dot Sensor

A magnetic reed switch (Meder Standex MK 20/1-B-100W) is located at the end of the pendulum arm and is triggered by a magnet in the end of the arm, thus generating dot closures when the pendulum oscillates. For operator convenience, the sensor is mounted on a linear slide mechanism with an adjusting screw (Figure 5). While generating a string of dots, duty cycle can easily be adjusted.

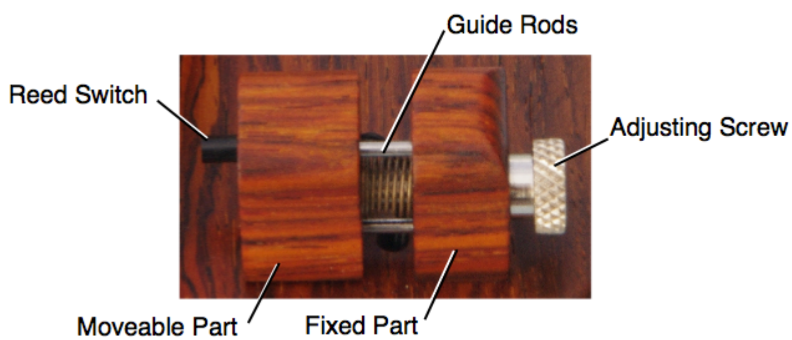

Figure 5. Dot sensor adjustment mechanism. The entire assembly is about 1.25 inches long.

Adjustment Screws

I have always noted that classic bugs use overly-coarse threads for sensitive adjustments, and I’m mildly annoyed by the need for a second hand to tighten the locknuts. In the Woodbug, extra-fine pitch threads (#10-56) are tapped in Delrin inserts that are then pressed into wooden mounts. Thumbscrews are machined from brass (later nickel plated) and threaded with a #10-56 adjustable die that is oversized to guarantee an interference fit. This provides high drag, a long service life, and no need for lock nuts.

For the fixed dash contact, a hybrid insert, split into Delrin and brass portions, is pressed into the mount. A wire is then soldered to the brass part. All contacts are machined from Sterling silver and diamond-polished to 1 micron.

Pendulum

The Woodbug uses a conventional horizontal pendulum with a spring-steel spring. To minimize total system inertia, a very limber spring was chosen, made of 8-mil feeler gage stock. The weight arm is made of Gabon ebony, and the brass weight weighs only 6 grams. Speed adjustment range is 18 to 40 WPM.

Damper

Quite a bit of experimentation went into the damper, whose purpose it is to quickly stop motion of the pendulum upon release of the lever. With the very small amount of kinetic energy in the Woodbug, this is not a trivial task. A conventional bug's damper, which operates by momentum transfer to a weight and then dissipation via friction, was scaled down and tested with various geometries and materials but was never satisfactory. Then, various compliant materials were tested with mixed results. Ultimately, a low-durometer polyurethane was selected and mounted at an angle so as to maximize point-loading on its surface (Figure 6). Slow-motion movies, taken on a smart phone (Try it! Works great!) showed that all motion stops after just one reduced-amplitude cycle.

Figure 6. Closeup of the damper, with its soft polymer material mounted at an angle so as to maximize point force.

Bearings

Double-shielded precision ball bearings support the main pendulum and the dash arm, with one bearing above and another below. Nearly all bug and key craftsmen have switched to these modern bearings, thus avoiding the adjustment, wear, and damage problems of traditional bugs.

Keeping it Put

Weight of the Cocobolo base alone is insufficient for vigorous use, so I cast a block of lead which is set into the bottom of the base. Another discovery was that selection of material for the feet is more critical than I imagined. A very low durometer rubber (e.g., 3M Bumpons) were my first choice in that they are very sticky. But that compound is overly-compliant, and the entire bug acts like it's sitting in a bowl of Jell-O! After some more experiments, a much stiffer rubber sheet material was selected (butyl rubber diaphragm sheet), cut into thin disks, and glued into place.

Performance

Here are my operational impressions of the Woodbug. The primary goal of low inertia and high sensitivity was clearly met. I found that I could send dashes somewhat faster on this bug though I'm still in need of more practice getting used to it. Operating forces can be adjusted to a very low level, though you can also set the spacings very wide and return forces quite high to emulate a conventional bug. While your first impression is that of a delicate device, it turns out you can really slam it around if you are old-school. Magnetic return action is positive and snappy. The dash contact is very solid. The wooden fingerpiece never feels cold. The bug weighs enough to prevent any walking about. Adjustments have a silky feel to them and I do not miss those locknuts at all!

A drawback of magnetic sensing for dots is that it seems more likely that you may produce a short dit, as compared with conventional spring-mounted dot contacts. It takes practice to overcome this tendency.

Adjusting the pendulum rest position against the damper is more critical than conventional bugs. In the quest for extreme sensitivity, it's also possible to adjust the throw on the pendulum to a small very distance (less than 8 mils). However, this is asking for trouble because damping may be unsuccessful, resulting in an extra partial dit no matter how hard you try.

Overall, I'm very happy with the final build and look forward to some quality air time. Wonder what I'll build next?