Iambic Key Paddles for a Mobile Radio Control Suite

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12/23/2016
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Introduction

As part of my mobile radio control project, I needed a set of keyer paddles - both to allow CW operation on the HF rig, and to allow command inputs to the system controller for the radios. I have a set of Bencher iambic paddles and am particularly fond of iambic operation. However, the Bencher is heavy and somewhat delicate. The car installation will affix the paddles to a particular location, so I didn't need a massive base. I also wanted something that was more forgiving of abuse. Finding nothing on the internet that was both affordable and suitable, I finally decided that I would have to build my own.

Nearly all CW keys are, at their heart, simply a means to make and break an electrical contact. However, the configuration and "feel" of these contacts takes on a greater significance than with most switches since each operator develops his or her own preferences as to travel (related to contact gap), tension, position, etc…. This complicates the design of these devices since the contact closure gap and tension need to be adjustable. The operation needs to be smooth as well, so that there are no "catches" or "glitches" with regard to the feel of the contact closure operation.

A traditional keyer paddle has one paddle arm with two contacts. Move the paddle one direction and you get a "dit" – move in the opposite direction and you get a "dah". Even though there are two contacts, there is only one moving part. An iambic key has double the overhead of a traditional keyer paddle since it requires two, separately articulated key switch closures, one for "dit" and another for "dah". The paddles are positioned so that they are adjacent and generally "appear" to be one paddle.

With an iambic keyer paddle, the traditional movements for "dit" and "dah" are the same, but there is an additional movement, the "squeeze", where both the "dit" and the "dah" contacts are closed at the same time. This causes a cadence of "dit-dah-dit-dah…" to be send by the keyer circuit for as long as the dual contact is maintained.

The choice of traditional electronic keyer, the mechanical "bug" keyer, or iambic keyer is generally a hot-button topic with some CW operators. For me, I learned iambic at an early age, having built one of the early Heathkit models, and so this is my mode of choice. Additionally, there are many subtleties to iambic operation. These are controlled by the keyer circuit and are not relevant to the mechanics of the iambic paddle, so these won't be discussed here. The focus of this presentation is the paddles themselves.

Simple, Simple, Simple…

Simple is usually better. I know this, but must sometimes take extraordinary steps to ensure that I follow the mantra. For this project, simple suggests many things: reduced cost, reduced fabrication time, increased robustness. There are those who have suggested that I use touch-sensitive technology to accomplish this task. While mechanically this would be incredibly simple (requiring no tensioning or other moving parts), I find the concept of touch-sensor-CW to be very difficult to warm up to. I am used to "feeling" the paddles as I send, and this is not possible with touch-sensor paddles (once you "feel" a paddle, you are sending). Thus, I am forced away from this particular brand of "simple".

As part of the mantra, I started with the simplest CW appliance: the straight key. For this application, I decided to turn the straight key on its side, and this formed one half of the iambic paddle. An identical piece would form the other half. I used 0.25" x 1" drawn-aluminum stock to cut the paddles and other aluminum pieces. While this material is a bit "soft and gummy" compared to some of the other machinable alloys of aluminum, it is easy to obtain at the local hardware store, and is also relatively inexpensive.

I decided to use the contacts salvaged from a 30-A thermal fuse (two of them) for the paddle side of the electrical contact. These are soldered to a small piece of FR-4 PCB material which is attached with epoxy to the paddle arm forming an insulated contact. The second half of the contact is a brass shoulder screw that is selectively plated with electrolysis silver. The base material is grounded, so the brass shoulder screw forms the ground side of the "dit" and "dah" contacts.

The "sideways" paddles each have a 1/8" axle made of stainless steel that passes vertically through the paddle. This axle is secured to the paddle with 2-56 setscrews. An upside-down, "U-shaped" structure secures the "top" of the axle, and the base secures the "bottom". *Note: The keyer paddles were designed to appear as most other paddles one might find on a typical HF bench and many of the photos of this project present them in this way (with the baseplate as the bottom). In actuality, they will be flipped over such that the entirety of the mechanism will be on the bottom of the baseplate. Hence, "top" and "bottom" are relative terms with respect to the final application.*

I originally wanted to use standard ball-bearings to secure the axles to the structure. However, to simplify the design and save some cost, I decided to use cup-point setscrews and then grind a matching point on to each end of the axles. This point would interface with the setscrew much like a lathe workpiece would interface to a dead-center for turning. The axle only turns a fraction of a degree, and I applied graphite powder to help lubricate the interface.

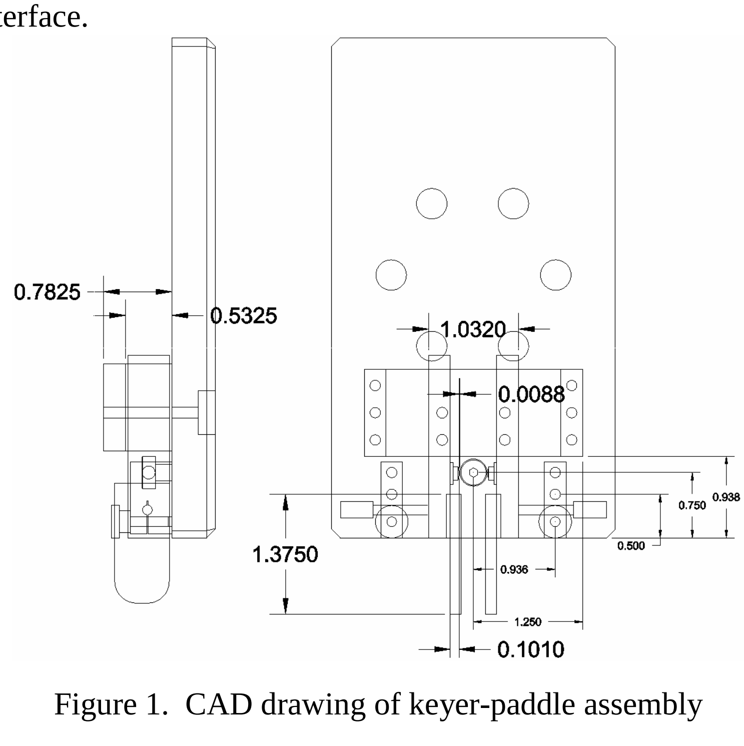


Figure 1. CAD drawing of keyer-paddle assembly

Figure 1 illustrates a CAD drawing of the design. This drawing does not adhere to strict drawing practices but is rather intended to model the parts needed for the design. Thus, hidden lines are not correctly shown. My bencher paddles provided some guidance on paddle spacing. The remaining dimensions were chosen to fit within the desired footprint. From the drawing in Figure 1 (drawn to scale), the different pieces were broken out and dimensioned. These pieces were then fabricated using milling and drill-press operations:

Baseplate (1), aluminum
Paddle arm (2), aluminum
Axle (2), stainless steel
Gap adjust block (2), aluminum
"Top" axle support (1), aluminum
Support riser (2), aluminum
Finger pad (2), lexan (polycarbonate)
Contact pad (2), FR-4 and Ag contact
Ground contact screw (1), Ag plated brass
Tensioning spring (2) (originally, one was to be used, but this was later changed)
Assorted screws, setscrews, nuts, and washers

The baseplate was fabricated from a piece of scrap that has already been machined to finish quality. Thus, this piece simply needed to be cut to width and trimmed before it was ready for the necessary machine steps.

The gap adjust block, risers, and top axle support came first, then the baseplate holes and c-bores (the opposite side of the baseplate needs to be free of screw-heads). The paddle arms and finger pads were last. Tapping operations were grouped into two or three mass-tapping sessions. Overall, it took about a week and a half, including two weekends, to get all of the basic pieces finished.

Under Pressure…

Originally, I chose to stretch a spring between the back-end of the two paddles to set the tension which would hold the electrical contacts open. Since this end was on the opposite side of the pivot point, the tension between the arms would force the arms open on the operator side and away from the ground contact. Pressure from the operator fingers would close the desired contact(s). However, the combination of spring choice and geometry resulted in much more force than was feasible.

I went back and re-examined my Bencher paddles. The main problem was that I didn't have a good idea about the quantification of the force required for a "properly" adjusted set of paddles. I knew what felt right, but I didn't know how to express that in terms of force or moment units. As it turns out, I also didn't really know how my bencher paddles worked. I'd looked at them a number of times, but just never tried to figure out what was going on with the tensioning assembly.

A while back, I decided to replace the spring on my Bencher paddle. The original had been over stretched, and was no longer symmetrical. I had difficulty finding a replacement until I stumbled upon some springs at the local hardware store. They were the correct diameter, but only half the length I needed. However, that meant I could string them in series to get nearly the exact length needed for the bencher paddle. An easy fix.

When I set out to re-design my tensioning scheme, I decided to use the same springs. As it turns out, this provided an interesting solution to my problem of force quantification. Because the springs were the same, I could analyze the bencher setup to determine the moment that would result from a given adjustment. This would be in terms of the spring-force constant times the spring displacement. Since the new springs on the Bencher were the same ones I would re-deploy for the new paddles, I could normalize out the spring-force constant when comparing the two systems. This resulted in a set of values for paddle moment that could be calculated from caliper measurements of the Bencher assembly, and then transferred to the new design.

Figure 2 illustrates a free-body diagram of a paddle-spring assembly. The moment (T) is calculated about the pivot point. Af is the arm of the finger pressure point and Ff is the finger point force. Conversely, the spring arm is As and spring force is Fs in the diagram. The moment, T = AF and will have the same force-distance units as the A and F values.

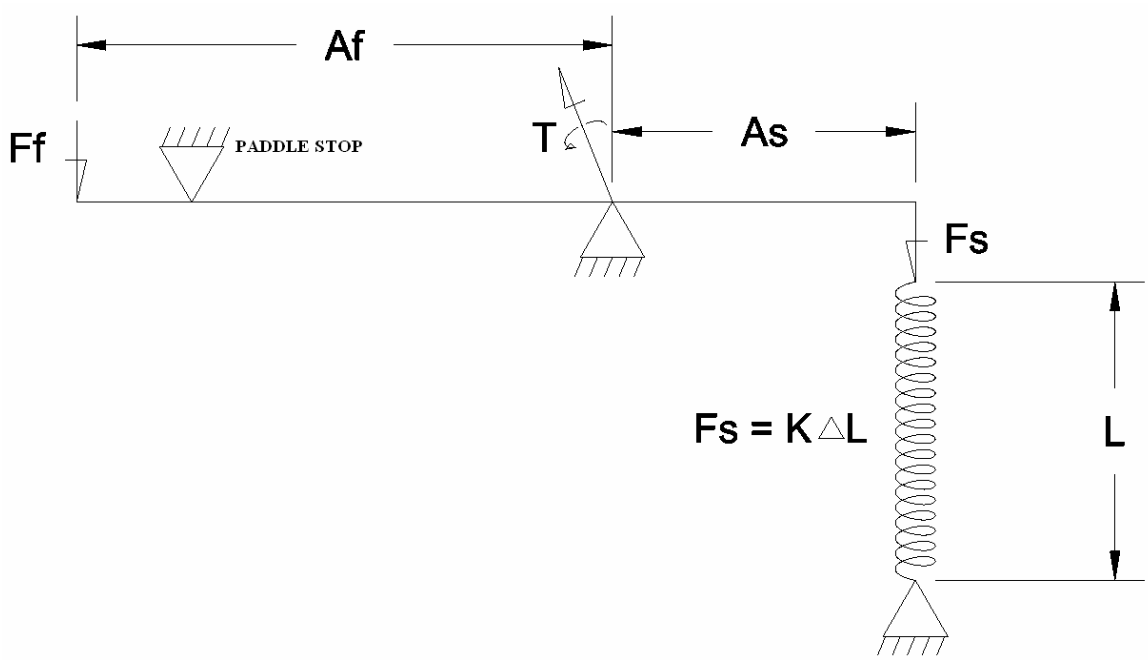


Figure 2. Moment vs. Force free-body diagram (the direction of T is perpendicular to the plane of the page)

Ff is the force needed to move the paddle to close the electrical contact. $Tf = Af * Ff$. For the spring, $Ts = As * K\Delta L$, where K is the spring force constant, and ΔL is the change in spring length from the relaxed (zero force) length. In a steady state configuration, these two moment values are equal and opposite giving: $Af * Ff = As * K\Delta L$ (for a net moment of 0).

Since the goal is to derive a value for the finger-pad force, we can re-arrange this equation to solve for $Ff = KAs\Delta L/Af$. With the exception of the spring constant, K, All of the remaining variables on the right side of this equation can be measured from the Bencher paddle.

The same equation can be written for the new paddle design, using measured values for the moment arms and spring lengths. These variables are denoted with a prime symbol " ' ":

KAsΔL/Af = KAs'ΔL'/Af'

Now the spring force constant can be divided out of the equation, and we are left with:

AsΔL/Af = As'ΔL'/Af'

This allows the forces and moments of the Bencher configuration to be replicated in the new design by satisfying the above equation using the values measured from the Bencher paddle, and filling in values from the new design (less one that will be solved for by the equation). The result is finger forces that closely match those of the Bencher paddles, with some room for adjustment.

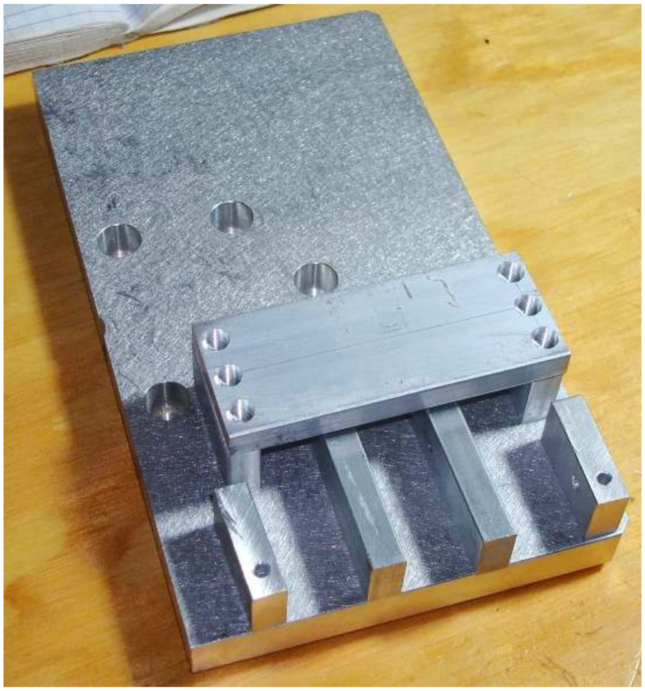
The other result of the Bencher analysis was the discovery that their mechanism allowed tension adjustment with a near-constant spring length. By adjusting the moment-arm of the spring force (by moving the end of the spring perpendicular to the direction of the tension – e.g., changing the "As" dimension), the paddle moment (and thus, the finger force required on the paddle face) could be adjusted across a range of near-zero to max without changing the length of the spring. This was quite a revelation as it means that the spring length doesn't change much in operation. This translates to a more constant force and more predictable operation (not to mention reducing cyclic stress on the spring).

This was quite different from my original design, where the spring would move a considerable amount (a little more than the contact gap) when a paddle was pressed (and would move 2 times as far when both paddles were pressed together). While the distances moved were relatively small in relation to the spring length, it might be enough to be noticeable to the operator.

The re-designed configuration still would see some length differential when the paddles were pressed, but it would be much less than before. Also, the two paddles were now decoupled, so the forces wouldn't further change if two paddles were pressed together.

Now, I finally had a working set of paddles. Some finish work remained, but I wanted to get some testing in before spending time on the last steps. If all goes well, I will be able to move on to the next phase of the overall project. It is possible that the axle-setscrew pivot might not be able to maintain low-friction operation when exposed to temperature and wear. In this case, it may be necessary to return to the idea of using ball-bearings to support the axles. Fortunately, the existing structure can accommodate this with just a few additional machining steps.

Photo Gallery

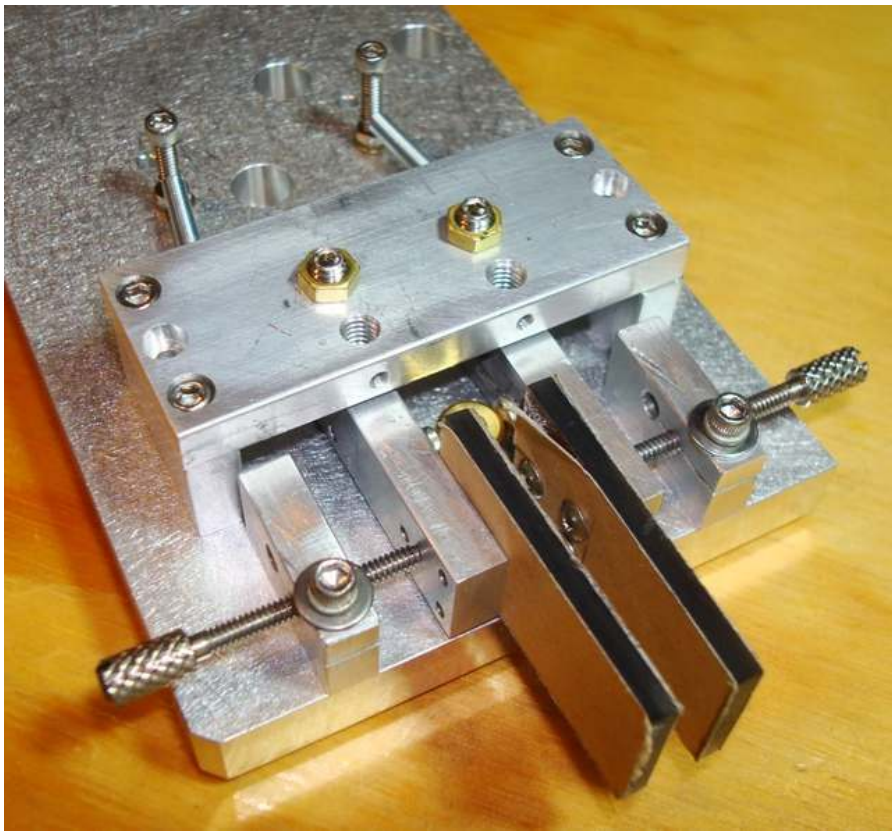


Early mock-up of the major sub-components

Paddle axle with ground end-points (below) and grinding setup (right).

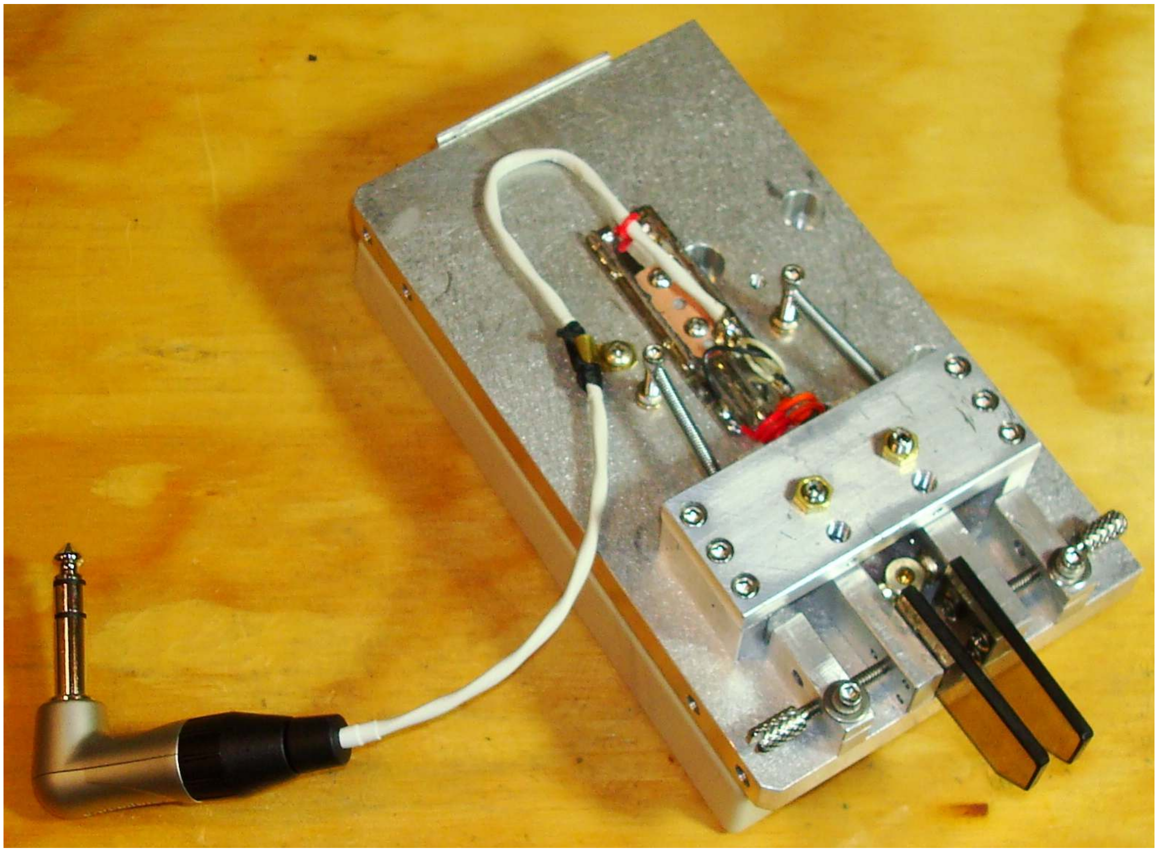
The workpiece was placed into the drill chuck (at the time, I did not have a 1/8" collet). The Dremmel tool was supported by a bar clamped under the work-surface. By resting against the vise jaws and the angle bracket, it was easy to hold in place. The mill Z-axis feed was used to set the depth of the cut into the end of the axle. The mill table Y-axis feed was used to slowly advance the tool into the workpiece to create the end-points.

Close-up of one of the paddle assemblies. The contact is soldered to a 0.062” thick piece of FR-4 material cut to match a milled out depression in the arm. A wire will be soldered to the left side of this contact assembly and routed to a terminal on the baseplate.



First test-assembly with all of the major pieces in place. The springs attach to ½”, 2-56 screws that thread into the side of the paddle arm pieces. Yet to do: the finger pads need to be finished, the brass shoulder screw needs to be Ag plated, and the gap-adjust finger screws need to be shortened. Also, an optional shield plate will attach to the top of the axle support piece. This will serve as the “table top” when the keyer assembly is in its installation configuration.

Mockup of the keyer paddles in their installation configuration. The keypad unit above is part of the user interface to the system controller.



Finished Paddle Assembly (shown up-side-down). The short cable connects to the keypad unit that installs on top of this assembly. A wedge-lock is used to attach the keypad unit to the top of the paddle base-plate (the lower section of the keypad enclosure can be seen attached in this image).