The Millennium Bug Project Continues:

The RotoBugs

by

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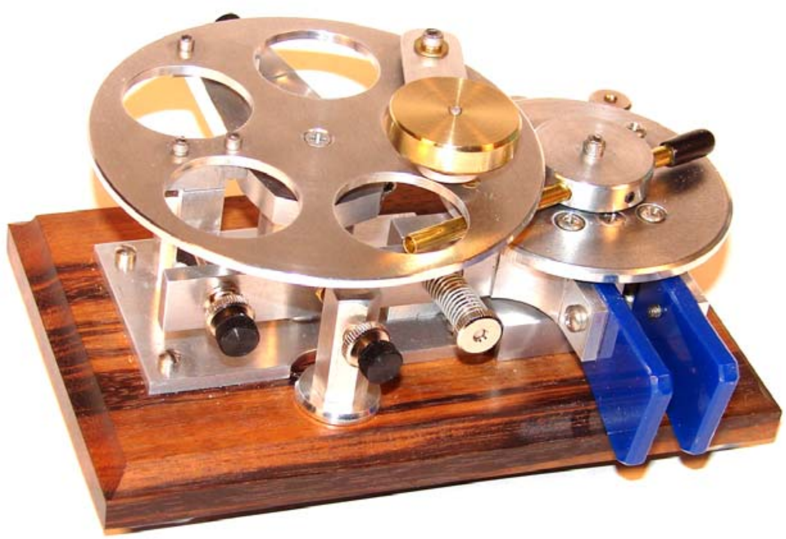


Five years ago, at the beginning of the decade, I began a project that I thought would certainly be over by now. But it isn't, and it continues to be an enjoyable challenge. I had set out to make a new kind of bug – one that overcame some of the problems with conventional bugs. Initially, the goal was to make a bug that would have a wide speed range, be simple to adjust, and be easy to learn to operate.

Out of these efforts eventually came the PaddleBug and several of its relatives. This basic design replaced the traditional pendulum mainspring with ball-bearing pivots and a magnetic oscillator system. It also replaced the dot contact with a magnetic reed switch and eliminated the need for a noisy damper system. The two-lever design made for smoother sending, because it speeded up the process of making a dot-to-dash transition. Finally, it worked by releasing stored energy, rather than by forcing the pendulum into motion. This gave it a very light touch with minimal paddle movement. It was called a PaddleBug because it could also double as an iambic paddle with no change in its basic configuration.

An outgrowth of the PaddleBug was the family of DoubleBugs. These instruments are fully automatic, making both dots and dashes. The basic design is a double-lever, double pendulum mechanism. All attempts at making a single-pendulum have not been very successful (on my part and on the part of all others who have tried). There are good reasons, to be found in the dynamical properties of mechanical oscillators, that make this approach very difficult. Some ideas are still kicking around, and someday there may be a breakthrough.

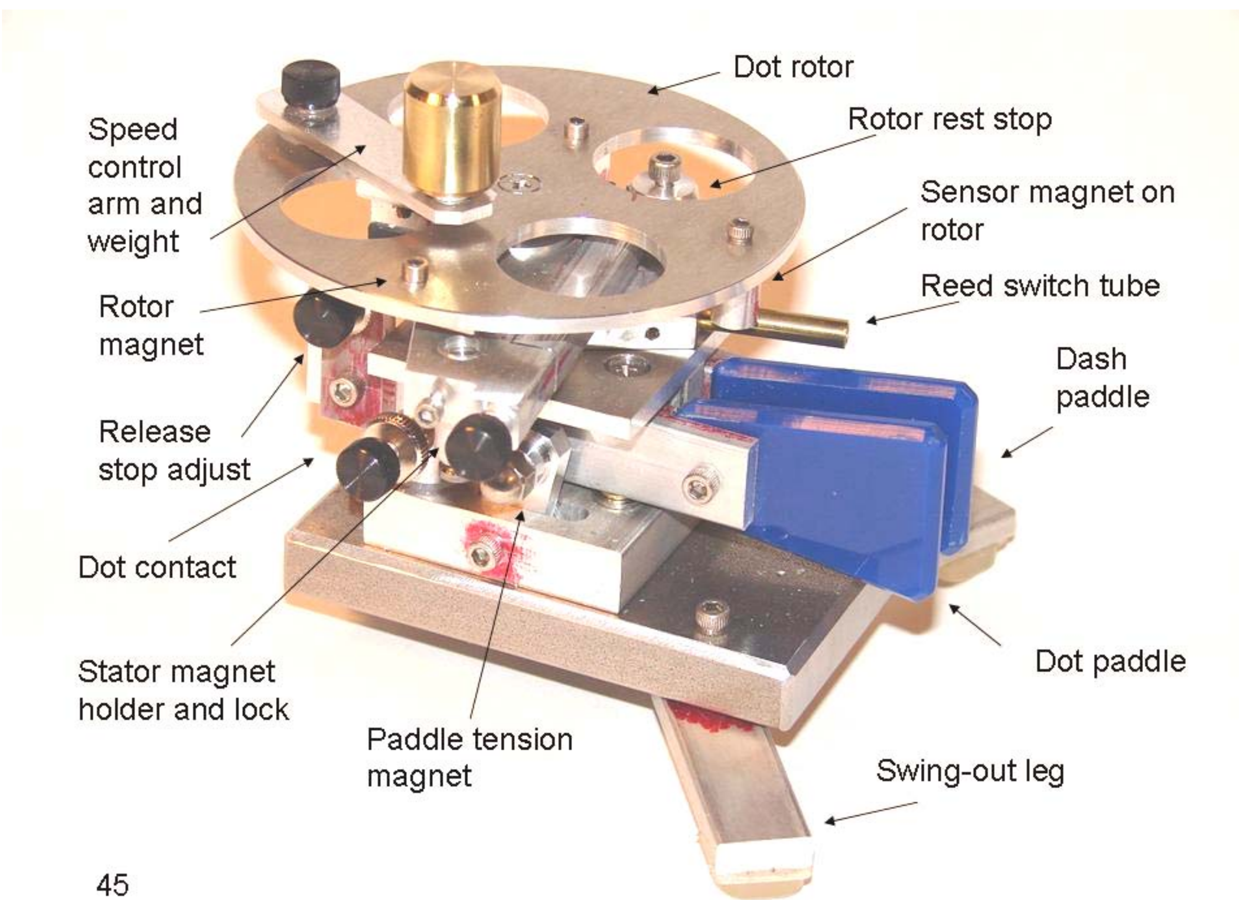
In the meantime, the basic PaddleBug design continues to evolve. Further experimentation over the past several months has led to a new kind of instrument that I like to call a RotoBug.

Why the RotoBugs?

Although the PaddleBugs appear to be good performers, there is room for improvement (or at least the design process has suggested further ways to reach the performance goals). The pendulum mechanism in the PaddleBug requires a sliding weight to regulate speed, a magnet assembly for the oscillation, a magnetic contact assembly, limit stops, and precision bearings. All of these functions take up space, and I have tried many different combinations and locations to fit all of them along the pendulum. But why must the pendulum be linear? If it were circular, these functions could be distributed over the whole 360 degrees available. So the process began.

The Basic Design

This design uses many of the component parts of the previous PaddleBugs. To make the instrument as compact as possible, it was decided to position the rotor axis to the rear of the paddle contacts and forward of the paddle pivots. A vertical pillar houses a spindle shaft on which the rotor pivots, and miniature ball bearings at the upper and lower ends of the shaft insure freedom of motion with little friction. The vertical pillar also provides support for two extension arms. One of these carries the fixed rotor magnet, and it is adjustable in an arc centered on the pillar. A locking mechanism, accessible from the moving end of the arm, keeps the adjustment from drifting. The other arm bears a brass tube containing a reed switch for sensing the position of the rotor. This is also adjustable in an arc and in and out to control the sensitivity and dot spacing. The rotor, which has several large holes drilled through it to reduce the inertial mass, bears the fixed magnets, one that interacts with the magnet on the adjustable extension arm ("stator magnet"), and one that actuates the reed switch on each oscillation of the rotor. Two projections extend down from the rotor. The one at the front of the instrument is engaged by an adjustable screw on the dot paddle. Movement of the dot paddle allows the rotor to move freely (under the influence of its magnets). The other projection engages a screw mounted to the top of the upper plate of the paddle mechanism. This screw sets the resting position of the rotor and prevents backward travel. Dot-paddle tension is supplied by adjustable opposed magnets beside the paddle. In this dual-lever design, the dashes are made by an independent dash paddle with its own set of tensioning magnets. The basic speed of the dot-generation is set by the interaction between the stationary magnet on the extension arm and the magnet mounted on the rotor. A brass weight on a pivoted arm located at the edge of the rotor provides fine control by varying the moment of inertia.



Principle of Operation

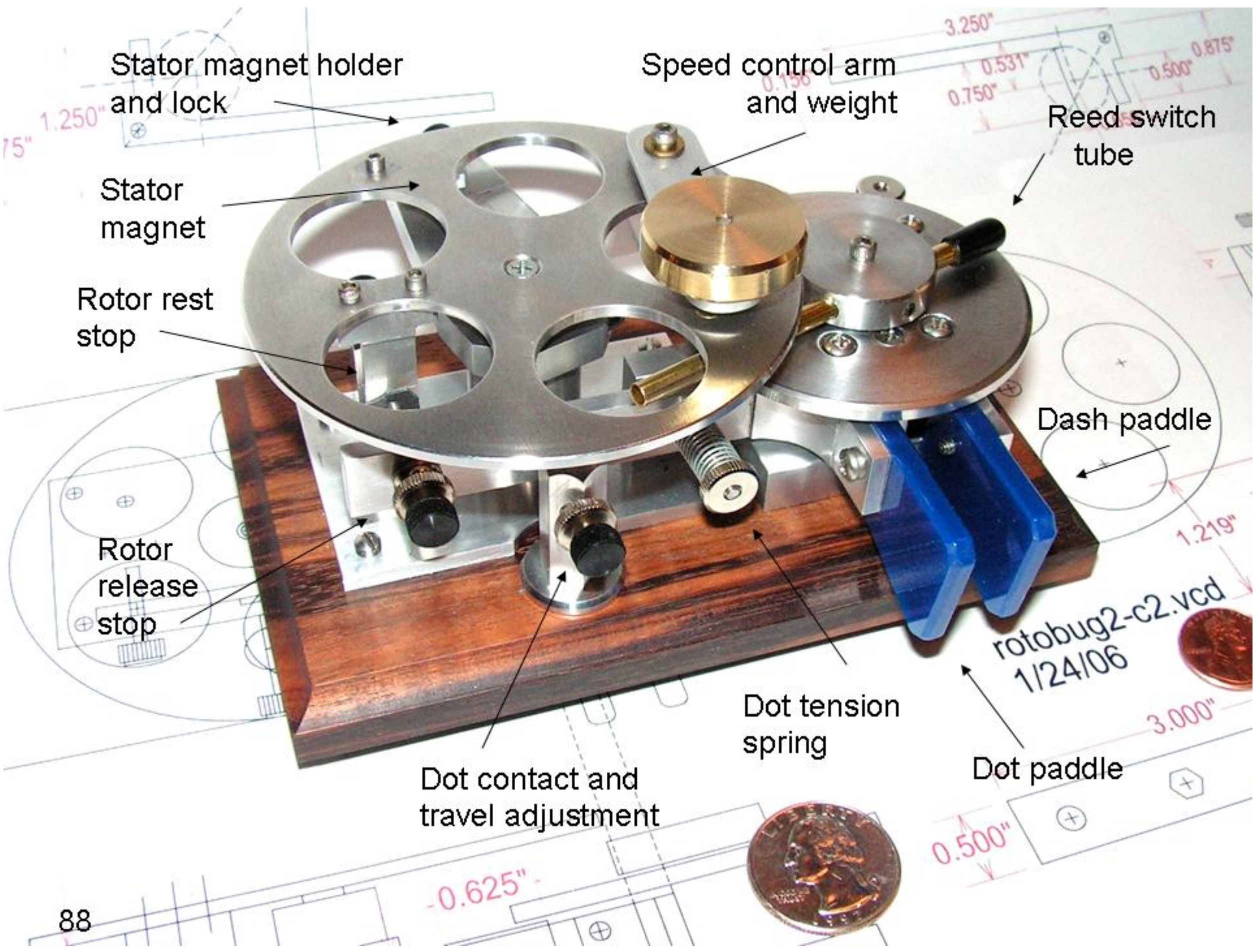
At rest, the attraction of the rotor magnets (fixed and rotor-mounted) would tend to move the rotor counterclockwise (CCW), but this movement is opposed by the release stop on the dot paddle, with the force being supplied by the paddle-arm magnets. When the paddle is moved in the “dot” direction, it releases the projection extending down from the rotor. As long as the paddle is pressed, the rotor will continue to oscillate about a point a few degrees CCW of its rest position. With each oscillation, the switch magnet on the rotor closes the contacts of the magnetic reed switch. Releasing the paddle forces the rotor back to its rest position. Dashes are made by the usual contacts on the dash paddle. Moving the speed-adjusting weight on its pivot arm away from the center of the rotor decreases the speed of the dot stream over a wide range. In its essential functions, this design is equivalent to the more conventional PaddleBug design, but it is more compact and it is easier to adjust. It has proven itself on the air over a period of time with satisfactory results.

Problems with RotoBug No. 1

The prototype, despite being built on a steel base, is a little light for the size of its footprint. If the same weight were spread out over a larger area, it would be more stable. The design of the central pillar and spindle bearings was a bit complicated to machine and it resulted in an instrument that seemed a bit too tall (this might just be an esthetic problem). Because of the relatively low ratio between paddle movement and rotor displacement, paddle travel is a bit high; this potentially limits the speed of the instrument. The design of the center pillar requires that the paddle tensioning be magnetic. This works well, but is a bit complicated to build.

RotoBug No. 2

The development of the prototype was put aside temporarily to try a new approach – the right-angle RotoBug. This instrument retains the basic frame of the paddle-bearing and contact assembly of the prototype, but it places the vertical rotor-bearing pillar (with a simplified design) beside the paddle assembly. This allows some of the rotor functions to be place closer to the base of the unit, reducing its overall height. It also allows a longer lever arm on the dot paddle so that the fingerpiece movement can be minimized and rotor movement can be made larger. The dot contact can be moved away from the paddle assembly, and spring tensioning can now be used for both dot and dash levers. Height is further reduced by using the top of the paddle-bearing frame as the mounting place for the reed-switch carrier tube. This design retains the pillar-mounted rotor magnet adjustment and locking system, with the extension arm moved to the rear of the unit to prevent crowding of functions at the front of the interest. The speed-setting weight works as before.



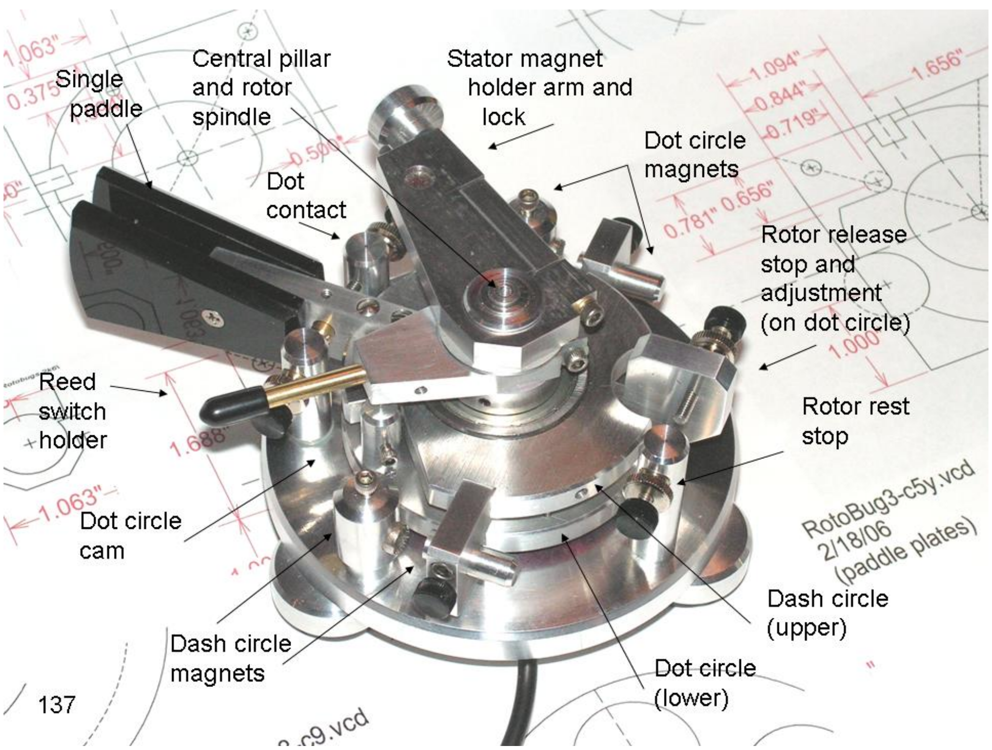
This bug performs quite well, and its design has corrected most of the problems with the previous version. While it looks a bit strange, it performs as well as the original PaddleBug design, and it has found a permanent place in the shack. In the meantime, the initial prototype has been redesigned to overcome its problems, and there has been a digression into an interesting design challenge.

The Coaxial RotoBugs

Partway through the RotoBug development, a design for a bug with a truly rotary structure came to mind. The paddles, rotor, stops, and both magnetic functions (rotor magnet and position sensor) would all have the same center. It would be built as a "stack of rings" all placed on a central pillar. The design would be single-lever with separate dot and dash contacts.

Construction

The initial attempt is shown below (the rotor has been removed for clarity). The bug is built on a circular base 4" in diameter (made from 3/8" aircraft aluminum), supported by three circular feet. The center pillar contains the upper and lower bearings for the spindle that holds the rotor. This internal assembly is held in place with a locking collar at the top of the pillar, which is mounted with a single screw at the center of the base disk. Stacked on the center pillar are a spacer ring, the dot-circle bearing, another spacer, and the dash-circle bearing. Above these is a 1/4" retainer ring held with setscrews to the shaft. It is positioned so that drawing the pillar mounting screw tight holds all of the parts firmly against each other.



The dot circle (the lower of the two) and the dash circle (the upper) have 1-3/8” holes that fit around the central bearings and they are secured by setscrews. Each ring has a magnet holder that faces a stationary magnet post on the circular base. They are offset up (dot circle) or down (dash circle) so that they are at the same level as they face the stationary magnets. The dot circle carries the release-stop for the rotor mechanism, and the paddle (with two fingerpieces) is attached to the dash circle.

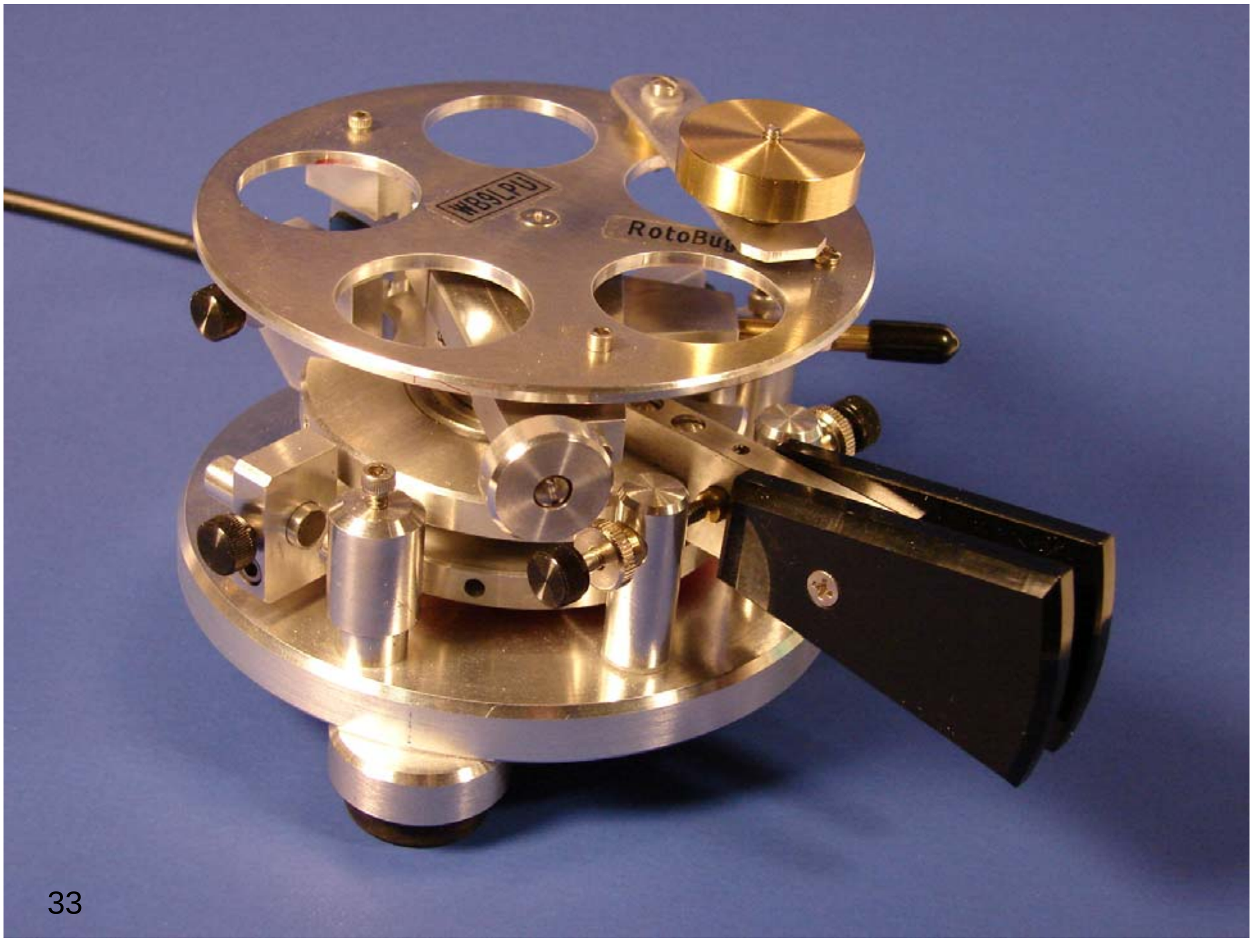
Above the retainer ring is the holder for the reed-switch carrier. The switch is housed in a brass tube whose position can be adjusted to different angles. The wires from the reed switch pass through the ring assemblies via a channel milled in the side of the center pillar. After a thin spacer ring, the fixed magnet assembly is mounted on the pillar. This is also adjustable to different angles, with a locking mechanism accessible from its outer end (as in the previous two designs). It carries a strong permanent magnet (the “fixed” rotor magnet) whose position can be varied up and down. In the view above, the rotor has been removed. It has the same magnets, speed control arm and weight, etc. as the previous RotoBugs.

The rotor is mounted to the top of the spindle shaft. It carries a rare-earth magnet (“moving rotor magnet”) for the oscillatory system and another for the reed-switch assembly. The moving magnet can be adjusted towards or away from the central axis to change the force of attraction to the fixed magnet. A stop extends down from the rotor to be engaged by the adjusting screw on the dot circle. A fixed stop on the base limits the backward movement of the rotor. Finally, an arm attached to the rim of the rotor carries a brass weight, which can be moved in an arc. When the weight is positioned in the exact center of the rotor, the speed will be the greatest, and when it is swung away from the center, the speed will decrease proportionally. The other adjustments (like the dot-to-space ratio) are not affected by the speed adjustment.

Operation

At rest, the attraction of the rotor magnets (fixed and rotor-mounted) would tend to move the rotor counterclockwise (CCW), but this movement is opposed by the release stop on the dot circle, due to the force supplied by the dot-circle magnets. When the paddle is moved in the “dot” direction, the dash circle engages the dot circle with an adjustable cam and moves the dot-circle stop away from the rotor extension. As long as the paddle is pressed, the rotor will continue to oscillate about a point a few degrees CCW of its rest position. With each oscillation, the switch magnet on the rotor closes the contacts of the magnetic reed switch. Releasing the paddle forces the rotor back to its rest position, with the force being supplied by the dot-circle magnets.

When the paddle is moved in the “dash” direction, the dot circle remains stationary, and the dash circle moves to close its contact points. The dash-circle magnets provide its restoring force. The finished Coaxial RotoBug is shown below.

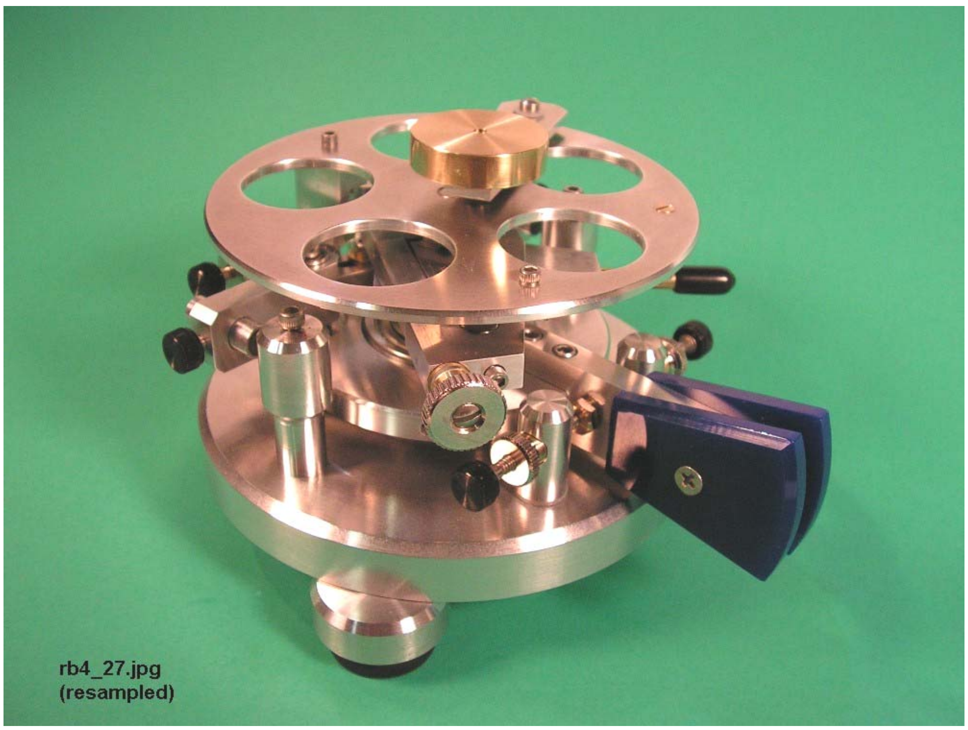


Comments on the bug operation

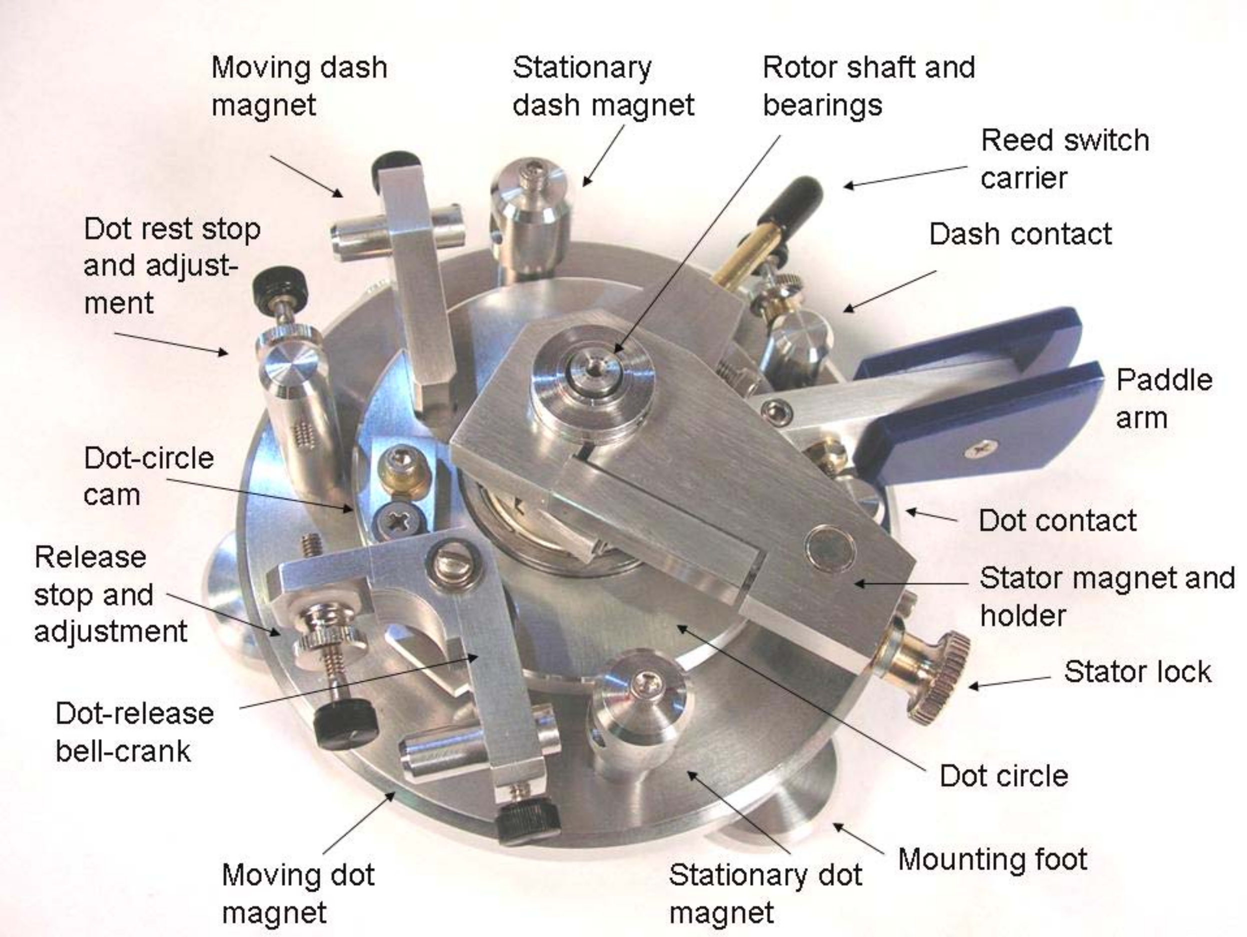
This bug is very smooth and steady in its operation and holds its adjustments very well. Making the initial adjustments is rather critical, for the reasons that will follow.

Because both the paddle circles and the rotor share a common center, no “lever multiplication” is possible. (All of the previous versions did have significant lever action.) Lack of a lever advantage means that a fairly large paddle movement is required to give the rotor enough room to oscillate. This large paddle throw increases the transition time from dot to dash and slows the overall operational speed. Limited compensation is possible by setting the rotor magnets for a smaller range of motion, but this makes the adjustment of the reed-switch magnet more sensitive. In the final analysis, this attempt was successful enough for a first try, but there is some room for improvement.

The Second Coaxial RotoBug



The chief shortcoming of the first coaxial bug was its lack of a lever advantage to allow a large enough rotor movement for a small paddle movement. The solution found to address the problem was to use a bell-crank mechanism whose pivot was away from the system center. An adjustable lever ratio was set by a moveable wheel-tipped cam activator on the dash circle. The use of the bell-crank eliminated the need for the dot circle. With a rubber “tire” provided for the cam actuator wheel and with shock-mounting provided for the paddle-arm contacts, the bug is very quiet in operation. The reduced paddle movement allowed smoother operation at higher speeds, with more leeway in the adjustments. This bug has been used on the air for some time and details of its construction have been refined. The functional parts (with the rotor removed) are pointed out in the figure below. It does appear to be an improvement over the first coaxial RotoBug. In its present state it probably represents the most that can be gotten out of the basic design.

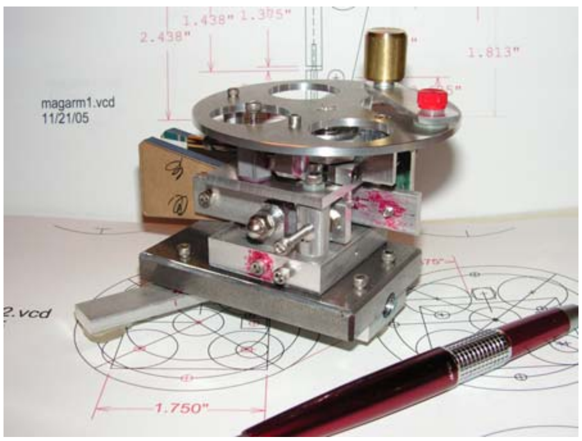


Future Directions

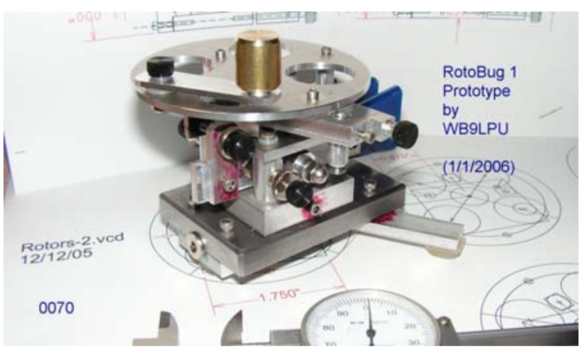
With the basic designs of the RotoBugs (especially Nos. 1 and 2) in hand and working well, the opportunity to combine them into a fully-automatic instrument has presented itself, and design and construction are underway. The dot-generating mechanism is a refinement of RotoBug No. 1, with some changes in location of the rotor pillar and magnet functions. It will be located at the left end of the instrument, and the dash-generating mechanism is a mirror-image of RotoBug No. 2. There will also be room for a straight key at the right end of the unit, and the overall footprint will be about the same as the second RotoBug.

More views of the RotoBugs

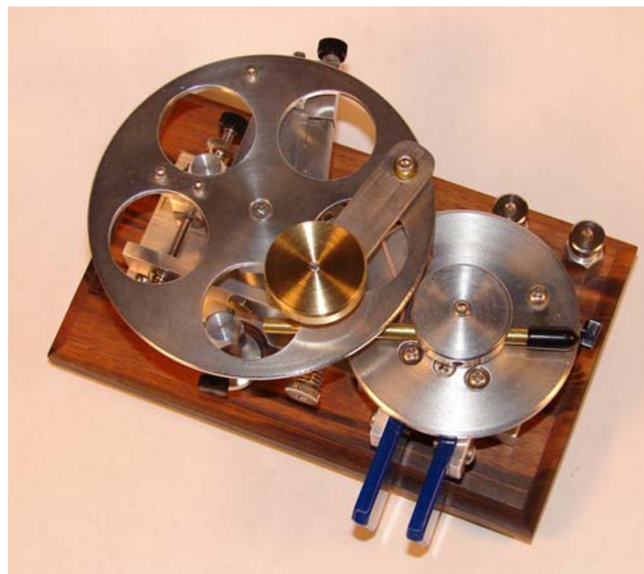
Below is an assortment of pictures of the four rotobugs, including views of the assembly of RotoBug No. 4.



Rotobug No. 1 prototype, early stage



RotoBug No. 1, now more refined (cleaned up a little). This was used on Straight Key Night of 2006 (within the rules, I hope).

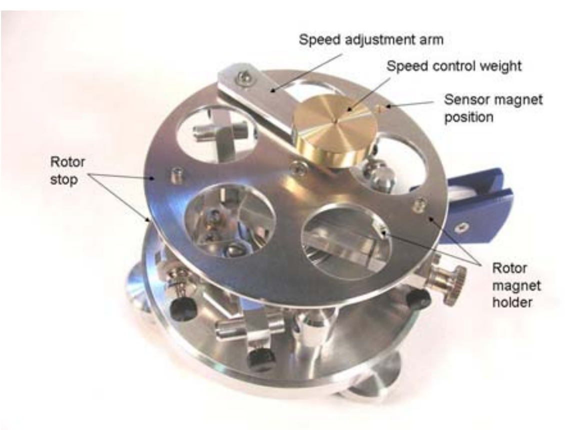


A top view of Rotobug No. 2

RotoBug No. 2, from the dash side.

Top view of RotoBug No. 3

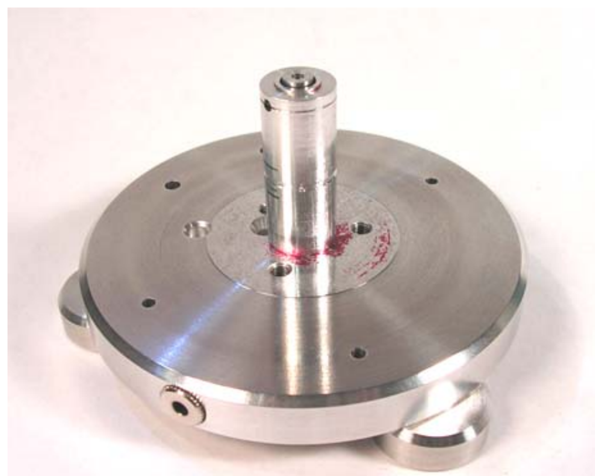
Bug No. 3 with its rotor removed.



The rotor section of Bug No. 3. The speed adjustment arm moves in an arc, transferring mass from near the center (high speed) to the rim (low speed).

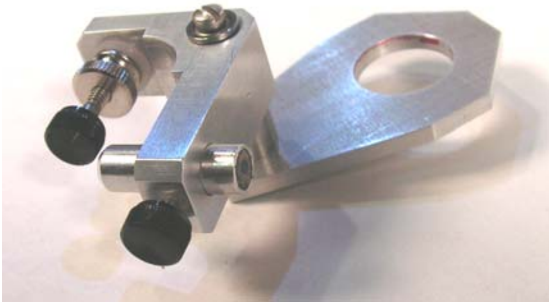
Below are a series of views of the assembly of RotoBug No. 4.

The rotor bearings, spindle, central pillar, and locking ring.

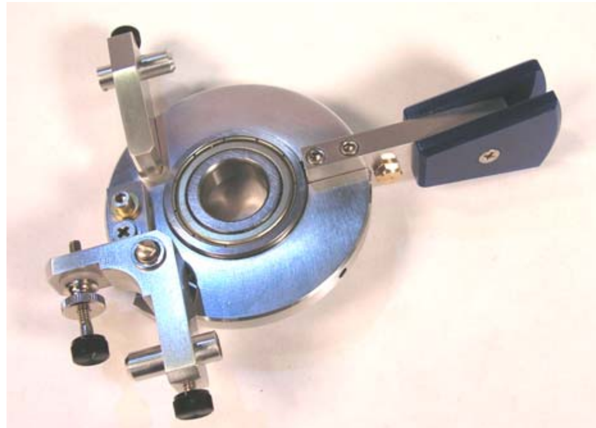


The central pillar mounted on the base. The phone jack in the base is for electrical connections – there was not much room for conventional binding posts. The three holes surrounding the central pillar were used in the machining process.

The magnet holders, contacts, and the rotor rest stop are mounted on the base.



This is the bell-crank mechanism mounted on its carrier, which then mounts to the central pillar, as shown below.



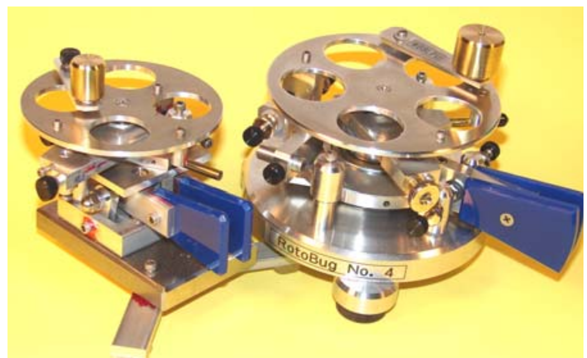
The paddle circle, with its central bearing, shown in relation to the bell crank mechanism.

All of the paddle mechanism parts are in place. The bell crank is shown below.

RotoBug No. 4, finally finished.

The box contains a code practice oscillator built into its lid – the "proof of the pudding" is in the sound of the CW that the instrument can produce.

The RotoBugs have given a good account of themselves on the air, and RotoBug No. 5, the fully-automatic version, is in its early stages of construction.



So the project has come full-circle, so to speak. The goal of building a very different kind of bug has been an enjoyable challenge, and has provided an opportunity for lots of learning (and mistakes that are not shown here). Look for the RotoBugs on the air on 40 meters some night soon.

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