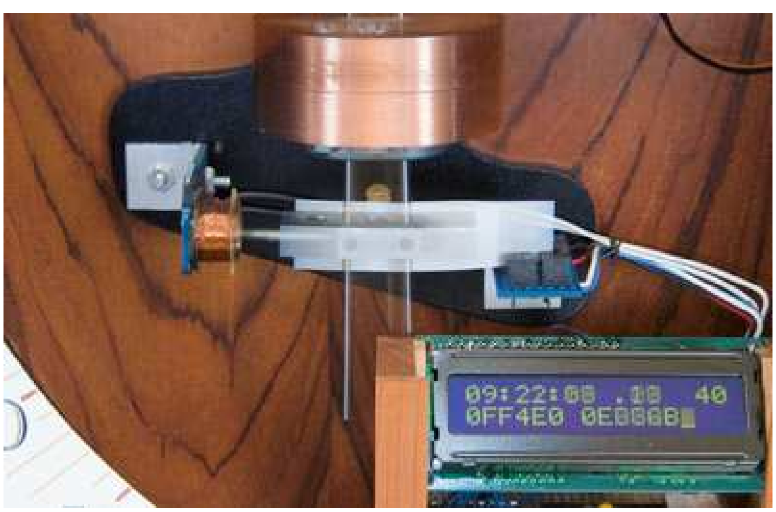
In May 2003 I took pendulum #7 and fitted it into case #2 (built 1974). Everyone loves the hands. They are positioned using model airplane servo motors.

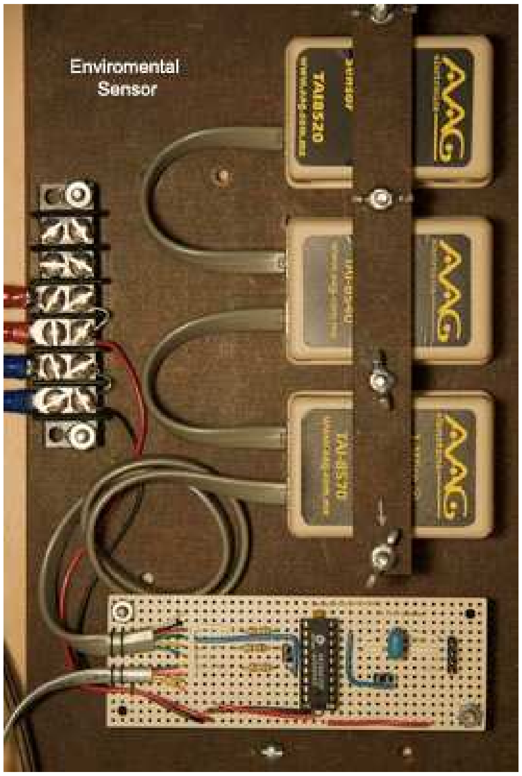
This clock uses algorithmic rating. The number of true microseconds per cycle is added to an accumulator. A second (or two) is added to the time on overflow. Without overflow a second is skipped. All setting is done using an IR remote so that the pendulum is never stopped or touched. Since start of operation the pendulum has slowly speeded up by more than 50 microseconds per cycle. (1 second period)



This photo (above) shows the two optical sensors with the shutter stopping in the center of the limit sensor. Also the current rating factor of 0FF4E0 (hex) is shown. The speeding up of pendulums running on beryllium copper flexure (reported by some other HSN person) is still a mystery.

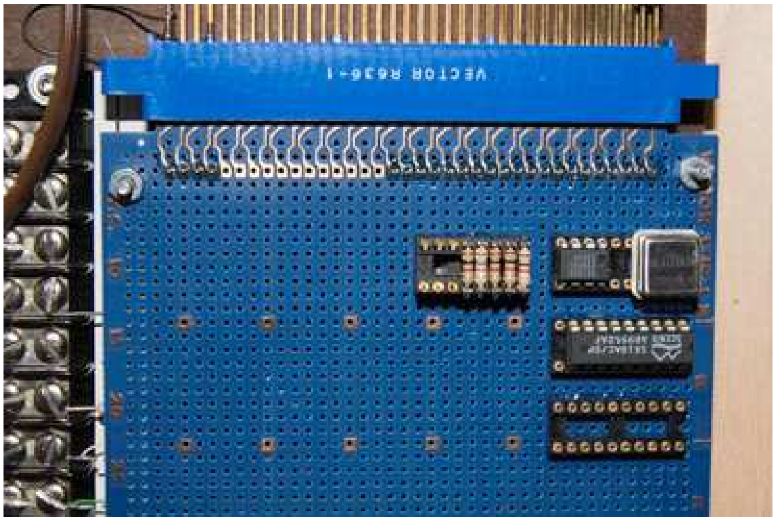
In early 2005 I got pendulum #8 running in a laboratory case. The four electronic modules are (from the top):

The GPS (Garmon 25 oem unit) which produces an accurate 1 microsecond pulse tied to the atomic clocks. (No photo)

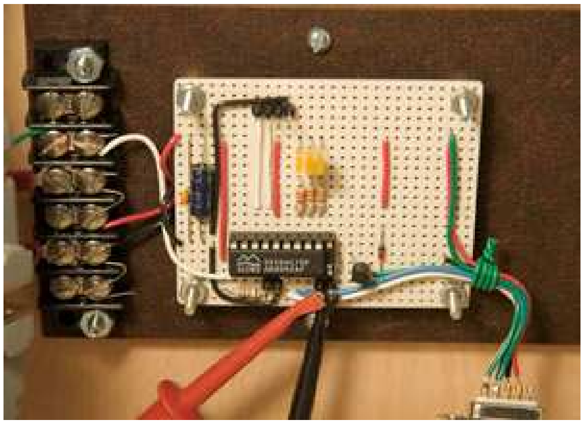


An environmental monitor reads temperature, relative humidity, and barometric pressure. The results are sent via RS232 to the logging computer. Quite accurate.

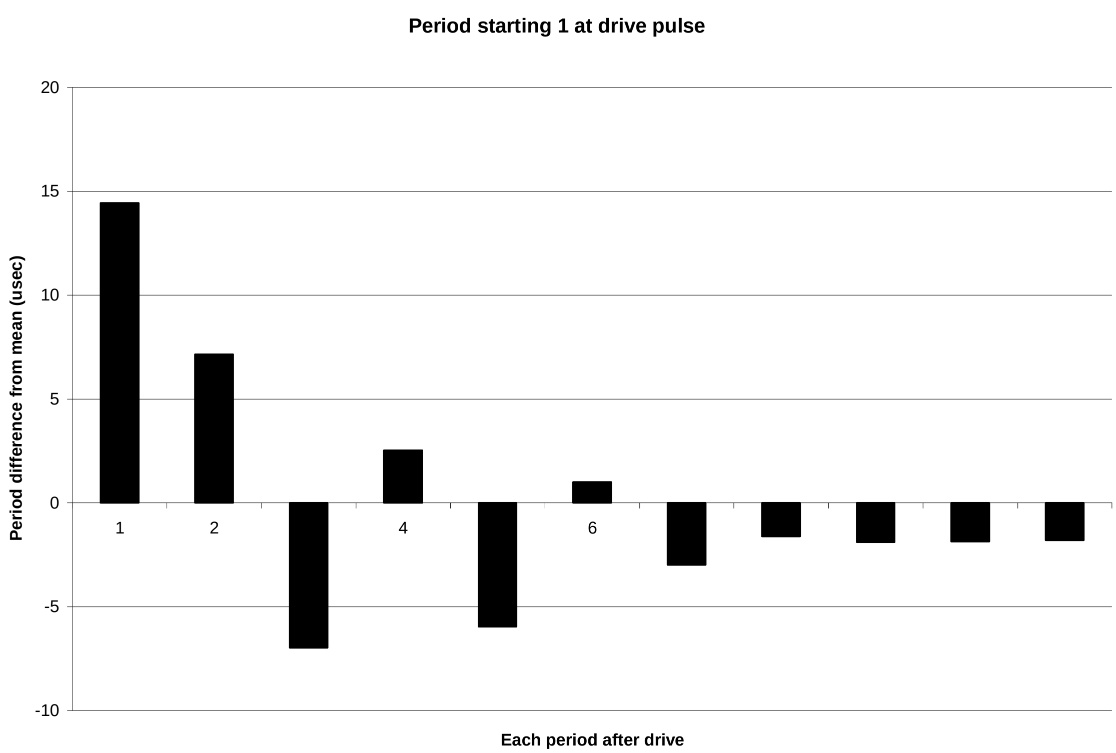
http://www.aagelectronica.com/aag/index.html

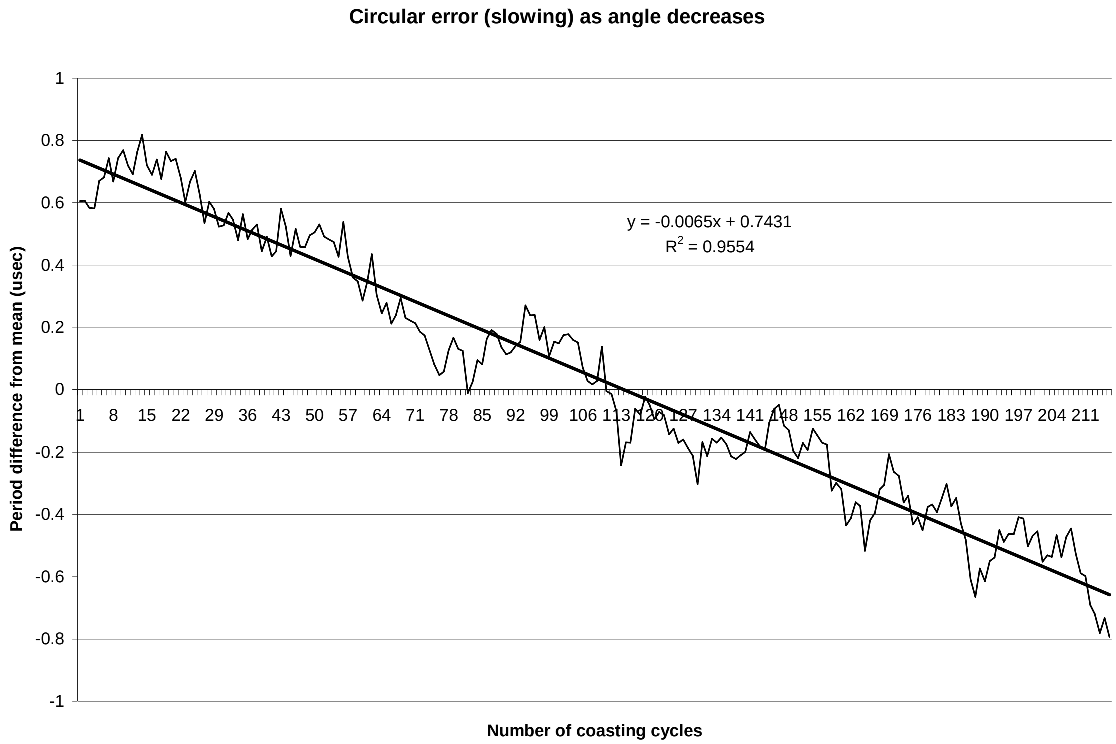


This timer reads the interval of the pendulum and the GPS second. This way the temperature coefficient of the crystal is removed. Next to the crystal is another temperature sensor. The tempco of the crystal can be accurately seen and shows the parabolic shape it is supposed to show. At room temperatures this is about 0.25 microseconds per degree C.

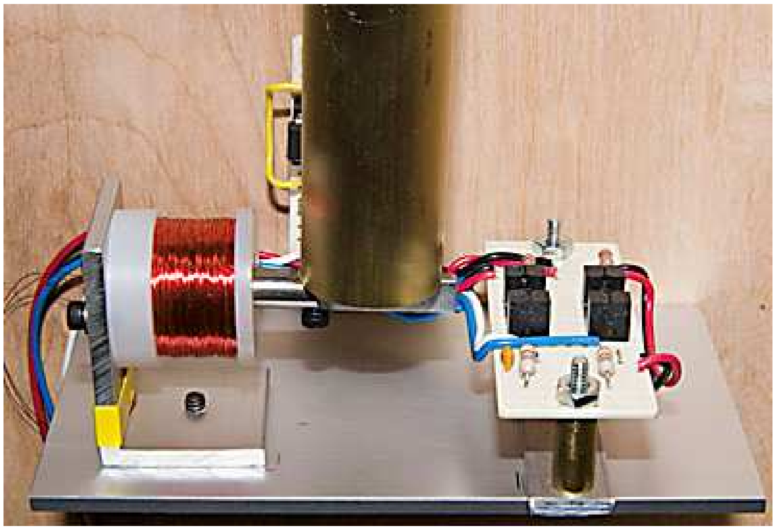


The drive computer can be reprogrammed on the fly without even powering the system down. This way I can try various drive algorithms. I have even tried letting the system coast down for many minutes to show the circular error. Also I have shown that driving strokes actually take longer than coasting ones. Also I have shown that it is generally better to drive the pendulum more often. Normally I drive on demand using the limit sensor. The current model drives about every 13 cycles. (1.506 second period.) A serial line reports drive actions. In addition the response of an under damped second order system is clearly shown in the period of cycles of following a drive cycle.





So 6.5 nanoseconds per coasting cycle



The bottom of pendulum has a single steel armature which serves both the solenoid and the IR sensors (black boxes.) The left is set at the center of swing and the right is the limit sensor. I calibrated the shutter/sensor performance on the cross-slide of my lathe and find the limit constrains the swing to better than 0.001 inch (1 inch total travel.)

At top is the flexure. Two springs running at above 3500psi. The pendulum is bobless. It is a single 7/8 inch C360 brass rod.

Obviously this system has a huge tempco, about 14 microseconds per degree C. The simple design allows me to more accurately model thermal response and to accurately model the ‘barometric’ error. This is really a buoyancy error having more to due with the temperature and water content of the air than the barometer. This system shows no ‘Clock Quakes.’

This pendulum shows a great deal of period effect from vibration of the house. This I can show in contrast between stormy vs. calm days. The distribution of period variation is a beautiful Gaussian.

I can now more accurately model thermal lag. But more work is needed. It turns out that there is a simple difference equation (one of the ones used for digital signal processing) that replace the complex thing I was using in my paper on thermal response.

So I am further along in modeling a pendulum running under household conditions.

Comments? Thoughts?

March 11, 2006, Los Altos, CA. Bob Belleville