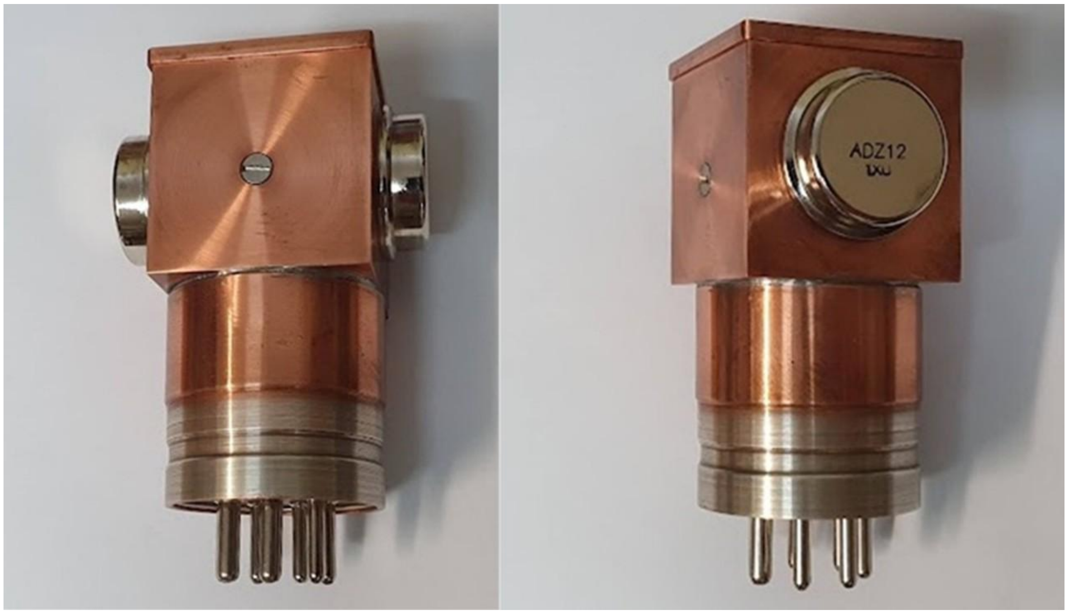
The Robust Electronic Radio Vibrator Replacement.

(H Holden DEC. 2025)



Background:

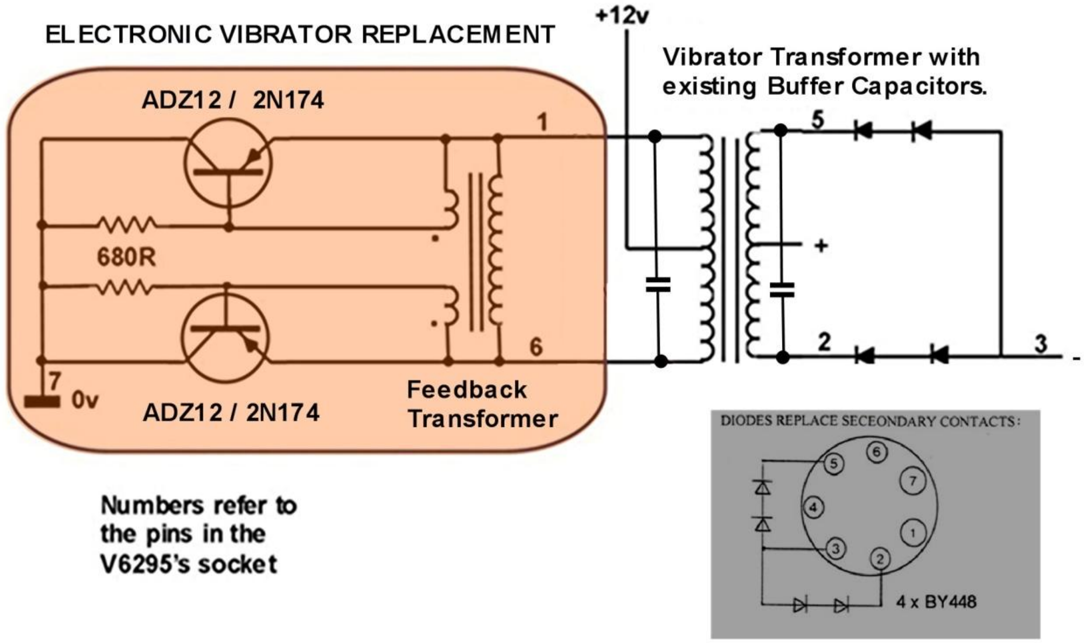
I started designing these devices many years ago, primarily to replace the 12V synchronous unit used in my vintage ZC1 Communications radio.

After a number of design iterations I concluded that the better design was the simple one. The basic circuit consists only of 5 electronic components:

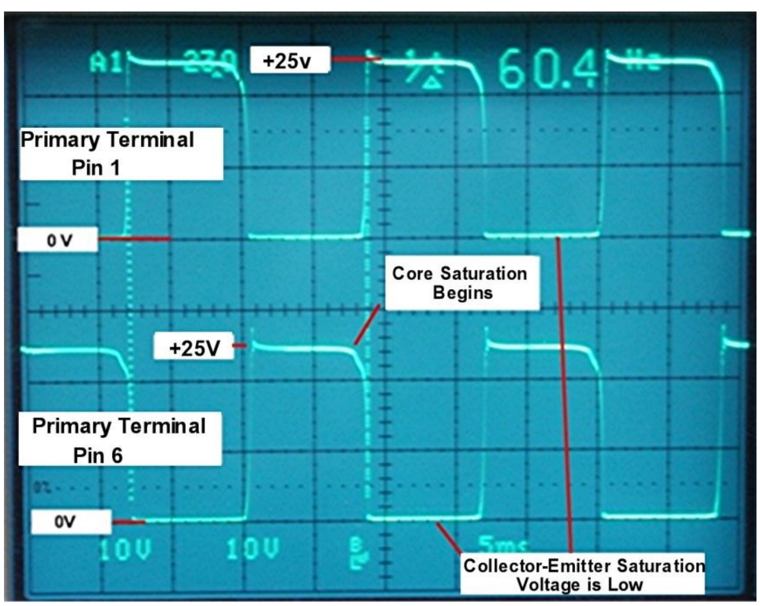
Two low frequency Germanium power transistors.

Two resistors

One laminated iron core feedback transformer.



The circuit results in the vibrator transformer itself and its magnetic properties determining the frequency of oscillation. Typically, run in this mode, the vibrator transformer, designed for 120Hz operation, runs along in the region of 50Hz to 70Hz:



Also in this instance the “slow” Germanium power parts have a significant advantage, apart from their low Collector-Emitter saturation voltage drops of below 200mV, they have a long storage time in the order of 20uS.

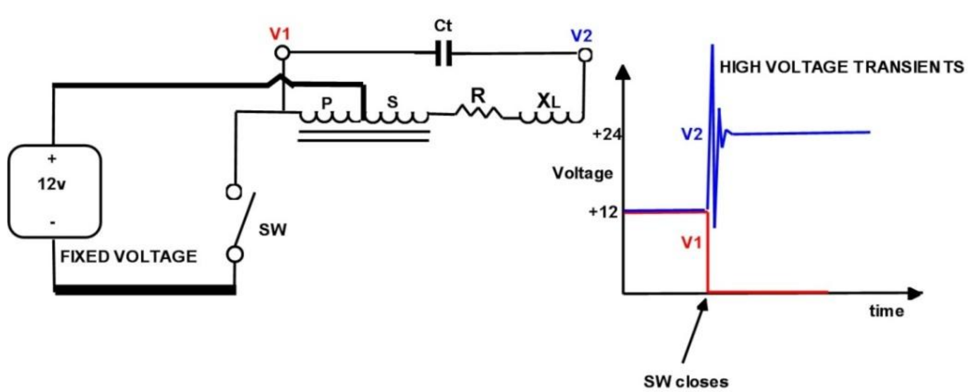
This allows the transistor, with a long storage time, coming out of conduction, to snub off the brief high voltage leakage inductance related transients, which appear on the rising edge of the primary terminal waveforms. These can be near 70V to 100V even with the vibrator transformer’s normal buffer capacitors in place.

The Germanium power switching transistors (unlike Mosfets or Silicon transistor parts) completely eliminates this issue and they provide a very clean primary switching waveform devoid of high voltage transients around the switching points.

The diagram below shows how these transients come about. When a DC voltage is switched across half the primary winding P by abruptly connecting primary terminal V1 to common, this effectively shorts the primary out, from the *alternating current perspective*. This has the effect of eliminating all of the inductance in the other primary half S, all *that is magnetically linked*. But the coupling is never 100% and leakage inductance and leakage reactance XL remains.

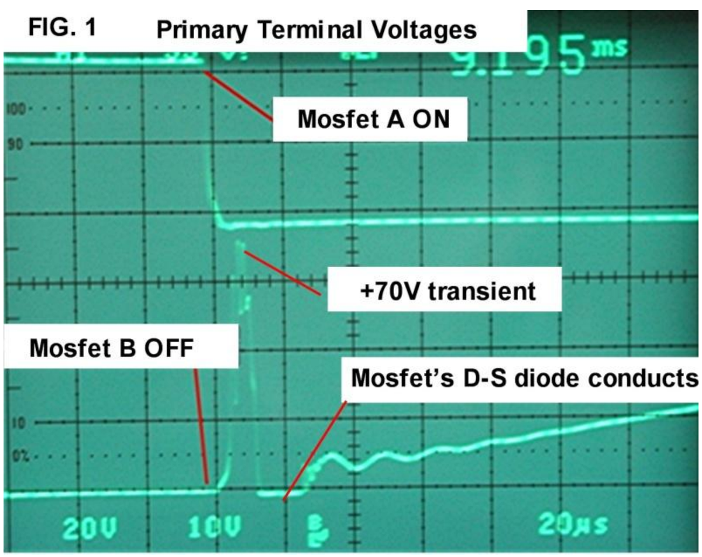
As the free primary terminal (V2) attempts to charge the capacitances Ct to twice the supply voltage, the leakage inductance in series creates a resonant circuit and oscillations riding occur on the the rising edge of the voltage waveform on V2.

THE LEAKAGE REACTANCE PROBLEM:



With typical vibrator transformers, when the primary halves are switched rapidly, the first positive half cycle of the leakage inductance related oscillations begins about 8uS after the Transistors (or Mosfets) change their switching state and appear on the primary terminal and the device which has just previously rapidly switched off, effectively uncoupling itself from that primary terminal. The main initial transient is over by about 16uS.

And the diagram below show how these transients occur on the leading edges of the rising aspects of the square waves on the primary terminals. They are also there with the electromechanical vibrator and the usual snubber capacitors do not eliminate them (unless grossly increased in value by a factor of 10)



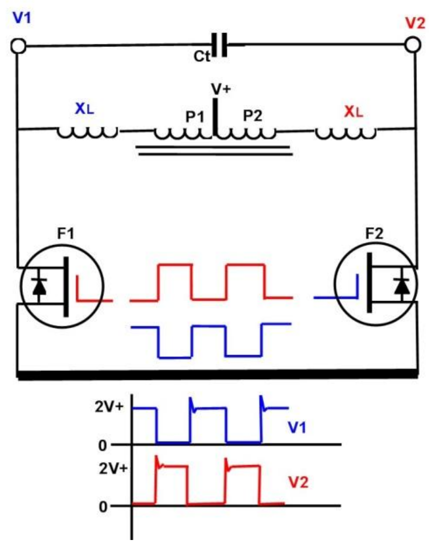


Figure 1, above is a recording of the situation seen using modern fast parts, such as Silicon power Transistors or Mosfets and a close examination of the switching with the delay time-base. These modern parts switch synchronously on and off in very short time frames in well under 1uS. As a result the high voltage from the leakage inductance appears very shortly, after the switching point. The D-S diode in the Mosfet’s case snubs of the negative going part of this oscillation.

In the case of the vintage slow Germanium parts, the situation is much better and the rise in voltage on the primary terminal of the “slow” device coming out of conduction eliminates this transient and a much cleaner switch waveform results. In this case, the slow parts are helpful. Also the transistor coming into conduction is less abrupt and that helps too as there is less for a shock excitation of the resonant components. The changeover switching process is slowed to around 400uS. This degrades the efficiency only a little and it is a better situation for the transistors and the transformer’s insulation and also reduced chance of RFI.

Hi performance “fast” Germanium power parts are available, a good example being the 2N1908 which have low storage times in the vicinity of only 1.5uS almost rivalling some Silicon parts. However for this application I would not recommend these. It is much better to use the slower parts with storage times in the 20uS region. Mostly these suitable transistors are the ADZ12, 2N174, ASZ16, ASZ17 and NKT404, which were devices intended for Audio and low speed switching applications.

MECHANICAL CONSTRUCTION:

This project was much more of a challenge in Mechanical Engineering than Electronic Engineering. This is nearly always the case.

Why have the transistors on a heatsink?

When Power devices are handling more than one amp of current, it really does pay to have adequate thermal coupling to a good heat sink. And this is even if the power devices in a switching mode barely even warm up in normal use, with no heatsink, which at first thought might not seem logical.

One issue these days, is that designers calculate the thermal dissipation in a switching scenario and conclude that the power Mosfet or Transistor, which has a very low Rds ON value, or a low C-E saturation voltage drop in the transistor case, has such a low thermal dissipation, that the part can just sit on the pcb alone and no heat sinking is required. This may be true, most of the time, when everything is normal. But the notion is devoid of "thermal insurance" Also some power parts can be set up with low R value current sensing resistors to limit the current with feedback, to reassure the designer that no heat sinks are required, but again this also relies on the control electronics operating normally.

However, under overload or fault conditions, or other abnormal circumstances including power supply brown out, or a slowly rising supply voltage, may cause the transistor not to fully saturate or the Mosfet not to be fully enhanced. The device's junction, with no heatsink backup, can heat up violently & quickly melting the junction. This sort of thing explains spontaneous failures in power handling switching devices that are not applied to heatsinks because it appeared on face value, on the design parameters for thermal dissipation, that they did not need them.

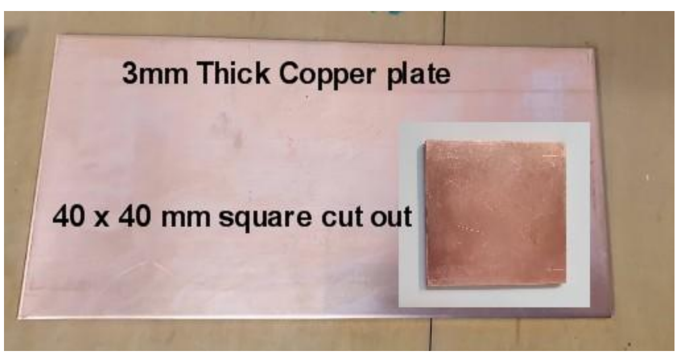
With electronic controls alone, the only thing protecting the semiconductor junction was the control of it and the low voltage developed across the device while it was conducting in *normal use* limiting the power dissipated within it. You will see this sort of thing, for example power Mosfets on pcb's carrying 5 Amps, sitting on the pcb alone and running as cool as a Cucumber, until one day, due to an abnormal condition, they melt their junctions.

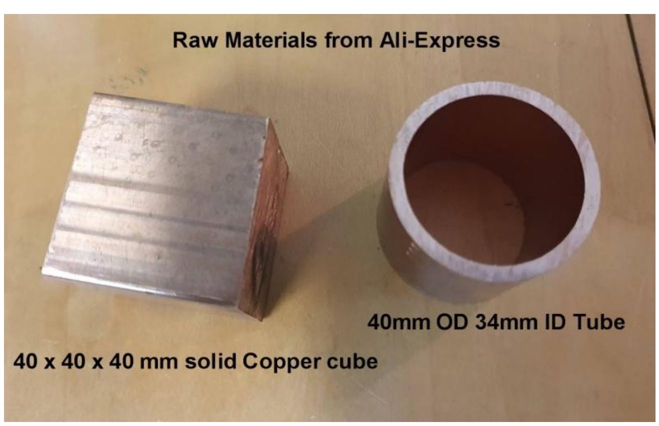
Therefore regardless of the "normal running conditions" and calculated mild thermal dissipation in any power switching device, my policy is to always put power switching devices on a reasonable heat sink, to be there to absorb the heat in the event of any abnormal operating condition.

Replacing a vibrator, which is a round canister, is awkward because there is no flat surface to attach a power semiconductor to.

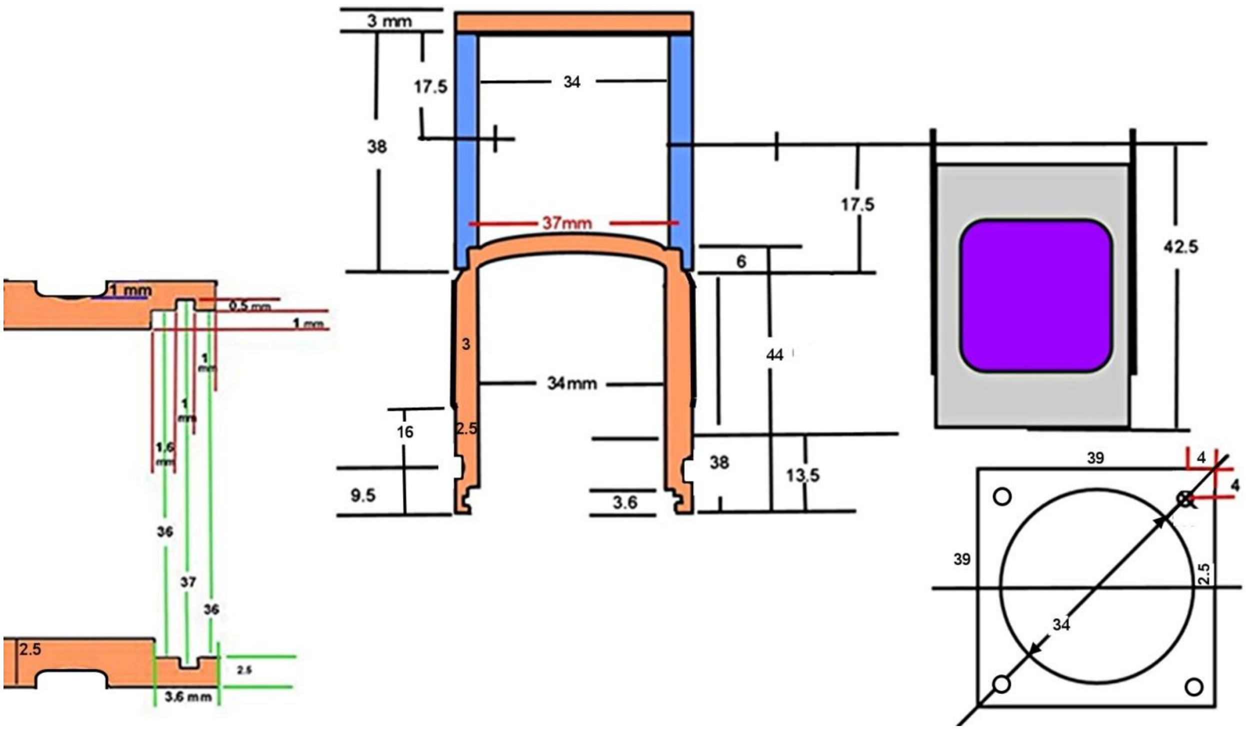
It was mentioned in the movie Hidden Figures, that the mathematical challenge to find the "go-no go point" for capsule re-entry was the point where the orbit had to change from a Circular one, to a Parabolic one. In the similar way, to obtain a flat surface, the replacement vibrator canister has to change its geometry from a Circular one, to a Rectangular one.

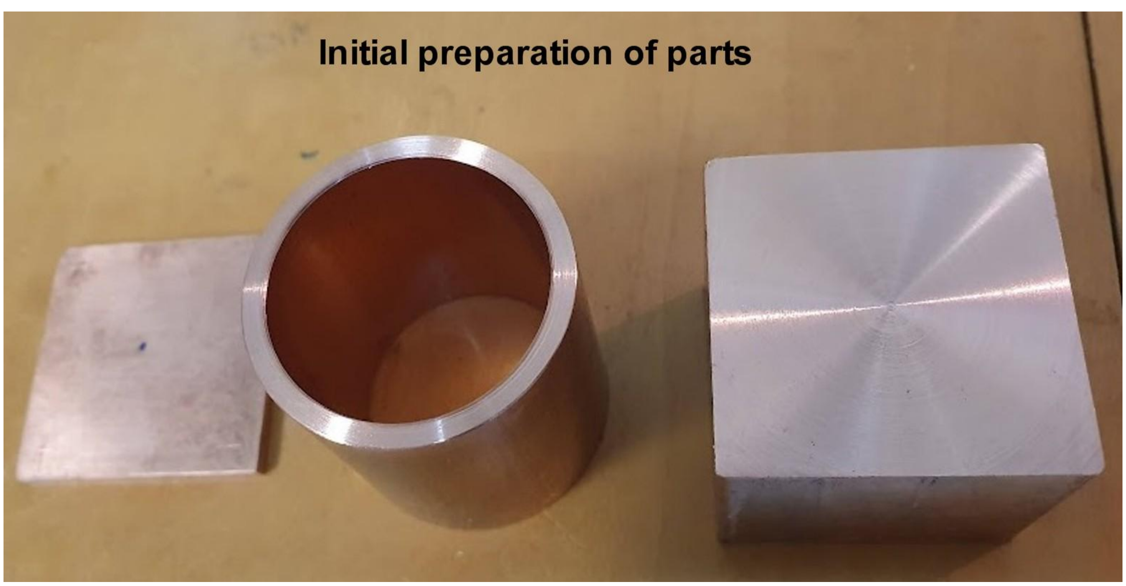
I started out with a 3mm thick plate of Copper to make the lid. I cut it out with a hand saw and filed and finished the edges. It was going to be a challenge to make the Copper housing. I only have a small Sieg C1 Mini-Lathe. And Copper is difficult to machine. I decided on Copper because the Transistors used are solid Copper, housing types, albeit bright Nickel plated and I had not machined many items from Copper and wanted to learn more of the difficulties.





I realized I would not be able to machine the whole object as it was 76 mm long sans the 3mm thick lid. So I decided to make it in two halves and machine a 6mm long overlap to fit them together and then solder them.





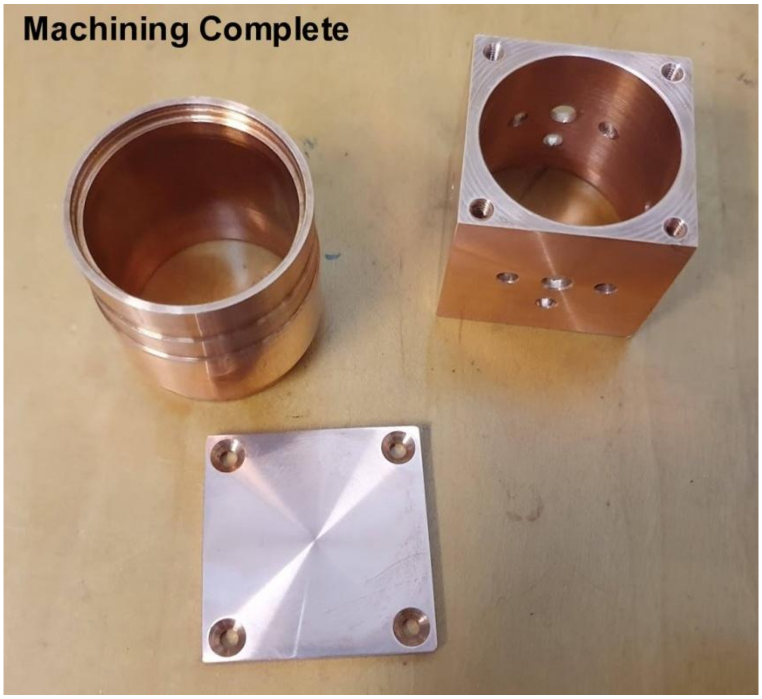
To get started I faced the end edges of the cylinder and the copper cube.

The Tubular section was relatively easy to machine, but still being Copper it was more difficult than aluminium or brass. I held it in an independent 4 jaw chuck and aligned it with a dial gauge.

With Copper in my lathe I found I could only remove very small amounts in the order of 0.04mm at a time and it required copious cutting oil. Any more than that, the tool would tend to bite heavily into the material and stall the lathe.

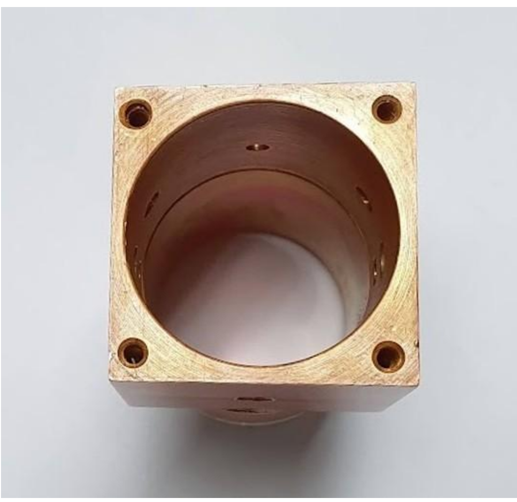
The hardest part of all was machining out the 34mm diameter hole in the copper cube. The largest drill I had to start the hole was 13mm. It took over 200 passes with the the boring tool taking only 0.04mm at a time to get the hole to 34mm internal diameter and it used up about half a can of cutting oil (there would have been a much quicker way to do this with a bigger lathe and better tools)

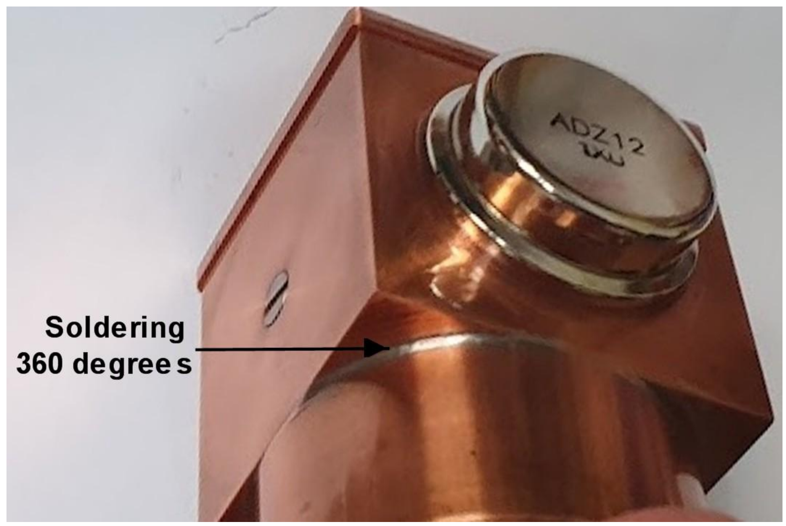
Also, I had a Milling attachment and I used the milling tool in the 3 jaw chuck to plane the copper cube down from 40 x 40 x 40mm to 39 x 39 x 38mm tall and then finished the surfaces with papers up to 1200.



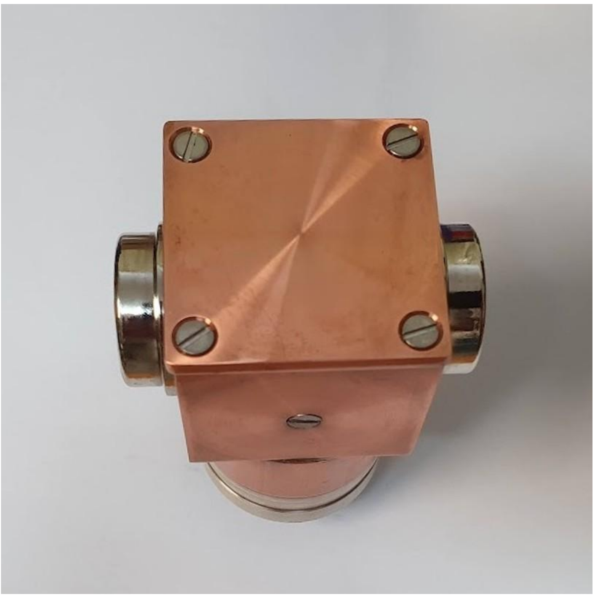
The screw threads are 1/8 BSW, this is a good size for soft metals such as aluminium or copper. It has a thread pitch similar to a 4-40 UNC, but is 1/8" (3.175mm) diameter, vs the 2.75mm diameter of the 4-40 screw.

Then I soldered the two pieces together with the aid of the gas stove. I left a groove to help retain some solder. I found that the solder dispersed well into the 6mm long sleeve like interface, even though it was a firm press fit by hand.

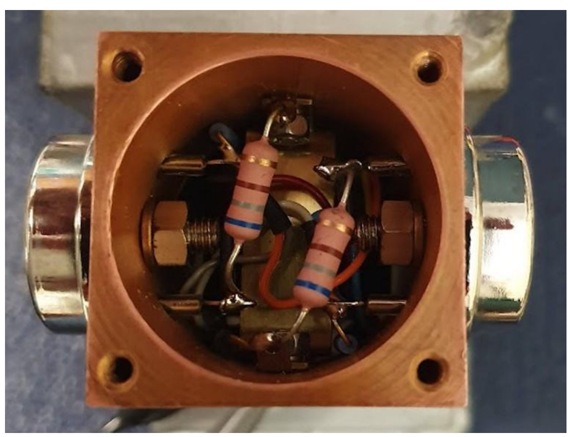




I wanted to keep the Copper finish because of its somewhat Steam-Punk look so I lacquered the body with clear Dupli-Color spray (except where the transistors mounted) This paint product is extremely adherent to shiny metals. But where the vibrator plugs in there is a metal earthing clip. For that I Silver plated it with a rubbing solution typically used for restoring vintage silver plated Tea Pots.



View from the Top with the lid removed:

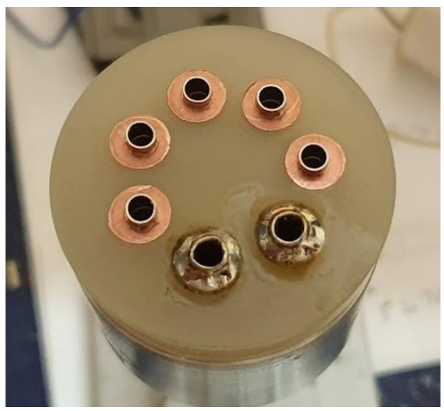


Due to the fact, with this circuit configuration, the Transistor collectors are grounded, that avoids the need for any insulating washers and gives a very good thermal and electrical bond between the transistor's collectors and the Copper housing. It is hard to see in the photo, but the transistor B & E wires are insulated with clear heat shrink sleeving.

The UX-7 base is held in with some 1mm diameter Piano string wire in a groove. I made the groove using a modified parting tool. This wire is very springy and stiff and easily made into a spring clip which snaps into position. Some varnish was added to prevent rotation of the base.

To make the UX-7 base, in the past I had some tools to make these, using FR-4 pcb material. Rather than compressing the Brass pins over, which can split them, instead I solder these to the pcb foils after pressing them into the slightly undersized holes in the fibreglass. The Diodes which replace the secondary contacts are fitted to the UX-7 base.

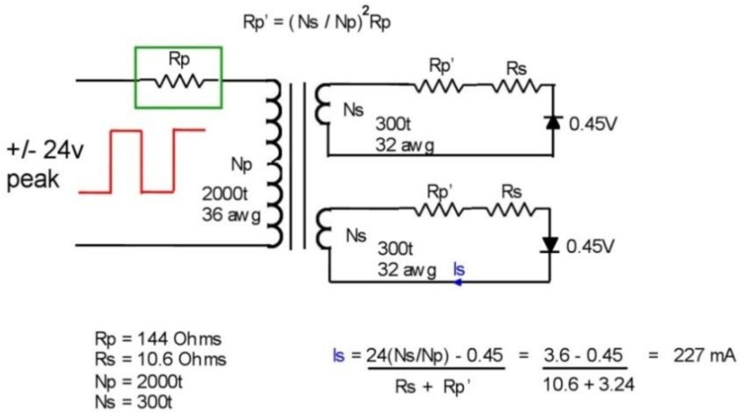

Tools for making UX-7 Base



Making the Feedback transformer:

This small transformer has a 1 square centimetre cross section laminated iron core. There are 2000 primary turns applied first of 36 AWG wire, followed by a bifilar 300T turn windings of 32AWG for the secondary. It was designed on the basis of the calculations below.

One feature of it was being to keep the secondary DC resistance where it could eliminate the need for an additional two base bias resistors. Also the transformer was designed for a low maximum flux density of about 0.5 Teslas (Webers per square meter) so that it was well away from saturation itself and would not interfere with the vibrator transformer being the determinate of the operating frequency. (Of note it is possible to arrange it so that the feedback transformer can be the determinant of the operating frequency, but that arrangement can be less stable)



The photo collage below shows the transformer being wound. I do this on my mini-lathe to and have a turns counter attached. I also varnished the transformer in a jar of varnish with a partial vacuum applied.