IMSAI 8080 Restoration for The Centre For Computing History at Cambridge, UK.

January 19, 2020

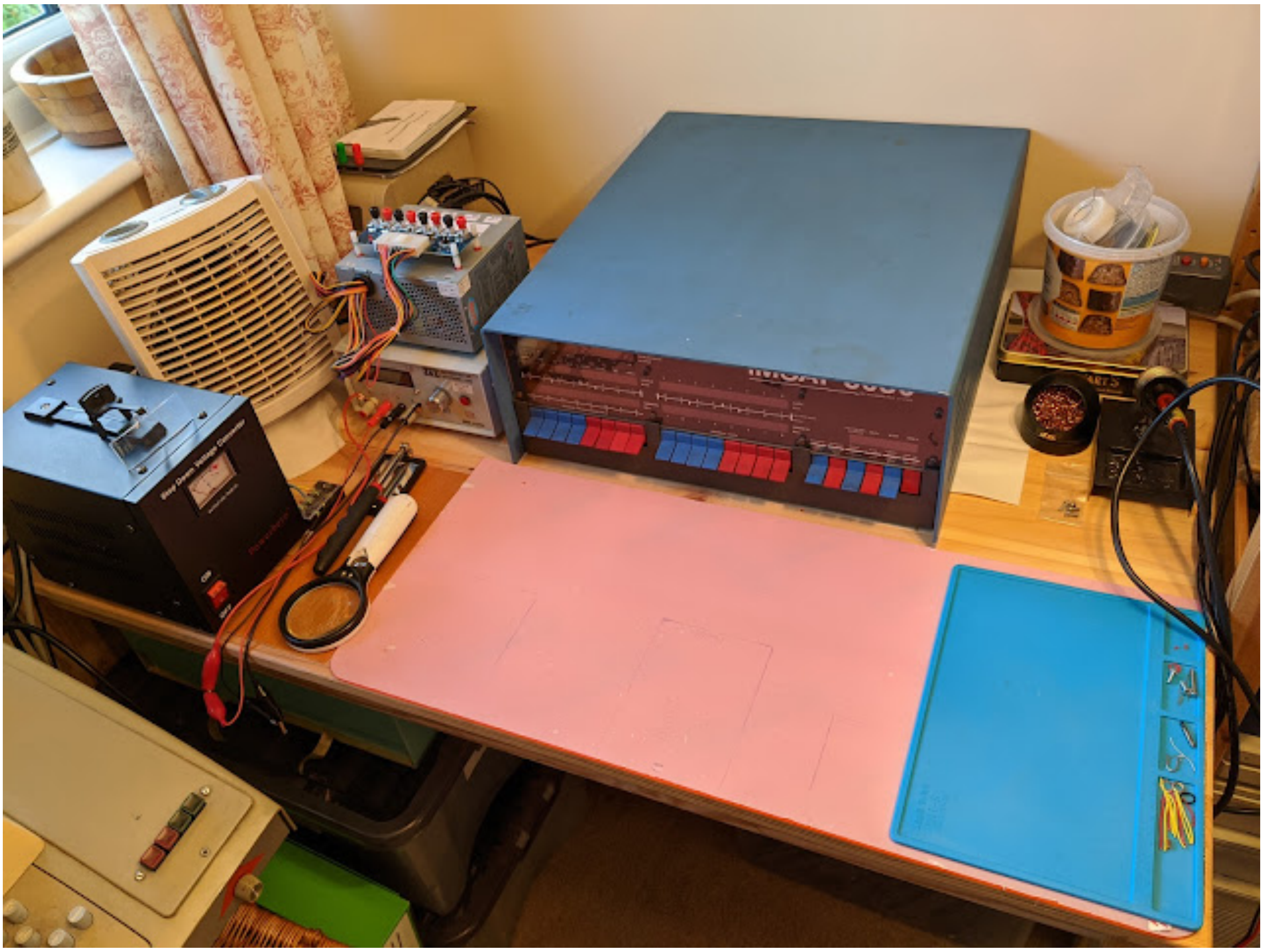
BLOG PART 1: What Have We Actually Got?.

09/11/2019 - Ross Milbourne.

Welcome to this Blog. The intention is to restore the computer to full working order, such that it may be used for public demonstrations.

Here is the machine in question, before work commences:

and here is my workspace:



The Blog will be a step-by step guide to the restoration and will, hopefully, be of use to others who wish to follow a similar path with their own equipment.

I am no expert when it comes to electronics, being much more a software than a hardware person, so I am learning a lot as I go along. I will not be offended, therefore, by those with greater knowledge sharing it with everyone in the comments.

IMPORTANT NOTE:

No attempt will be made to switch the machine on at this stage. One of the most tragic mistakes made by so many people who inherit or decide to sell their own machines which have been in the loft for 30+ years - for example on Ebay, is to 'give it a quick try' to see if it works. They know that if they are able to demonstrate some life in the machine, it is likely to realise a higher price. However, IT IS NOT A RISK WORTH TAKING.

All too often, the seller will report that, when they plugged it in and applied power, there was a pop/bang, followed by the appearance of smoke which smelled very unpleasant - or it worked for a few seconds and then went dead, etc.

Often, what has happened is the PSU has failed, due to capacitors that have dried out, or other components have failed with age and poor storage conditions. This can cause very undesirable voltages/currents to be applied to the main circuitry, resulting in further damage. This can be catastrophic on delicate equipment, and should be avoided.

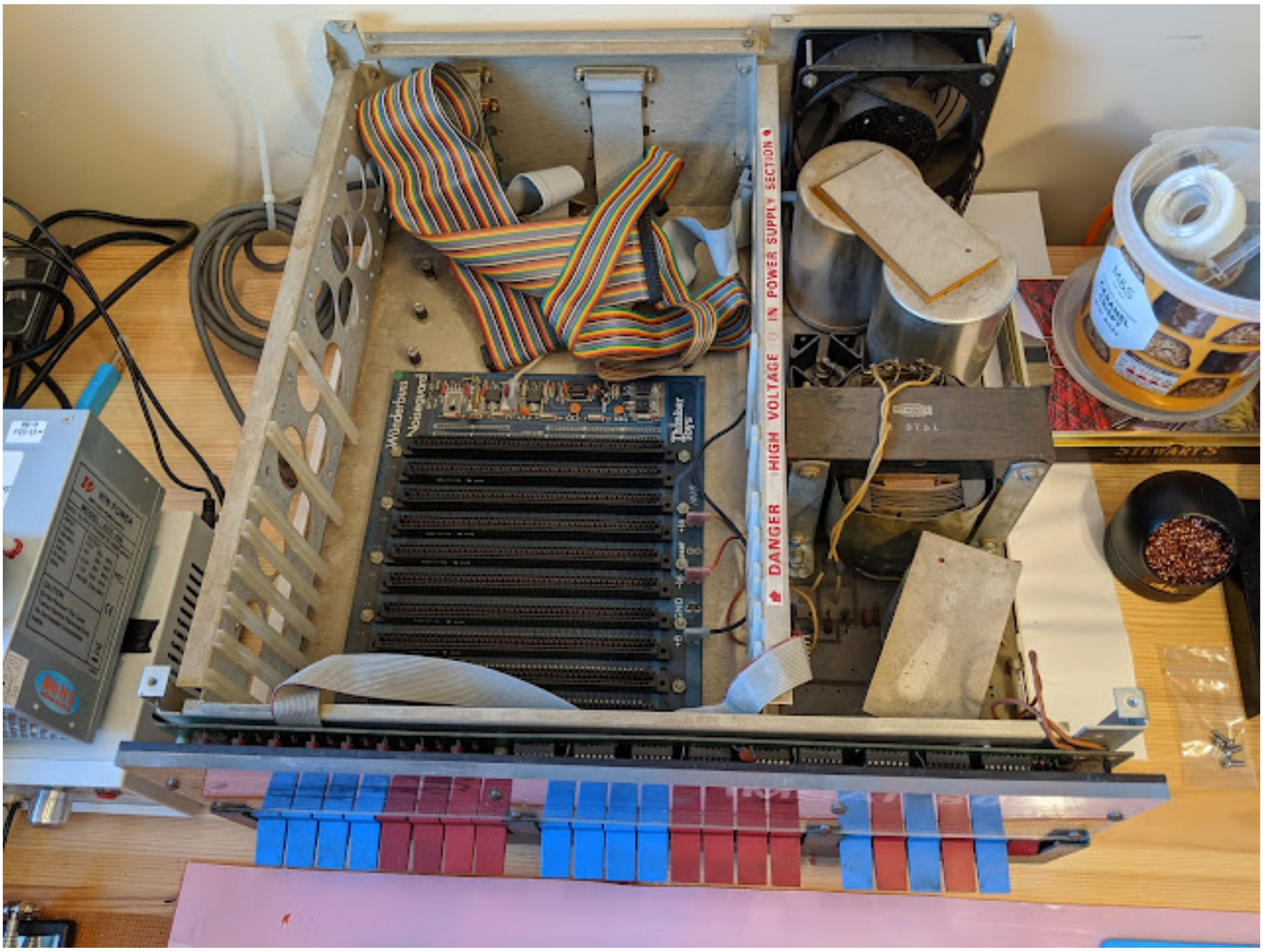
Along with the dreadful handling experience with many courier services these days, this is the other main cause of rare machines being damaged.

The message could not be clearer- DON'T BE TEMPTED.

END OF IMPORTANT NOTE.

The starting point is to undertake a fairly quick visual inspection, to determine what we actually have on our hands. Very often, equipment of this age will have undergone a number of modifications in its lifetime, with faulty parts being replaced, performance upgraded, and functionality enhanced.

The removal of two screws on each side of the top cover, allows for very easy access to the workings:



A good starting point is to attempt to date it as accurately as possible, so that we can determine what should or might have been present when originally purchased. One of the most helpful items in that respect, with the IMSAI 8080, is the serial number. This is to be found on a metallic label, usually on the outside of the rear panel. In our case, however, it was lurking on the inside, behind the backplane:

Serial Number 003550

I have a database of machines that have come up for sale in recent years, or are in various collections - both private and in museums. This can be very useful in providing a rough idea of when it was manufactured, along with what some of the major component parts should look like.

The numbering of IMSAI 8080 machines actually started at 001001, with a batch of 25 machines delivered in December 1975. This was probably a smart marketing ploy to make it look as though the machine was more successful than it really was to early buyers. In our case, therefore, it was the 2,550th machine off the production line.

From data gathered to-date, this appears to place it just after the middle of the original production of circa 4100 machines made in 1976. Serial numbers from 001002, delivered in December 1975, through to 005104, delivered around the end of 1976, help us to position it very roughly within that year to around mid July.

There are four separate serial number series known to-date:

The first machines ran from 001002 upwards and the last I know of is 005104 (or 00590? where the last digit cannot be seen in the photo). There will be more.

The second series just had a 1 placed at the front, but carried on from where the last series left off. The lowest number I know of today is 1006782 from that series and the highest is 1013228.

It is safe to assume from theferefore that at least 12,227 machines were produced from this, the main series.

The third series is from 1979 onwards, when Fischer-Freitas had taken over the parts and rights. I have only come across one machine in that series, number 25050A.

The fourth series is a bit of a mystery. A machine turned up with the serial number that has a prefix of 'I' and a number of 101110. It can be seen at: http://pc-museum.com/046-imsai8080/

The machine is in Sweden. Could it be that the 'I stood for 'International', and IMSAI created a separate numbering system after opening up that market? It certainly has the last of the types of transformer used, and the capacitors appear to have late 1977 date codes.

Further help is available by looking at the large capacitors in the PSU. Very often, there are a pair of 95,000uf units and another pair of 10,000uf units. These nearly always have a date code stamped on them, and our machine is no different.

Manufactured Week 23 of 1976

Manufactured Week 23 of 1976

As these capacitors do not appear to have been replaced then, from these dates, we can now say with certainty that the computer was manufactured sometime after May 30th 1976 (i.e. the end of week 22).

Originally, most earlier machines were shipped with the standard EXP-6, 6-slot IMSAI backplane or, optionally, the EXP-4 or EXP-10, 4 and 10-slot IMSAI backplanes.

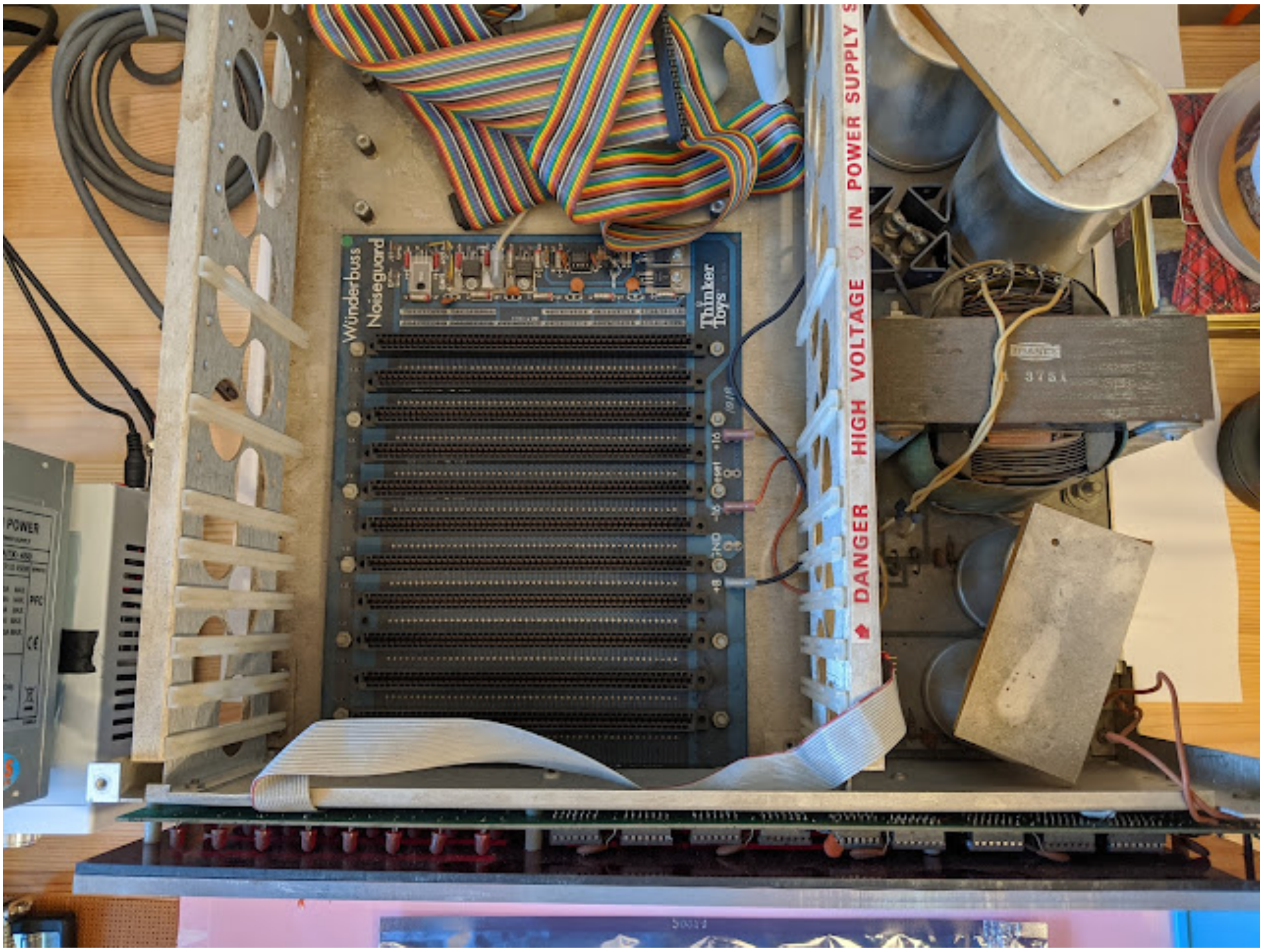
In our case, we can see that the backplane is a 'Thinker Toys - Wunderbuss Noiseguard' unit. Such alternative backplanes were not offered as options by IMSAI, prior to bankruptcy and the subsequent sale of their assets to Fischer-Freitas in 1979, so we know it is a replacement.

The move to a more sophisticated backplane like this, with in-built active termination, often coincided with an upgrade from the original S-100 8080 CPU board, to a Z80-based alternative, running at twice the clock speed. This increase in speed on the S-100 bus was made more reliable by a better backplane.

IMPORTANT NOTE:

Throughout the restoration, take detailed photographs that you can refer back to. A good example shown here, is the positioning of the four large electrolytic capacitors in the PSU. If you reconnect them the wrong way round and reverse the polarity when you reassemble, they will be damaged beyond repair.

END OF IMPORTANT NOTE



Thinker Toys Wunderbuss Noiseguard Backplane

In September of 1976, the standard IMSAI backplane was changed to one that contained 22 slots. We can see that there are only 8 pairs of card guides fitted, so the machine pre-dates that change.

So, with the capacitor date of after May 30th 1976, and the backplane change of September 1976, we have narrowed it down to a 4 month period.

However, we have one more clue - in August of 1976, IMSAI dispensed with the use of a large, heavy-gauge aluminium support sheet under the backplane - presumably to save costs. At the same time, they switched to using nylon screws to support the backplane. We can see that these are fitted to our machine and the aluminium support plate is missing, so can now say that it was manufactured in August or September of 1976.

This is pretty consistent with the serial number, and gives us further confidence that, on the face of it, nothing, so far, is untoward.

As already mentioned, this date can also be important in allowing us to begin to compare what parts the machine is made up from today, with what the options were at the time of purchase, to determine what is likely to still be 'original' in that respect.

We can see from the photo that there are a number of legacy ribbon cables in the machine. The main multi-coloured ribbon was for connection to a hard drive and S-100 controller, both of which are no longer present, so that cable can be removed. It is not attached to the chassis.

That leaves 3 more cables that are attached to the backplate of the chassis. The multi-coloured cable has a DB25 connector bolted to the chassis and the other end would have probably connected to the parallel port on an appropriate S-100 board.

The two grey cables also have DB25 connectors bolted to the chassis. The other end of each of those cables cables leads to a 25-pin edge connector. It is not clear what these were for, although they may well have been for two serial ports.

None of them are required for the future configuration, so will be removed and stored.

BLOG PART 2: What Have We Actually Got? (Part 2) + Power Supply Considerations.

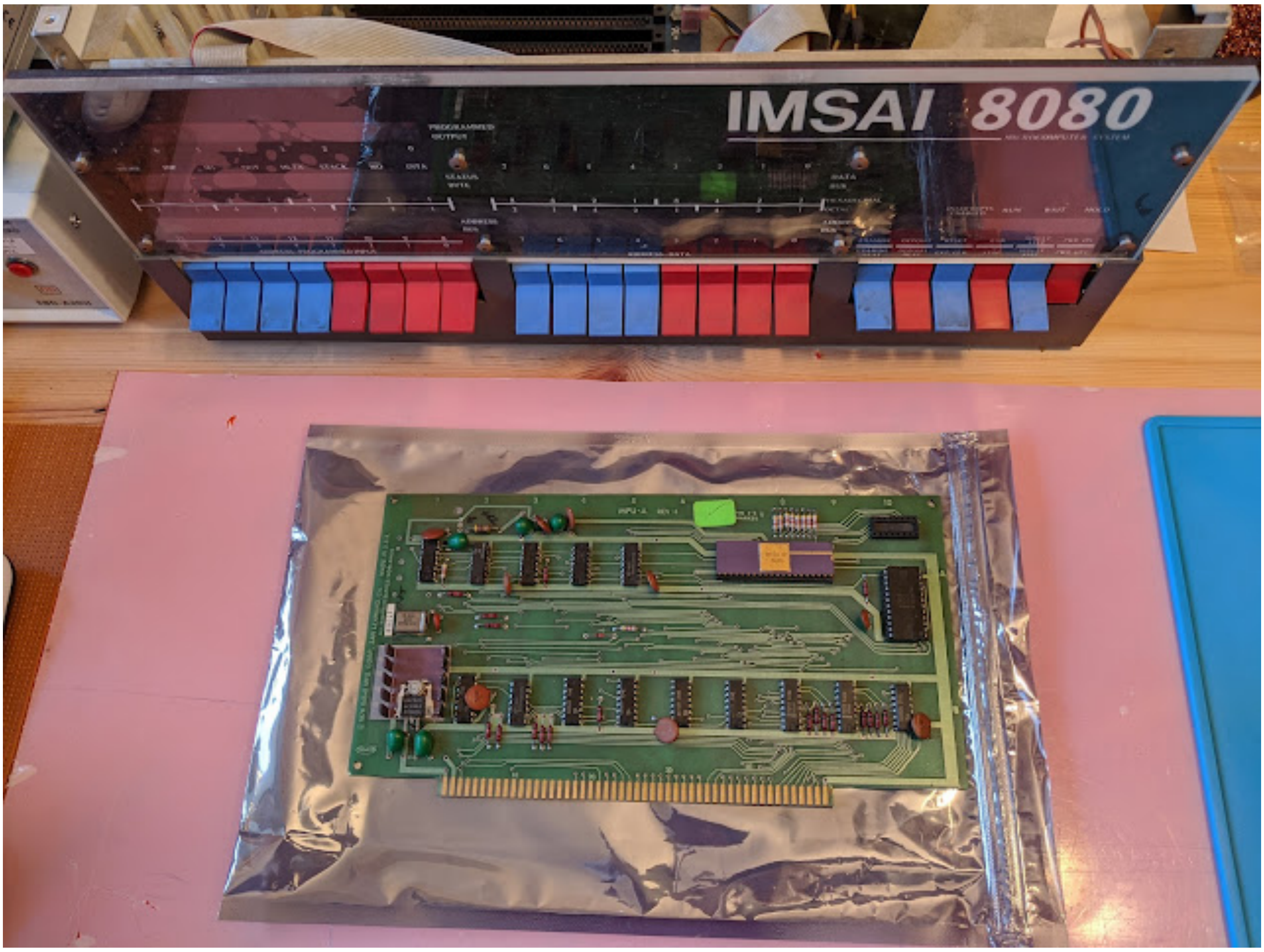
10/11/2019

IMPORTANT NOTE:

Early ICs are easily damaged by static electricity, carried by many people due to the clothing worn. Observe correct handling procedures at all times, through the use of anti-static storage bags and the wearing of wrist straps that are connected to Earth when handling the boards and their ICs.

END OF IMPORTANT NOTE.

The only S-100 board that came with the machine is the CPU card:



MPU-A Rev 4 S-100 CPU Board

This revision of board was used for all but the very earliest machines, where the green silkscreen was not present.

If we look at the board, we can see that most of the ICs are soldered directly to the pcb. This is unhelpful when troubleshooting and replacing faulty ICs. The use of sockets makes it much easier, so if I ever do replace a soldered IC, I put a socket in place.

In this case, however, it is useful in helping to determine an earliest manufacturing date. By looking at the latest date of the IC which is soldered to the pcb, we can say that it must have been manufactured on or after that week.

In our case, we have a number of N8T97N ICs that were manufactured in week 46 of 1978. This proves that the CPU board is not original to the machine. Nevertheless, it is an exact replacement, and not a modern reproduction.

Next, we turn to the Front Panel pcb:

It is apparent that the black plastic sheet with the legends printed on it has stuck to the clear perspex front cover in some places, creating an undesirable 'wet' effect. This can be caused by the surfaces not being clean, but it can also be caused by the hex head screws being over-tightened when putting it back together, so we need to watch for that.

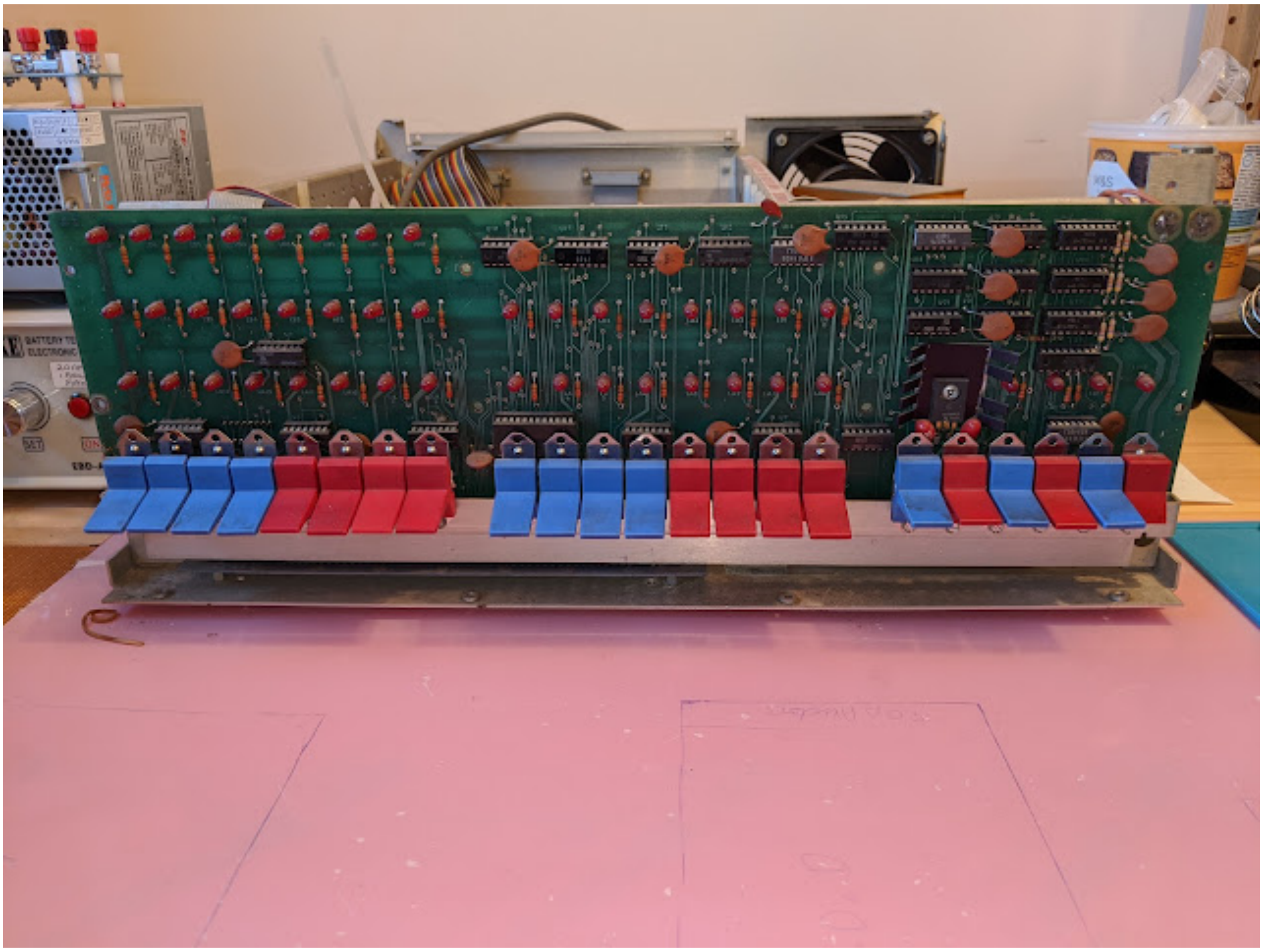
First, we remove 4 screws underneath the front edge of the machine, which hold the grey escutcheon in place.

Next, by removing the 8 long hex-head screws holding the front panel in place, we can expose the Front Panel pcb itself. Take care when removing the screws to catch all of the round plastic spacers between the pcb and the chassis which will fall off the screws.

The main panel artwork consists of several layers as can be seen here:

Front Panel Artwork Plus Escutcheon

The pcb itself is actually plugged into the front S-100 slot and that is all that is holding it in place now. The entire unit, including the paddle switches can simply be unplugged and laid on the workbench in order to work on it. The only constraint in that respect is that, in our case, the mains power switch cables are soldered to the board. They can be de-soldered if required. Many people cut these cables and use simple plug connectors to make maintenance easier going forward.



Front Panel PCB

It is worth noting at this point that the red and blue plastic paddles are all original. They commonly get broken or pop off and then get lost. It is usually easy to find red replacements, including modern reproductions, which will be a good colour match. The same cannot be said of blue paddles. Modern reproductions are readily available, but are invariably a much lighter (and in my opinion less attractive) shade of blue. Luckily we have no problems here and, in addition, all the paddles move freely.

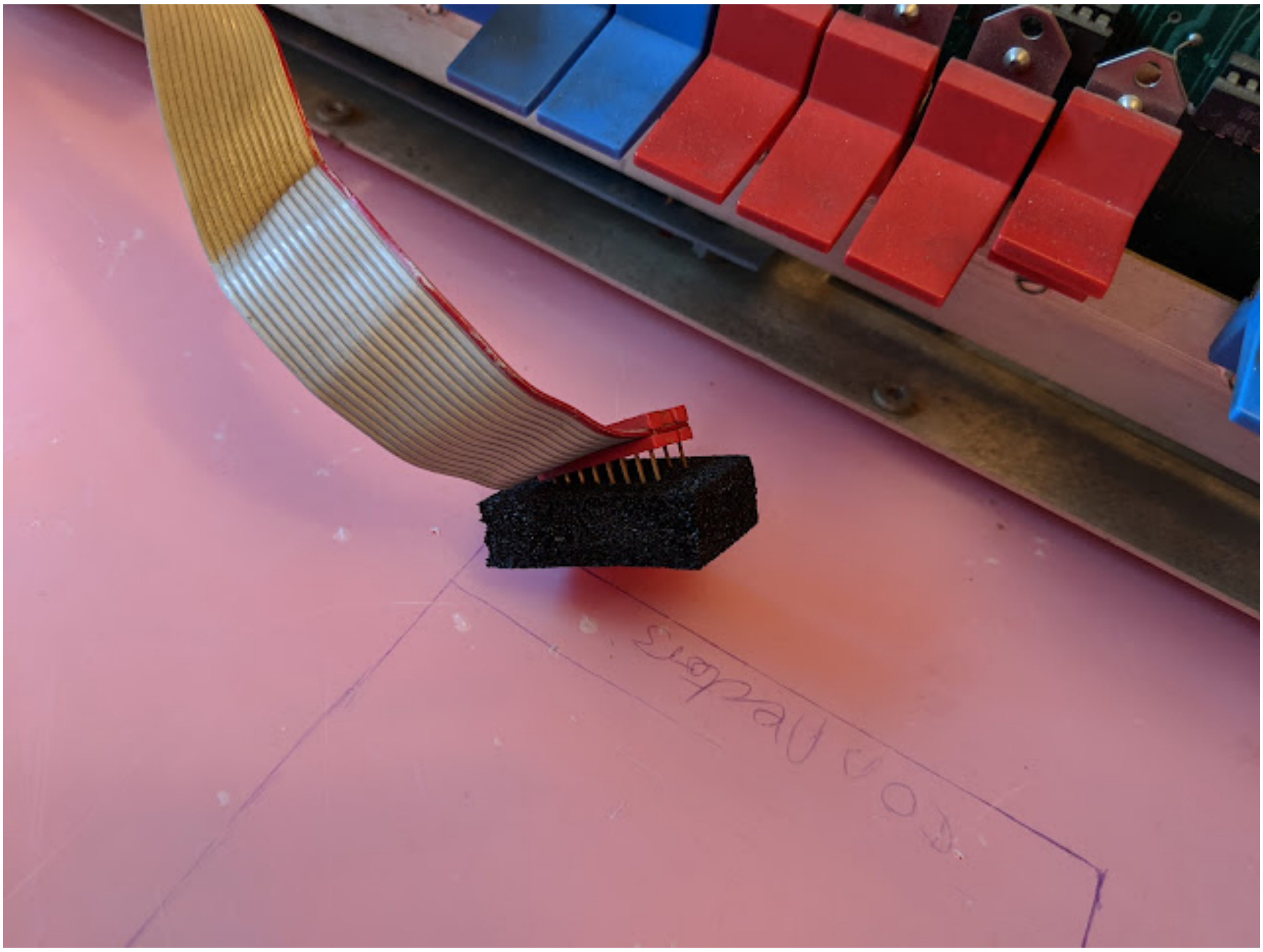
One thing to take careful note of at the top right of the pcb are the two soldered contacts. These are the live mains wires that go in and out of the red on/off switch at the bottom right. It is potentially very dangerous not to have these contact points covered when working on the machine. For that reason, some vinyl insulating tape will be applied to them.

Luckily, the majority of ICs on the Front Panel pcb are socketed. This will make it much easier to fault-find in due course. A quick visual inspection reveals a lot of dust and some corrosion on a few of the contacts, but a deep clean of the board, and IC contacts - by removing, cleaning and replacing them - will put that right. Contact cleaner can be used on the sockets.

What is of interest here is that the dates of some of the ICs is much later than the established date of manufacture for the main machine. The ICs are all socketed so it is difficult to prove, however if it were just one or two ICs that were of a later date, we might reasonably assume that they had been replaced as faulty. In our case, we have quite a few that are later than the main chassis manufacture date of August/September of 1976.

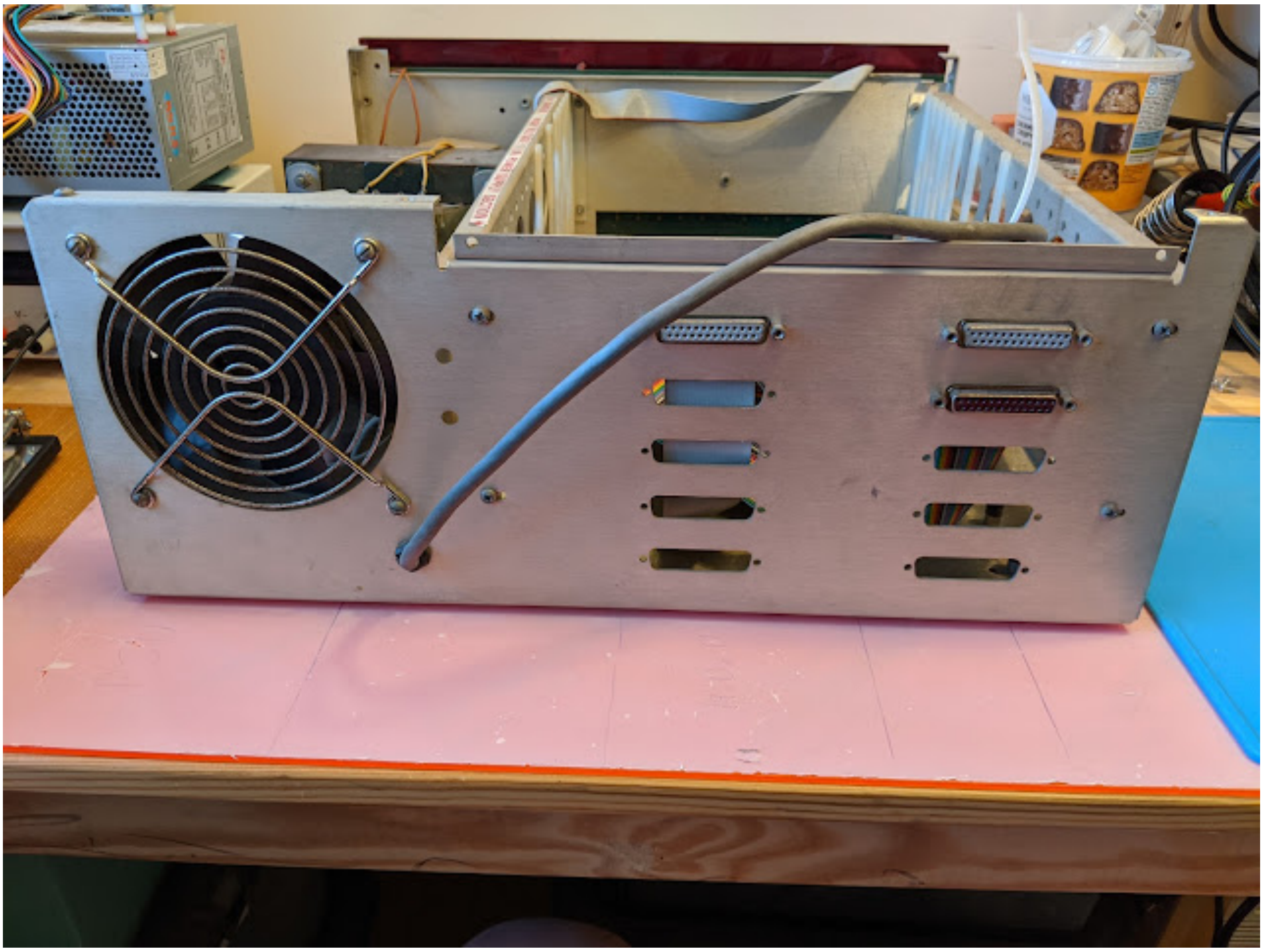
It is reasonable, therefore, to conclude that the Front Panel pcb is a later unit. It may well have been a replacement for a troublesome original. There is no problem with that per se - it all forms a valid part of the machine's history. It is only the purist, who may be looking for complete, unchanged originality, who could object. The machine will work just as well as it is.

The ribbon cable which runs from the Front Panel pcb and connects to the CPU Board has been disconnected. It is wise to use a piece of foam to protect the pins while we are working on the machine: they are easily bent/broken otherwise.



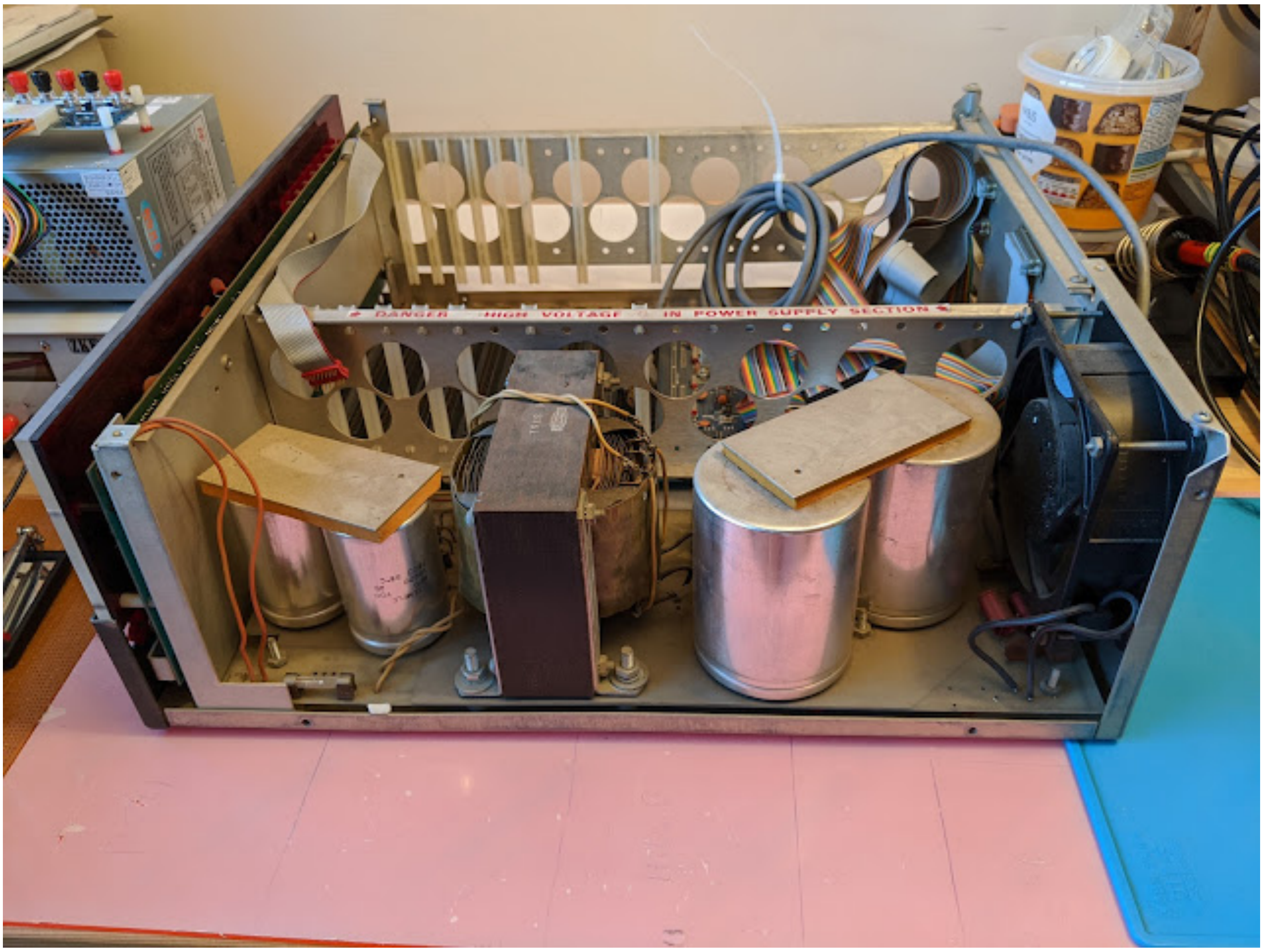
Front Panel to PCB Board Connector

Here are some further views of the machine, taken before it is dismantled any further:



Back Panel

Left Side of Chassis



Right Side of Chassis, showing PSU

The next thing it would be useful to determine, is what mains voltage and frequency the machine has been configured for. In our case, there is no information on the back panel to help us with that. We can see from the mains lead, that terminates with a USA style plug, that we are probably dealing with something that is configured to run from a 115v, 60Hz supply.

However, that is not enough. IMSAI used different transformers over time and they had different capabilities and characteristics. One of the most dangerous problems are those transformers which are designed to operate only on 60Hz, and not on the 50Hz supply we have in the UK and much of Europe. Not dealing with this correctly will often lead to saturation of the transformer core, followed by overheating and failure.

We can provide a 115v, 60Hz supply fairly inexpensively, through the use of 12v leisure batteries, connected to an appropriate DC to AC Inverter. Another popular alternative is to bypass the main linear PSU and provide the required DC feeds with modern, switching power supplies. Each approach has its merits and drawbacks.

Most IMSAI transformers, including this one, were able to operate on either frequency, and different taps on the transformer would raise or lower the voltage to some degree, to compensate for increased current draw caused by adding more S-100 boards. Time to take a closer look and consult the manual...!

The transformer in question is a Tranex, model 4-3751. In the manuals, this is mounted onto a pcb assembly referred to as model PS-28D. It provides unregulated +8v, +16v and -16v DC outputs, from a single-phase supply of between 110-120vac. Maximum power output is 500 watts.

At a nominal 117vac, the transformer provides taps for 0, +10% and -10%, to deal with line voltage variations and machine loading - i.e. will operate from 105vac to 129vac.

At 117vac, with no load, the DC outputs will be +9.7v, +18v and -18v.

At 117vac, when connected to a resistive load, the DC outputs will provide 28amps at +7.0v, 4.5amps at +13.5v and 4.5amps at -13.5v.

IMPORTANT NOTE:

If you are not very familiar with the internal working of power supplies, or do not feel confident about it, DO NOT TOUCH. Dangerous voltages/currents lurk within, that can cause injury or death if not handled correctly. They do not need to be switched on to hurt you. If they have been turned on, the large capacitors you see will have been charged, and this takes time to dissipate when the supply is disconnected.

END OF IMPORTANT NOTE.

With old equipment that has not been used in a long time, it can be very useful to check that you do not have a short-circuit in the PSU (e.g. within the main transformer - or in a shorted capacitor), when you power it up FOR THE VERY FIRST TIME ONLY. One 'belt and braces' device often used for this is the light bulb current limited test.

It is easy to forget that a reasonable percentage of vintage equipment was probably put into storage in the first place, when it had developed a fault........

The bulb is wired in series with the live rail, rather than across the live and neutral rails as normal. Note: one consequence of this is that the bulb does not light up when you plug in and switch this setup on - on its own. If you don't remember this, you will end up swapping bulbs out thinking they have blown! There needs to be a load connected between the live and neutral rails before current will flow through the bulb. If the load is 0.25amp or greater, the bulb would light fully. Less than that and the brightness would be reduced accordingly.

Before performing a test, it is very important to disconnect the outputs of the PSU from your delicate circuits! You want as little theoretical load as possible at this stage, and don't want to run the risk of applying undesirable voltage/currents to the machine circuitry if there is a fault.

At 240vac, a 60w bulb will limit the current to 0.25amp and is a good value to choose, because we are all familiar with how bright a 60w bulb should be when operating at its normal voltage/current.

The bulb will light up fully if there is any short circuit, but hardly at all if only a small amount of current is flowing - which is, for example, what you would expect if you have disconnected the output load(s).

When you switch it on, you can immediately switch it off again if the bulb lights up more brightly than you expect it to. That can serve to minimise any damage.

(The power meter attached to the circuit in the picture is optional).

Current Limiter

Once we have established that we do not have a short-circuit in the PSU, we can move on to use various other pieces of equipment to perform other tests.

For example, when ready to do so, we can test the stated DC output parameters, using something like a ZKE EBD-A20H load tester:

ZKE EBD-A20H Electronic Load Tester. 20Amp, 30v max.

After disconnecting our circuitry from the PSU outputs, we can see what voltages are being produced by the PSU, and simulate running each of the outputs at different loads, up to their stated maximum, using this equipment. It provides current up to 20amps and voltages up to 30v, which is more than sufficient for most vintage microcomputers like the IMSAI 8080.

In my own experience, it is best to bring the source voltage up slowly on old equipment. There can be little doubt that it reduces thermal shock, and the number of components that fail as a result - a highly desirable thing on delicate and rare equipment. It has the additional benefit of allowing us to carefully adjust the source voltage to exactly what we want it to be, regardless of the daily variations we see from our electricity supplier. This includes ramping the voltage up above the supply by up to 10% where required.

In the same way, we can use digital meters attached to the DC output to measure the voltages and current draw, and bring the supply up to but no higher than is safe to run the circuits. On the IMSAI 8080, the current draw will depend upon the type and number of S-100 boards that are fitted at any one time. Our PS-28D should be capable of running the +8v DC output rail at loads of up to 28amps (although personally I would not recommend stressing at this maximum level. 20amps would be a more sensible limit to set).

The higher the current draw, the more the voltage will drop. The machine configuration does not change very often, so we can measure what it should be under normal conditions, with no faults present, and then bring the machine up slowly, over a number of seconds, to these levels - protecting the circuits in the process.

A Variable Transformer (Variac) is a good way to achieve this. There are a number of very poor quality units for sale on Ebay, but one notable exception is the Ravistat:

Ravistat 10-P-1 Variable Transformer (Variac) - 10amp continuous load max.

The heavy-duty construction of this unit makes the extra investment well worth it.

In many circumstances, expert opinion is that you should remove your aluminium electrolytic capacitors from the power supply and test and reform them separately, if they have stood unused for any great length of time.

It seems to be generally accepted that this should involve applying the rated voltage of the capacitor, through a resistor, for a period equal to 5 minutes, plus one minute for each month of storage/last use. If we assume our machine has not be used since about 1980, that is about 8 hours. I cannot argue with the wisdom or the rationale of doing this, other than that I would not go near the rated voltage. It may well have dropped with age and, in any case, there is no benefit in reforming at a voltage much above the normal working voltage when not under load.

What I would also say, is that from personal experience with equipment PSUs using large capacitors, such as that fitted to the IMSAI 8080, this has not proven to be necessary in the past. By running the initial tests and then setting things up as described in this article - before bringing the source voltage up one step at a time, over a period of several hours with a Variac, using a relatively small load on each of the outputs, it has never failed to get the PSU running properly (unless it was already faulty of course).

IMPORTANT RETROSPECTIVE NOTE:

As will be seen from later Blogs here, experience with reforming the large PSU filter capacitors, after removing them from the circuit, has demonstrated that it may be necessary to reform large capacitors over a much longer period than a few hours, and that a much more scientific approach is needed than simply winding up the Variac over a period of a *few hours.*

In our case it sometimes took 60 hours to complete the process. It may well be that the PSU functions with less time taken, but clearly the capacitor is not going to operate as effectively as it should in filtering out mains voltage fluctuations.

END OF IMPORTANT NOTE

Going back to the specifications in the manual, we recall that, at 117vac, when connected to a resistive load, the DC outputs will provide 28amps at +7.0v, 4.5amps at +13.5v and 4.5amps at -13.5v.

We have the Electronic Load Tester that we could use on the main +7.0v output to provide a 2amp load, that represents 10% of our expected running maximum (i.e. 20amps rather than the 28amps maximum it should be capable of).

Alternatively, we could select appropriate wire-wound resistors.

For the + and - 13.5v outputs, to run them at about 10% of the 4.5amp maximum - i.e. 0.45amps, two 30 Ohm (or similar), wire-wound resistors, capable of carrying more than 6 watts are needed. In fact, 50 watts would provide a good margin, to stop them getting too hot. The following type work well and are available at low cost, on Ebay:

Typical wire-wound load resistors

In that approach, we are never running the capacitor at its rated voltage, far from it in fact. With the large 95,000uf capacitors, for example, they are only reaching +8vdc at the end of the process, against a rated voltage of 15vdc. Nevertheless, it has always worked for me.

Starting at 25vac and increasing by 25vac every 30 minutes, over a few hours, the PSU has always been found to be producing the expected outputs. Have I just been lucky? Have the Temple capacitors used by IMSAI just stood the test of time really well? It is a lot easier and more convenient to reform them in this way rather than dismantling the PS-28D assembly and removing the capacitors, then reassembling.

All that said, I have decided that, while I am at it, I am going to completely disassemble the machines major parts - to clean them and carry out a visual inspection. On that basis, I will take the opportunity to remove the four main capacitors from the PS-28D assembly, test, reform and refit them. I will still carry out the phased startup of the whole PSU over a few hours, once it is all back together, as it costs me nothing to do so and will be gentler on everything while we get the machine running once more.

Another consideration which many people wonder about is the fan at the rear. Apparently, this should be wired so that, when operating, it is sucking air from the outside (because that is the coolest air) and blowing it into and across the PSU. We will check that in due course, after the initial test of the PSU - during which test the fan will be disconnected.

It should be noted that the fan will not start spinning until a certain minimum voltage is applied, so we should disconnect it when we are bringing the machine up slowly for the very first time, over an extended period, on the Variac, to reform the capacitors. Failure to do so runs the risk of burning the fan out. This is not necessary in the future, however, when we are just bringing the machine up over a few seconds, to avoid thermal shock.

Whenever we are going to switch the machine on, it is important to have an inrush current-limiter fitted into the supply circuit. This serves to protect against sudden, often momentary, current surges being created. Large capacitors in the PSU, such as the four in our PS-28D assembly, will rapidly soak up a large amount of current, until they become saturated. That can put an big strain on the transformer, causing the windings to fail, as well as on the rectifier components.

We have also seen that using a Variac has significant benefits that we wish to take advantage of, but there is a snag. Even when turned right down, a huge momentary current of several hundred amps can be generated across the windings, causing component failures downstream. This too can be safely absorbed by the in-rush current limiter.

Ameritron ICP-120 In-rush Current Limiter

IMPORTANT NOTE:

In order for an in-rush current limiter to do its job, it is ESSENTIAL that it is used as the main on/off power switch for the equipment. That means leaving the on/off switch on the IMSAI 8080 in the ON position all the time and using the in-rush current limiter, plus the Variac, to control the power.

END OF IMPORTANT NOTE.

BLOG PART 3: Power Supply Considerations (Part 2) + Machine Disassembly + Reforming The PSU Filter Capacitors

11/11/2019

While we are on the subject of the power supply, we can take a look at what we intend to use to carry out the initial tests on this machine, along with the alternatives.

We are working on the assumption that the machine is configured to run on 117vac at 60Hz. This will be verified at a later stage, by checking the wiring on the transformer. On the PS-28D Assembly we have, the available documentation is silent on the question of which primary taps are used for +10, and -10% source voltage variations. Only the 117vac position is known.

In our case, we will use a pair of 12v Yuasa REC-22-12I, 22Ah deep-cycle batteries wired together in parallel, to provide a 44Ah capability.

Two Deep Cycle 12V 22AH AGM/GEL Batteries Wired in Parallel

An intelligent 3-stage 8A pulse charger is permanently connected.

Permanently Connected AGM/GEL 12V Battery Charger

The batteries are connected to a 3000 watt peak, 1800 watt continuous, 60Hz, pure sine wave 12vdc to 110vac inverter made by Peak Power:

We need a pure sine wave inverter, to make the supply closely match a normal sine wave, and avoid potential damage to components.

3000 watts is the rated maximum peak, however what is much more important is the continuous rating of 1800 watts. This will provide up to 16 amps at 110vac, which is more than enough.

The output will then be fed to our in-rush current limiter and, from there, into the Variac, before being fed to the machine.

Instead of batteries and an inverter, we could have used a normal 2Kw, 240vac to 110vac step-down transformer:

The only difference is that we would be running at 50Hz rather than 60Hz. In this case, it does not matter, because the Tranex 4-3751 transformer in the PS-28D PSU assembly can safely handle both of these mains supply frequencies.

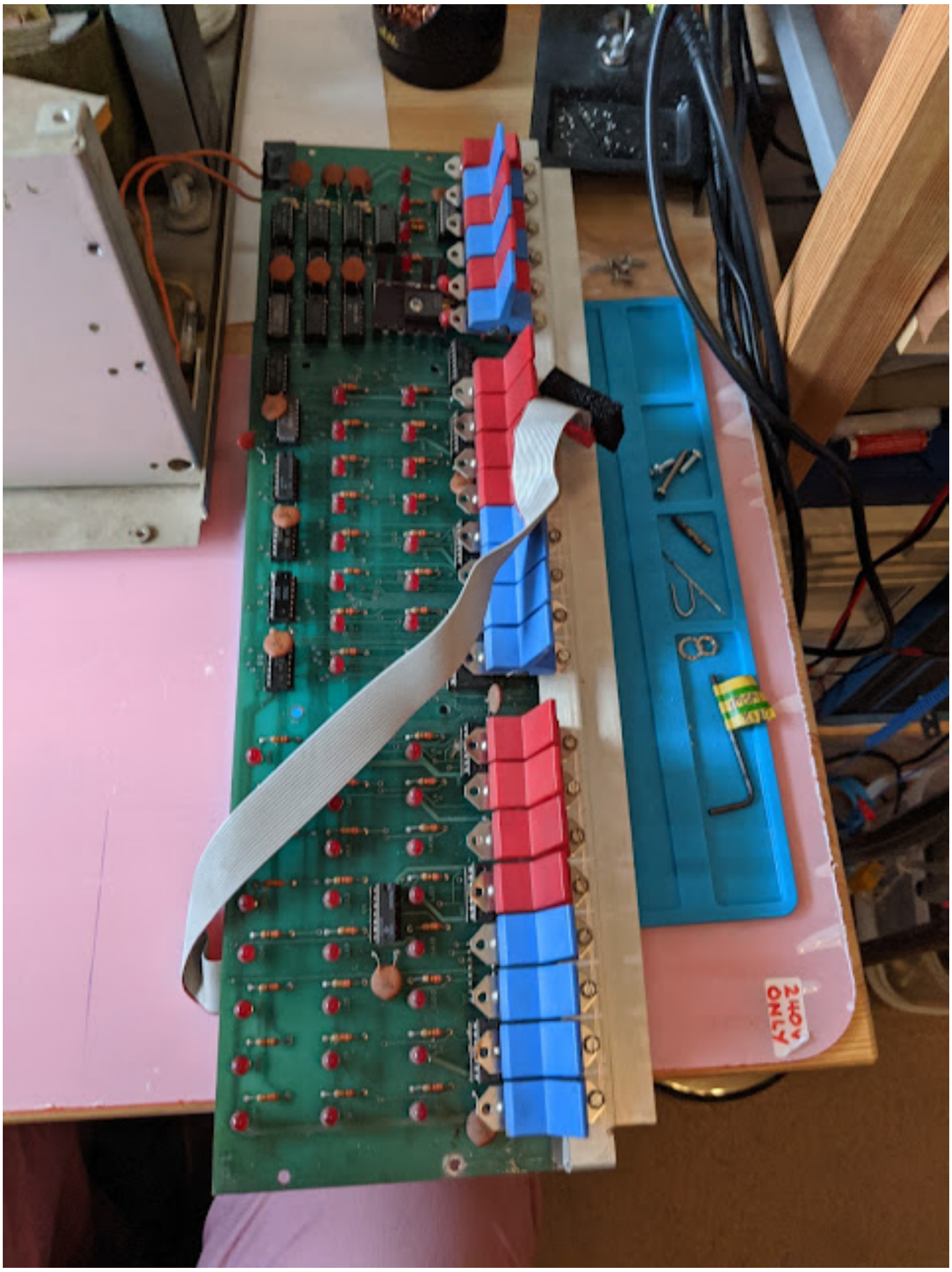
IMPORTANT NOTE:

If in doubt, use the 60Hz supply. That will not cause damage either way. A good example is the standard Altair 8800.

END OF IMPORTANT NOTE.

So, now that the theory of applying power has been dealt with, it's time to take the machine apart. We still have not switched anything on yet of course........

The Front Panel pcb is easily removed now, it simply pulls out of the front S-100 backplane slot. The two live rail cables in the top right corner are desoldered so that the board comes free, making it easier to clean, and work on if there are problems.

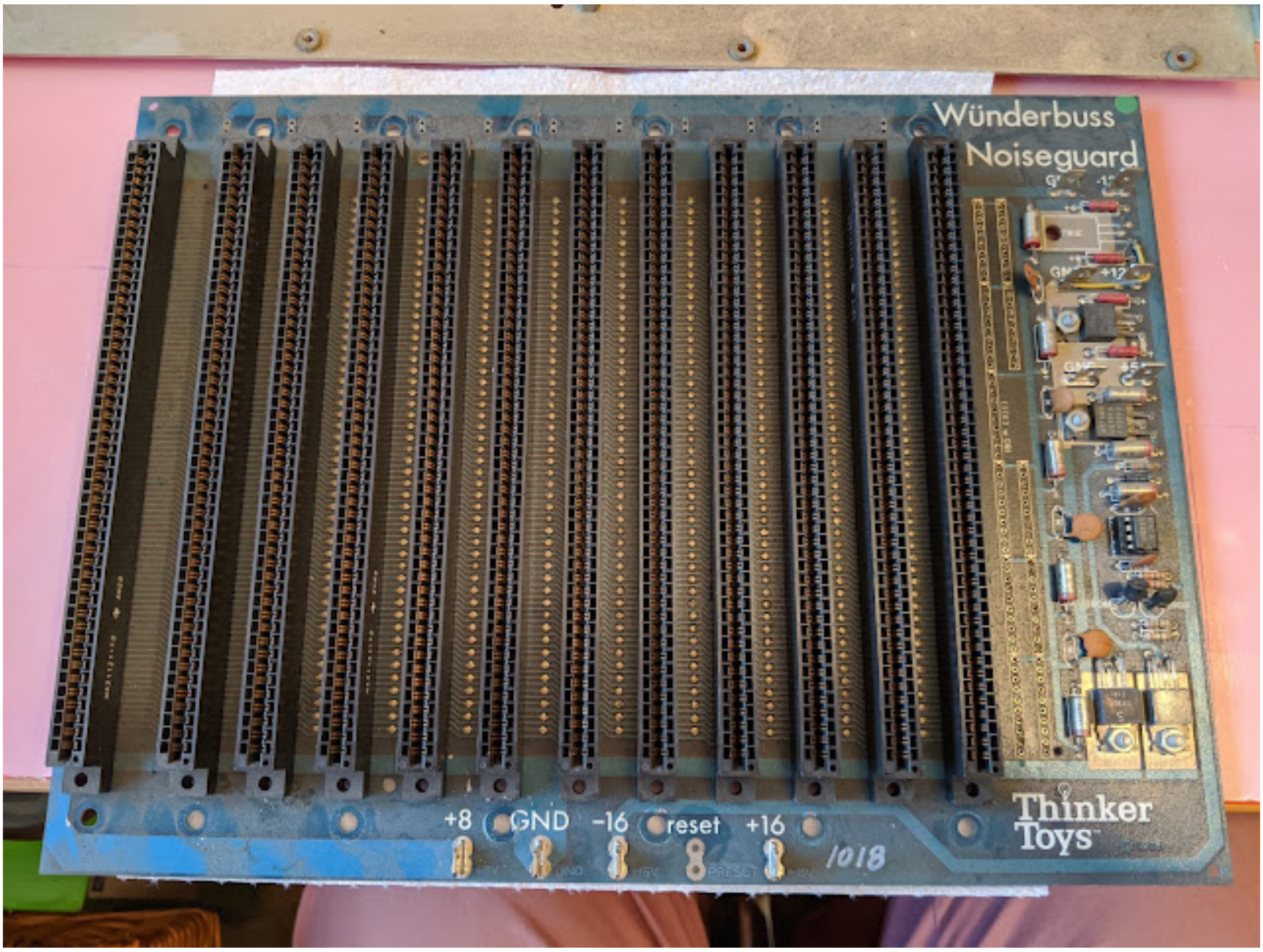


Front Panel pcb

The Wunderbuss backplane is held in place by nylon bolts with metal nuts down each side. Care must be taken if your machine is fitted with these nylon bolts, as they tend to go brittle with age and can easily break when removing the nuts. A tiny amount of PTFE-based lubricant does not go amiss on those where you feel resistance. Fortunately, those on this machine still felt supple and the nuts came off without a problem - albeit slowly! Only 5 needed some lubrication. If you feel resistance, stop and lubricate.

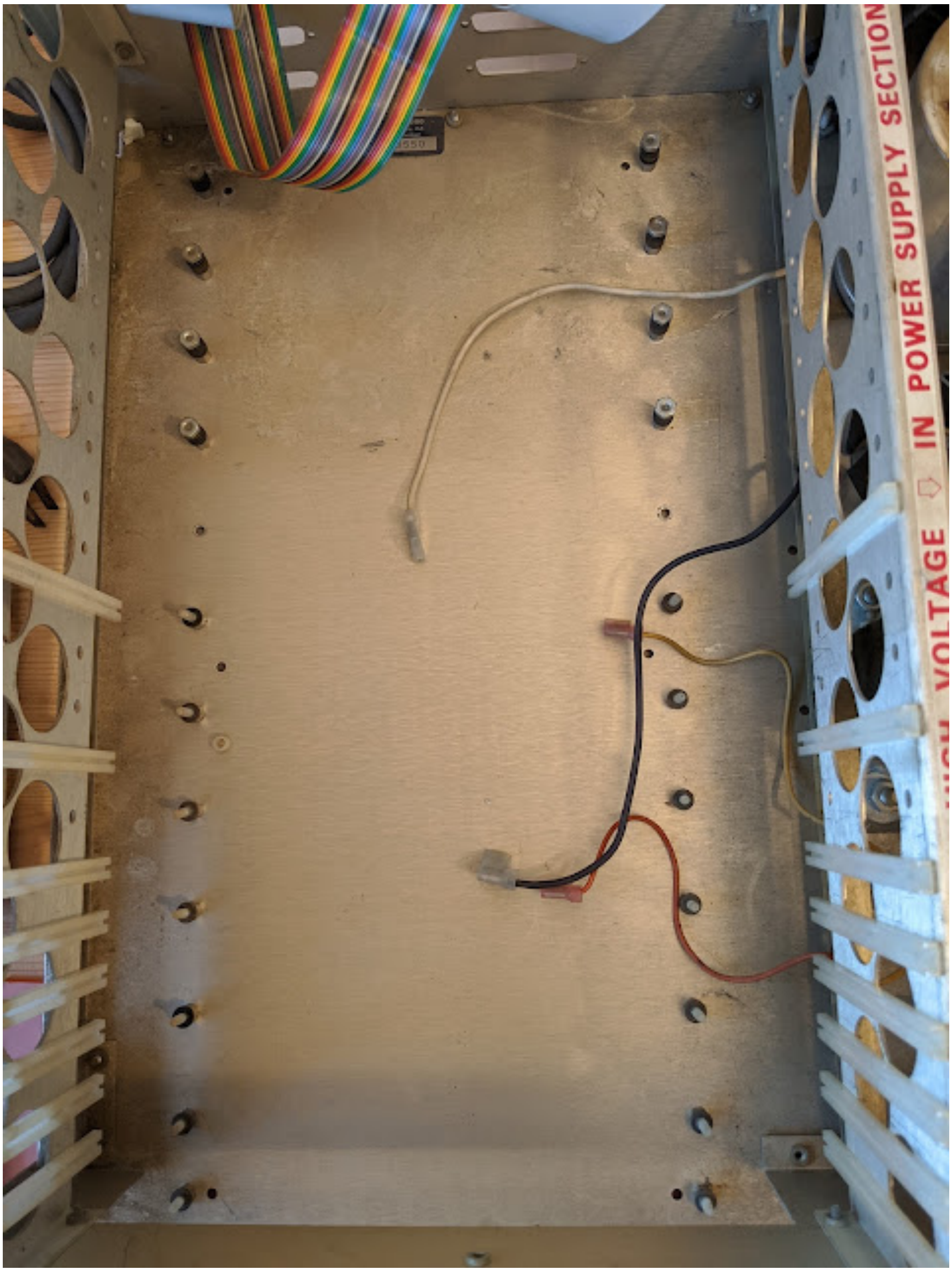
An invaluable tool for removing and refitting the Backplane nuts

Tip: this is the same tool used to remove the nuts on the Front Panel switches on an Altair 8800.



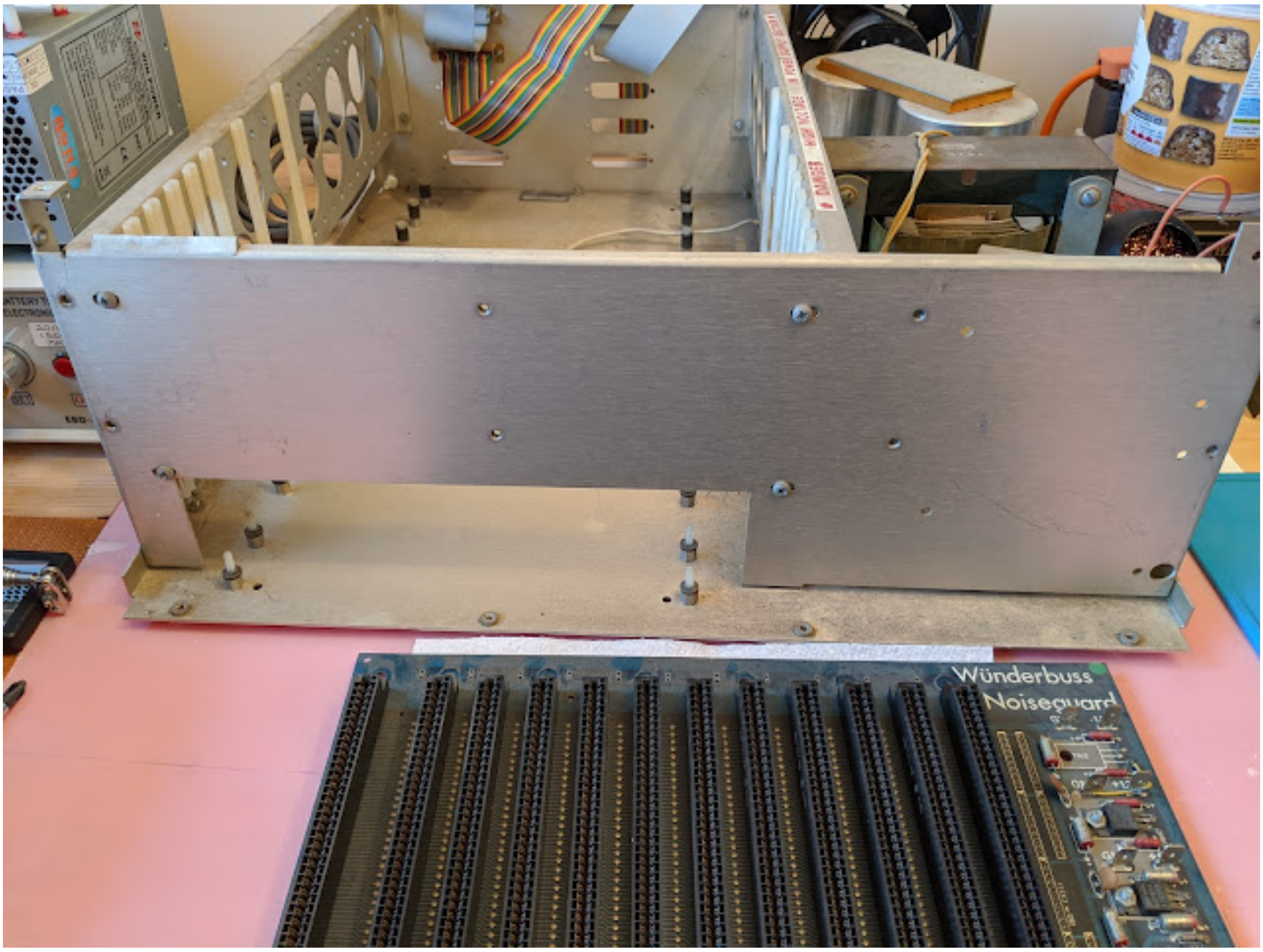
Wunderbuss Noiseguard Backplane

The contacts in the slots are filthy and will require careful work to clean them without bending any of the pins, which are easily damaged or distorted.



Chassis with backplane removed - exposing nylon bolts

Years of grime can be clearly seen all over the machine.



Front Panel and Backplane removed

Pretty simple so far.....

Old Data Cables From Rear Panel

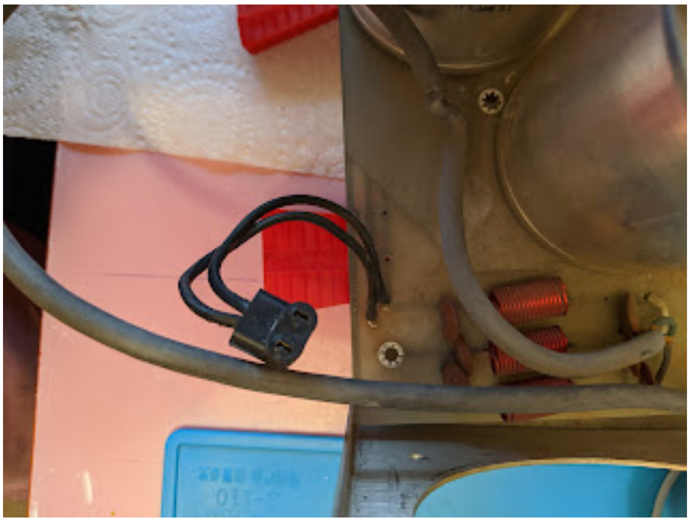
The redundant data cables from a past life have been removed and placed into storage.

The back panel is now clear of cables. It is very unusual for the serial number label to be found inside the machine. It makes it likely that we are dealing with a kit-built machine by a home hobbyist. Although IMSAI made few if any machines themselves in the early days, the dealers built them for customers and invariably put the label on the outside of the Back Panel.

The next task is removal of the PSU. This is quite a difficult job, and there are various ways to tackle it. Firstly, the nine nuts and washers holding it down need to be removed, as can be seen in the following photos:


IN POWER

At this point, the fan should be disconnected and then it and the fan guard unbolted from the back plate. Luckily, in this case there is a removable plug on the side of the fan itself.



To gain access to the PSU PS-28D assembly, consisting of a pcb + transformer + capacitors, etc. in order to pull it up from the bolts securing it to the base of the chassis, we could remove the card guide rail that runs down the centre of the machine. It is only secured by two screws at each end.

The problem is that each of these has been carefully fixed in position within a slot, to make sure that the distance across to the other rail is only just wide enough to allow S-100 boards to slot into place yet be held firmly in position.

By undoing them, it can take a fair bit of work to get them back in exactly the same places.

Personally, I prefer to simply lift the pcb, with everything attached to it, carefully, a bit at a time, and put chocs underneath as I work around the base. It is especially important to support the full weight of the transformer with your hands while doing this, and get something underneath the pcb, under the transformer, to stop it exerting a lot of downward force on the pcb, causing it to bend. This is quite tricky and takes a bit of time and practise. Don't attempt to rush it.

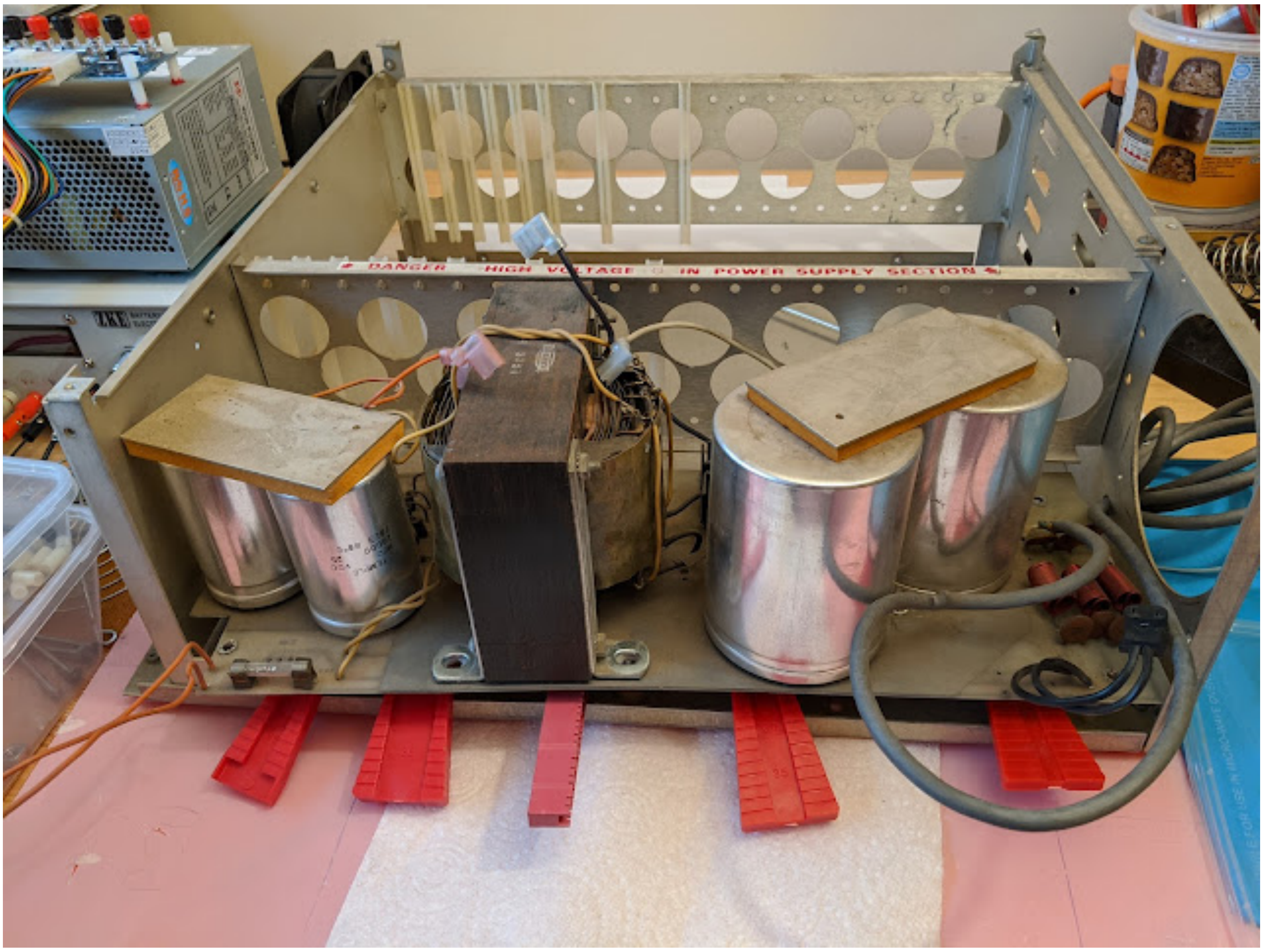
The bolts are quite long and you have to lift the entire assembly about an inch all round to get it off, with the centre rail getting in the way in the process.

If you find this uncomfortable, revert to plan A and remove the centre rail so that you can get full access. You still have to be careful not to let the pcb bend during removal, but it will be easier. As mentioned, however, the trade-off will be having to get the rail back in the right place afterwards.

When finished, it should be tipped onto the side with the transformer edge closest to the ground: This takes the weight off the pcb.

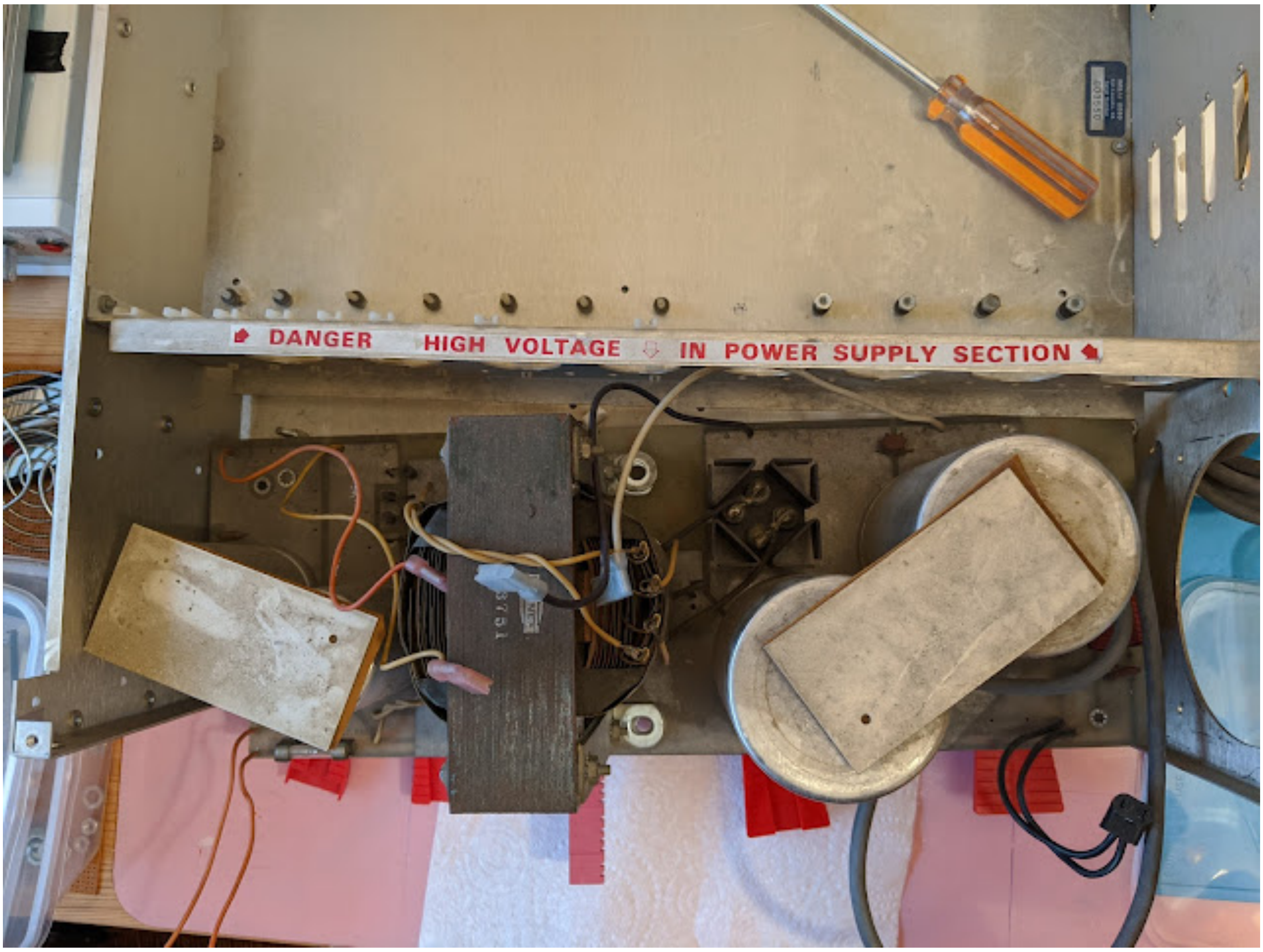
Another approach would be to desolder the four wires that are attached from the transformer to the pcb. However, although it is easy to get at and remove the top two, on the right side in the photo, it is much more difficult to get at the bottom two on the left side in the photo. You could, of course, cut the wires close to the pcb and then resolder them before refitting later, if you have some slack.

If you feel confident that you can desolder the transformer without damage, it has the advantage that the transformer can be lifted off altogether, making removal of the rest of the assembly much more easy to handle.



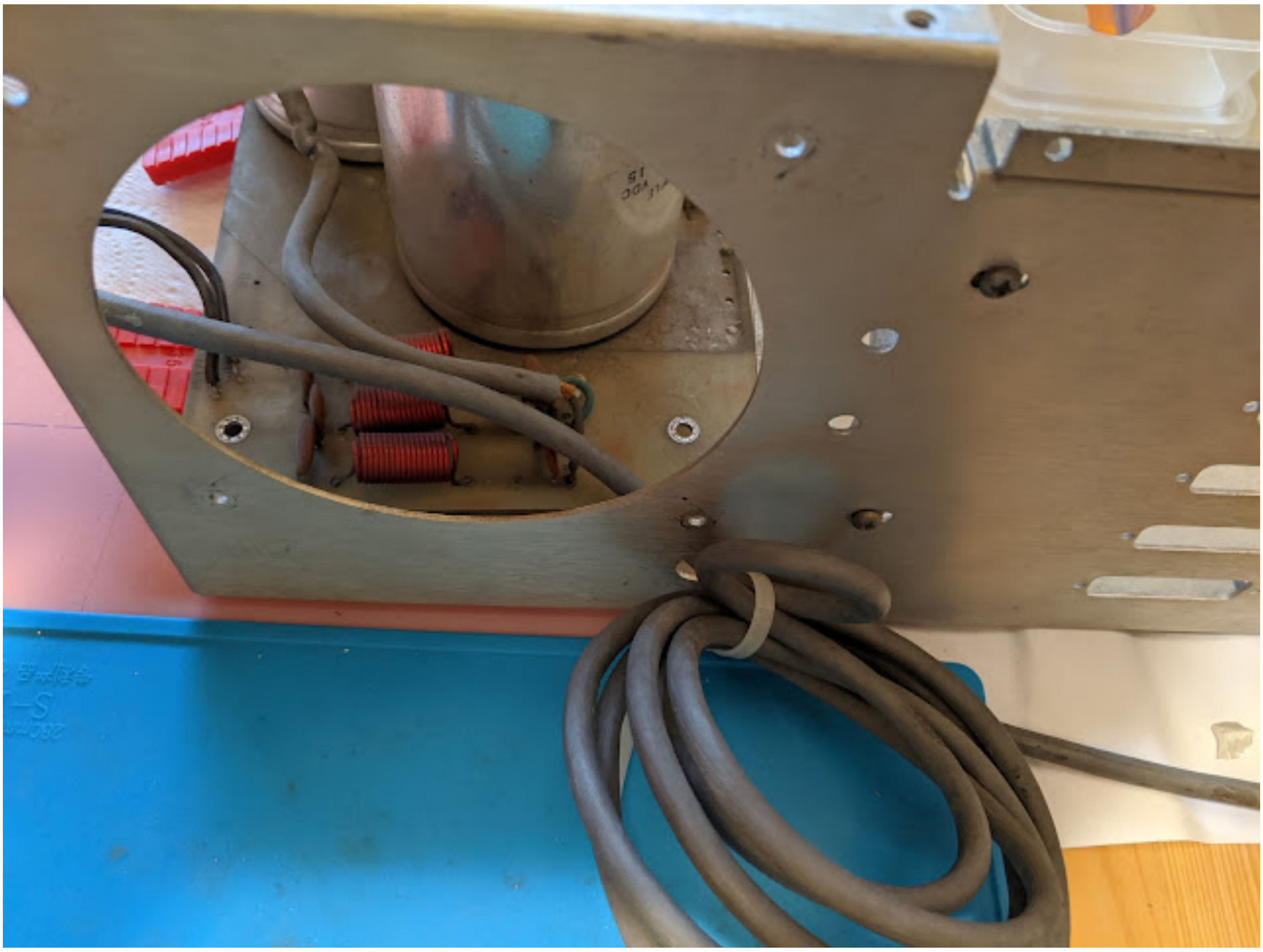
Chocs placed under the assembly during removal

Once free of the bolts, the easiest way to remove the assembly is to hold underneath the transformer part of the pcb with one hand and tilt the assembly up to the left until it clears the chassis.

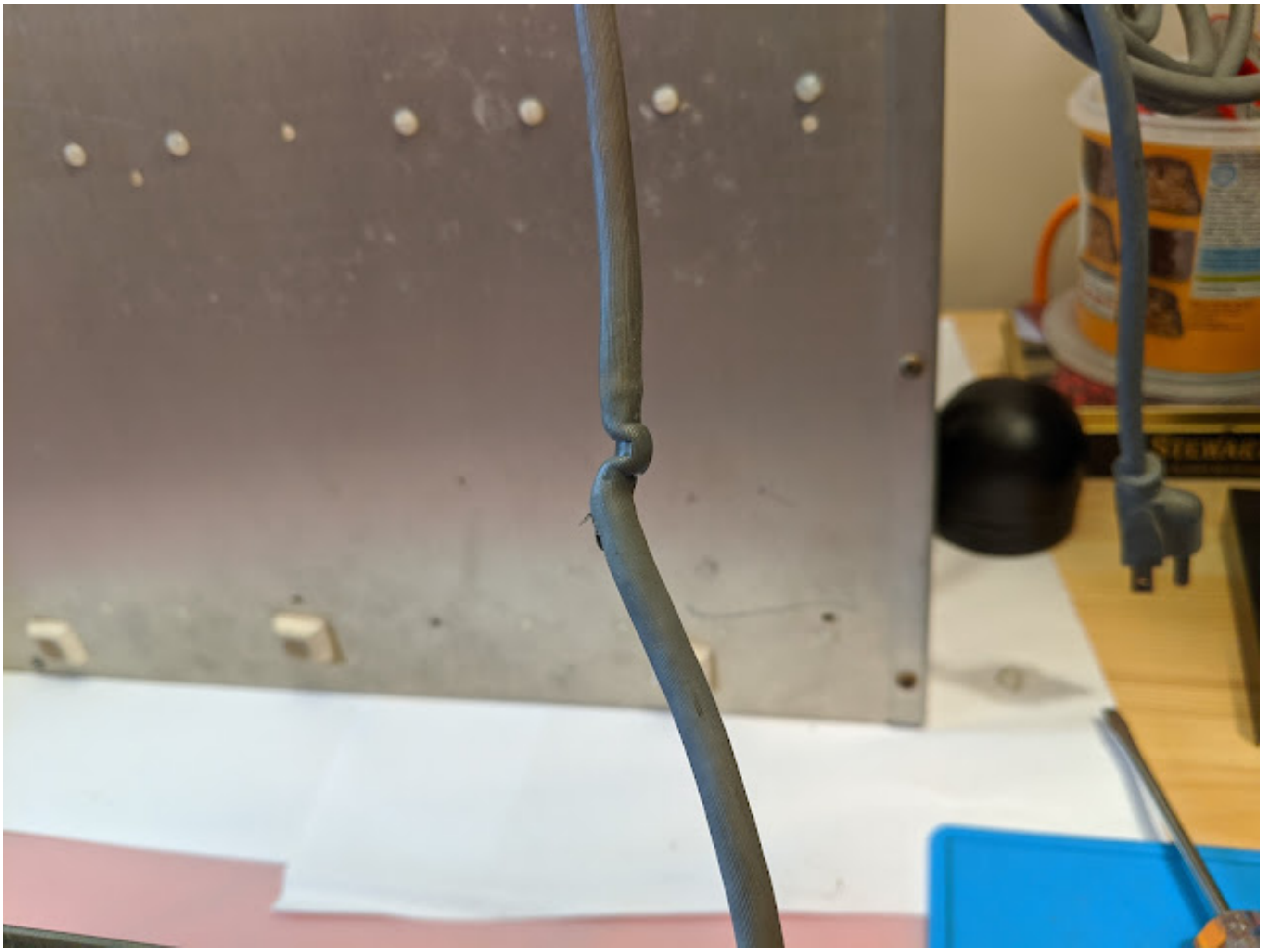


Ease the assembly off the nine upright bolts

If, as in this case, the mains cable is held in place on the Back Panel, with a strain-relief grommet, then remove it and feed enough cable through to allow the PSU assembly to be lifted off the chassis.



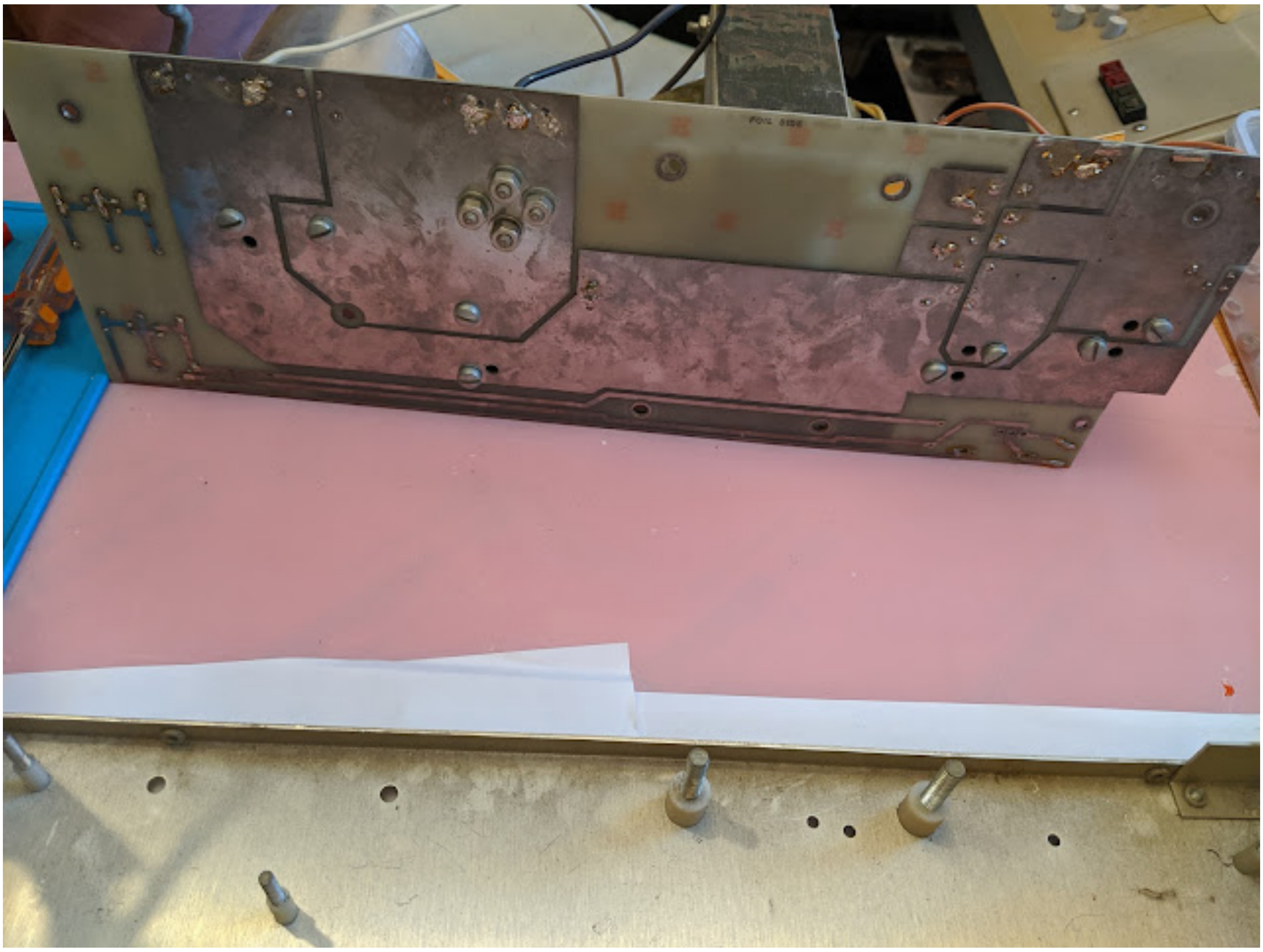
Mains cable Strain-relief Grommet removed


Section of mains cable from where the grommet was removed

Now carefully lift the whole assembly over onto its side, making sure the transformer is applying no weight to the pcb.

Finally, we have the PS-28D Assembly where we can get at the underside

Now we are able to access the bolts which secure the four large capacitors in place, on the underside of the pcb.

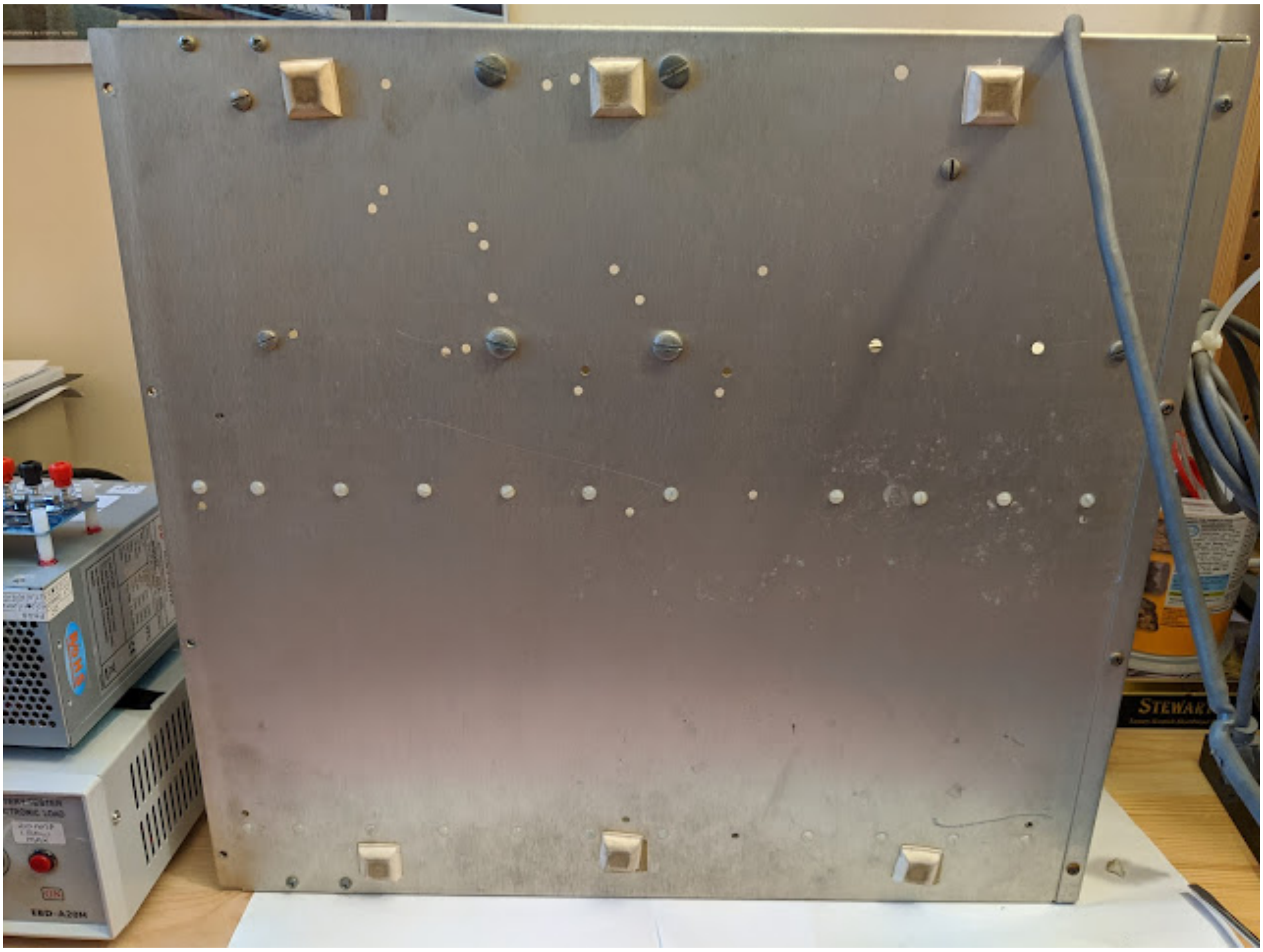


Underside of PS-28D pcb

The PSU area of the chassis can now be easily accessed for cleaning, as can all the rest.

PSU area of Chassis

At this point, it is easy to check the number and condition of the rubber feet on the underside. As can be seen, there are none along the centre line, so more will need to be added, after cleaning. The IMSAI 8080 weighs a lot, especially the transformer, and the bottom can become distorted in that area over time without good, evenly spread, support.



View of underside of chassis

Check the pcb version of the PSU for future reference, e.g. when referring to the manuals.

PSU PS-28D assembly, pcb Version Number

Now we can carry out initial tests on the large capacitors, using a Capacitance Meter and an ESR Meter:

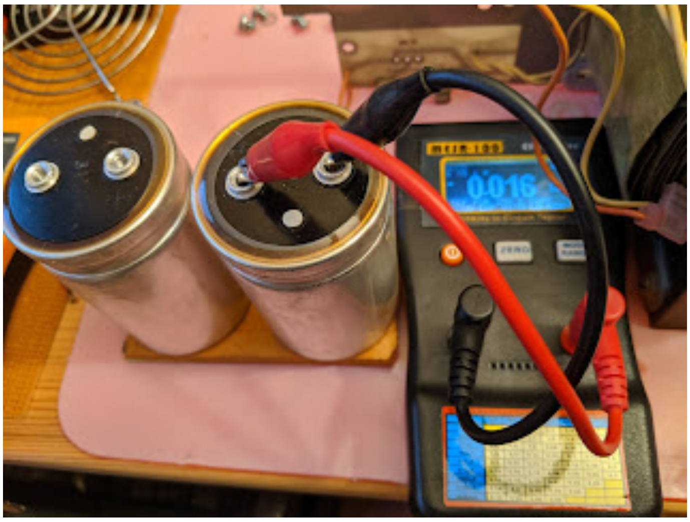

97.80 mF


10.032


9.774 mF


0.027
ZERO


0.008
ZERO


0.016
ZERO

The results can be summarised as follows:

(The tolerance on these large aluminium capacitors can often range from -20% to +80%)

The highest capacitance ESR we can usefully measure with our meter is 10,000uf. After that, the result is going to be so close to zero ohms that it can't be measured accurately. I have included those ESR readings we obtained here for the sake of completeness.

95,000uf, 15vdc **Capacitor A**

Capacitance: 112,500uf (18% over) = PASSED

ESR: 0.027

95,000uf, 15vdc **Capacitor B**

Capacitance: 97,800uf (3% over) = PASSED

ESR: 0.008

10,000uf, 25vdc **Capacitor C**

Capacitance: 10,032uf (< 1% over) = PASSED

ESR: 0.016 (10,000uf @ 15v worst case = 0.08 or more) = PASSED

10,000uf, 25vdc **Capacitor D**

Capacitance: 9,774uf (2.2% under) = PASSED

ESR: 0.013 (10,000uf @ 15v worst case = 0.08 or more) = PASSED

These initial results would indicate that we are okay to proceed with all four capacitors and attempt to reform them.

12/11/2019

TIME FOR A CAREFULLY CONTROLLED EXPERIMENT:

REFORMING THE ELECTROLYTIC CAPACITORS

The majority of the charge stored in large power supply filter capacitors is not used. When the ripples in the source AC voltage causes the DC voltage to exceed the value required, the job of the capacitor is to absorb the extra voltage. When it falls below that which is required, the capacitor tops it up. To do this, the large capacitor needs to store a large reservoir of charge and has to be able to react rapidly to the ripples.

To be effective in this respect, the capacitor needs to be reformed to a voltage that is equal to the normal voltage supplied to it by the transformer, plus a margin that will cover the changes caused by ripple in the source AC supply. We will use +10%. Many articles talk about reforming to the rated voltage. This is not a good idea on vintage capacitors, because age can lower the rated voltage. Exceeding it will destroy the capacitor.

The need to reform the four large electrolytic capacitors, that have lain idle for so long, has led us on a journey of discovery in terms of the best way to do it. I have shared my thoughts and findings on this in a lot of detail here. Feel free to skip straight to the results/conclusions in Blog Part 4.

At the foot of today's Blog, I have copied two separate articles on the subject, with respect to vintage computers, for those who are interested. The second article is more sophisticated, and has the advantages of a permanent test setup that may appeal to those who expect to do this kind of thing on a regular basis.

For our purposes, however, we are going to go into more detail and use a hybrid approach, drawing from both but also adding to it. The two articles take a fairly rough and ready approach, whereas we want to be quite precise - especially with the value of the resistor used. This is the key difference.

When the following articles talk about reforming at the rated voltage, the assumption is that we use the maximum rated voltage printed on the side of the capacitor. Personally, I do not like that idea, as you are literally pushing an old capacitor to its limits.

Also, in a situation where the capacitance tests above the rated value, there is, apparently, another potential problem with old capacitors. The increased capacitance can mean that the electrolytic breakdown voltage has been reduced, so these capacitors can be expected to fail at lower than rated voltages.

At this stage, we are going to take a conservative approach and are only going to reform at up to the normal working voltage (under load) for the system in which it is deployed, not the maximum rated voltage. There does not appear to be any disadvantage with that approach: after all, that is the state we would find the capacitor in were it to have remained in regular service.

On the other hand, reforming at the maximum rated voltage on an old capacitor, runs a higher risk of causing it to fail.

In our case, the IMSAI manual tells us that this should involve running them at working voltage (7vdc for the 95,000uf and 13.5vdc for the 10,000uf capacitors) - with an appropriate resistor in series, between the capacitor and the positive terminal, to limit current flow.

We will revisit this question, if the reforming process works as expected on the first capacitor. In the real world, the transformer will be providing 8vdc to the 95,000uf capacitors, along with the normal ups and downs inherent in the mains supply. We might expect this to create something of a 'tidemark' in the capacitor at that voltage level, when not operating under load.

If all has gone well, then the intention would be to reform again, this time at 8.0vdc +10%, i.e. 8.8vdc. That should, hopefully, be closer to reality, allow a reasonable margin, yet be well within the rated voltage of +15vdc. With the 10,000uf capacitors, we will use 13.5vdc to begin with, then move up to 16vdc + 10% = 17.6vdc, against a rated voltage of 25vdc.

Maximum Allowable Leakage (in Microamps)

Standard Aluminum Electrolytic Capacitors

Capacity in µF	3V	6V	10V	15V	25V	50V	100V	200V	400V	500V	600V
1.0	5	5	5	5	5	5	5	10	20	25	30
1.5	5	5	5	5	5	5	8	15	30	38	45
2.2	5	5	5	5	5	6	11	22	44	200	220
3.3	5	5	5	5	5	8	17	33	220	240	270
4.7	5	5	5	5	6	12	23	47	260	290	320
6.8	5	5	5	5	9	17	34	220	310	350	380
10	5	5	5	8	13	25	50	270	380	420	460
15	5	5	8	11	19	38	230	330	460	520	570
22	5	7	11	17	28	200	280	400	560	630	690
33	5	10	17	25	41	240	340	490	690	770	840
47	7	14	24	35	200	290	410	600	823	920	1010
68	10	20	34	190	250	350	500	710	990	1100	1210
100	15	30	50	230	300	420	600	860	1200	1340	1470
150	23	45	230	280	370	520	730	1040	1470	1640	1800
220	33	220	280	340	440	630	890	1270	1780	1990	2180
330	50	270	340	420	540	770	1090	1540	2180	2440	2670
470	220	320	410	500	650	920	1300	1890	2600	2910	3190
680	270	380	500	600	780	1100	1560	2250	3130	3500	3830
1000	330	460	600	730	950	1340	1900	2710	3790	4240	4650
1500	400	570	730	900	1160	1640	2320	3290	4650	5200	5690
2200	490	690	890	1090	1410	1990	2810	4020	5630	6290	6890
3300	600	840	1090	1330	1720	2440	3450	4870	6890	7700	8440
4700	710	1000	1300	1590	2060	2900	4110	5970	8230	9200	
6800	860	1210	1560	1920	2470	3500	4950	7120	9890		
10000	1040	1470	1900	2320	3000	4240	6000	8570			
15000	1270	1800	2320	2850	3670	5200	7350				
22000	1540	2180	2810	3450	4450	6300	8900				
33000	1890	2670	3450	4220	5450	7700					
47000	2250	3190	4110	5040	6300	9200					
56000	2460	3480	4490	5500	7100						
68000	2710	3830	4950	6060	7820						
100000	3290	4650	6000	7350	9490						
150000	4020	5690	7350	9000							
200000	4650	6600	8500								

Use 100µA MAX LEAKAGE RANGE

Use 10KµA LEAKAGE RANGE

Table of Maximum Allowable Leakage Values

Selecting an appropriate resistor for the test is crucial in the approach we are going to take.

We want the resistor to allow enough current to flow in order to see whether or not the maximum allowable leakage current is reached or not.

In this case, we look up the capacity of 10,000uf at a voltage of 13.5vdc in the above table. We can get pretty close by taking the nearest voltage above and below and estimating based upon the difference. For example, for a 10,000uf capacitor at 15vdc, it is 2320 microamps. At 10vdc, it is 1900 microamps.

For 13.5vdc, therefore, we estimate based upon the difference between the two of 420 microamps. the difference is 5vdc and the voltage we are going to use is 3.5vdc above 10vdc, so we take (3.5 / 5) x 420 and add that to the lower figure of 1900, giving 2,152 microamps.

In our case, the capacity of 10,000uf matches a value in the table, so we need do no more. However, if the capacity lay between two of the values in the table, then we would need to make a further adjustment, to take this into account.

We would calculate the above microamp value for our chosen voltage - for the nearest capacity value, either immediately above or below, and then estimate our microamp value for our capacity, by pro-rating the leakage value accordingly. (A worked example of this follows, for the 95,000uf capacitor)

The resistor we select should allow us to test for this maximum allowable leakage current, once the leakage current has stabilised over time during the test.

To allow 2152 microamps (.002152 amps) of leakage current to flow, at 13.5vdc, we would need a resistor value of 6,273 Ohms maximum. That resistor would need to be able to carry at least 0.03watts. We would round this up to a rating of 1/4watt.

For the 95,000uf, 15vdc capacitors, that we are going to run at 7vdc, we need to look at the table again. This time we take an estimation between 6vdc and 10vdc, at the nearest capacity of 100,000uf. This gives us a value of 4650 at 6vdc and 6000 at 10v, so we get 4988 microamps. We then adjust that to be 95,000 / 100,000 of this value to arrive at 4739 microamps.

To allow 4739 microamps (.004739 amps) of leakage current to flow, at 7vdc, we would need a resistor value of 1,477 Ohms maximum. That resistor would need to be able to carry at least 0.03watts. We would round this up to a rating of 1/4watt

If we select resistors with higher values than these, the resistor itself would be stopping the leakage current going any higher than the maximum allowable leakage value and potentially falsifying the result.

The duration of reforming is suggested to be approximately 5 minutes, plus 1 minute for each month of storage as a rule of thumb. This could, therefore, be about 8 hours for each capacitor in our case. This is only a rough guide, however. What is much more important, is to wait until the leakage current stops falling at each stage, however long that takes. *(Follow-up: in fact, the rule of thumb has proven to be wholly inadequate. It has taken 40+ hours to get the numbers to stop falling so, if you have the time, leave it to run as long as possible)*.

As time is not of the essence, but salvaging the rare original capacitors is a priority, we will go one step further here and perform the process in 3 stages, each at increasing voltages. We will prorata the maximum allowable leakage current at each voltage. (The time for it to stop falling is also anticipated to be a relative proportion of the estimated time at full working voltage - e.g. Stage 2 would be 2/3rds of 8 hours, etc.).

At the time of writing, there are reasonable quantities (about 50) of 'new old stock' Mallory 95,000uf, 16v capacitors of the same dimensions still available online, and also a number of the Mallory 10,000uf 60v capacitors. The higher voltage rating is fine, so they are a suitable 'drop-in' replacement.

One problem is that often we want to have the inner workings of these machines on display, with a perspex lid in place of the normal one. The Mallory units were never fitted as standard and are light blue instead of silver, so do not look 'original'. It would be possible to remove the plastic sleeve to improve this if necessary. Hopefully, in our case, it won't prove to be.

So, for our 95,000uf capacitor, 2.33vdc will be at a maximum allowable leakage value of 1580 microamps, 4.66vdc will be at at maximum of 3159 microamps and the final stage will be 7vdc at at maximum of 4739 microamps.

We will only progress to the next stage if it passes the previous.

IMPORTANT NOTE:

It may seem a little odd but, in our case, the leakage current could be calculated from the voltage drop across the resistor alone.

This is made possible, because we have carefully chosen the resistor value - to allow up to the maximum allowable leakage current, but no more.

The voltage drop is simply measured by placing Voltmeter leads in parallel across the resistor.

The leakage current, however, has to be measured by placing an Ammeter in series with the circuit, between the capacitor and the negative source terminal.

On this basis, it would be easiest to simply use the voltage drop measurement to work everything out.

The formula to use, when looking at the voltage drop, would be:

(Voltage drop / Source Voltage) x Maximum allowable Leakage Current (for the Source Voltage in question) = leakage current.

So, if we were carrying out the Stage 2 reform, on the 95,000uf 15vdc capacitor, using a source of 4.7vdc, and we saw a voltage drop across the resistor of 1 volt, the leakage current would be:

(1 / 4.7) x 3159 microamps = 672 Microamps.

As the leakage current is so important, however, it is good to double-check things, so I would recommend having both the voltmeter and ammeter in place, and checking they agree with each other.

END OF IMPORTANT NOTE.

When you first start up the process, at 1/3rd of the highest voltage you are going to eventually attempt to reach (the working voltage), allow time for the voltage drop measured across the resistor and the leakage current, being measured at the output of the capacitor, to continue to fall. On large, old capacitors, this could take hours.

We are in no hurry, so we can afford to be patient and, once the leakage current stops falling altogether, check if it is at or below the maximum allowable leakage value for that voltage. If not, the capacitor should be discarded.

As we are reforming an old capacitor, the leakage current may not reduce as quickly as it would after the reforming process is complete.

Once the leakage current has stopped falling, disconnect it from the circuit and measure the voltage across the terminals of the capacitor. If holding charge properly, the voltage recorded should equal the voltage of source supply we are using at that point. If so, then carry on. If not, then the capacitor is faulty to some degree, so halt the reforming process and consider discarding the capacitor, depending upon how far below the source voltage it is. Personally, I would use -10% tolerance as a guide.

IMPORTANT NOTE:

It is especially important on the final stage to wait until the leakage current stops falling. In some cases, this could take many hours more than we have already allocated using the formula of 5 minutes plus 1 minute per month of storage. The attempt to reform cannot be considered complete, at the working voltage, unless this is done.

END OF IMPORTANT NOTE

It would be wise to repeat the test again at full working voltage, after our reforming has finished, to see how well it has worked.

In this case, at the full working voltage of 7vdc, although it may well take a lot longer to stop falling altogether, the leakage current should drop away to near or below the maximum allowable leakage current in a minute or two at most.

If this does not happen, then the capacitor is not doing its job, and there is a risk of it overheating and possibly even exploding when placed in the system it was removed from. The capacitor should be definitely be discarded!

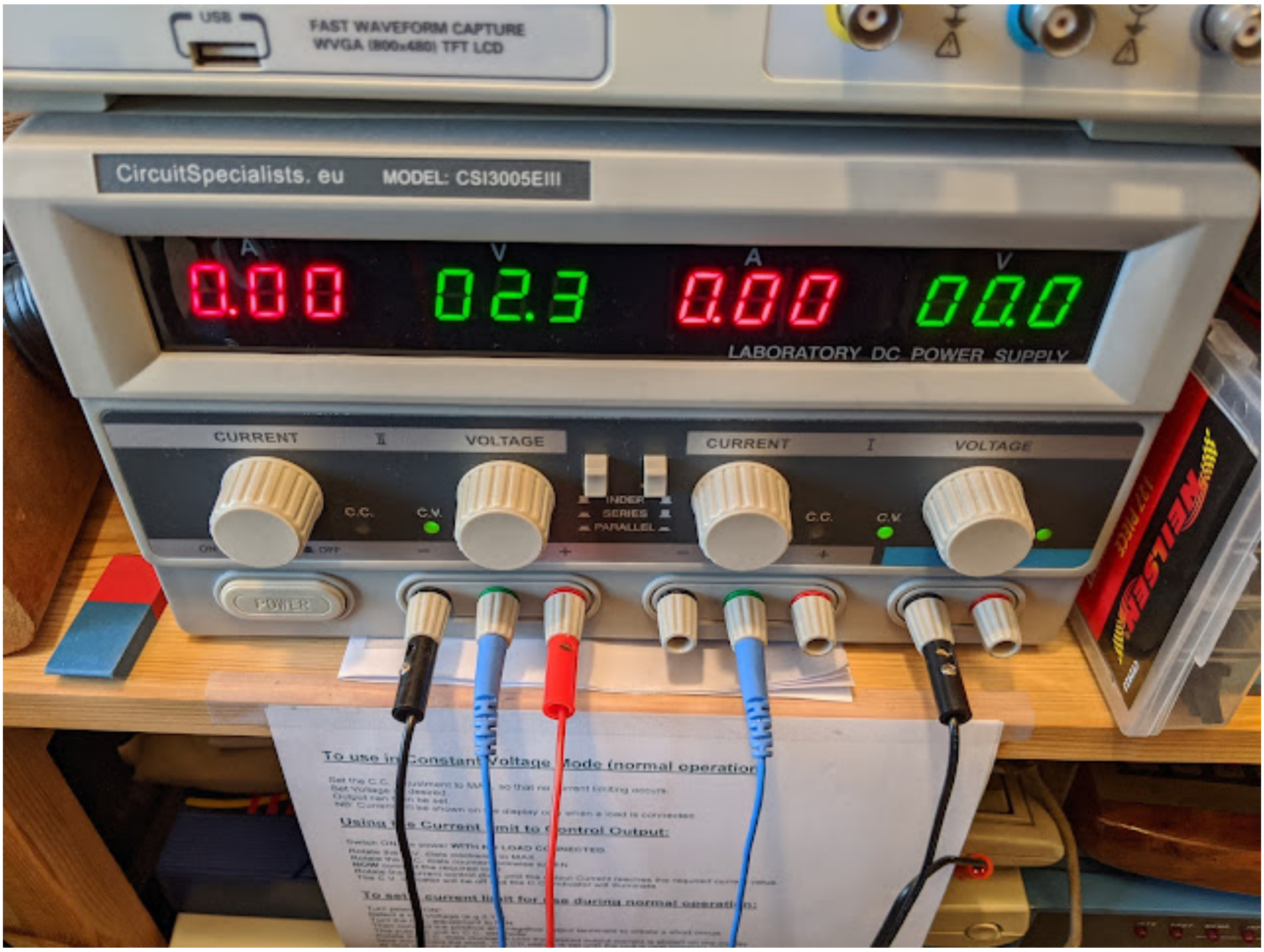
Also, if I found the leakage current was more than 50% of the maximum allowable leakage current when it stopped falling, then I would not use the capacitor.

IMPORTANT NOTE:

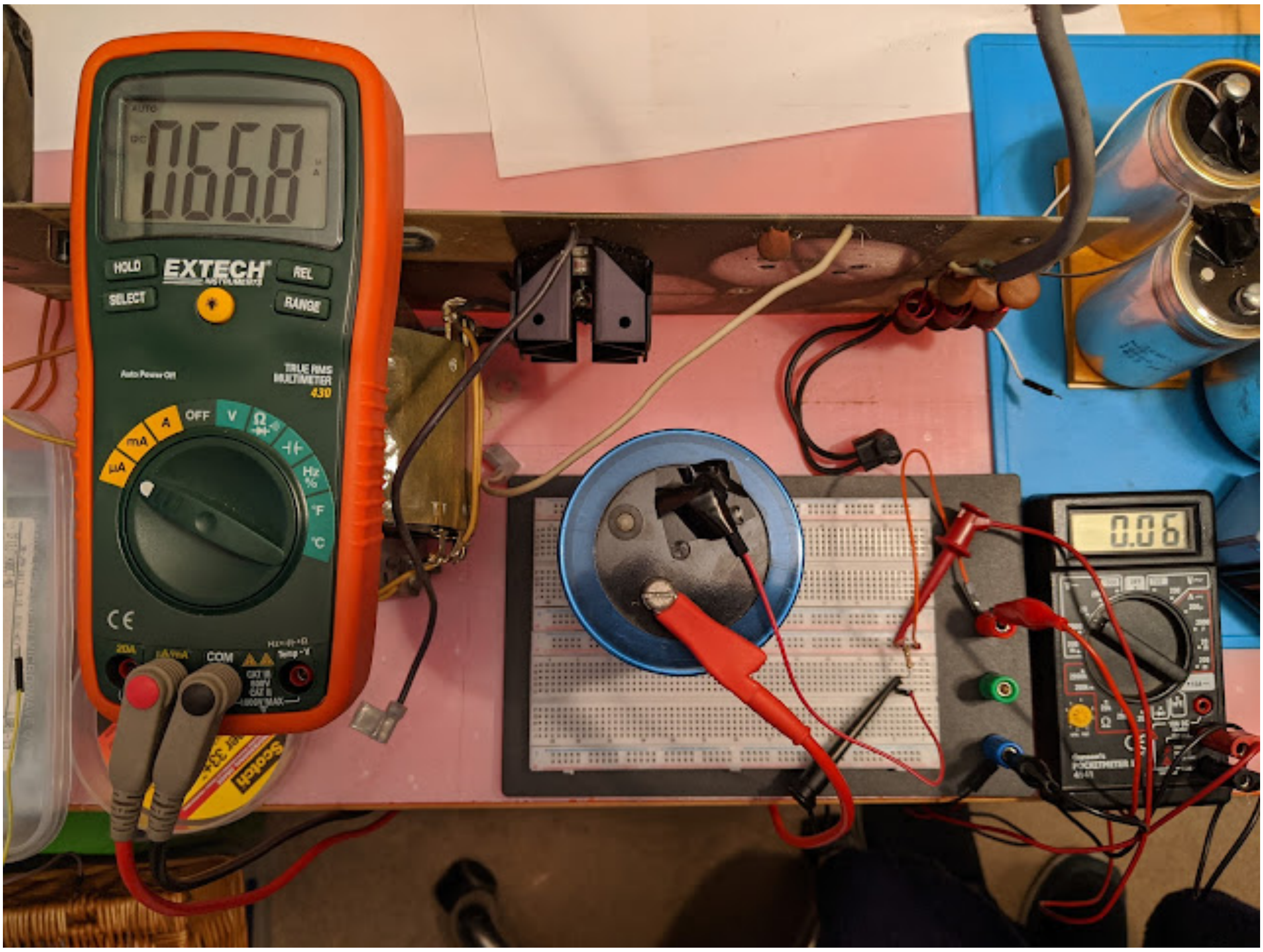
The capacitors need to be taken out of the circuit to be reformed. This could be done by just desoldering the positive lead, if that is easier - though more care is required not to damage the circuit while reforming in that situation.

It is a wise idea to wear safety goggles when in the vicinity of the capacitor being reformed. Even though our approach seeks to minimise the risk, old, faulty, capacitors can explode under test.

END OF IMPORTANT NOTE.



Start of Reforming - at 2.3vdc



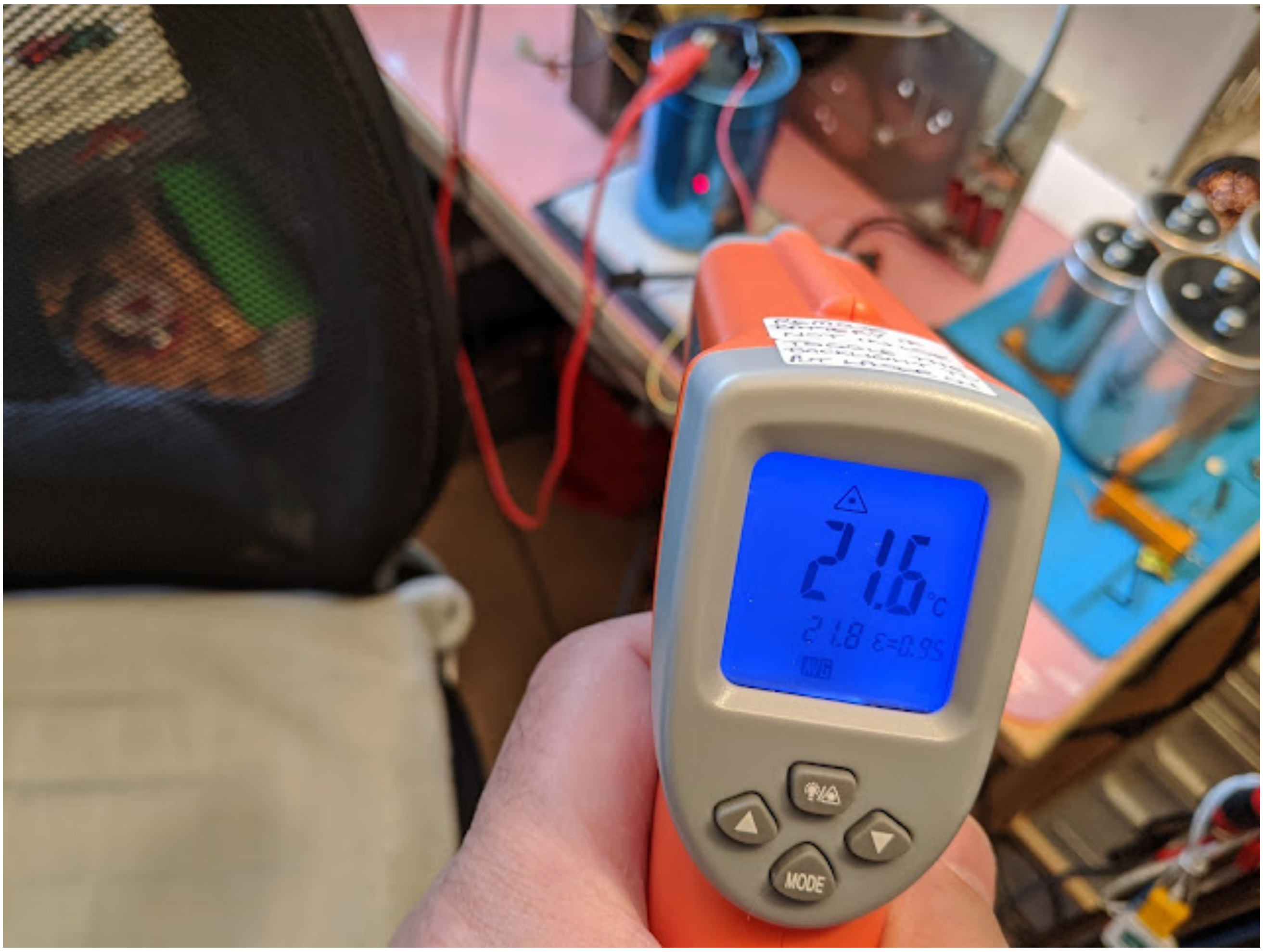
Reforming Setup

The above two photos show the reforming setup being tested out on a spare 95,000uf, 15vdc capacitor, starting at 2.33vdc. The leakage current is being measured by the meter on the left and the voltage drop across the resistor by the meter on the right.

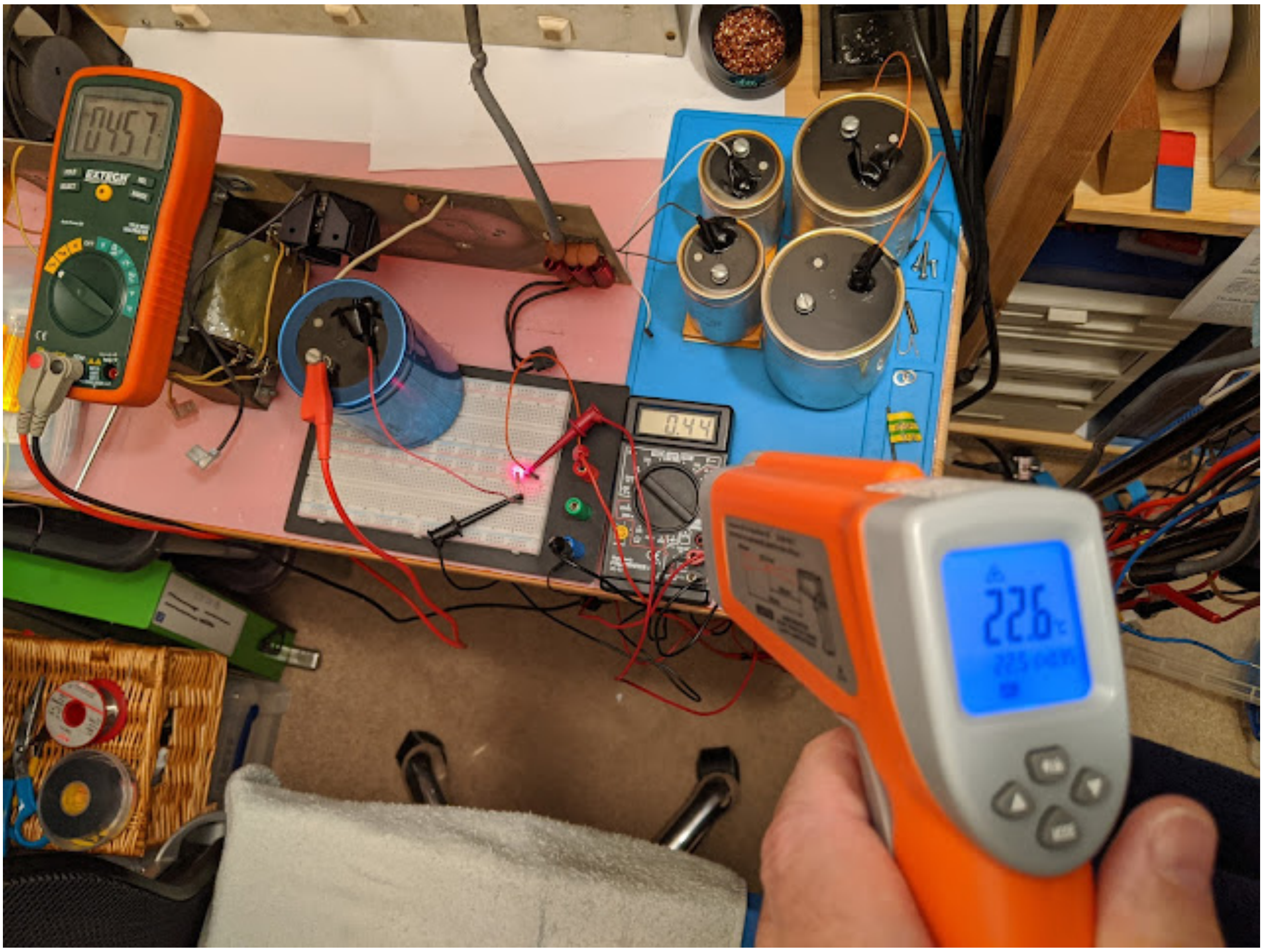
Monitoring the leakage current will tell us how much current is flowing, and the resistor we selected is of the correct rating to not allow more than the maximum allowable leakage current to flow.

This should avoid any significant overheating happening on either the resistor or the capacitor. However, theory is one thing and it assumes everything else has been connected correctly, etc.

If you have the equipment for it, therefore, a good double-check that all is well is to monitor the temperature of the capacitor and the resistor during reforming, with a Laser Temperature Sensor.



Temperature of Capacitor - Laser Gun



Temperature of Resistor - Laser Gun

IMPORTANT NOTE:

Make sure that you do not touch the terminals on the capacitor without having fully discharged it first. They can carry a significant charge which can cause injury or even death.

END OF IMPORTANT NOTE.

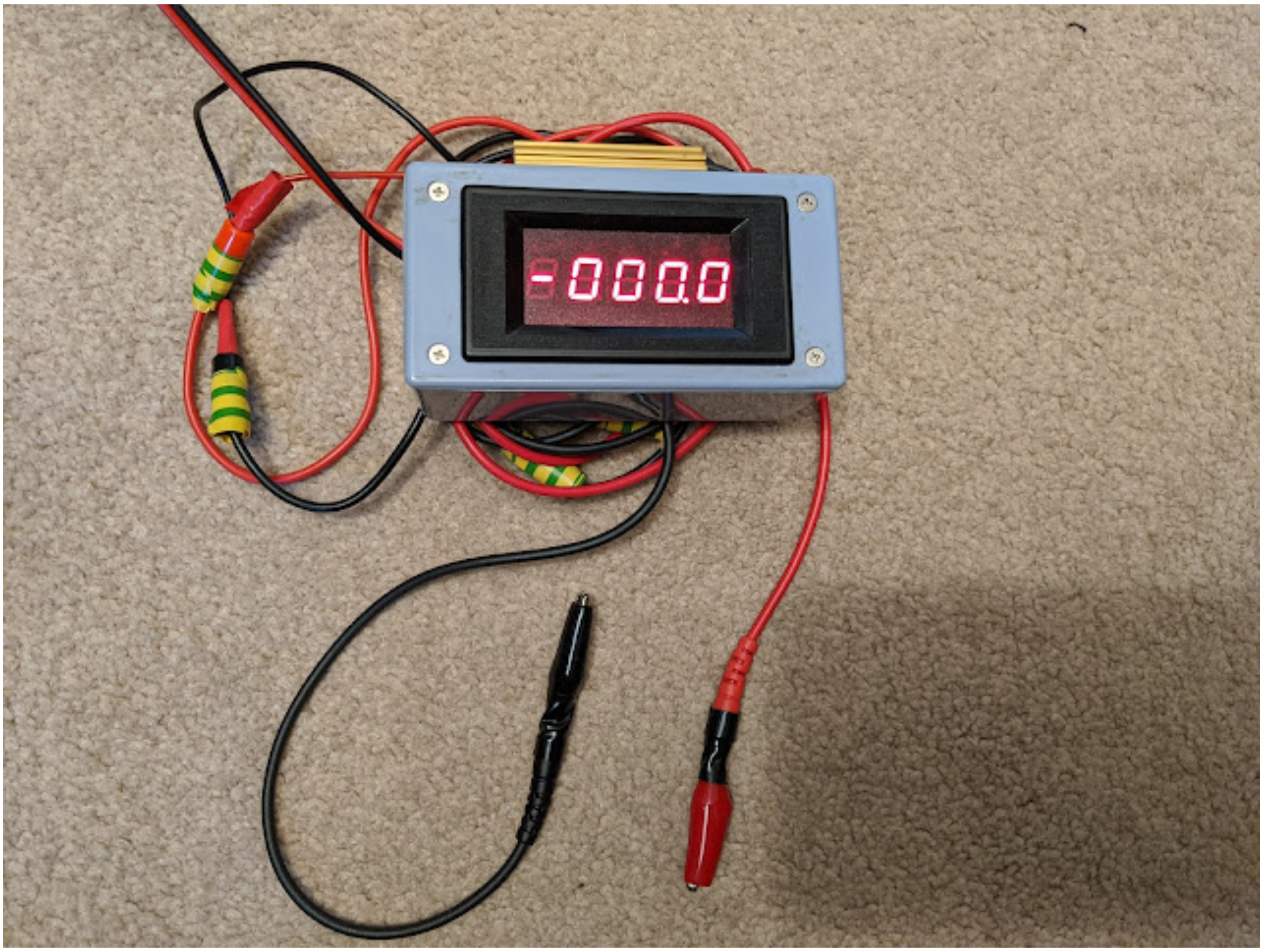
In the absence of information about the relative merits of simply increasing the voltage at each stage, or fully dissipating the charge before starting the next stage, we are going to let the charge out and start from scratch each time.

In any event, we will need to fully discharge the capacitor at the end of the reforming process on each capacitor, and need a safe way to do that. Any talk of sticking screwdrivers across the terminals should be avoided..!

An easy to make piece of equipment for discharging the capacitors and making sure they are safe, after reforming, is shown in the following photo. This uses an external 5vdc supply to display the voltage left in the capacitor as it discharges.

In my case, a 50watt wirewound resistor rated at 60 Ohms is mounted on top and connected across the terminals of the capacitor. The two wires of the voltmeter are wired in parallel to this.

On a capacitor rated at 50vdc, the resistor allows up to 0.83amps to flow, with a power output of 41watts. At that rate, the resistor could become hot to touch, so take care. If you need to test capacitors with a charge in excess of 50v, then increase the value of the resistor. That will, of course, slow down the discharge rate.



Capacitor Discharging Unit

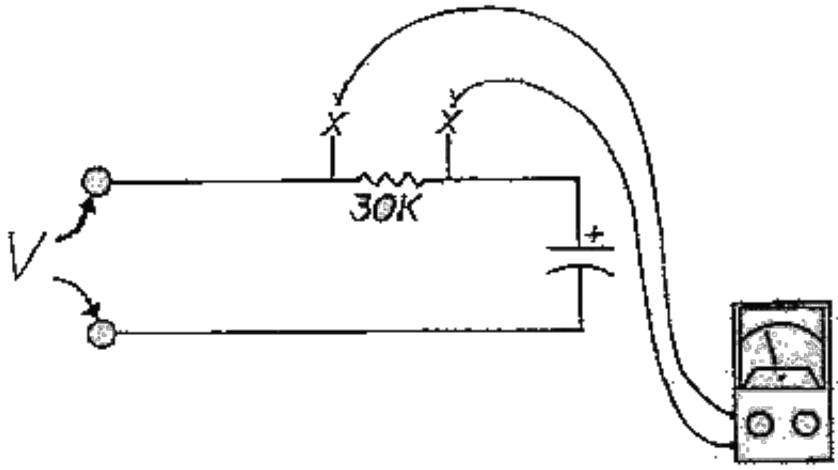
While waiting for the capacitors to reform, we can be getting on with long job of deep cleaning everything........

SUGGESTED APPROACH (1)

Reforming Electrolytic Capacitors

claim that most old electrolytics can be saved if the correct procedure is followed, regardless of how long they have been unused. Such capacitors must be "reformed". This process consists of applying rated voltage through a resistance (about 30,000 ohms, five watt) for five minutes plus one minute for each month of storage (see figure 6).

As the capacitor reforms, the voltage across the resistor will drop (measured at the Xs in Figure 6). If that voltage will not drop below 10% of applied voltage after one hour, the capacitor is probably beyond help.



Reforming Electrolytic Capacitors

The process of reforming an old aluminium electrolytic capacitor consists of the application of rated voltage, through a resistor, for a period equal to five minutes plus one minute per month of storage.

The electrolytics appearing on the surplus market have often been in storage for a very long period indeed. Some manufacturers use a visible code, of which the first two digits indicate the year of manufacture.

The circuit shown in the sketch above works reasonably well. Apply the rated voltage through a 5W resistor. Anything from 20K-50K will do, as this is far from a precision process. The meter is used to measure the voltage drop across the resistor; when no current is flowing, there will be no drop.

Obviously, when there is a large voltage drop (more than 20% of the applied voltage), there must be a significant current flow through the capacitor. The nature of a proper capacitor is to impede DC current flow, so when there is such flow, something must be wrong.

Note: Apply the appropriate D.C. voltage to the capacitor with a D.C. power supply. An old Kepco, Lamba etc. tube regulated lab power supply rig works great. Be sure to observe the proper polarity!

Within an aluminium electrolytic there is a large area of aluminium foil and an electrolytic paste. As the voltage is applied, current flows until aluminium oxide forms on the surface of the foil, because aluminium oxide is a very good insulator. If excess voltage has been applied during the electrolytics lifetime, it is possible that tiny welds exist which the oxide insulator cannot separate. When that occurs, the capacitor cannot "reform", and should be discarded.

If the amount of current flow (voltage drop across the resistor) is great initially, that is not a problem. If it doesn't start dropping within five minutes of application of voltage, a definite hazard exists. The current flow indicates that energy is being dissipated within the capacitor, in the form of heat. Excess heat may "pop" the electrolytic, causing the paste to spit out...a threat to eyes and paint.

It's also worth remembering (one forgets only once) that a good capacitor will store its energy for quite a while, and discharge it through the hand when picked up. It's smart, then, to discharge the unit deliberately, through a resistor equal to about one ohm per volt of charge.

A new capacitor should rapidly take a charge right to rated voltage, in which case only a small voltage drop will appear across the resistor. It is possible to reform capacitors in the circuit, of course, but if rectification is by solid state diodes and there is a large current flow, it is possible to destroy one or more of the diodes, or to damage the transformer.

Electrolytic capacitors can be dangerous. They can be charged to a high voltage and will retain that energy for quite a while. If the terminals of associated circuitry are touched, a severe shock and burn may result.

Another hazard associated with electrolytics is "spitting". Each of these cans is filled with, among other things, a thick fluid which can be extremely irritating. A small rubber safety plug is fitted to most electrolytics of recent manufacture. When the capacitor fails, internal pressure may go too high; the plug will blow and the fluid will spit out.

Electrolytic capacitors of a given capacity and voltage will vary considerably in configuration and size, from one manufacturer to the another. Ideally, there will be chassis space to permit mounting the "twist-lock" variety. Otherwise, the tubulars (such as the Sprague TVL 1720) must be packed, glued or clipped wherever space is available.

NOTE: The preceding information was obtained from an old copy of Tu-Be Or Not Tu-Be Modification Manual by H.I. Eisenson.

SUGGESTED APPROACH (2)

REFORMING ELECTROLYTIC CAPACITORS

Capacitors that have been out of use, whether in equipment or held in stock need to be reformed by the careful application of voltage so that the film is restored.

We can use the circuit below to reform components of all voltages and values.

A dc voltage is applied to the capacitor through a current limiting resistor, R1. This prevents damage to the capacitor and to the voltage source if the capacitor is faulty. Otherwise, should the capacitor have a large leakage application of voltage could cause the electrolyte inside the case to vaporise and the can to explode.

SW1 is used to charge and discharge the capacitor via R1. The discharge is essential at the end of the test for safety when high voltages are used. It also can be used to repeat tests of leakage current measurements with time after first application of the voltage.

A single voltmeter and 3-way switch can monitor the maximum (final) voltage, the voltage across the capacitor and the leakage current. 10k ohm resistors are included in the connections to prevent excessive current should the leads to the Digital Volt Meter (DVM) be shorted or it operated on a current range.

Although it is convenient to use a single auto-ranging meter, separate meters or a plug arrangement may be used.

The values shown are suitable for most reforming operations but R1 may be reduced to as low as 4k7 when dealing with large capacitance, low voltage components. The power rating must be sufficient to withstand the capacitor being short-circuit.

Set SW1 to “Discharge”.

Select a voltage of about 25% of the capacitor’s voltage rating and monitor with SW2 at “A”.

Switch SW1 to “Charge”

Observe the leakage current read on the meter (1 volt = 1 mA). This will normally start to fall after a few seconds. Occasionally it may rise and then fall back again. If it remains steady or continues to rise after 5 minutes, it is probable that it will not be possible to reform the capacitor.

Switching SW2 to “B” shows the voltage across the capacitor.

If the current has fallen to below that indicated in the above table, repeat operations 1 to 6 with higher voltages – two stages of 60% and 100% are usually adequate.

On final voltage, check that the leakage current is acceptable. Typically a reformed unit will have a leakage of about 20% of those in the above table. (The table is for 70^{o}C rather than 20^{o}C for the bench tests).

Ideally leave it reforming until there is no further decrease in the leakage current.

However, on large values reforming may take several hours and this may be done in the equipment if the initial leakage has been reduced sufficiently.

Discharge the capacitor by switching SW1 to “Discharge” before disconnecting it and handling.

Multi-section capacitors can also be reformed by connecting the sections in parallel. If they have different voltage ratings then apply a voltage that does not exceed the lowest voltage rating.

BLOG PART 4: Reforming The PSU Filter Capacitors (Part 2).

13/11/2019

We have taken another look at the reforming process and chosen to use a different method for calculating the value of the resistor to be used. The Part 3 Blog has been updated to reflect this.

No other progress has been made today, other than continuing to reform the capacitors, as I have been too busy for cleaning duties......

The reforming has finished on the 95,000uf, 15vdc test capacitor, running at 7vdc, which has gone well.

The final leakage current was 68.5 microamps, which is only 1.4% of the maximum allowable value of 4739 microamps. The voltage drop across the resistor measured only 0.06 volts. The voltage across the capacitor measured 7.00, as we hoped.

Reforming has now started on the four IMSAI 8080 capacitors.....

14/11/2019

I realise you should not really do it in a Blog but, in light of experience, some further modifications have been made to the text about reforming electrolytic capacitors in Blog Part 3. You may need to re-read it to pick these changes up if it is of interest.

Capacitor (A) 95,000uf 15v results, restarting the clock at each stage:

At 2.3vdc: (After 2:38 hours)

Leakage current = 72.7 microamps, Maximum allowable = 1580 microamps. (4.6%)

Voltage drop on resistor = 0.07vdc

Voltage across capacitor = 2.25vdc (-2%)

At 4.7vdc: (After 5:20 hours)

Leakage current = 276 microamps, Maximum allowable = 3159 microamps. (8.7%)

Voltage drop on resistor = 0.26vdc

Voltage across capacitor = 4.39vdc (-6.6%)

At 7.0vdc: (After 27:45 hours)

Leakage current = 144 microamps, Maximum allowable = 4739 microamps. (3.0%)

Voltage drop on resistor = 0.14vdc

Voltage across capacitor = 6.85vdc (-2.1%)

It has been very slow progress in getting this first capacitor up to specification. As can be seen, 27:45hrs at 7.0vdc so far, and 35:45 hours in total, before it can be said that the leakage current has all but stopped falling. I will leave it on for another 24 hours, just to see if it makes any difference.

In the meantime, the capacitor has been discharged and then put back onto the 7.0vdc source, to see how long it takes to charge now that reforming is all but complete.

IMPORTANT NOTE:

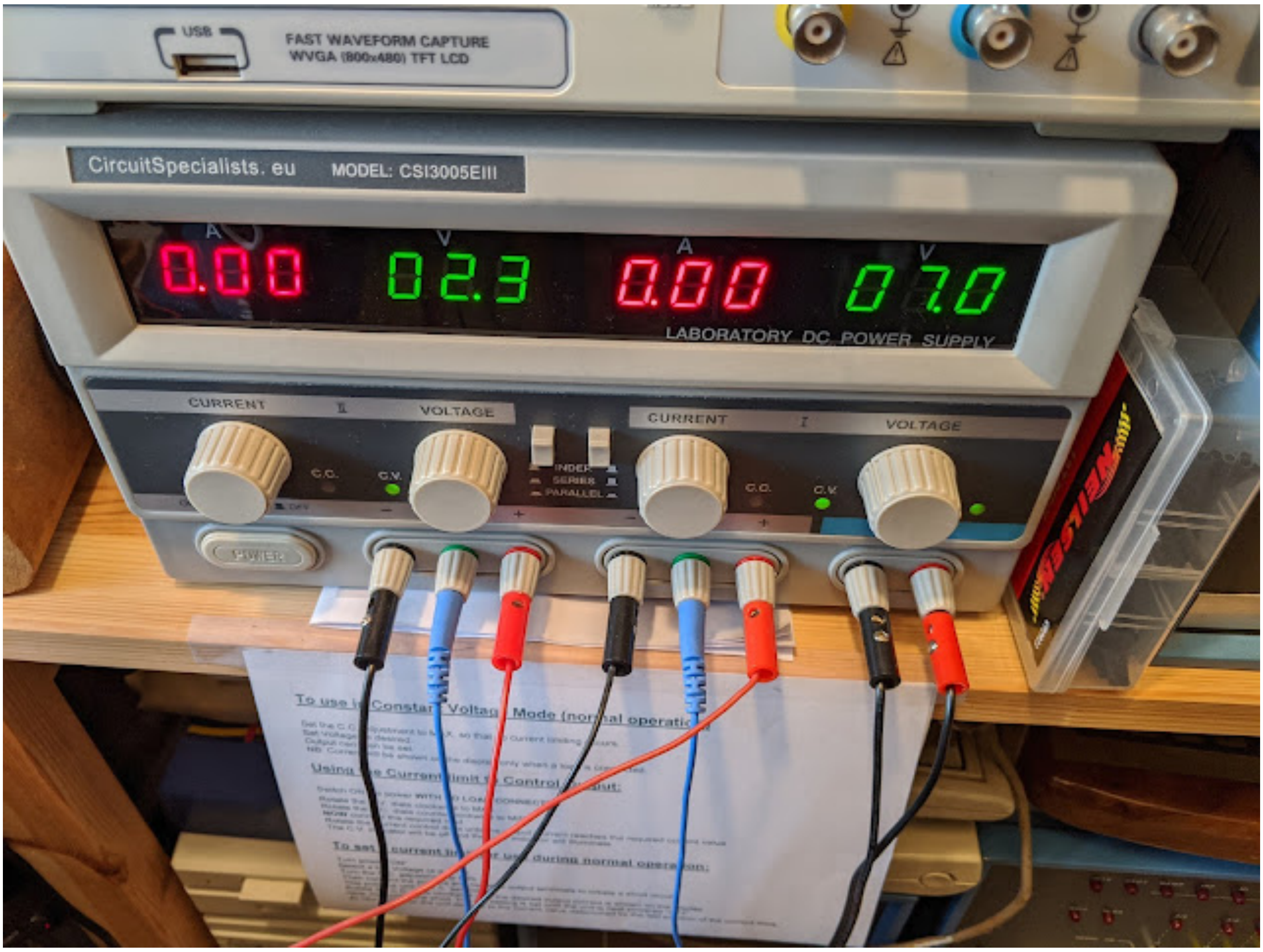
This has shown fairly significant results. The leakage current has dropped to 140 microamps and the voltage across the capacitor has risen to 6.85vdc in just 13 minutes. It took almost 25 hours to get to that stage yesterday prior to reforming.

We can safely say that the exercise has been a success with this method, and can continue to apply it now to the other capacitors.

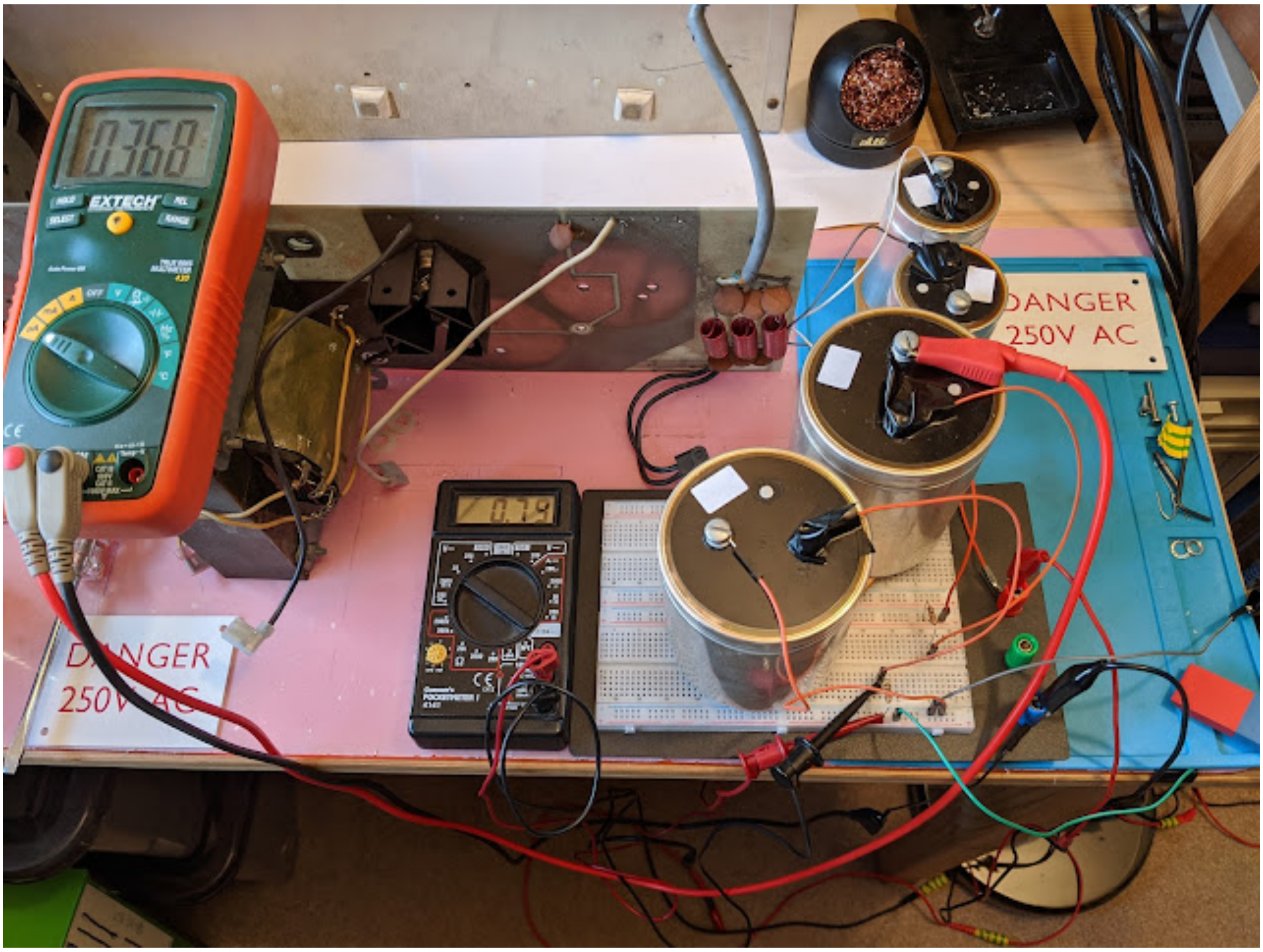
END OF IMPORTANT NOTE.

15/11/2019

We have linked up another source from the Bench Supply, and started on the next 95,000uf 15vdc capacitor while, at the same time, continuing to see whether we can get any more from Capacitor (A).



Using two sources in parallel to speed things up



Monitoring both reforming processes in parallel

Capacitor (B) 95,000uf 15v results, restarting the clock at each stage:

At 2.3vdc: (After 2:38 hours)

Leakage current = 137 microamps, Maximum allowable = 1580 microamps. (8.7%)

Voltage drop on resistor = 0.13vdc

Voltage across capacitor = 2.14vdc (-7.0%)

At 4.7vdc: (After 5:20 hours)

Leakage current = 338 microamps, Maximum allowable = 3159 microamps. (10.7%)

Voltage drop on resistor = 0.32vdc

Voltage across capacitor = 4.32vdc (-8.1%)

While reforming of Capacitor (B) is underway then, as mentioned in Blog part 3, this now takes us to the point of considering raising the voltage to 8.8vdc on reformed Capacitor (A). This will more closely reflect that provided by the transformer, including the ups and (downs) of the mains supply, yet be well below the original rated voltage of 15vdc.

We want to see how it deals with this circa 25% increase in voltage.

In order to deal with this increased maximum voltage we are going to reform at, we need to recalculate the value of the resistor to use 8.8vdc on a capacitor of 95,000uf.

You could just look up the nearest higher values in the table of maximum allowable leakage currents and use those (e.g. 100,000uf at 10vdc), but we want to be a little bit more accurate. We can't easily be precise, because the relationships between both volts and capacitance are not linear, but we can get a better estimate.

Referring to the table, we see that 95,000uf at 10vdc = 6000 microamps. At 6vdc, it = 4640.

There is a difference of 4vdc between the 10vdc value and the 6vdc value, which are the nearest above and below in the table.

At 8.8vdc, we are 2.8vdc / 4vdc above the 6vdc value. The difference in microamps is 6000-4640 = 1360 microamps. (2.8 / 4) x 1360 = 952. Add that to the 4640, and we get a rough estimate for what the microamps should be for 8.8vdc = 5592 microamps.

Having used the voltage to look up the value, we now need to take account of the capacitance too.

Because the 95,000uf is not found in the table, we look at the nearest value, which is 100,000uf. We can simply adjust the previous value we obtain on a pro-rata basis. (100 / 95) x 5592 = 5886 microamps (0.005886 amps).

So, to calculate the required resistor value, we have 8.8vdc / 0.005886 amps = 1495 Ohms.

First impressions appear reasonably favourable, in that applying 8.8vdc, we quickly reach a level of 8.12vdc across the capacitor, within a couple of minutes, before it stalls.

With the parameters involved, it would always normally take a couple of minutes to charge this capacitor anyway, so all is good in that respect.

IMPORTANT NOTE:

There are online calculators that will tell you how long to expect this initial rapid rise in voltage to take, before it slows right down - depending upon the voltage you are supplying, the capacitance of the capacitor and the resistor value you have chosen for your reforming circuit. In our case, it is 140 seconds, which is close to what we see.

END OF IMPORTANT NOTE.

We are now going to see how long it takes for the leakage current to stop falling, and how far the voltage figure increases toward 8.8vdc, if at all. Ordinarily, you would expect the voltage across the capacitor to pretty much equal the source voltage. In our case, it is initially stalling at 8% below that, which a bit of an unpleasant surprise.

When we had finished reforming at 7vdc, we reached a final voltage across the capacitor of 6.85v, which was only 2.1% below. It would seem from this that some further reforming is required at the higher voltage.

For Capacitor (A) Further reforming, raised to 8.8vdc

At 8.8vdc: (After 60:00 hours)

Leakage current = 86 microamps, Maximum allowable = 4739 microamps. (1.8%)

Voltage drop on resistor = 0.08vdc

Voltage across capacitor = 8.73vdc (-0.8%)

It has been worthwhile leaving the process of reforming running for an extended period of time, as it edges ever closer to the desired values. 60 hours may seem a long time, but if you are busy getting on with the restoration in other respects then it makes no difference.

The final test is to see how long it takes for Capacitor (A) to get up to a voltage of 8.8vdc, now that it has been reformed to that level. In this case, we will use a 30 Ohm wirewound 50 watt resistor, which will limit the current, but also charge it fairly quickly.

The current flow will be 8.8 / 30 = 0.29 amps, with a power output of 0.29 x 8.8 = 2.6 watts

The results were as follows:

After 1 minute, voltage across the capacitor was up to 8.70vdc, with leakage of 750 microamps.

After 3 minutes, voltage across the capacitor was up to 8.73vdc, with leakage of 318 microamps.

After 5 minutes, voltage across the capacitor was up to 8.73vdc, with leakage of 248 microamps.

So, very quickly after switching on, this filter capacitor used in the PSU will be up to speed and doing its job from a DC voltage point of view. The leakage current is also quickly under control and carries on improving.

Capacitor (A) can now be considered fit for purpose.

IMPORTANT NOTE:

This may end up leaving us with a dilemma. In order to get the capacitor up to source voltage quickly, we may need to reform it at higher than working voltage. However, we do not want to go too close to the rated voltage, for fear of damaging the capacitor, especially if the capacitance has risen with old age, as that will likely have lowered the rated voltage.

If so, the solution might be to reform and test it at ever increasing source voltages such that, eventually, it is able to reach the working voltage quickly, but the source voltage has not been raised too close to the rated voltage. If there is no middle ground, then the capacitor may need to be discarded.

END OF IMPORTANT NOTE.

The results of reforming Capacitor B, at 7.0vdc are in, and do not look too good.

Capacitor (B)

At 7.0vdc: (After 8:00 hours)

Leakage current = 820 microamps, Maximum allowable = 4739 microamps. (17.3%)

Voltage drop on resistor = 0.79vdc

Voltage across capacitor = 6.11vdc (-12.7%)

This is considerably worse that the leakage current of 436 we observed with Capacitor A after 8 hours of reforming, nearly twice as bad in fact.

We will now leave Capacitor B reforming at 7vdc for a further 19:45 hours, as we did with Capacitor (A), to see just how far we can get these figures to improve.

Capacitor (B)

At 7.0vdc: (After 62:00 hours)

Leakage current = 148 microamps, Maximum allowable = 4739 microamps. (3.1%)

Voltage drop on resistor = 0.14vdc

Voltage across capacitor = 6.84vdc (-2.3%)

Although these figures are not as good as with Capacitor (A), I expect that reforming at 8.8vdc will give us a working capacitor, so it is being discharged ready to start that process for a further 60 hours.

For Capacitor (B) the final results are:

At 8.8vdc: (After 72:00 hours)

Leakage current = 114 microamps, Maximum allowable = 4739 microamps. (2.4%)

Voltage drop on resistor = 0.11vdc

Voltage across capacitor = 8.66vdc (-1.6%)

The final test is to see how long it takes for Capacitor (B) to get up to a voltage of 8.8vdc, now that it has been reformed to that level. In this case, we will use a 60 Ohm wirewound 50 watt resistor, which will limit the current, but also charge it fairly quickly.

The current flow will be 8.8 / 60 = 0.15 amps, with a power output of 0.15 x 8.8 = 1.29 watts

The results were as follows:

After 1 minute, voltage across the capacitor was up to 8.50vdc, with leakage of 1720 microamps.

After 3 minutes, voltage across the capacitor was up to 8.66vdc, with leakage of 740 microamps.

After 5 minutes, voltage across the capacitor was up to 8.74vdc, with leakage of 328 microamps.

So, very quickly after switching on, this filter capacitor used in the PSU will be up to speed and doing its job from a DC voltage point of view. The leakage current is also quickly under control and they both carry on improving.

Capacitor (B) can now be considered fit for purpose.

For Capacitor (C), which is rated at 25V and 10,000uf, we need to calculate the value of the resistor to use. The maximum voltage we will apply is 16vdc (supplied by the transformer) + 10% margin = 17.6vdc.

You could just look up the nearest higher values in the table of maximum allowable leakage currents and use those (e.g. 10,000uf at 15vdc), but we want to be a little bit more accurate. We can't be precise, because the relationships in-between both volts and capacitance are not linear, but we can get a better estimate.

Referring to the table, we see that 10,000uf at 25vdc = 3000 microamps. at 15vdc, it = 2320.

There is a difference of 10vdc between the 25vdc value and the 15vdc value, which are the nearest above and below in the table.

At 17.6vdc, we are 2.6vdc / 10vdc above the 15vdc value. The difference in microamps is 3000-2320 = 680 microamps. (2.6 / 10) x 680 = 177. Add that to the 2320, and we get a rough estimate for what the microamps should be for 17.6vdc = 2497 microamps (0.002497 amps).

Having used the voltage to look up the value, we now need to take account of the capacitance too.

However, because 10,000uf is found in the table, we can just use the corresponding value, and do not need to make any further adjustment.

So, to calculate the required resistor value, we have 17.6vdc / 0.002497 amps = 7048 Ohms. A resistor of 7k Ohms, or even the more popular 6.8k Ohms will suffice.

Method of Reforming:

Use a resistor that is carefully selected to match the maximum allowable leakage current, taking into account the capacitance, and the voltage being applied. Use the table supplied in Blog Part 3.

As we are using a resistor to limit current, the capacitor will always take some time to reach close to the supply voltage. Calculators are available online to work this out. On large capacitors it can take several minutes.

IMPORTANT NOTE:

Reforming only works up to the supply voltage used for reforming. If you subsequently discharge the capacitor and attempt to apply a higher voltage, it will not reach that new voltage quickly. You would need to reform all over again, at the higher voltage.

Any attempt to apply a voltage higher than the rated voltage will likely destroy the capacitor. Old age can cause the rated voltage to drop. Therefore, you should not reform at a voltage that is even close to the rated voltage.

END OF IMPORTANT NOTE.

It is often suggested that we reform in 3 stages of equally increasing voltage, fully discharging the capacitor at the end of a stage. On the final stage, reform at the normal supply voltage (not the working voltage under load, which will be lower) and add 10% to allow for mains voltage fluctuations. This should still be well below the rated voltage - do NOT go close to the rated voltage.

CONCLUSIONS

What we have learned from detaching the capacitors and reforming them separately, is very important. In the past, we have used the time-honoured method of slowly bringing up the supply voltage of old machines like the IMSAIs, using a Variac, when they are brought out of storage after many years.

Although this has always appeared to work in many respects, in helping the machines to come up okay, in fact it actually hasn't in respect of the filter capacitors in the PSU. The capacitors have often come up to a voltage that seems a bit low, but acceptable. What is happening, however, is that not nearly enough time has been given to reforming them, and too low a voltage has been used anyway.

For example, using this method, which ends up applying the normal +8vdc from the transformer to the 95,000uf, 15vdc capacitors, it has probably brought them up to a working voltage of about 7.2vdc over the final few hours.

Over time, and with very regular use, this may creep up towards +8vdc but will probably not exceed it. We need the capacitor to be able to act as a smoothing filter in the PSU and, in this state, it can't.

In power supplies, capacitors are used to smooth (filter) the pulsating DC output after rectification so that a nearly constant DC voltage is supplied to the load. The pulsating output of the rectifiers has an average DC value and an AC portion that is called ripple voltage.

Filter capacitors reduce the amount of ripple voltage to a level that is acceptable. In a filter circuit the capacitor is charged to the peak of the rectified input voltage during the positive portion of the input. When the input goes negative, the capacitor begins to discharge into the load.

This can only happen if the capacitor has been reformed at a value higher than the normal +8vdc from the transformer, and so can now store charge above the +8vdc when given the chance to by momentary peaks in the supply voltage.

The main conclusion has to be, therefore, to remove the filter capacitors from the PSU and reform them separately, at a value (say 10%) above their normal input voltage from the transformer. They should not be reformed at a voltage close to their rated voltage in case that has dropped over time.

IMSAI 8080 Capacitors

Using a carefully applied method, reforming has been carried out successfully on the 95,000uf 15vdc and 10,000uf, 25vdc filter capacitors. It has taken much longer than the 'rule of thumb', so be prepared for that. It was over 60 hours in some cases.

The largest capacitors reformed have lost the ability to charge to the supply voltage, to a very small degree (1.0%). This was not the case with a 'new old stock' item so must, presumably, be down to previous usage rather than age or storage. The decision to subsequently reform to the supply voltage + 10% has more than compensated for this.

BLOG PART 5: Cleaning The Case & Chassis + Reforming The PSU Filter Capacitors (Part 3).

17/11/2019

Today, we have started to clean the case and chassis.

A range of cleaning products are used for this exercise, as shown in the photo below:

Computer cleaning products

We have: Methylated Spirit; White Spirit; Pledge Furniture Polish; Rubbing Compound; and Foam Cleaner.

The lid was one of the worst I have come across, in terms of the grime on it, and the degree to which it seemed to be embedded into the paintwork. It looks like it was used in an industrial environment. There are nearly always small areas of markings which are stubborn to remove, and this one is no exception.

The underside!

The process is a fairly standard one, where painted parts such as the lid are concerned.

The whole area is cleaned in small, circular movements, with Foam Cleaner to begin with. This is followed by White Spirit.

After this, a light clean with Methylated Spirit is used, having carried out a small test in an inconspicuous place first, in case the paint is easily removed by its use.

Wherever there are marks, an attempt is made to rub them off using the Methylated Spirits, with a little more force - again without risking paint removal.

This will deal with the majority of the cleaning required.

The secret weapon at our disposal, for those really stubborn stains, is rubbing compound. If you have ever used it to remove small scratches from your car paintwork, you will be familiar with its fairly miraculous properties.

Again, as this deliberately removes a microscopic layer of paint, great care must be taken with its use. I find that using the same area of the cloth for all subsequent applications of the compound, helps to protect against accidentally removing more than you intended.

Despite all of this, there are usually one or two marks that even this will not remove without damaging the paintwork. That just has to be accepted. We are not trying to make it look as though it has just come off the production line after all. If that were the case, a respray would be the logical choice.

It has taken the best part of an hours work to clean the lid, but all went well enough.

A final light clean with Foam Cleaner and then White Spirit once more, and then a nice heavy coat of Pledge Beeswax Furniture Polish, makes everything look much better, without looking new. Leave the polish to almost dry, before buffing with a soft cloth.

Foam Clean in action

Just the small paint chip on the top left to do

We can buy generic 'Altair/IMSAI Blue' in small, touch-up pots, for bits where there has been paint loss. This will hardly ever be an exact match, as age has changed the hue of the paint in many different ways on different machines. Nevertheless, it can look a lot better than bare aluminium shining back at you.

The paint colour required is RAL 5012, and satin works best. It is readily available on Ebay.

We will not bother with paint loss on the underside, where people have slid the lid off instead of lifting it. That is just going to happen again in the future, and can't be seen anyway.

However, we do have one small chipped area on the top, so will apply a small amount just to cover it.

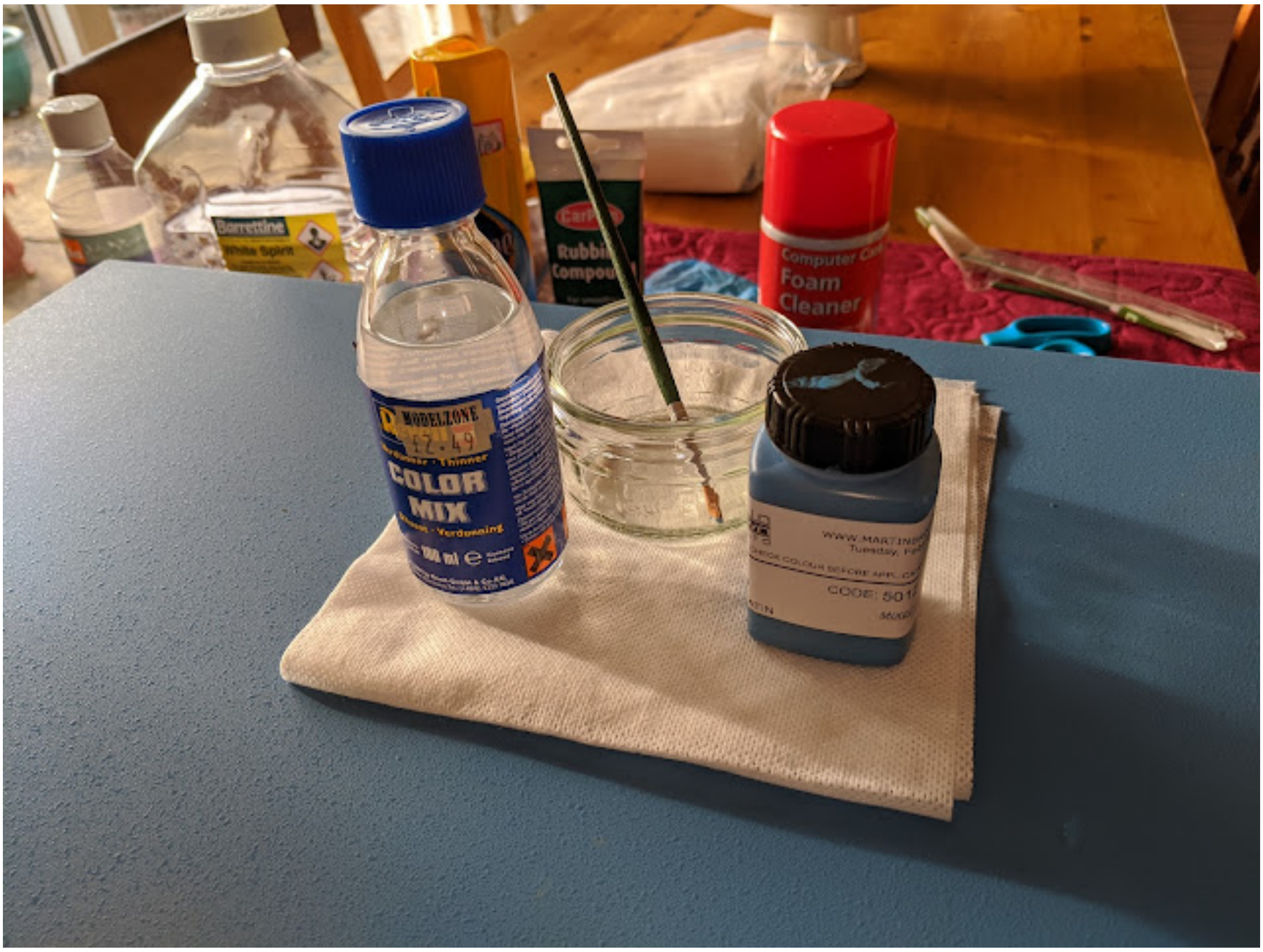
To do this, we just need to use a very small amount of White Spirit, to clean off the Polish over the chip. We then apply a tiny amount of paint and spread it thinly, sticking within the area of the chip and just taking the paint up to the edge all around it. Leave it for 8 hours to dry and harden, then just apply a little Polish to protect it.

The before and after are shown below:

The original paint colour RAL 5012 www.martinbrownpaints.com

An artists brush, a glass dish and some thinner help to get the right consistency to stipple the paint.

The touch-up can be 'aged', after drying, and before polishing that area again, by rubbing in a little grime into the paint that is then lightly cleaned off. It is almost impossible to get an exact match for 40-year old paint, but you can get a much better look than the bare aluminium.



After touch up.

While we are cleaning and touching up the machine, work is continuing on reforming the capacitors. The results will be updated here over time.

For Capacitor (C) 10,000uf, 25v the results, restarting the clock at each stage are as follows:

At 5.9vdc: (After 6:00 hours)

Leakage current = 10 microamps, Maximum allowable = 2497 microamps. (0.4%)

Voltage drop on resistor = 0.00vdc

Voltage across capacitor = 5.88vdc (-0.3%)

This result is good enough to warrant moving straight on to the next stage voltage of 11.7vdc

At 11.7vdc: (After 3:00 hours)

Leakage current = 2.7 microamps, Maximum allowable = 2497 microamps. (0.11%)

Voltage drop on resistor = 0.01vdc

Voltage across capacitor = 11.69vdc (-0.1%)

After only 3 hours, we have obtained very good results so will move to the full voltage.

At 17.6vdc: (After 25:00 hours)

Leakage current = 2.5 microamps, Maximum allowable = 2497 microamps. (0.1%)

Voltage drop on resistor = 0.01vdc

Voltage across capacitor = 17.6vdc (-0.0%)

It has taken considerably longer to get the same kind of results at 17.6vdc that were obtained at lower voltages. Nevertheless, after 25:00 hours, all is well.

The final test is to see how long it takes for Capacitor (C) to get up to a voltage of 17.6vdc, now that it has been reformed to that level. In this case, we will use a 30 Ohm wirewound 50W resistor, which will limit the current, but also charge it fairly quickly.

The current flow will be 17.6 / 60 = 0.29 amps, with a power output of 0.29 x 17.6 = 5.1 watts

The results were as follows:

After 1 minute, voltage across the capacitor was up to 17.58vdc, with leakage of 30 microamps.

After 2 minutes, voltage across the capacitor was up to 17.58vdc, with leakage of 21 microamps.

After 5 minutes, voltage across the capacitor was up to 17.58vdc, with leakage of 8 microamps.

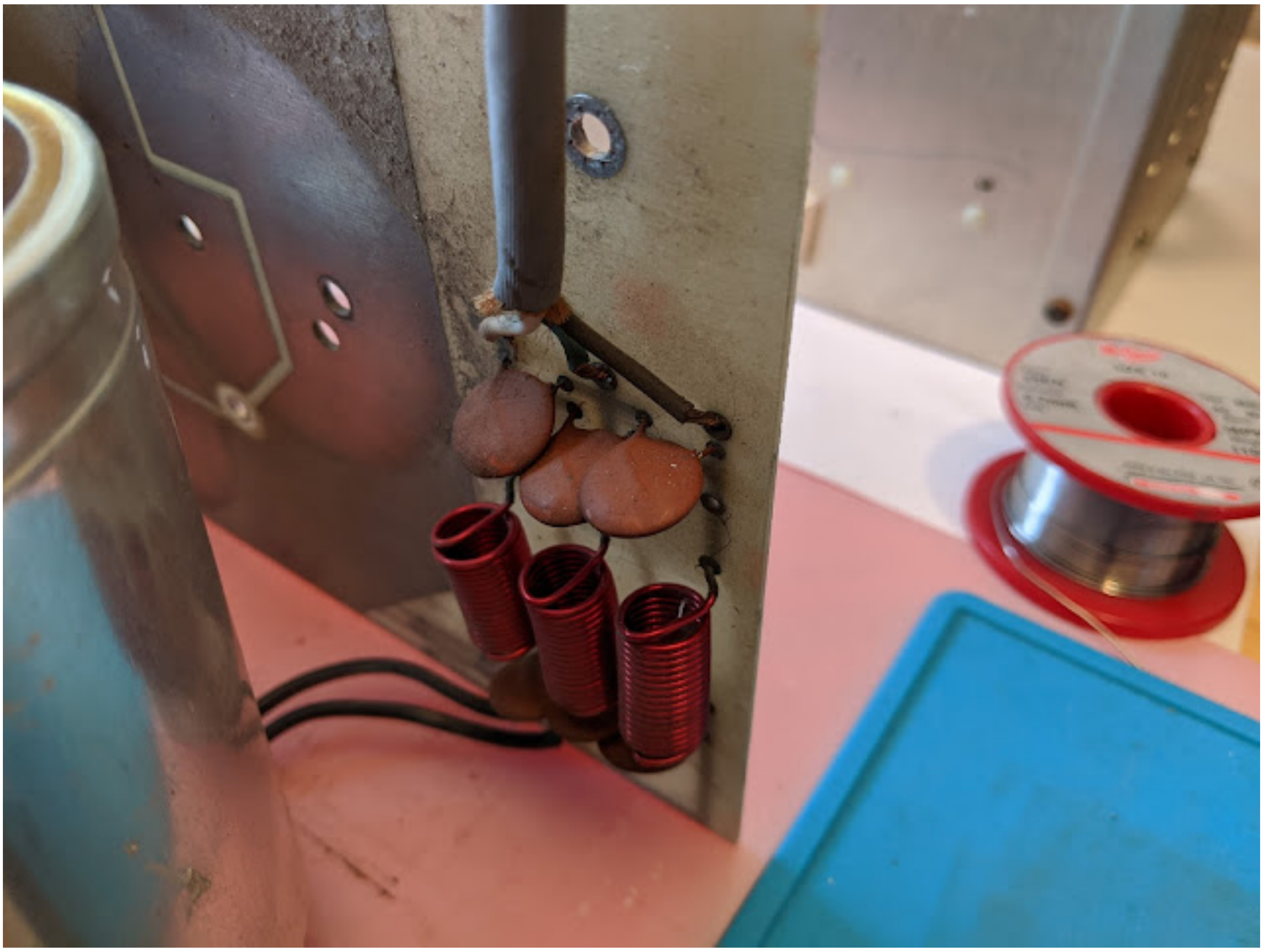
So, very quickly after switching on, this filter capacitor, used in the PSU, will be up to speed and doing its job from a DC voltage point of view. The leakage current is also quickly under control.

Capacitor (C) can now be considered fit for purpose.

19/11/2019

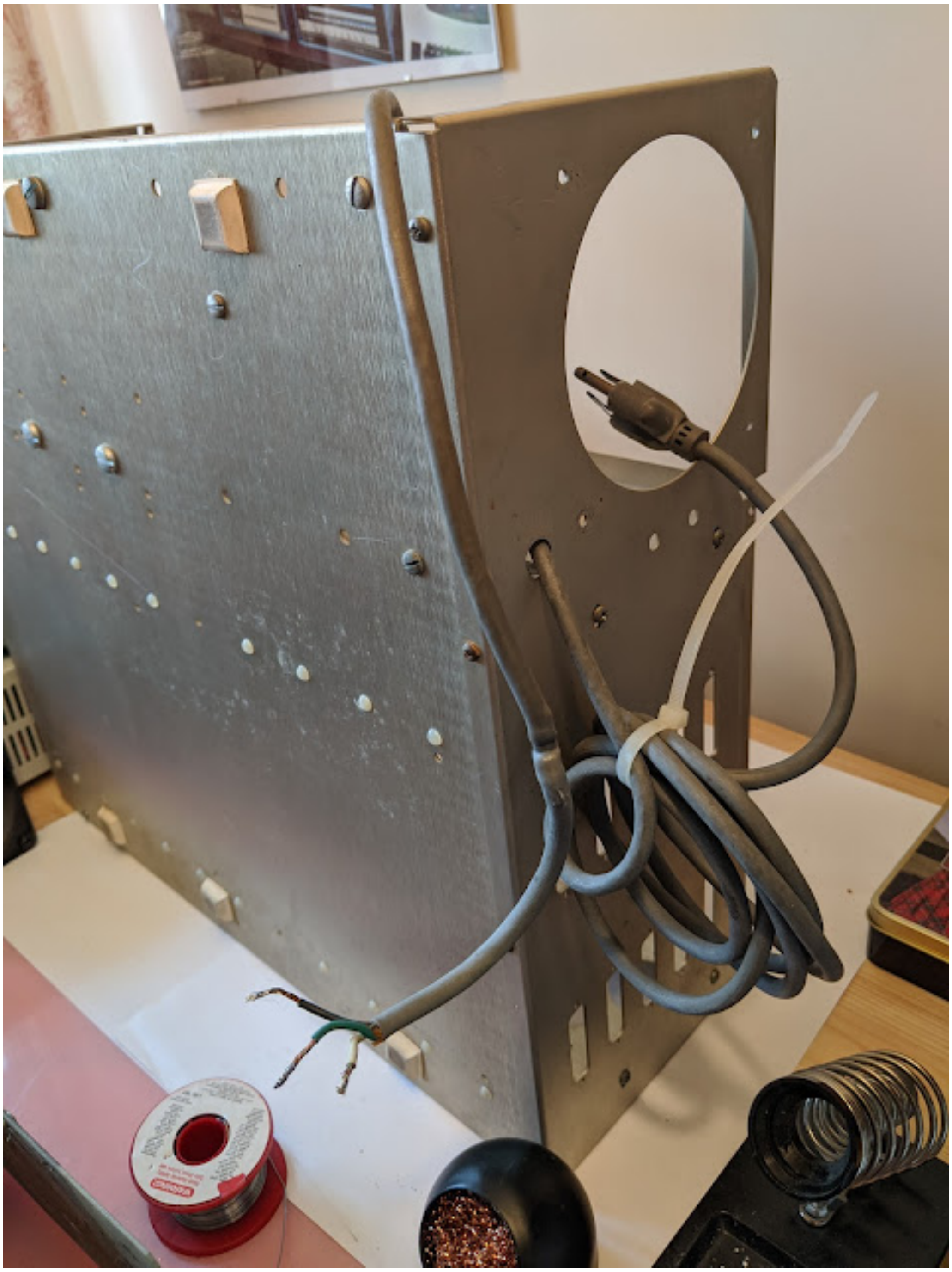
Back to cleaning……

Firstly, we need to remove the mains cable, to detach the PSU from the Chassis.



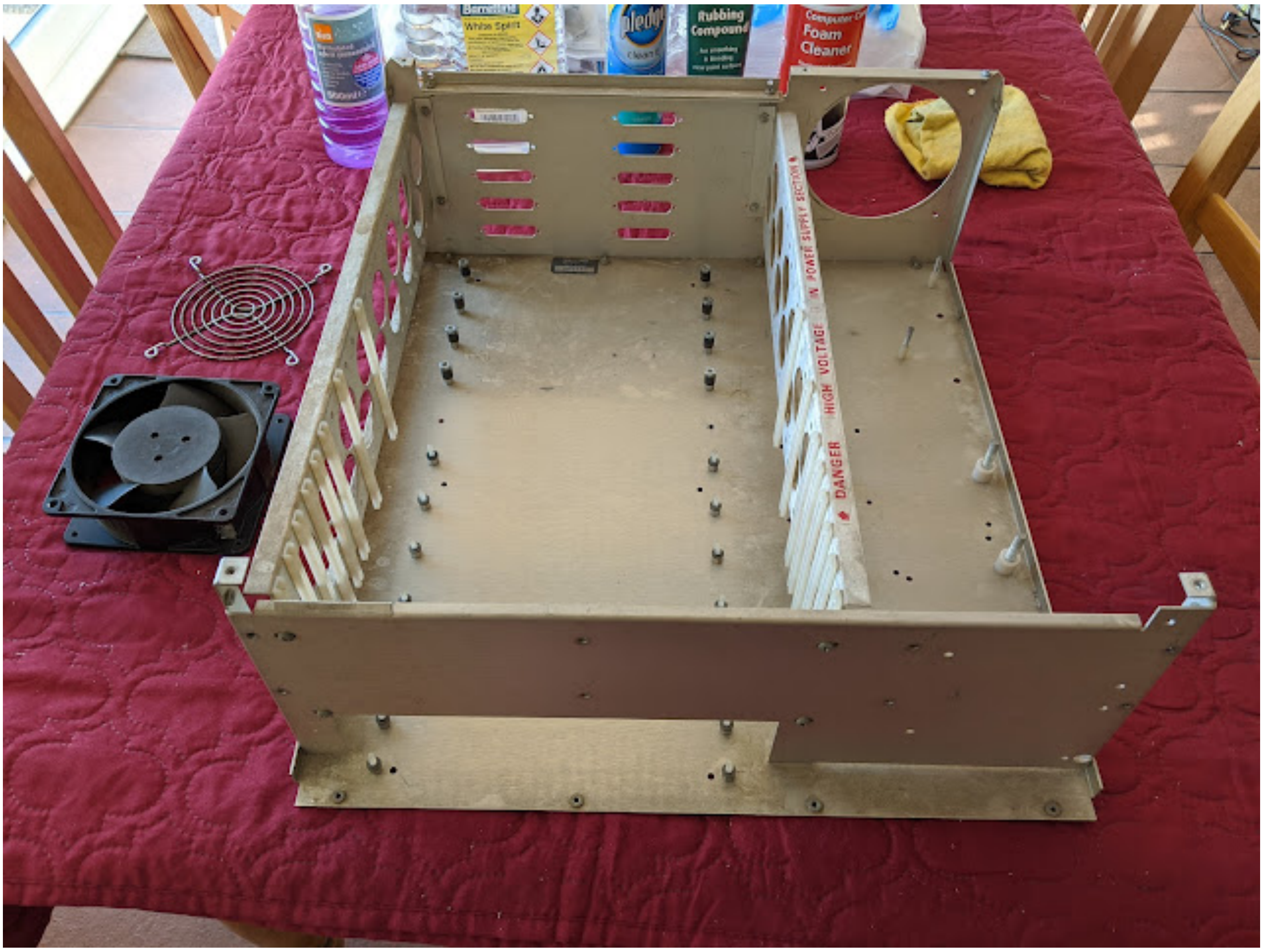
The incoming mains cable. The pcb has helpful colour code markers.

A 40W soldering iron is needed to desolder these 3 cables



Removed from the PSU and ready to pull through the hole in the chassis

Cleaning will be so much easier now that they are apart.

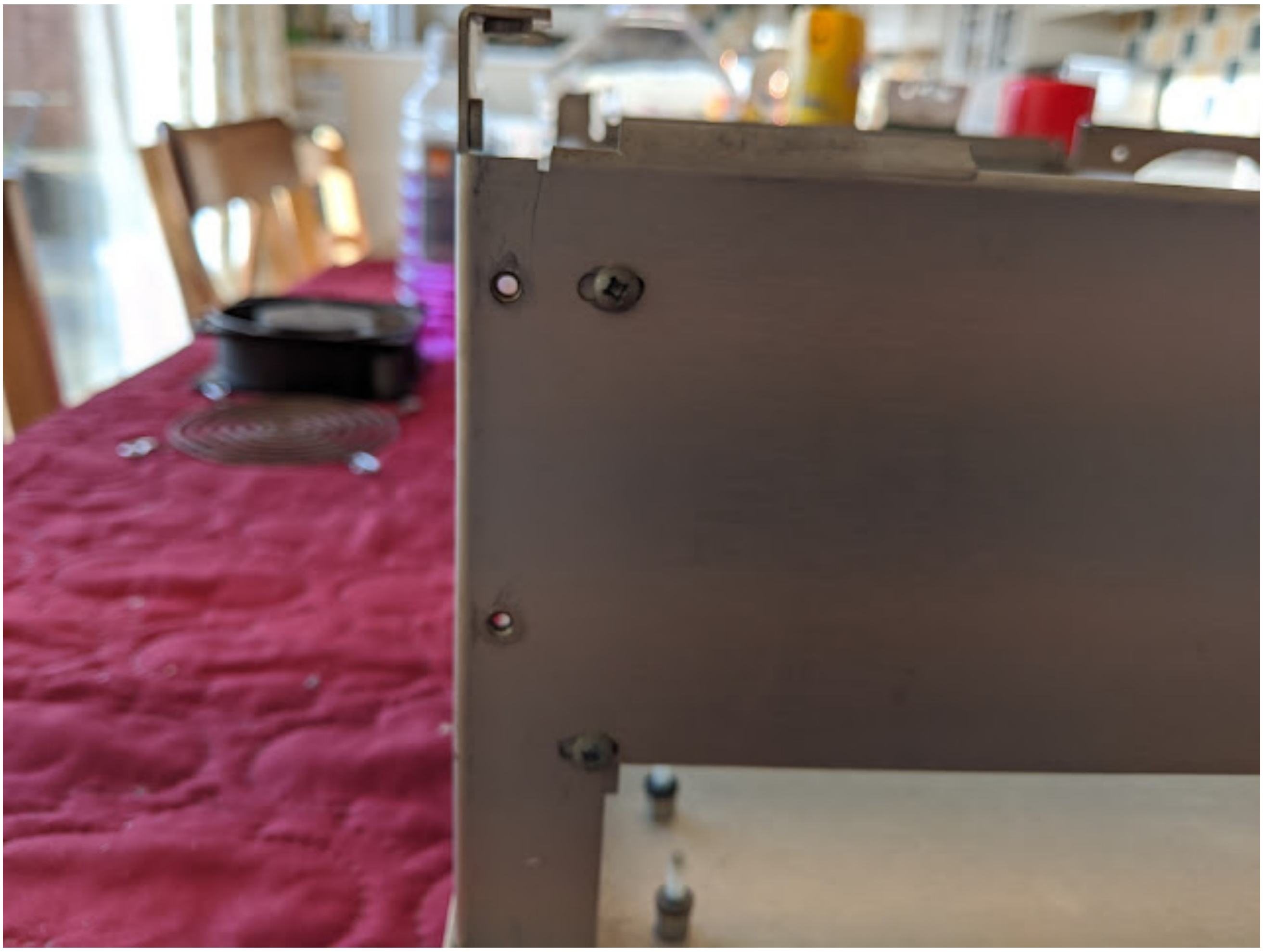


Bare chassis

Ready for the treatment.

43 years worth of grime

Great care should be taken not to get any cleaner on the serial number label. This is an important and valuable part of the machine.



Guide rail screws

The Chassis can easily be broken apart to make cleaning even easier, by removing the two screws at each end that secure the two guide rails. However, as can be seen, there is the ability to adjust them sideways to get the best fit for the S-100 boards. In my view, they are best left alone as it can be awkward to get them back in the right place.

It is still easy enough to get in to clean. Here is the finished article. With it being aluminium, Foam Cleaner is all that was required. We were not trying to polish it like new, just get all the dirt and dust off, retaining the original patina.

Clean and tidy - side view

Clean and tidy - front view

There are an insufficient number of original rubber feet to support the weight and distribute it evenly. The can lead to warping of the baseplate near the transformer, distorting the right-hand guide rail for the S-100 boards .

Underside View

We will fit a complete set of new, slightly higher feet, to avoid any weight on the originals, which are showing evidence of perishing.

Full set of 3M Rubber Feet fitted

The best feet, in terms of both grip and adhesive are 3M. Given the weight of an IMSAI 8080 and the fact this will be used for demonstrating to the public, they are a good option.

They are made of real rubber - a smell you never forget!

Pure black rubber feet

3M are the best all round

20/11/2019

For Capacitor (D) 10,000uf, 25v the results, restarting the clock at each stage are as follows:

At 5.9vdc: (After 0:15 hours)

Leakage current = 8 microamps, Maximum allowable = 2497 microamps. (0.3%)

Voltage drop on resistor = 0.04vdc

Voltage across capacitor = 5.87vdc (-0.5%)

This result is good enough to warrant moving straight on to the next stage voltage of 11.7vdc

At 11.7vdc: (After 4:15 hours)

Leakage current = 4.7 microamps, Maximum allowable = 2497 microamps. (0.19%)

Voltage drop on resistor = 0.03vdc

Voltage across capacitor = 11.6vdc (-0.9%)

After only a little over 4 hours, we have obtained very good results so will move to the full voltage.

At 17.6vdc: (After 24:00 hours)

Leakage current = 4.2 microamps, Maximum allowable = 2497 microamps. (0.17%)

Voltage drop on resistor = 0.02vdc

Voltage across capacitor = 17.59vdc (-0.06%)

The final test is to see how long it takes for Capacitor (D) to get up to a voltage of 17.6vdc, now that it has been reformed to that level. In this case, we will use a 30 Ohm wirewound 50W resistor, which will limit the current, but also charge it fairly quickly.

The current flow will be 17.6 / 60 = 0.29 amps, with a power output of 0.29 x 17.6 = 5.1 watts

The results were as follows:

After 1 minute, voltage across the capacitor was up to 17.6vdc, with leakage of 16 microamps.

After 2 minutes, voltage across the capacitor was up to 17.6vdc, with leakage of 13 microamps.

After 5 minutes, voltage across the capacitor was up to 17.6vdc, with leakage of 8 microamps.

So, very quickly after switching on, this filter capacitor, used in the PSU, will be up to speed and doing its job from a DC voltage point of view. The leakage current is also quickly under control.

Capacitor (D) can now be considered fit for purpose.

We are now ready to clean the PSU.....

Lay the transformer on its side, the one nearest to the edge of the pcb.

We can start by cleaning the underside.

PS-28D Assembly plus fan

Make sure you find, and put to one side, the 4 plastic washers that were underneath the transformer, between it and the pcb. We do not want to forget to fit them during reassembly....!

Four plastic washers

END OF BLOG PART 5

BLOG PART 6: Cleaning, Inspecting, + Refitting The PSU.

22/11/2019

Today we move on to start cleaning the PSU and putting it back into the chassis, prior to some stress testing.

In the main, white spirit is used, with a Safecloth and cotton buds, to wipe down the entire surface, removing all the readily removable grime.

Cleaning with White Spirit

Before we start cleaning, however, we need to carry out a close examination of all soldered joints on the underside of the pcb. Don't be afraid to check them for adhesion, once the PSU is back in position we will not be able to access them.

Anything we are not happy with should be redone now. A minimum 40 watt soldering iron will be needed due to the heatsink effect of the large areas of metal to which the wires are soldered.

Examination of soldered joints

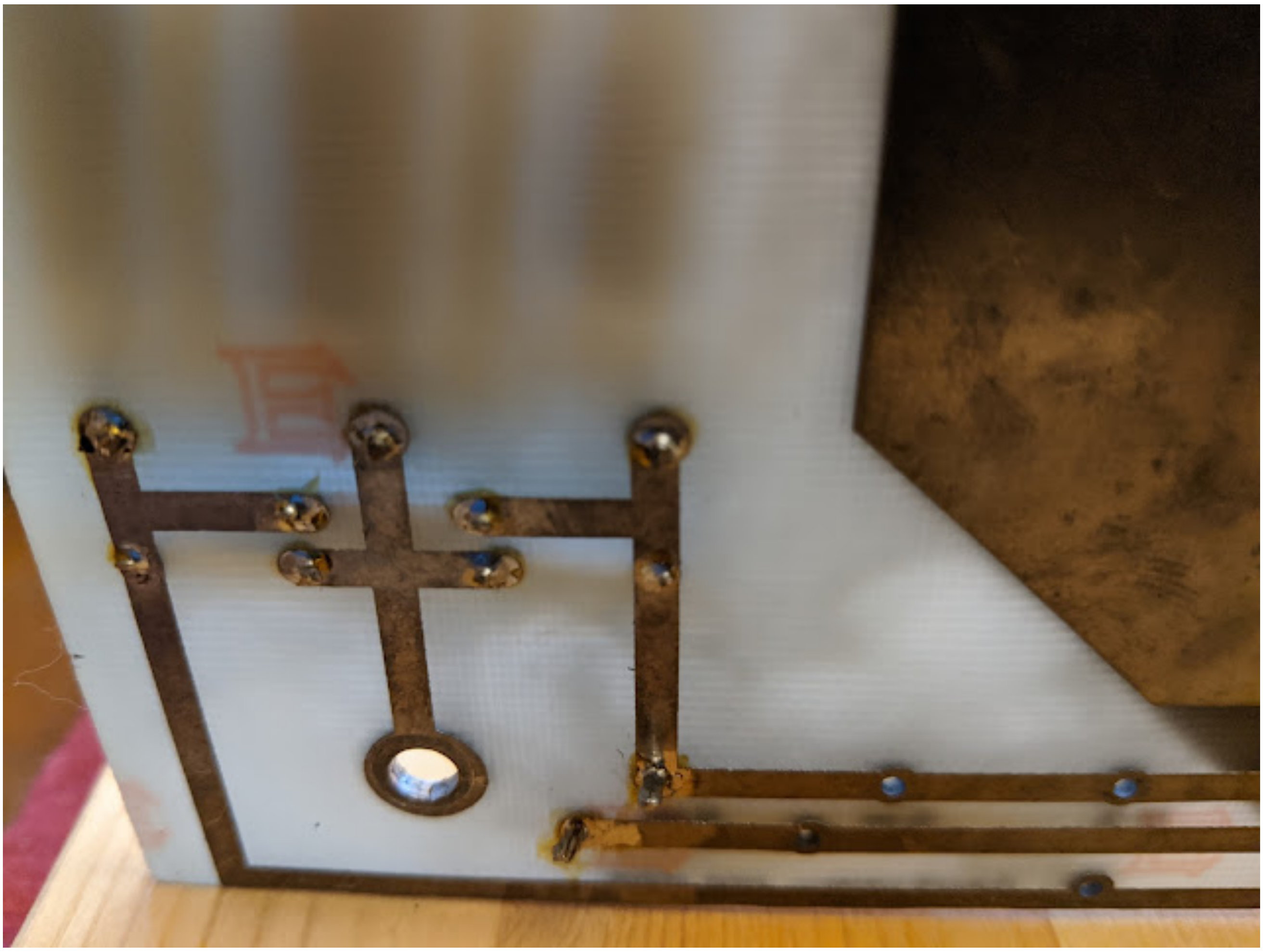
It is fairly apparent from this, that the original build was of a fairly amateur nature. This adds to the picture that this was a home kit-built machine, rather than having been assembled for a customer by a retail outlet. The contradiction being the sheer amount of dust and grime.

Examination of soldered joints

So far, so good though - all appears to be sound. The indentations around some holes helps to identify where the filter capacitors will need to be fixed back in place now that they have been tested.

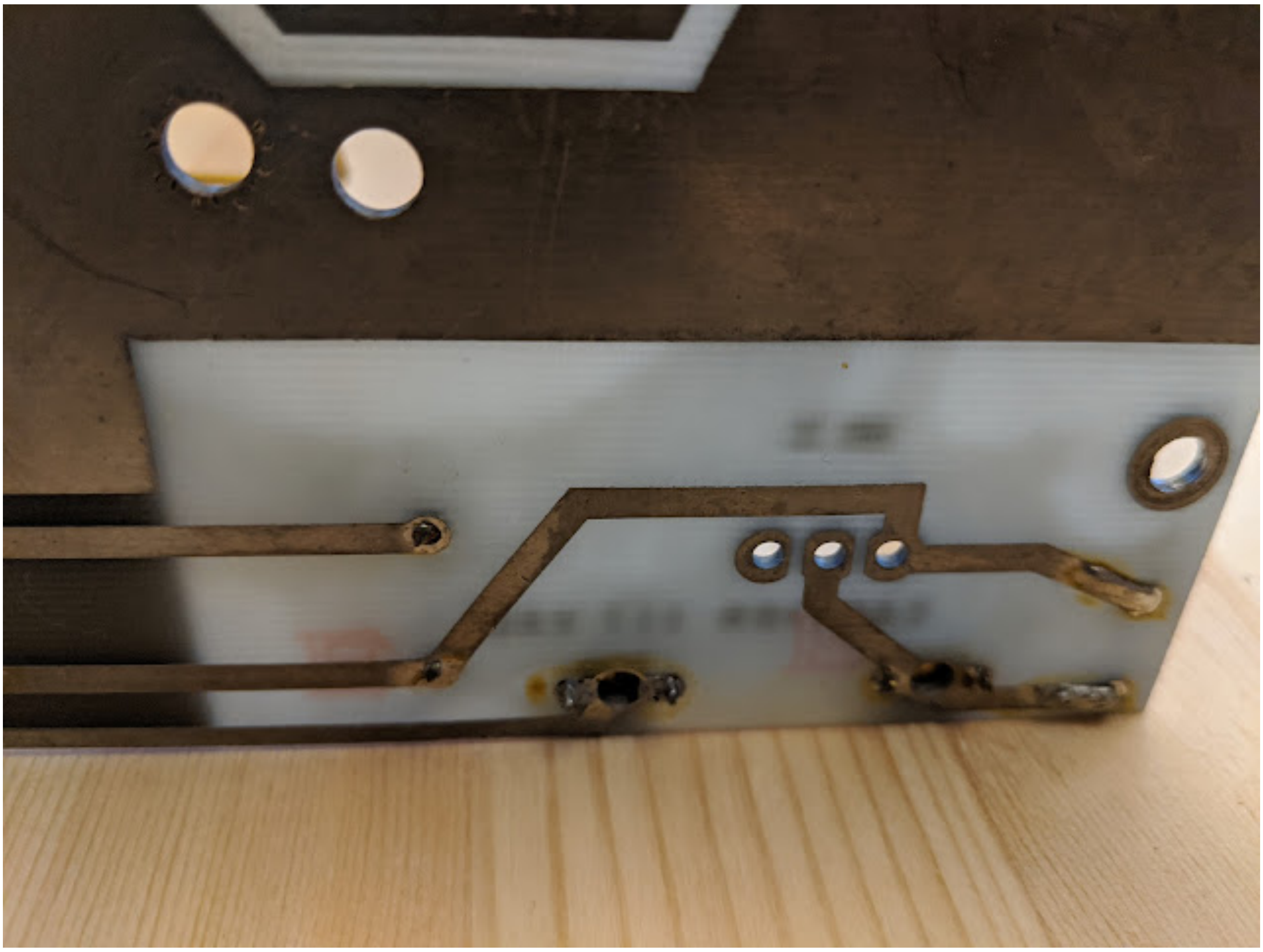
Examination of soldered joints

A grounding point. Clean this with a fibre pen.



Examination of soldered joints

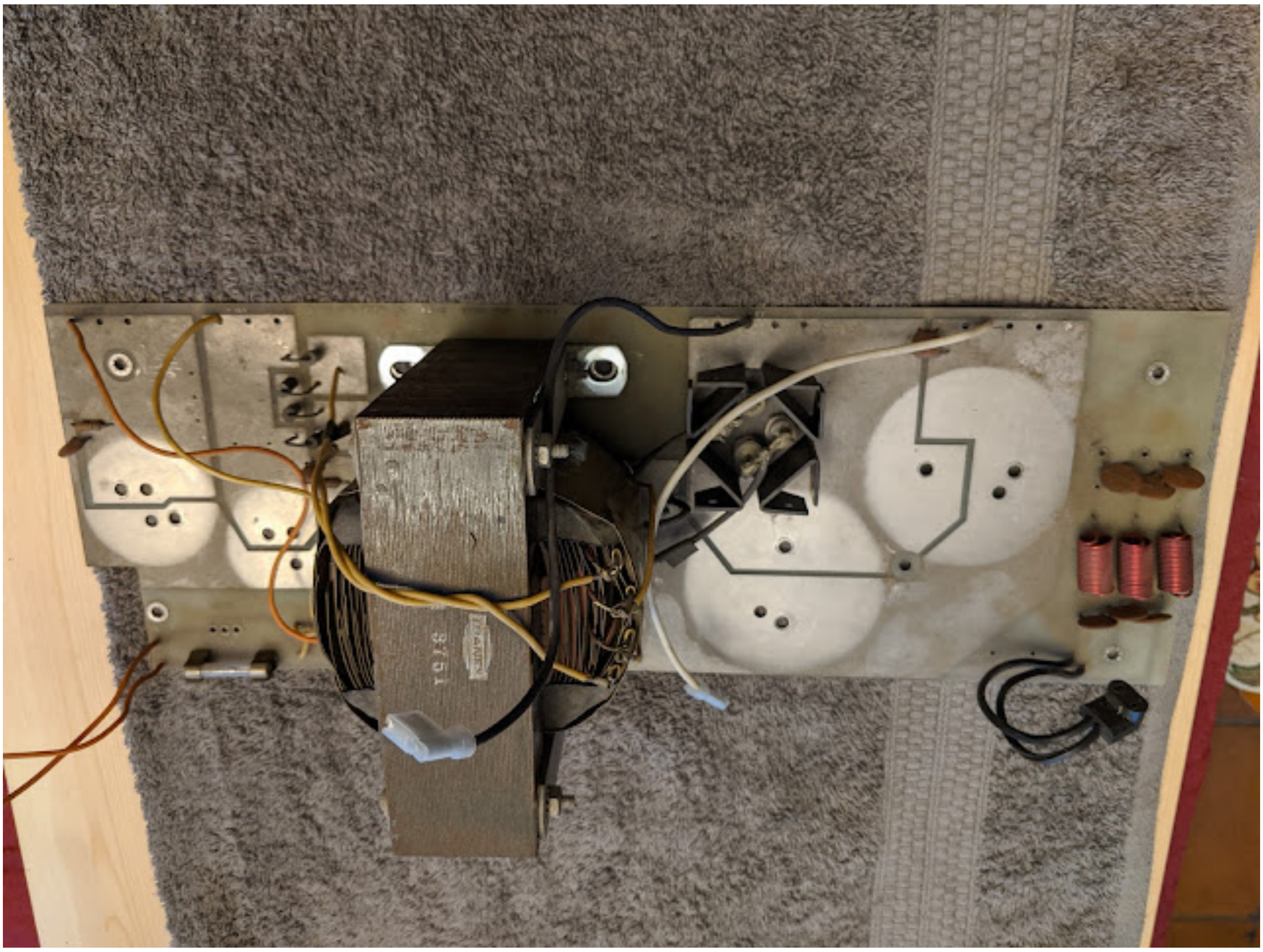
That completes the examination on the underside.



Examination of soldered joints

Fortunately, no joints appear to have failed, so we have no remedial work to perform.

Now on to the cleaning......



The top side of the PSU, covered in decades of dust and grime.

Safecloths with a little white spirit can be used to wipe over most surface areas. For those harder to reach places, cotton buds dipped in a little white spirit are fine.

Cleaning materials required.

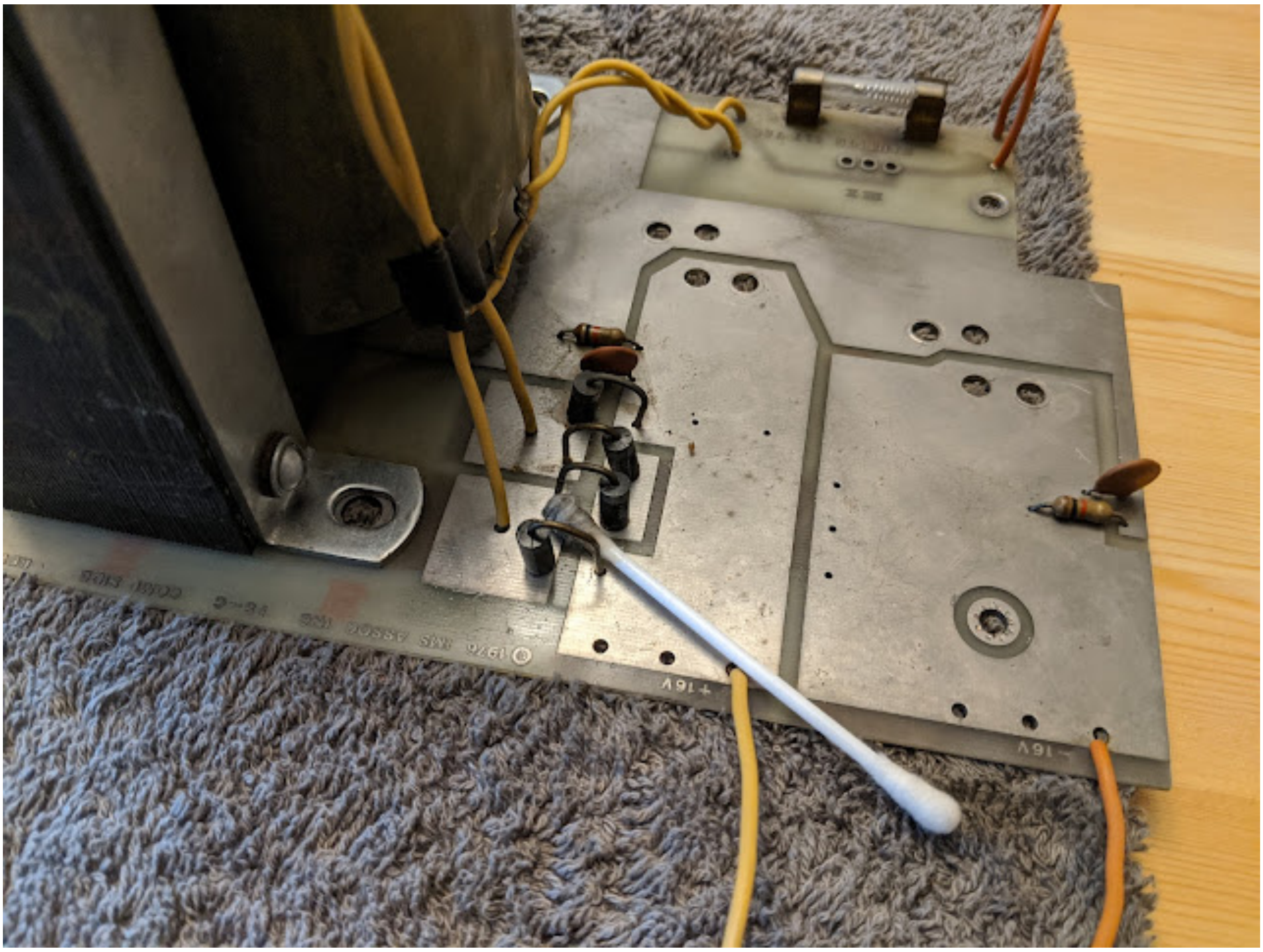
For some areas, such as the top of the transformer coils, we need to blow the dust out. If you have a proper air compressor, then great (done with care), if not, then a can of compressed air will do a reasonable job too.

Air Duster

The top of the transformer coils are a dust trap. Do not be tempted to use anything other than an air duster to remove it, otherwise you may damage the insulation.

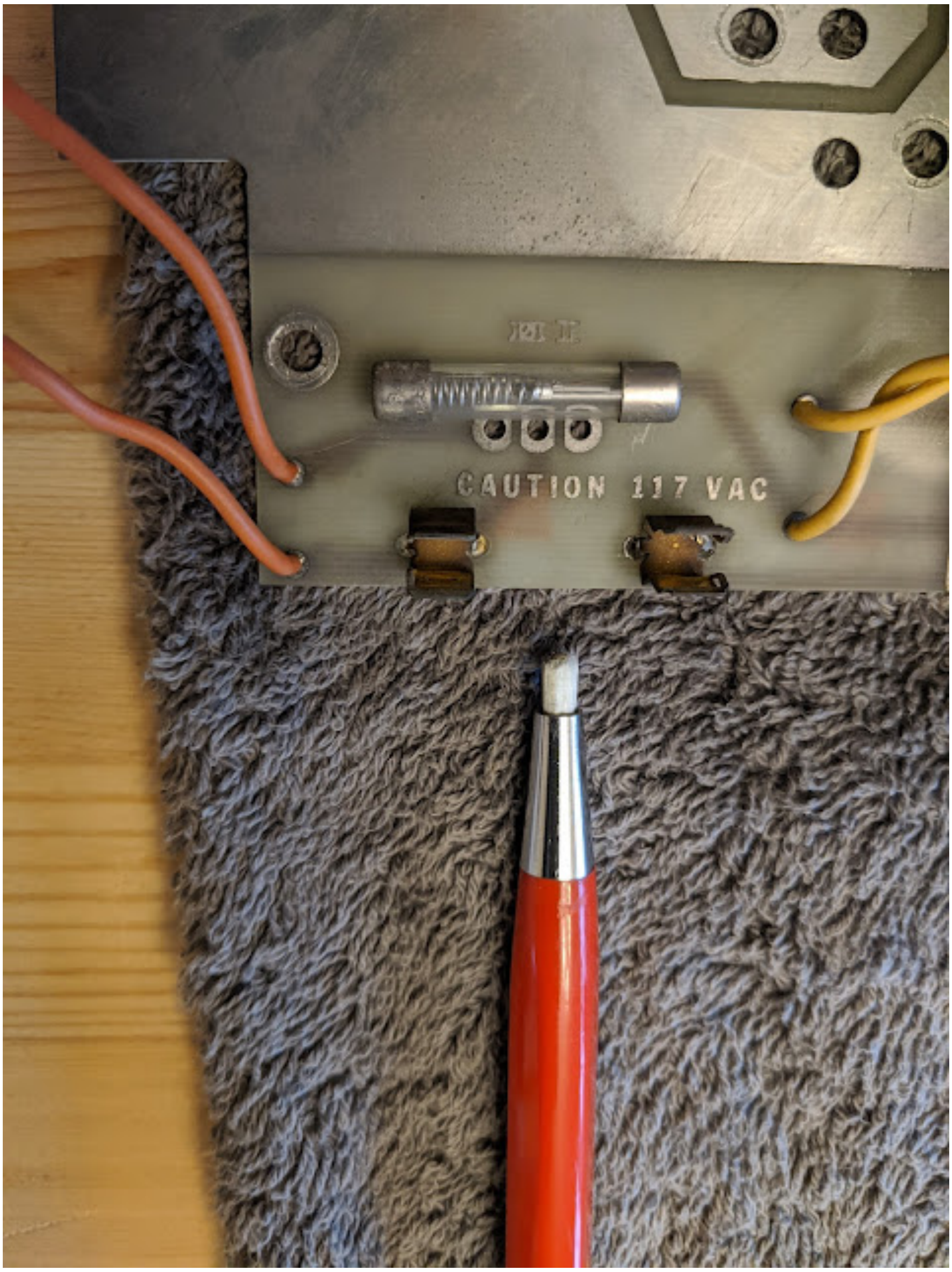
The top of the transformer coils.

Cotton buds are particularly good at getting between and around small components.



Cotton buds in action

If fitted to the pcb, as in our case, the mains fuse should be removed and it, and the metal surfaces of the fuse holder, should be thoroughly cleaned with a fibreglass pen.



A mains fuse and holder, with a fibre pen for cleaning

We need to identify the fuse used, and we will put a sticker onto the pcb to help others to replace it in event that it blows in the future.

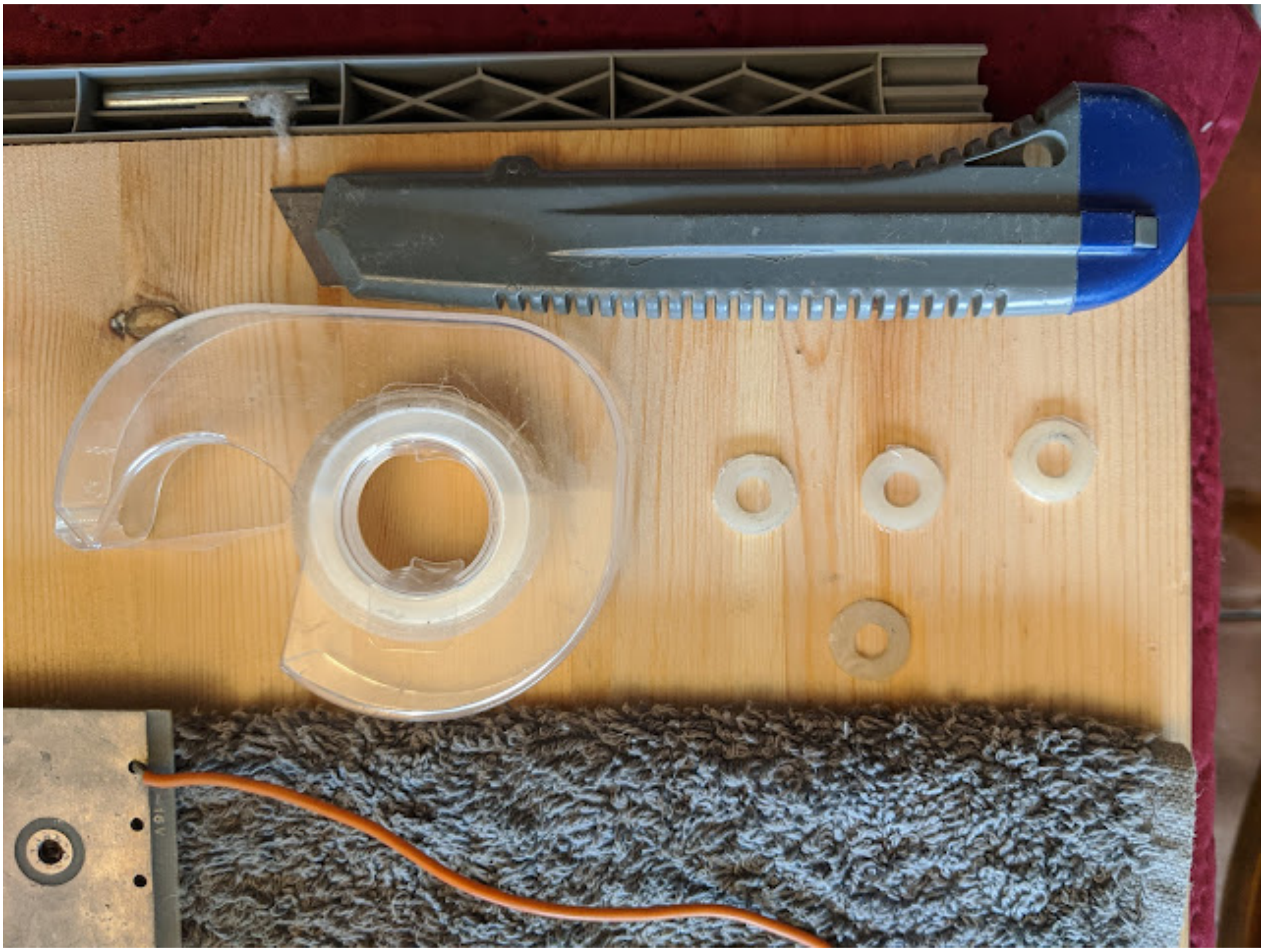
For this kind of closeup work, a couple of tools are recommended:

Firstly a pair of clip on magnifier glasses. these are typically used by miniature model makers when doing paintwork on miniature figures. In addition, a large magnifying glass, with built-in LED lighting. This version has a much more powerful small magnifying glass built in as well.

Tools for closeup work

The fuse turns out to be 5A, 125vac, slow-blow, which is typical for a USA machine. We will extrapolate later, when stress testing the PSU, whether that is going to be enough to cope with the 28 amp +8vdc supply when in full swing.

When trying to put the PSU back into the chassis, we will potentially have a problem with the four plastic washers that sit between the pcb and the transformer falling out of position. An easy way to tackle that is to put double-sided tape onto one side of the washer cut around it with scissors and then cut an X in the middle with a Stanley knife.

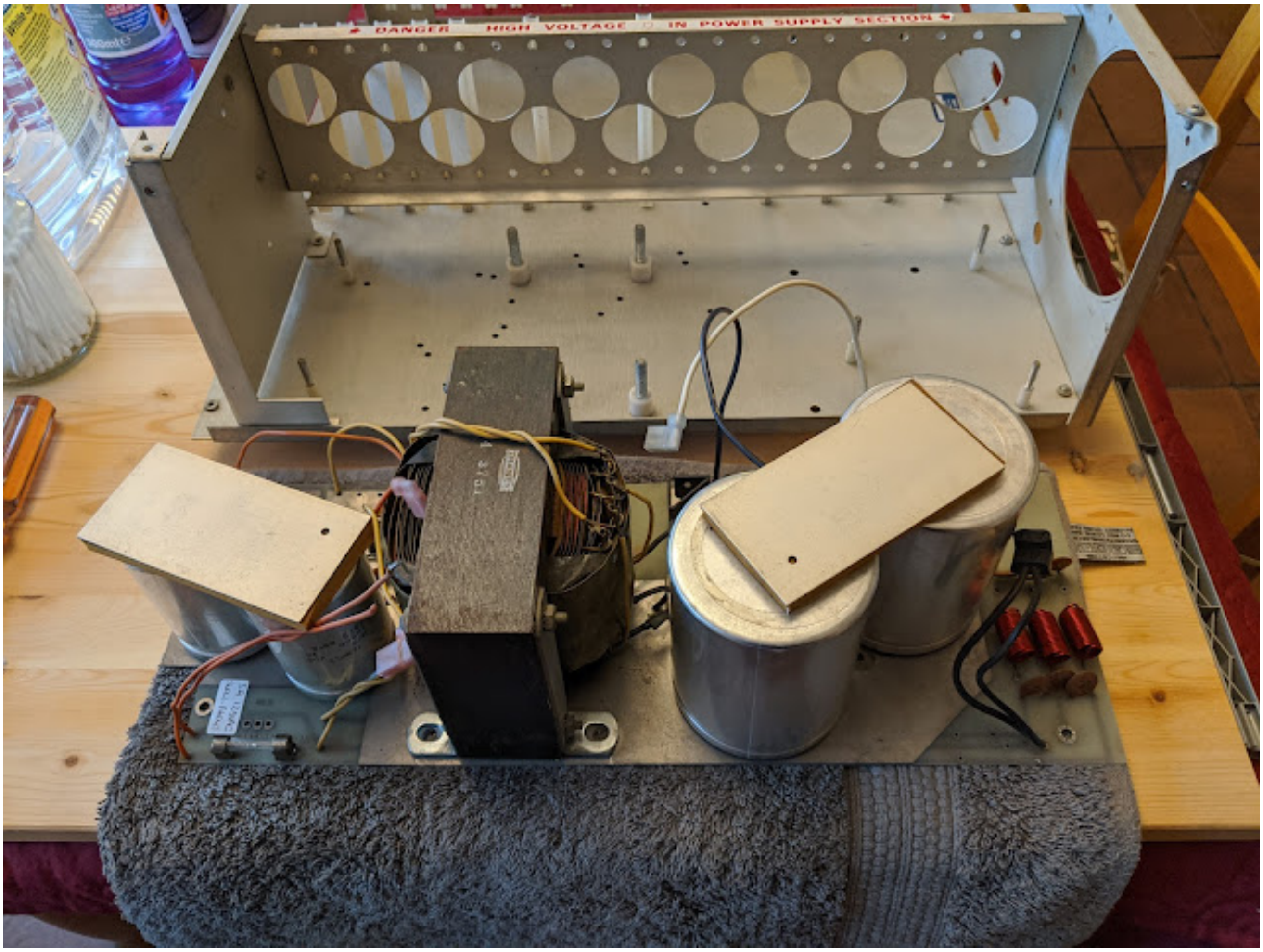


Double-sided sellotape and a Stanely knife.

The washer is now fixed in place on the pcb, and the slits cut in the tape will allow the bolts to pass through.

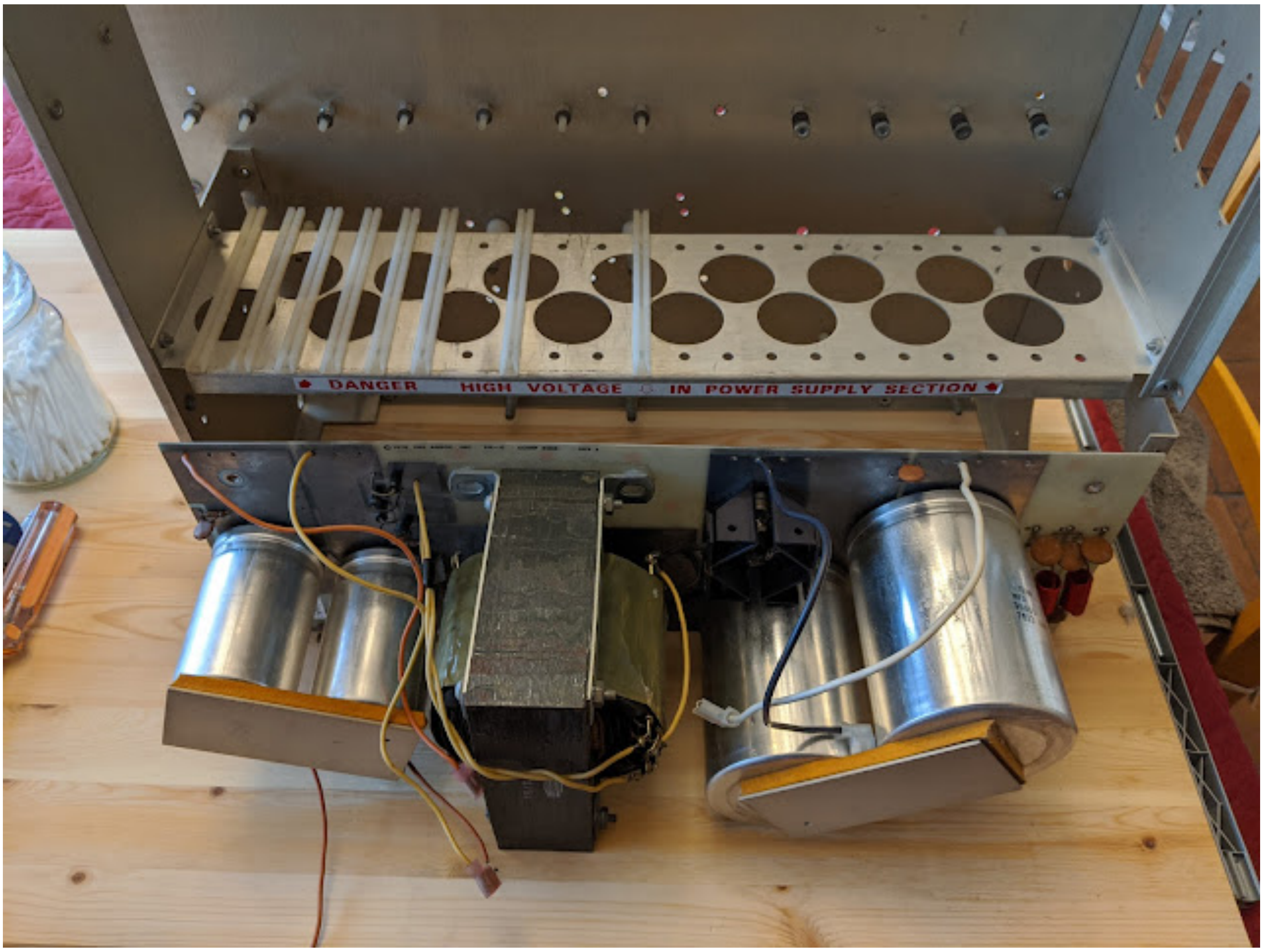
Plastic washer fixed in place on the pcb.

For the brave among you, here is the method for fitting the PSU into the chassis, without removing the centre guide rail for the S-100 boards. There is little room to work in this scenario, and great care must be taken not to allow the heavy transformer to exert too much force onto the pcb. Slowly, step by step is the best advice.



PSU ready to refit to chassis.

Lay both the PSU and chassis on their sides as shown.

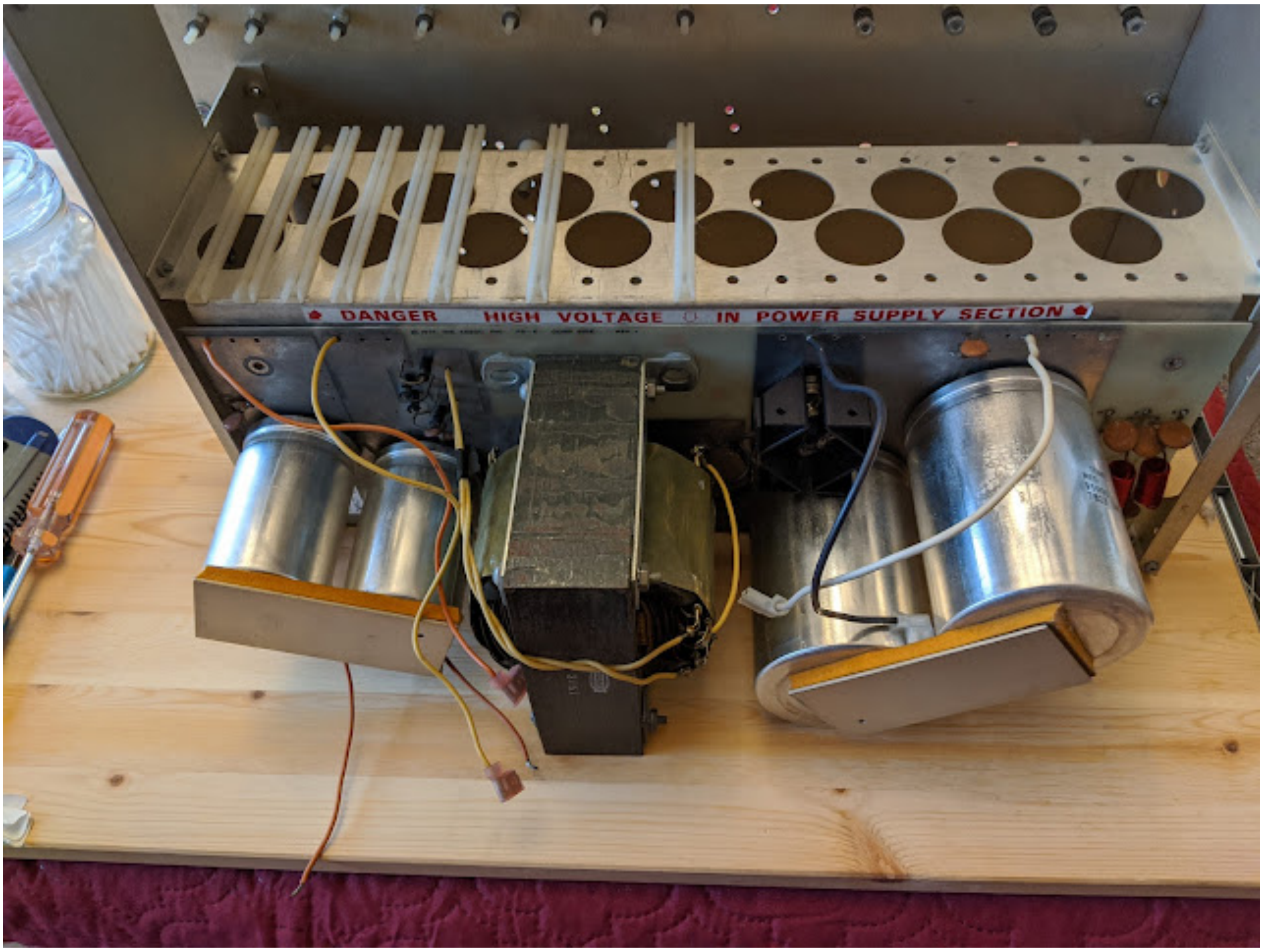


Chassis tipped onto one side.

Holding the transformer, lift the PSU carefully over the edges of the chassis and down into the first space.

PSU eased over first obstacle.

Rest the transformer onto the workbench so that it exerts no force onto the pcb.

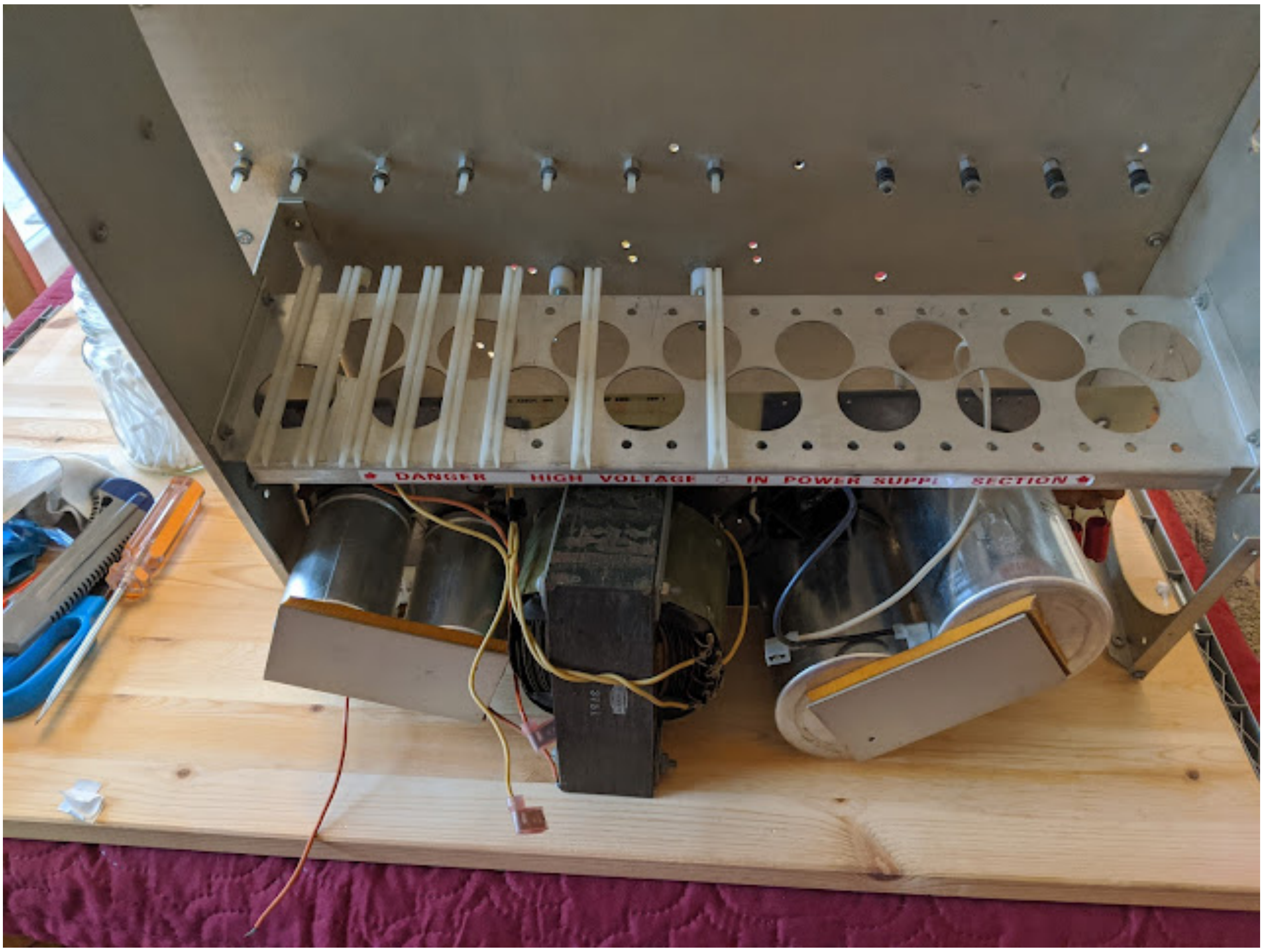


Transformer resting on workbench.

Now tilt the lightweight chassis forwards, in order to get the PSU under the guide rail for the S-100 boards, and then slide the bottom of the chassis forwards.

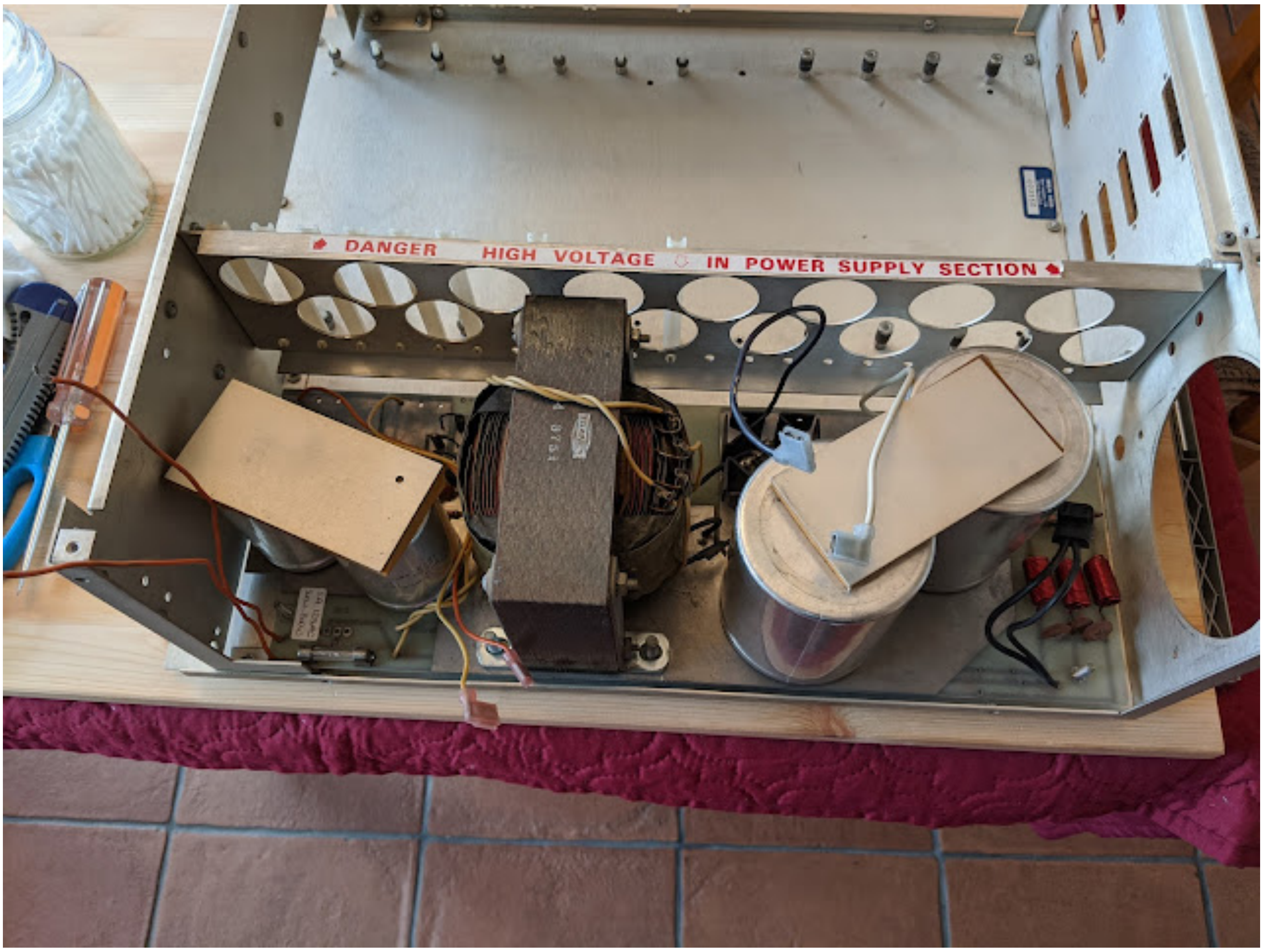
Tilting the chassis forwards.

The PSU is now ready to go onto the fixing bolts.



PSU goes under the guide rail..

Holding the transformer, lift and tilt everything back over and gently ease the pcb onto the supporting bolts. Pay particular attention to the bolts at each end as they are a tight fit and, if they get stuck, can cause the pcb to bend too much. The PSU is now ready to accept the nuts and washers to hold in in position. This takes a fair bit of strength.

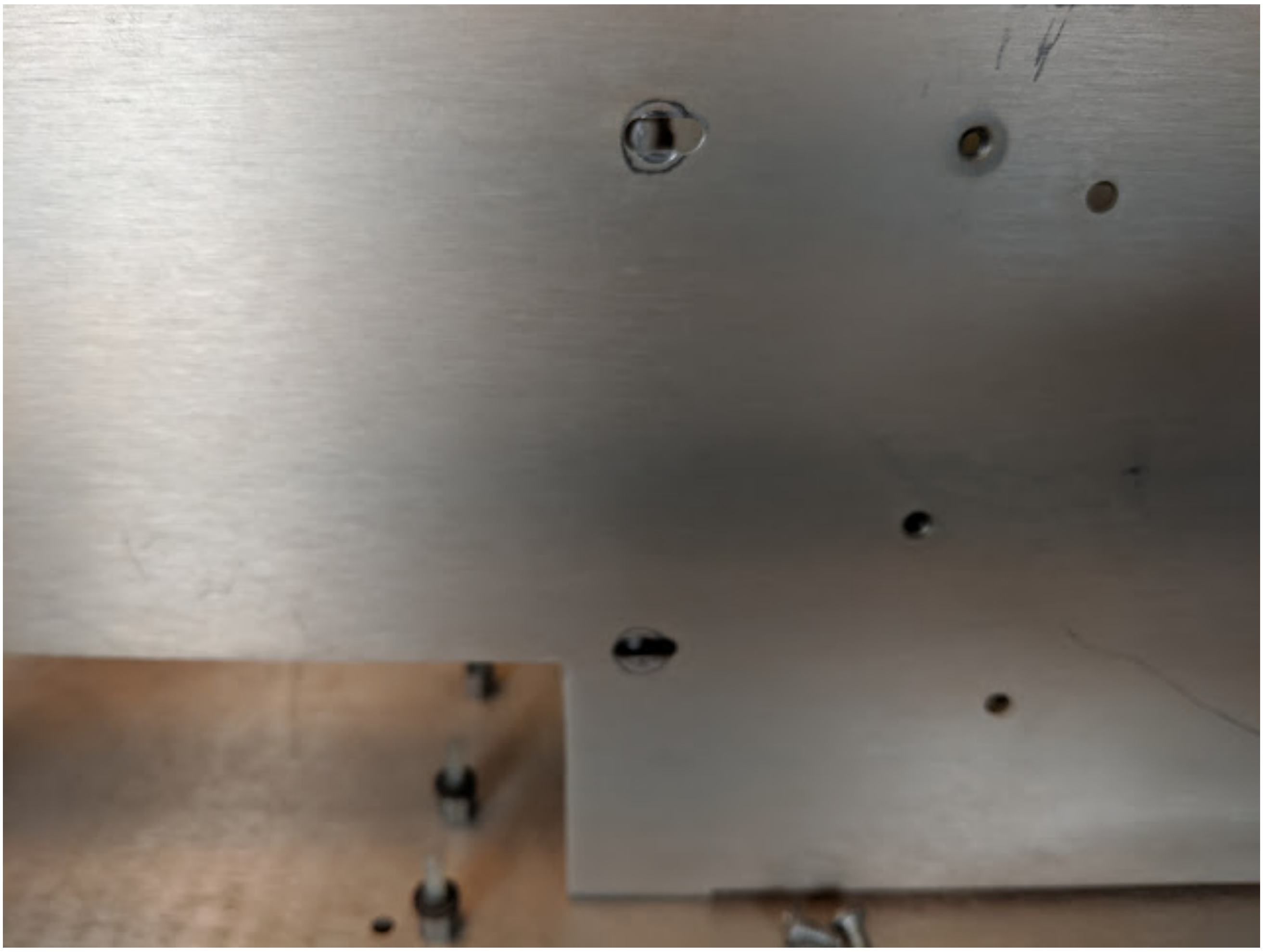


PSU in place on bolts.

Remember, that the reason for this approach is to avoid removing the centre guide rail for the S-100 boards as, otherwise, it would need to be put back in exactly the right place, which can be difficult.

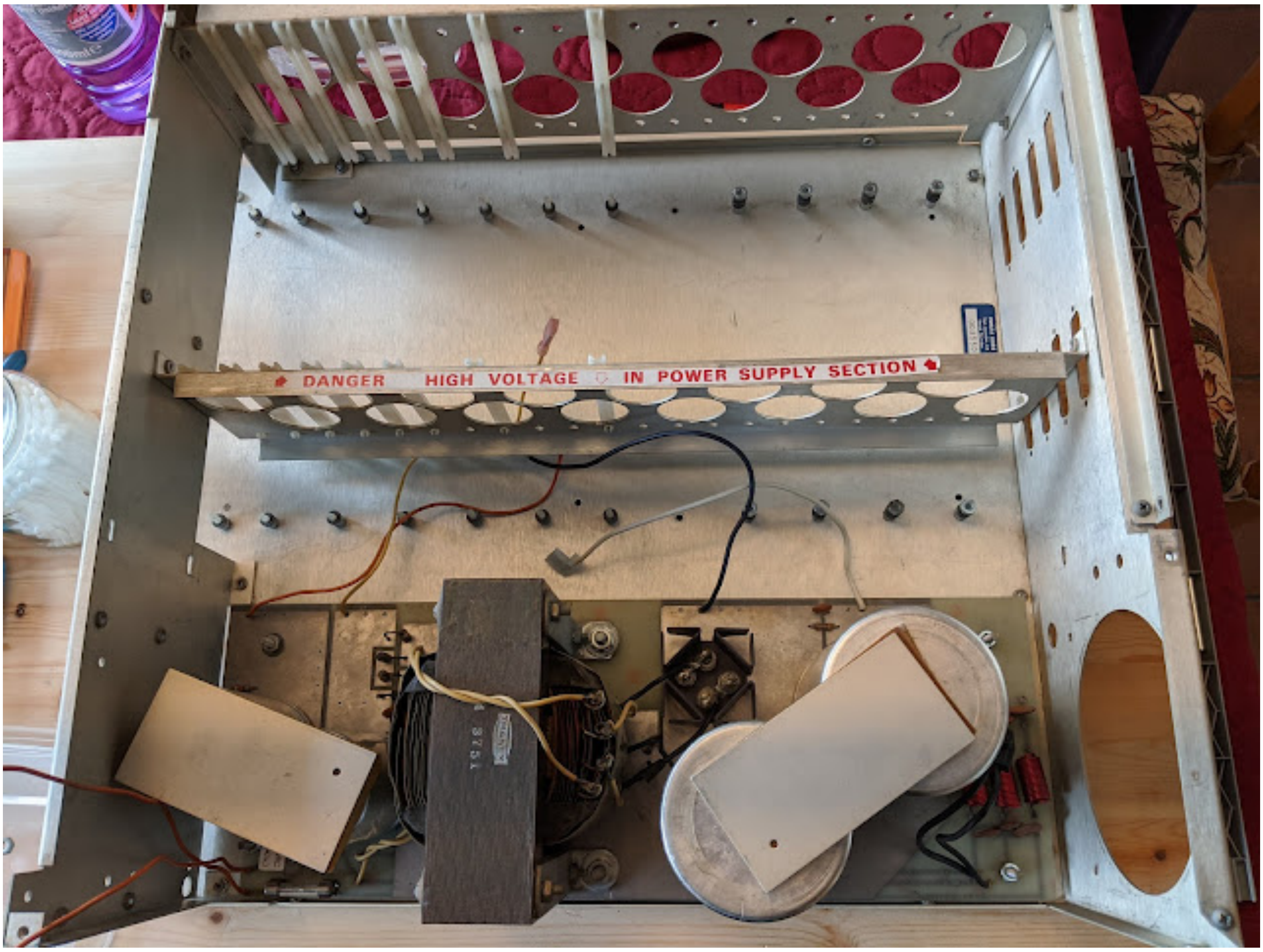
Nevertheless, you can use a few evenly-spaced S-100 boards in the future, to get it into position if required. So, if you do choose that route, then putting the PSU in can be a lot easier. It's a case of swings and roundabouts. Here is what happens with the other approach.

First of all, mark around the four guide rail screws with a pencil and remove them.



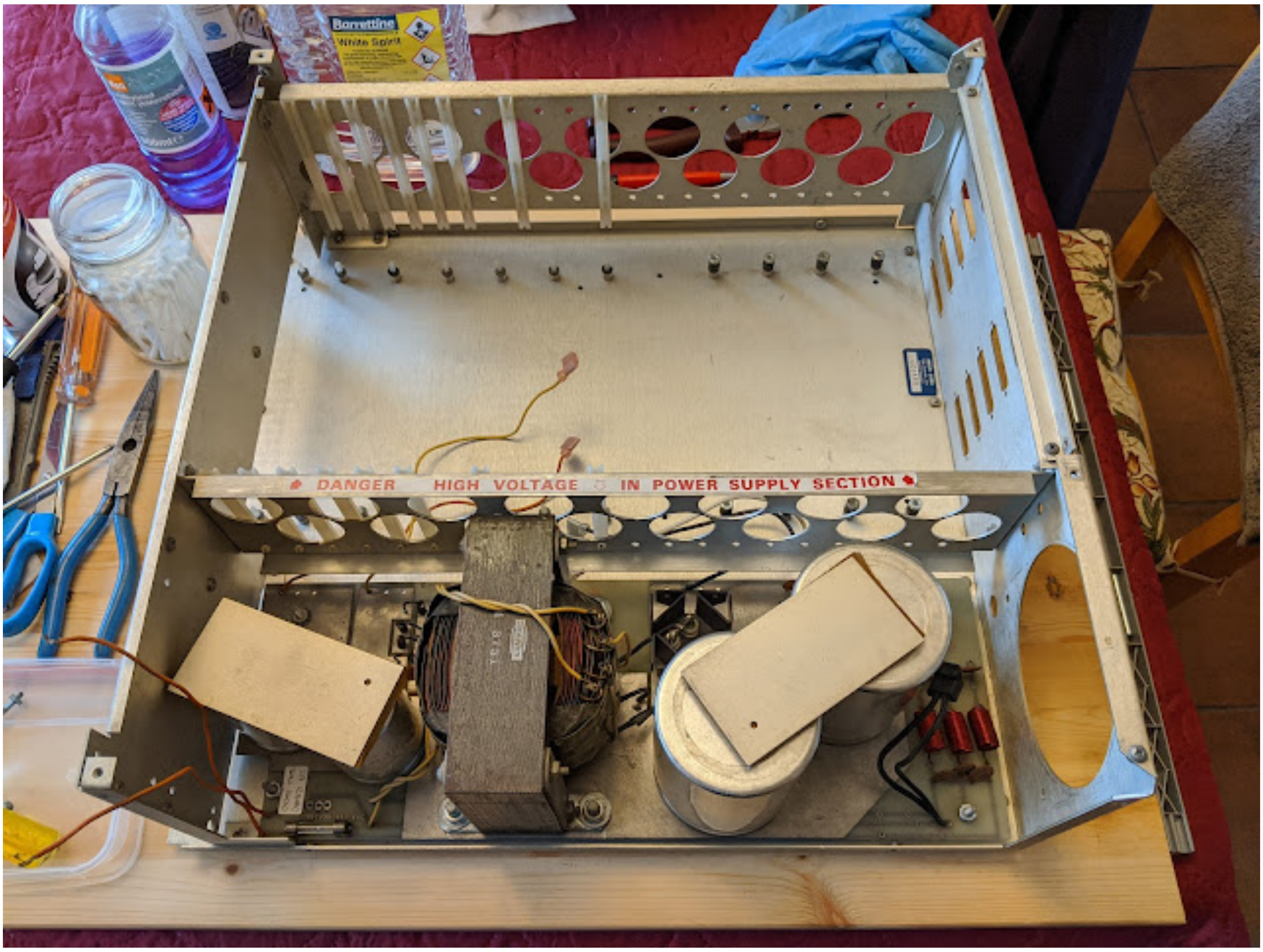
Mark around the guide rail screws with a pencil.

Now slide the guide rail away from the area of the PSU bolts and lower the PSU into position.



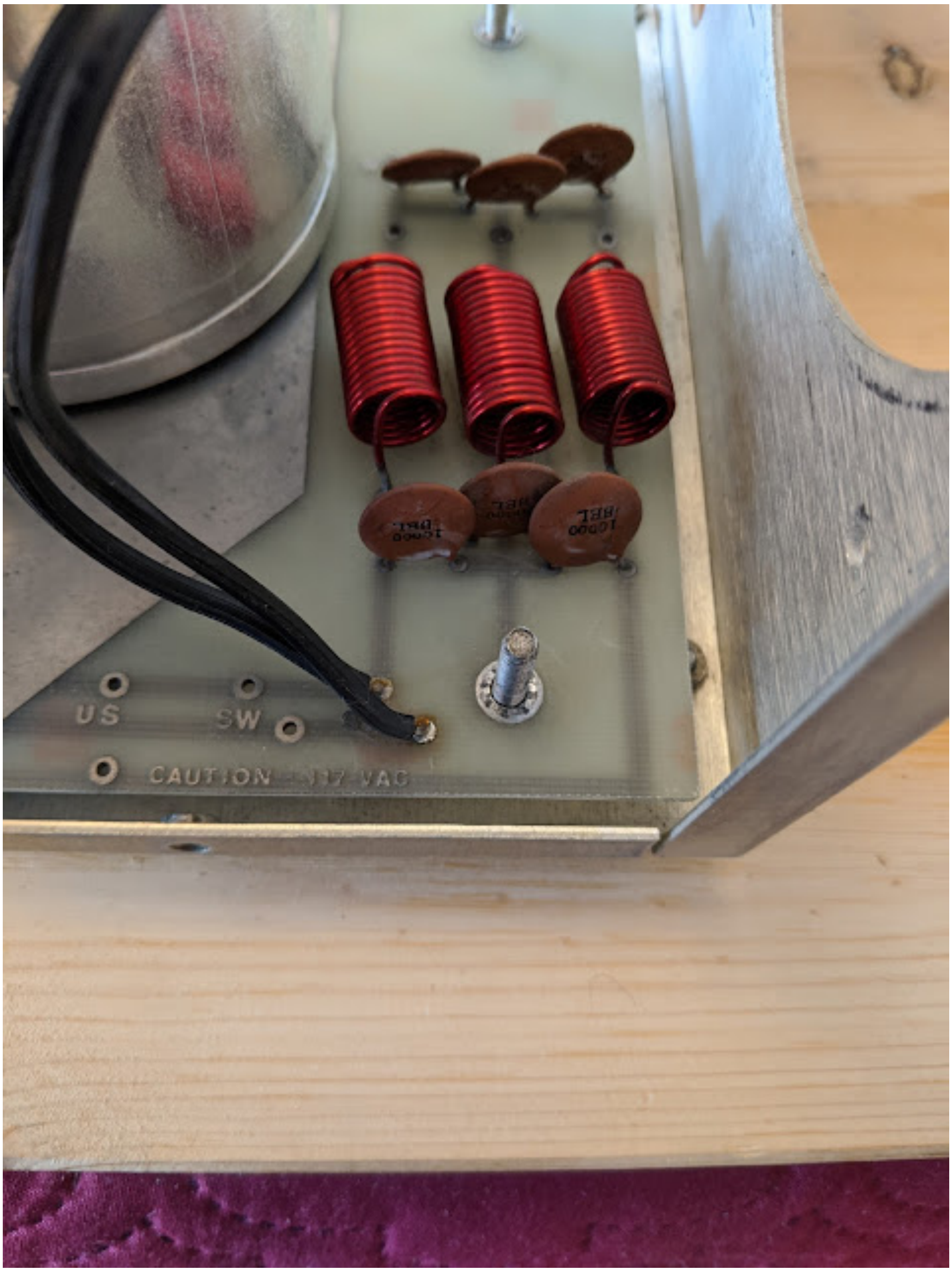
Guide rail moved out of the way.

Now the S-100 Guide Rail is screwed back into position, using the pencil outline marks.



Guide rail back in place and PSU bolts secured.

We want to test the PSU at this stage, before we go much further, but we need to make sure the nuts and washers are in place because we need things like this grounding point to be in operation.



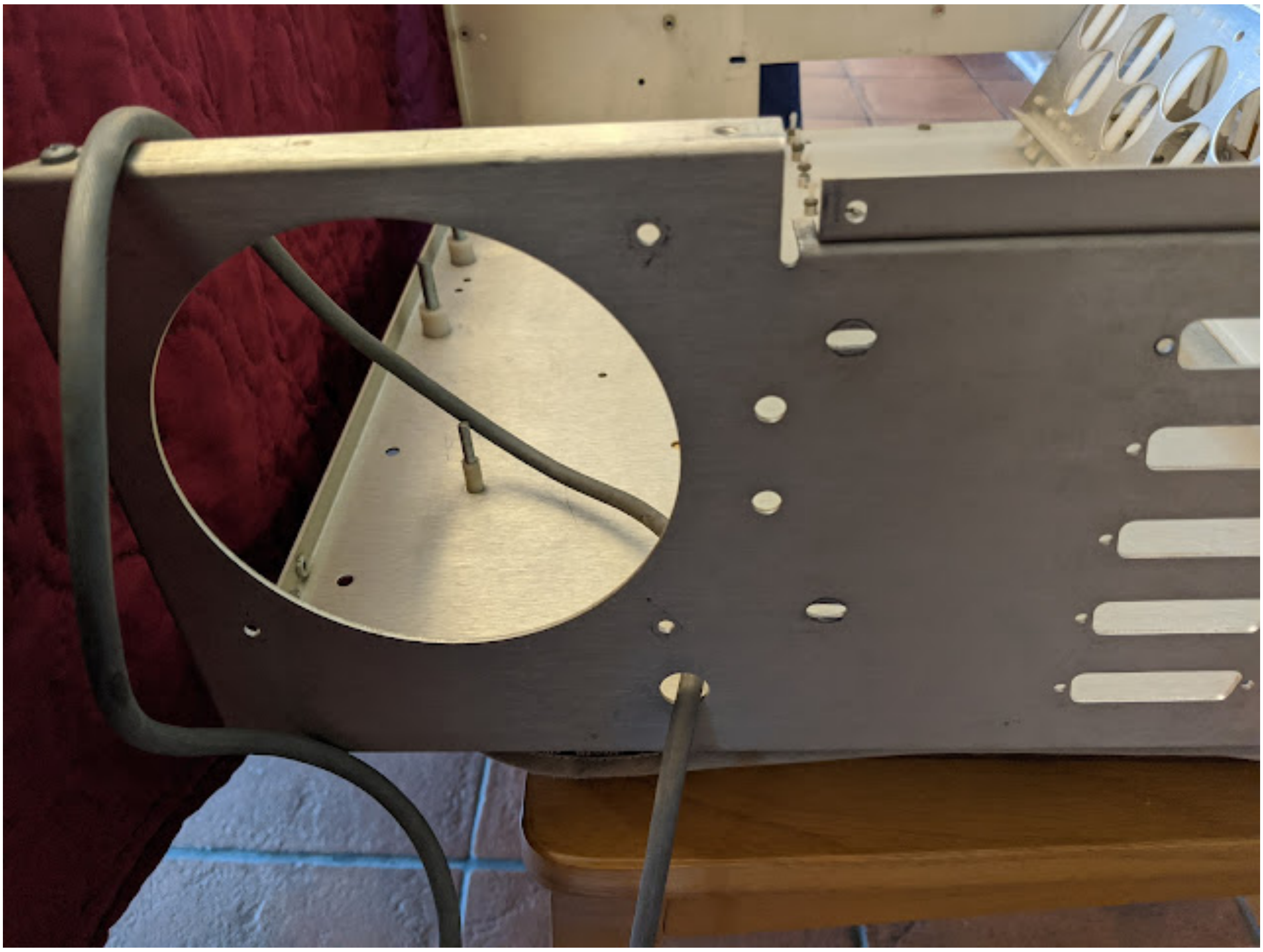
Grounding bolt.

A schoolboy error is well demonstrated here. The mains lead has not been soldered to the bottom of the PSU pcb before lowering it onto the bolts. So, off it comes again to do the job properly this time.....

We do not know if the mains cable has been damaged after years of holding the cable in place, so we simply remove that small section.

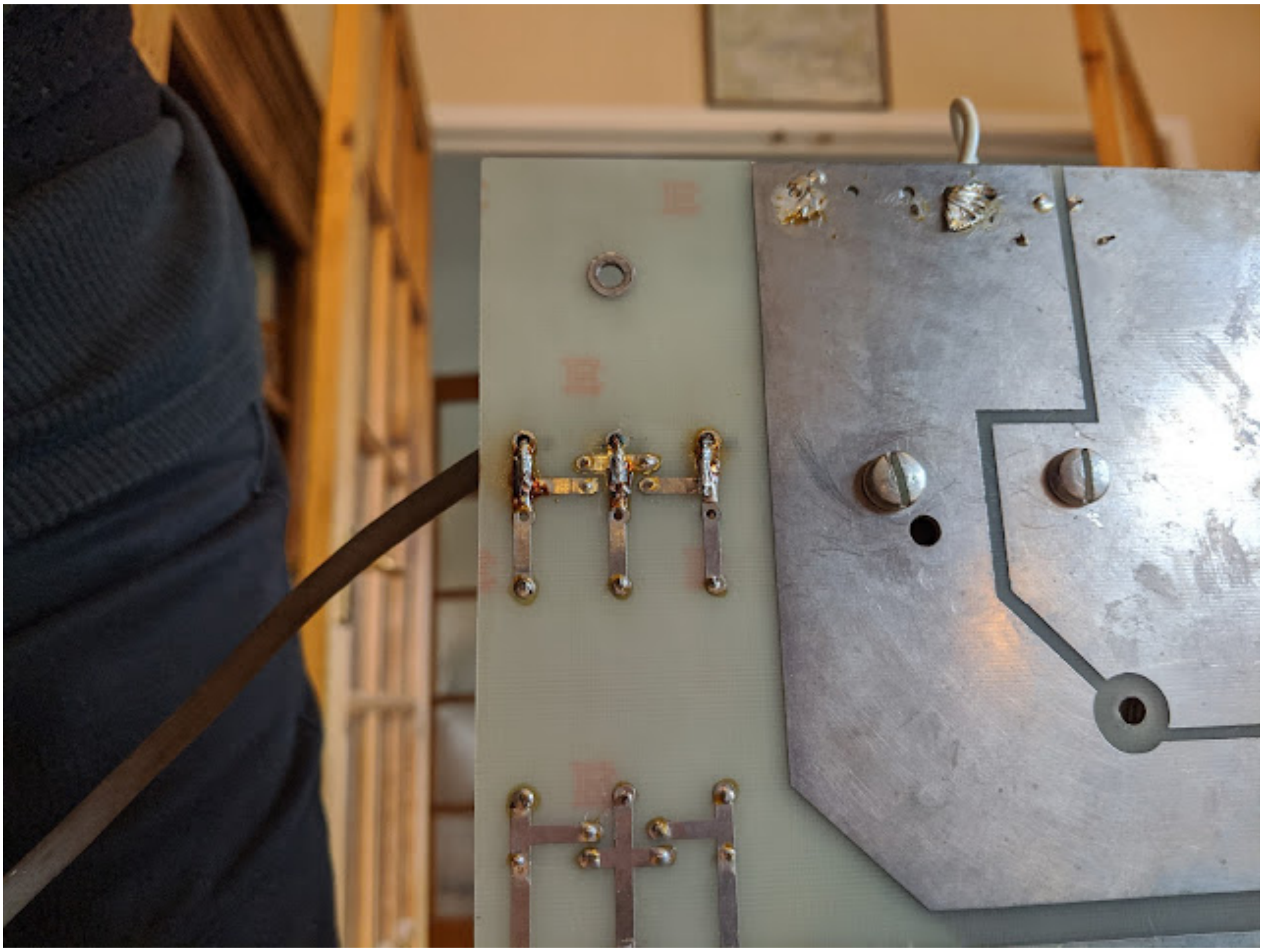
Piece of cable that had the strain relief on it.

Feed the cable through the hole in the Back Plate. The strain relief grommet will be added later.



Hole for mains cable in backplate.

Tin and solder the mains cable into place, observing the colour code printed onto the pcb. A minimum 40 watt soldering iron is required to get a good joint.

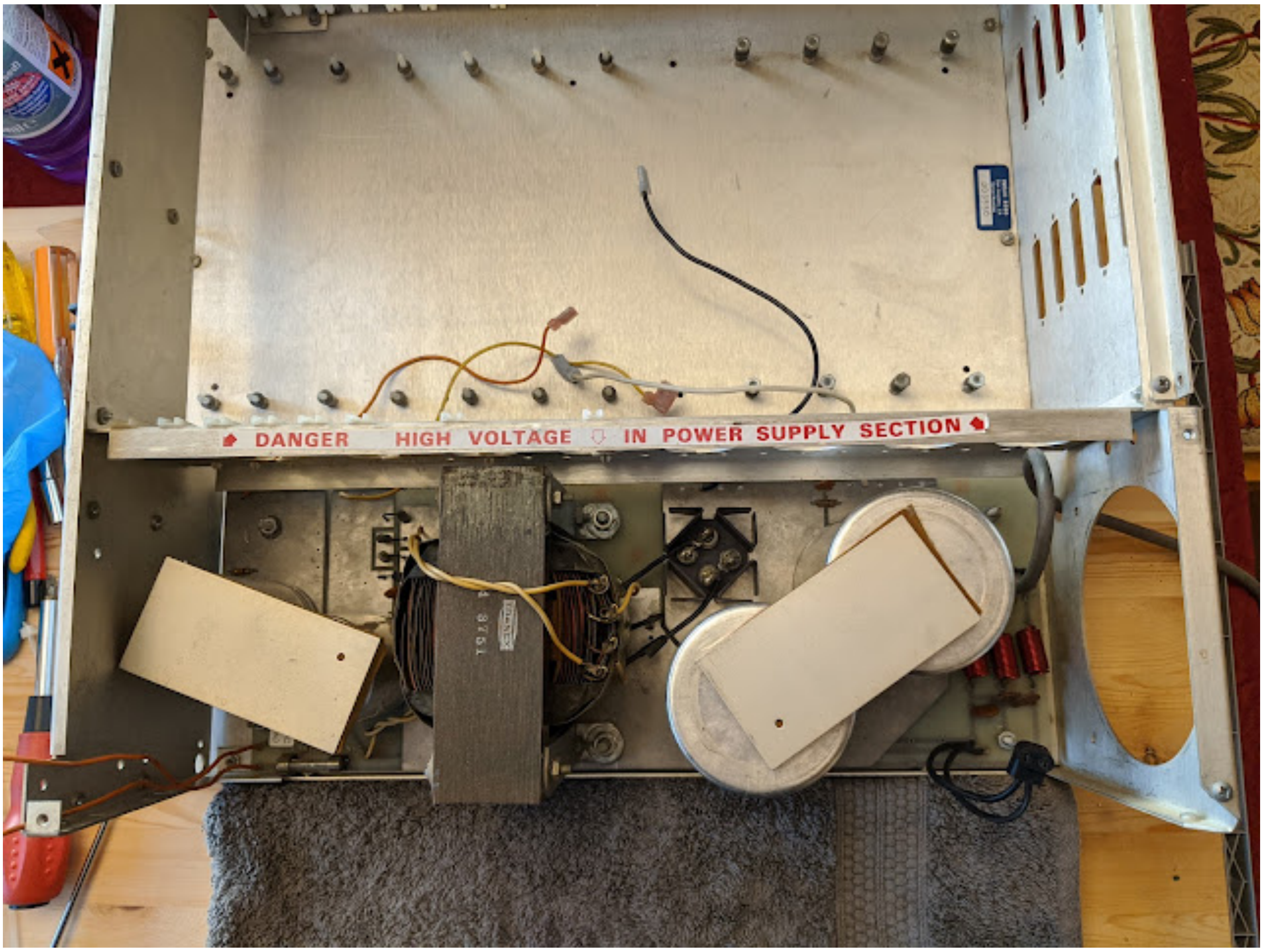


Mains cable soldered onto pcb.

The colour codes can just be made out where the cables go through the pcb.

Mains cable fed through from the top side of the PSU pcb.

Schoolboy error corrected, and PSU now back in place.



PSU back in position.

The mains plug itself should not be neglected. As can be seen, there is a significant film of corrosion on the pins.

USA mains plug.

IMPORTANT NOTE:

As usual, a fibre pen is used to clean up the contacts. When using a fibre pen, you should place a sheet of paper towel under the area being worked on, to catch the broken fibres and dispose of them safely. You should wear vinyl gloves to avoid the fibres getting into your skin. You should wear a face mask, to avoid breathing in the dust and fibres when carrying out the work.

END OF IMPORTANT NOTE.

We will get much less heat building up in the plug now, due to the decrease in resistance.

Cleaned mains plug contact pins.

IMPORTANT NOTE:

If your pcb is fitted with a mains fuse, check it is not too close to the chassis. This is a design flaw and a potential safety hazard.

END OF IMPORTANT NOTE.

As can be seen, ours is not good.

Mains fuse holder next to chassis.

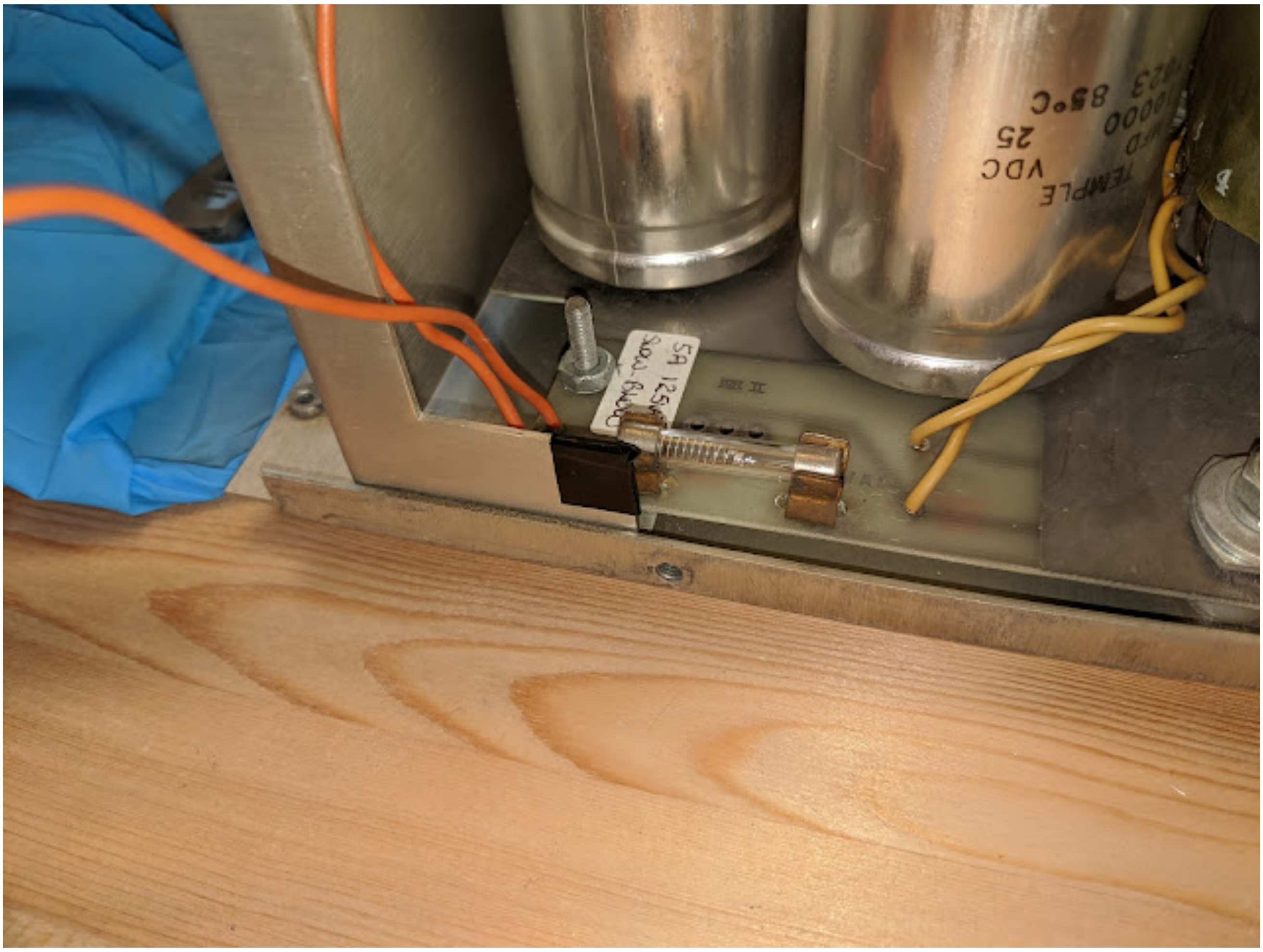
We need a very good quality vinyl tape. Scotch Super 33+ is very hard to beat. The extra cost is well worth it.

Scotch vinyl tape.

Cut tape to create a good fit that is wrapped around the edge of the chassis.

Vinyl tape applied to chassis.

This addresses the potential safety concern.



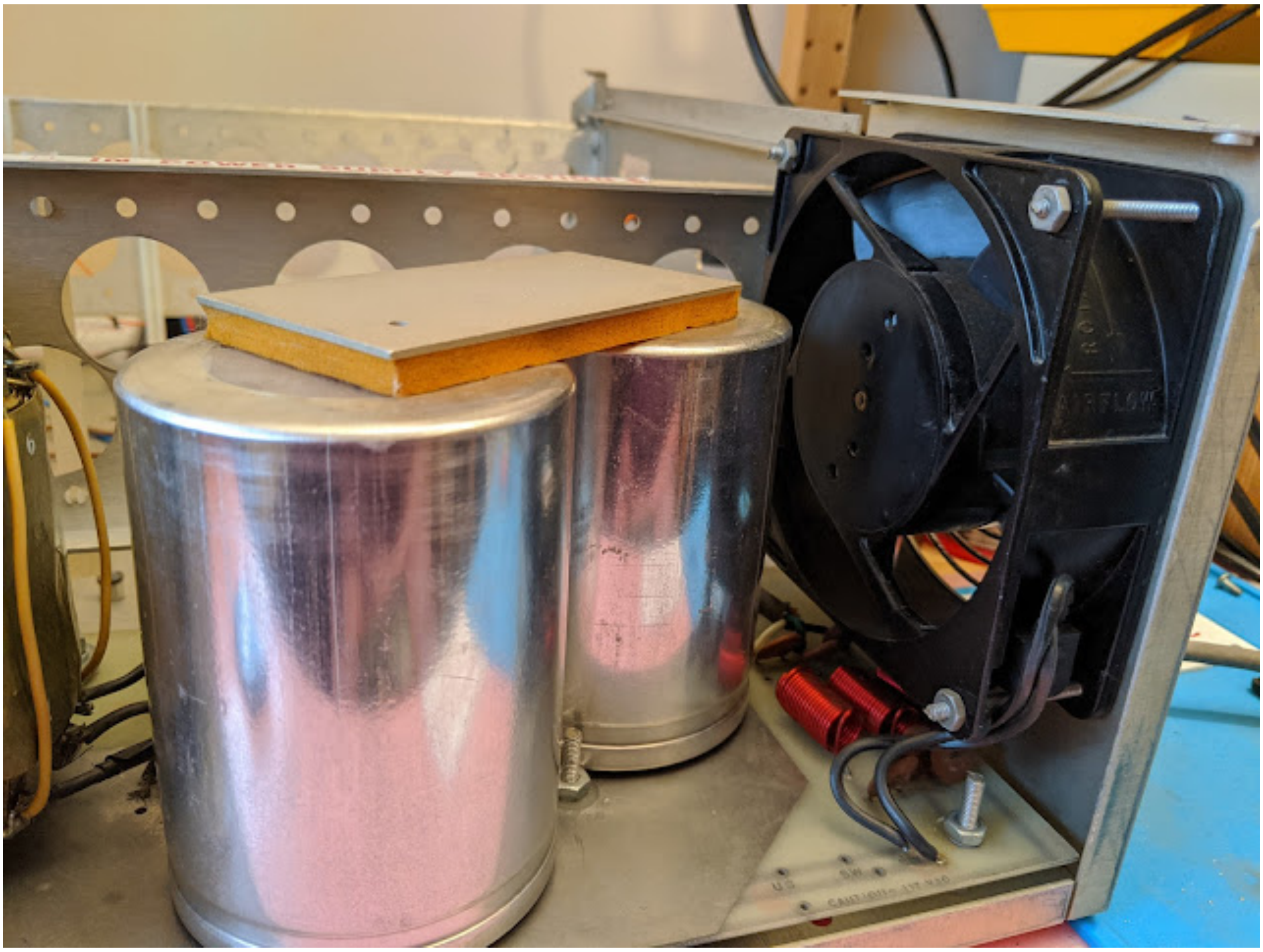
Tape in position.

BLOG PART 7: Testing the PSU.

23/11/2019

Today we are going to find out if the PSU works.

The PSU Fan has been cleaned, put back into the chassis with its guard, and connected to the PSU.



Fan put back onto chassis and connected up.

As the blades face outward, a guard is required.

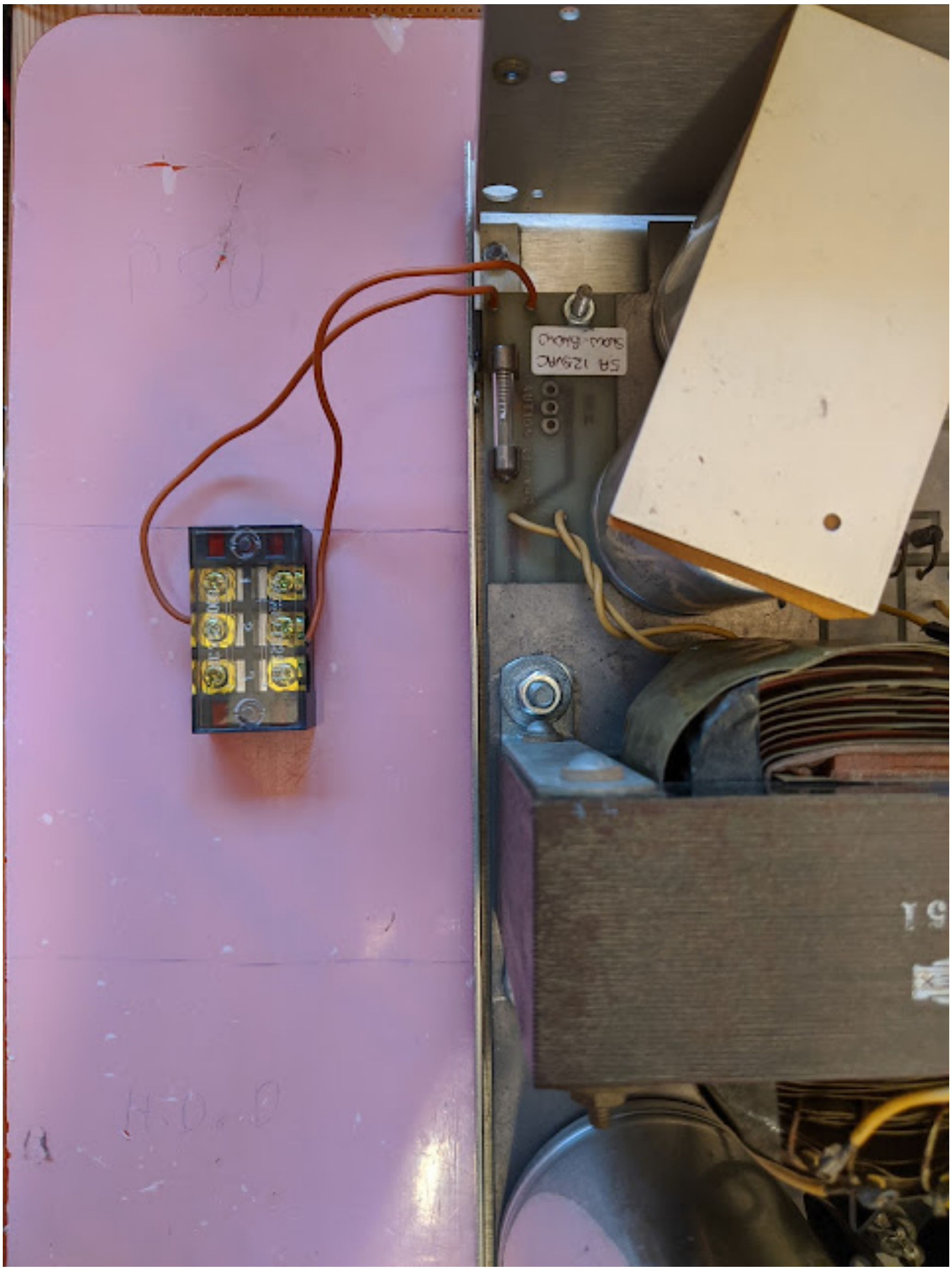
Guard in place over fan blades.

Next, we need to connect together the two mains wires that go to the Front Panel switch, as we do not currently have the Front Panel installed. The reason for this being that we need to control on/off to the machine via the In-rush Current Limiter, rather than the machine on/off switch.

IMPORTANT NOTE:

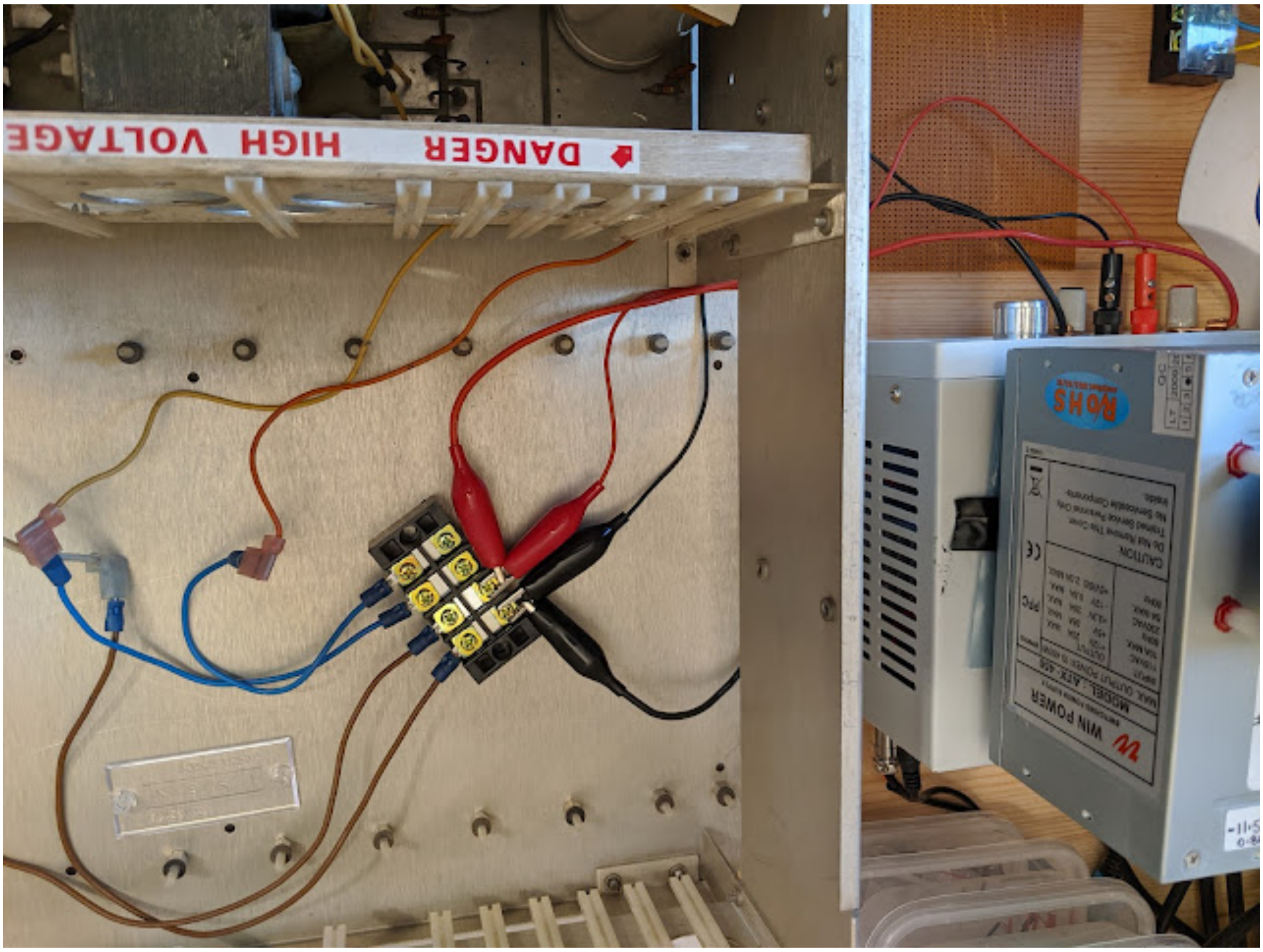
An In-rush Current Limiter will only do its job if it is allowed to control the flow of mains electricity. For example, if the In-rush Current Limiter was already switched on and you later switched the machine on, any current surge caused by the large filter capacitors in the machine PSU getting up to voltage, would not be absorbed by the In-rush Current Limiter, because it has already soaked up any surge when it was turned on, and cannot do that again until it is switched off and back on again.

END OF IMPORTANT NOTE.



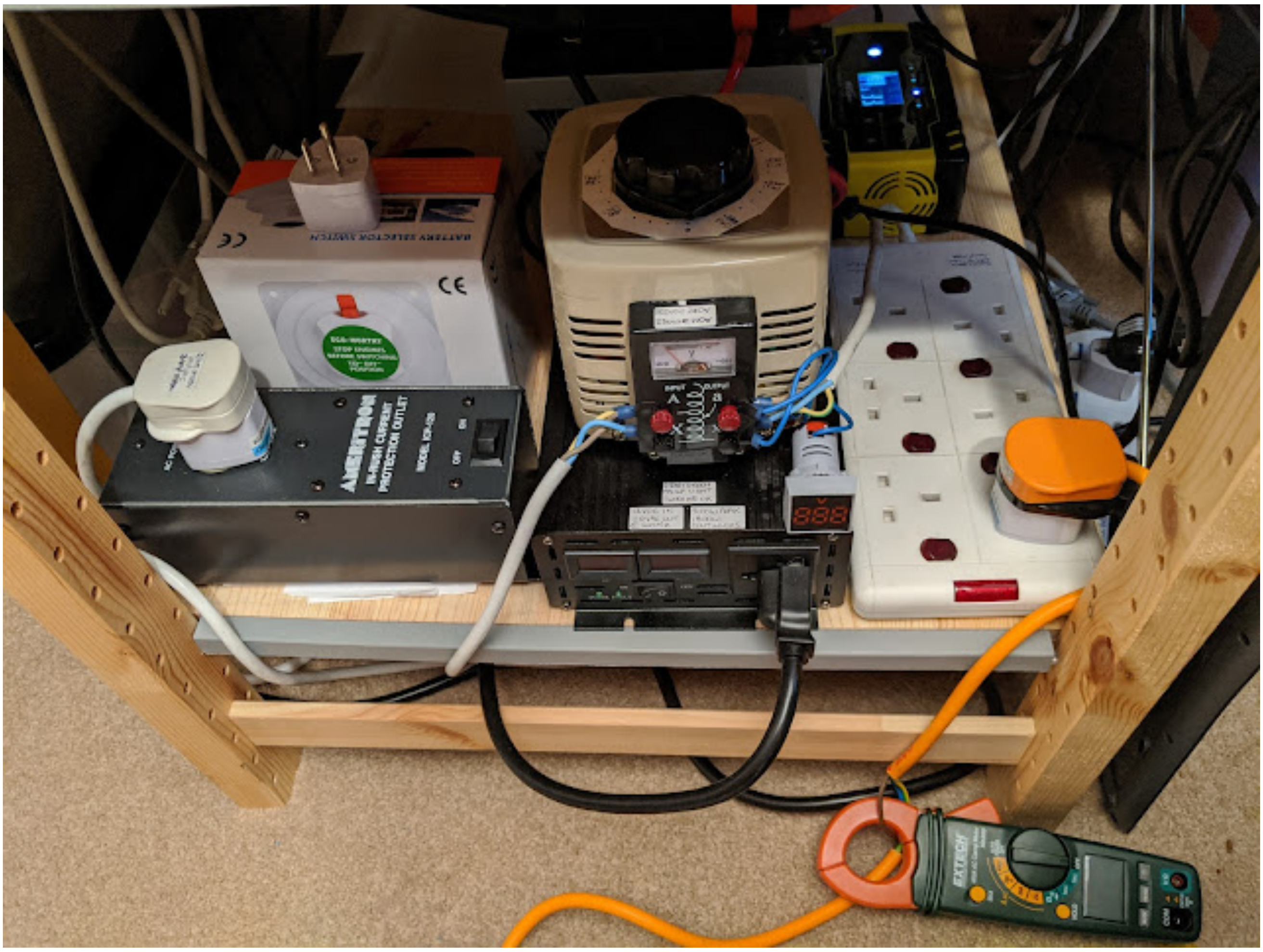
Setting the machine power supply permanently to ON.

As we have spade connectors from the PSU to the Wunderbuss Backplane, we create some temporary cables that will allow us to connect the ZKE Electronic Load Tester to each of the DC outputs and Ground.



Connecting PSU DC outputs to ZKE Electronic Load Tester

We have a 110vac 60Hz mains supply, provided by 12V batteries connected to a DC-AC converter, through an In-rush Current Limiter and then to a Variac.

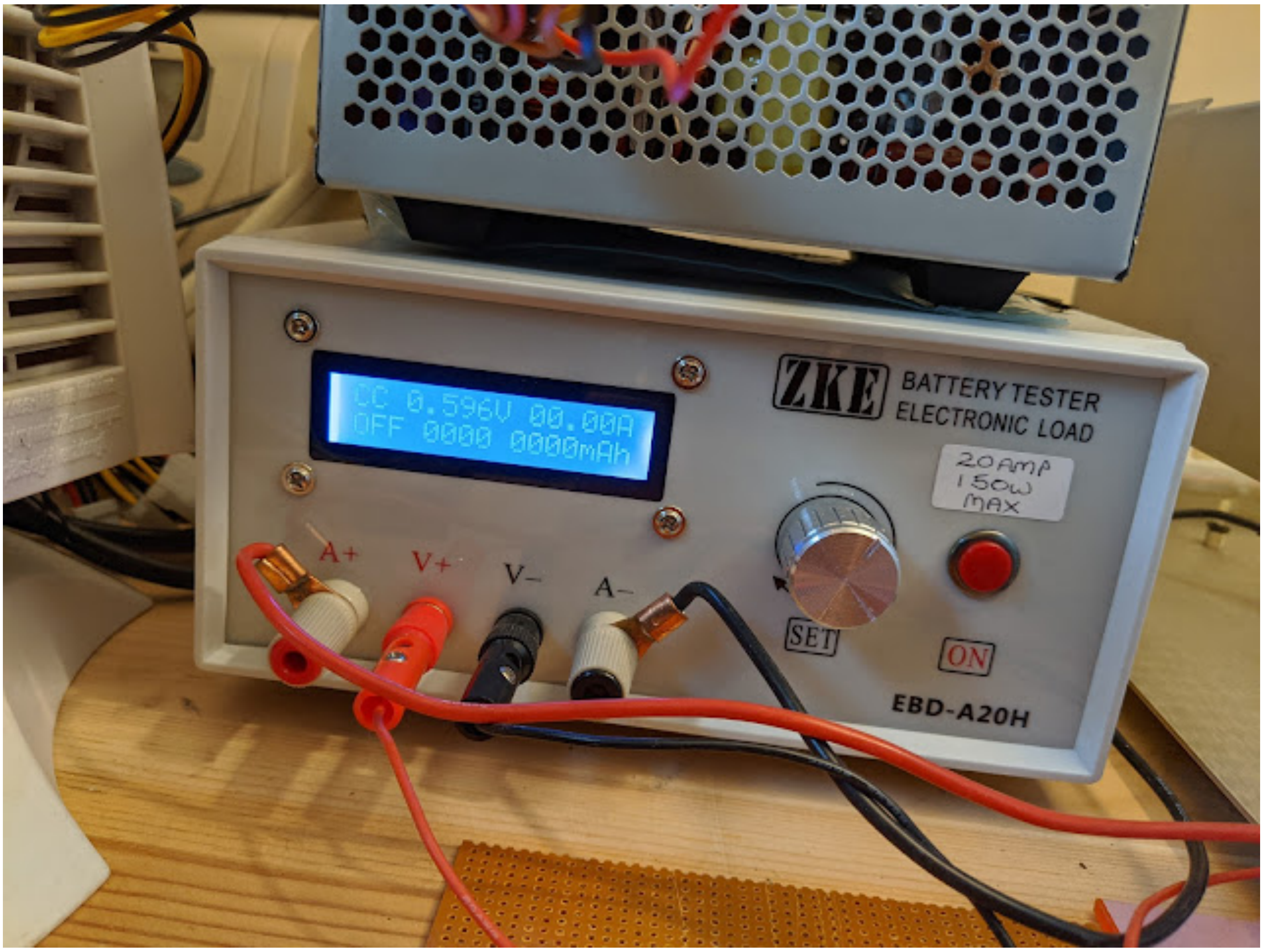


110vac 60Hz mains supply.

The PSU DC outputs are connected up to the ZKE Electronic Load Tester. This will measure the voltage being produced by the PSU and, later, will be used to provide and measure an artificial load to each DC output, in order to simulate the connection of S-100 boards.

At this stage, we are not going to apply any load to the DC outputs, we are simply going to measure the output voltages whilst not under load, to see whether the transformer and other components are working as expected.

At first, we are going to be very gentle and only apply a low AC mains voltage, using the Variac.

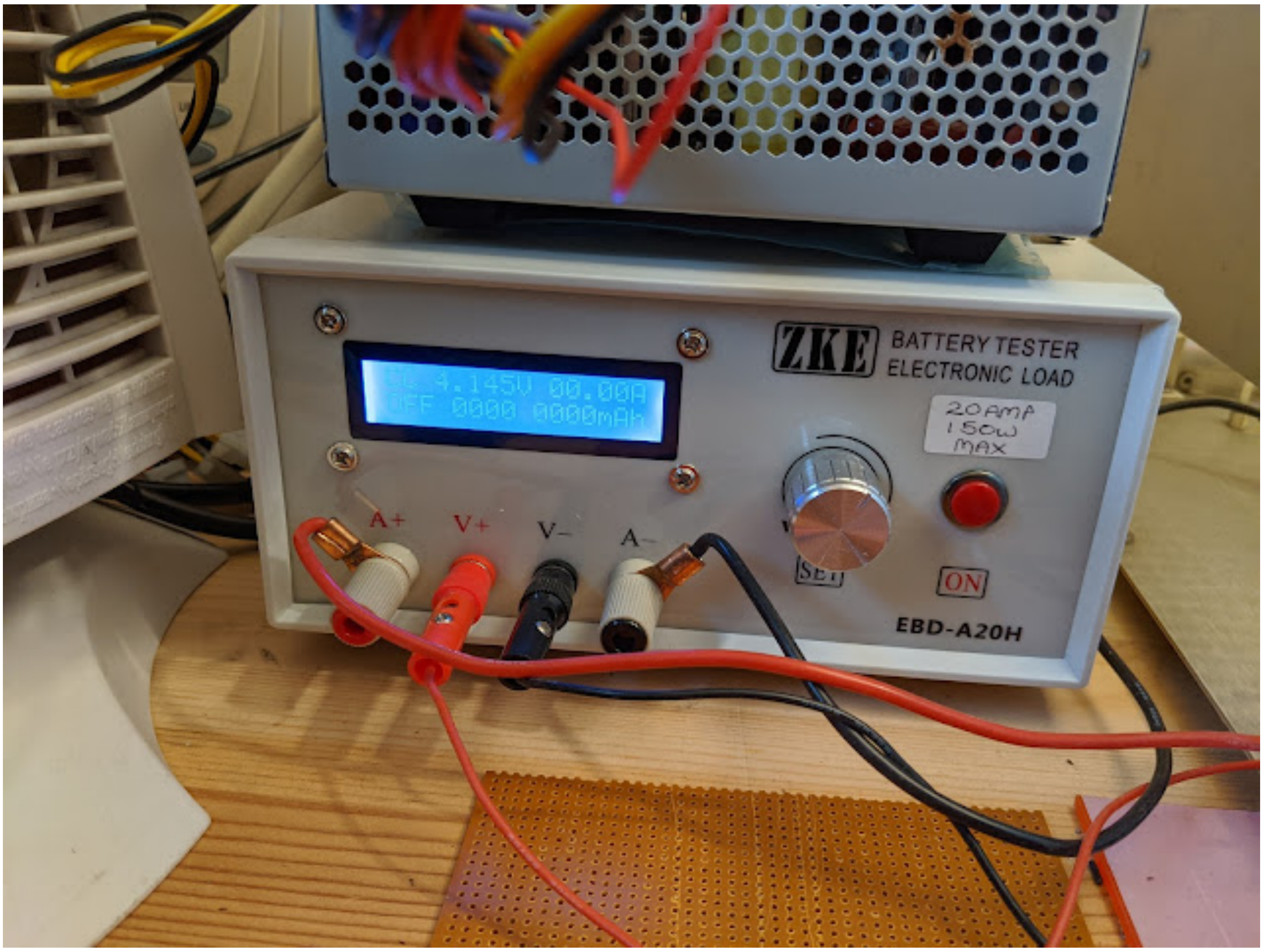


ZKE Electronic Load Tester

Easy does it, step by step, observing the PSU all the time for signs of trouble.

Starting up the USA supply slowly, with the Variac.

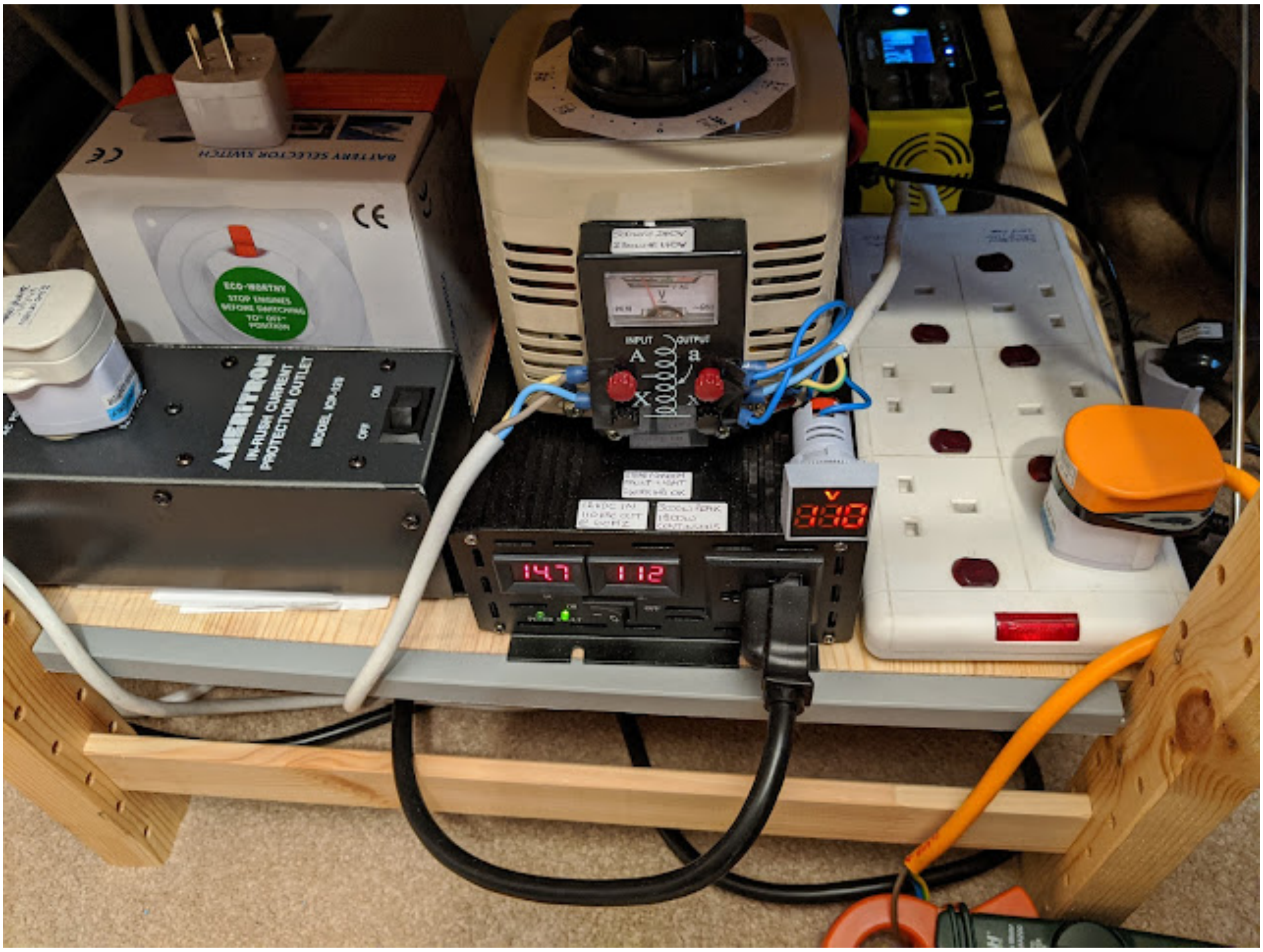
We could see that a small DC voltage is being output on the +8vdc, +16vdc and -16vdc lines, so we slowly raise the input voltage to 80vac and check that the DC voltages are all increasing too.



+8vdc output line reading +4.145vdc with 80vac input from the mains supply.

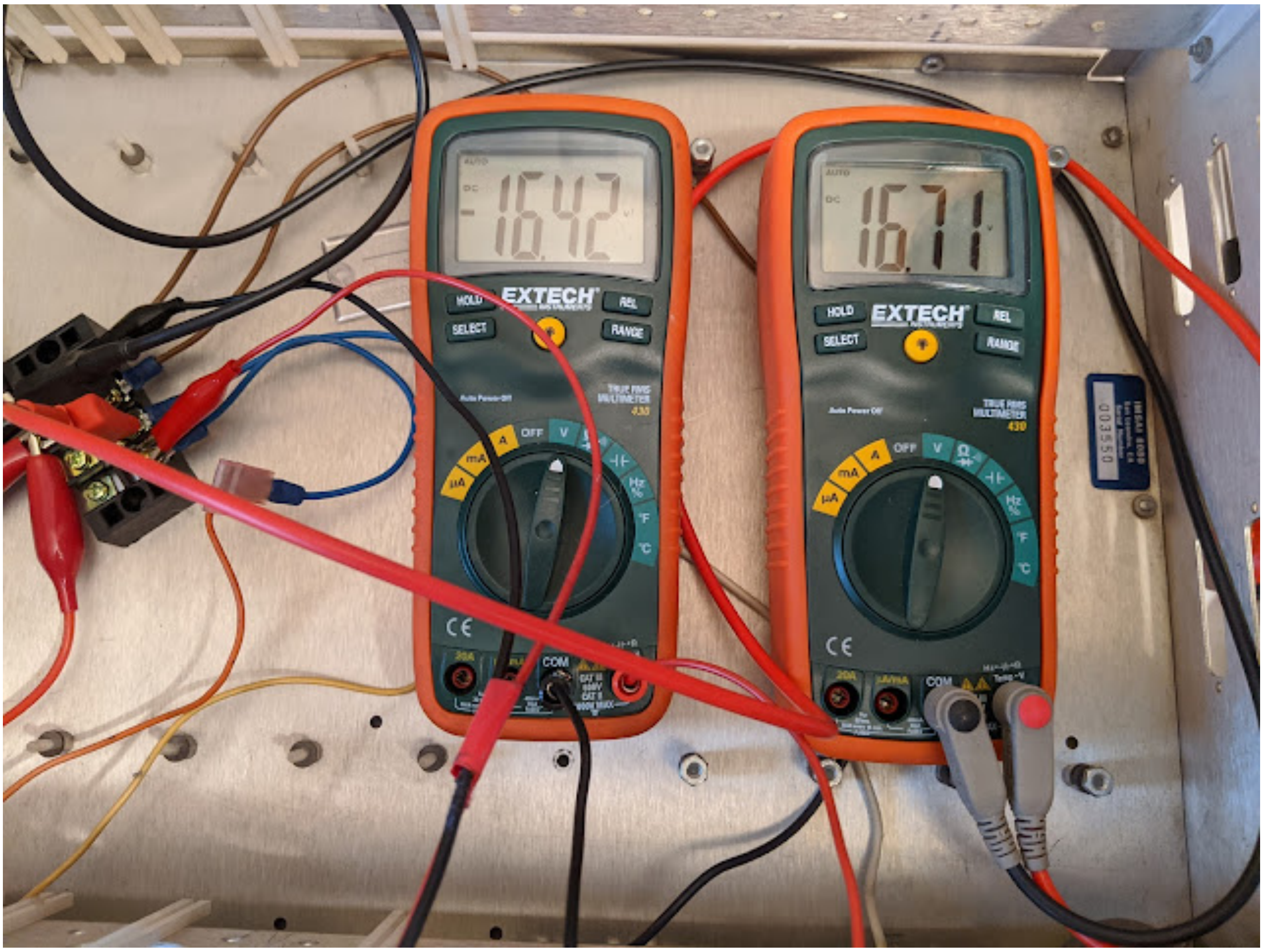
It appeared that all was working well, so the input voltage was raised to 110vac.

The PSU fan was spinning quietly from about 30vac, proving it was working, but by the time we reach 90vac, it was rattling just a little.



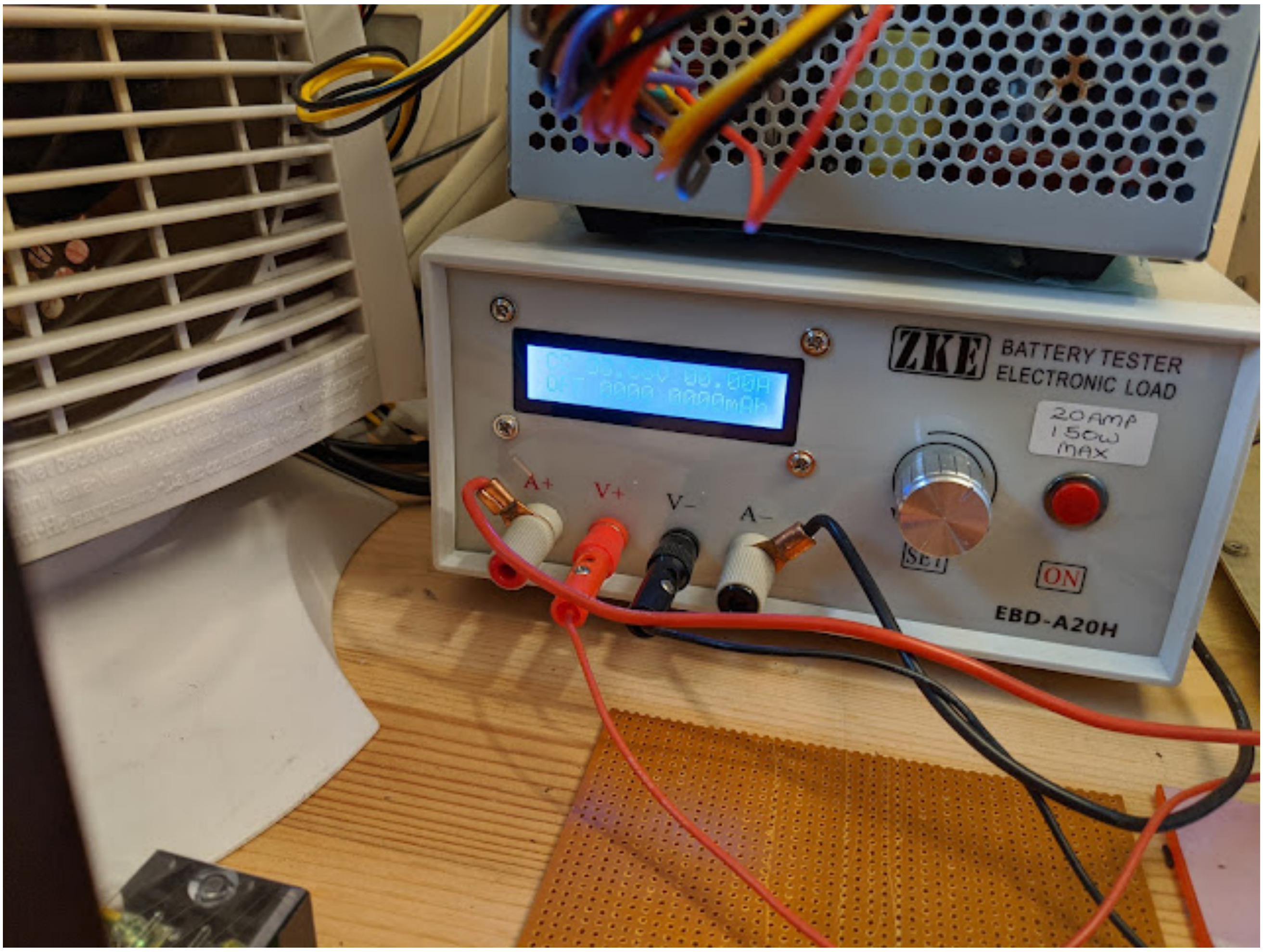
Input voltage raised to 110vac

+16 and -16vdc lines look good.



+16vdc and -16vdc lines.

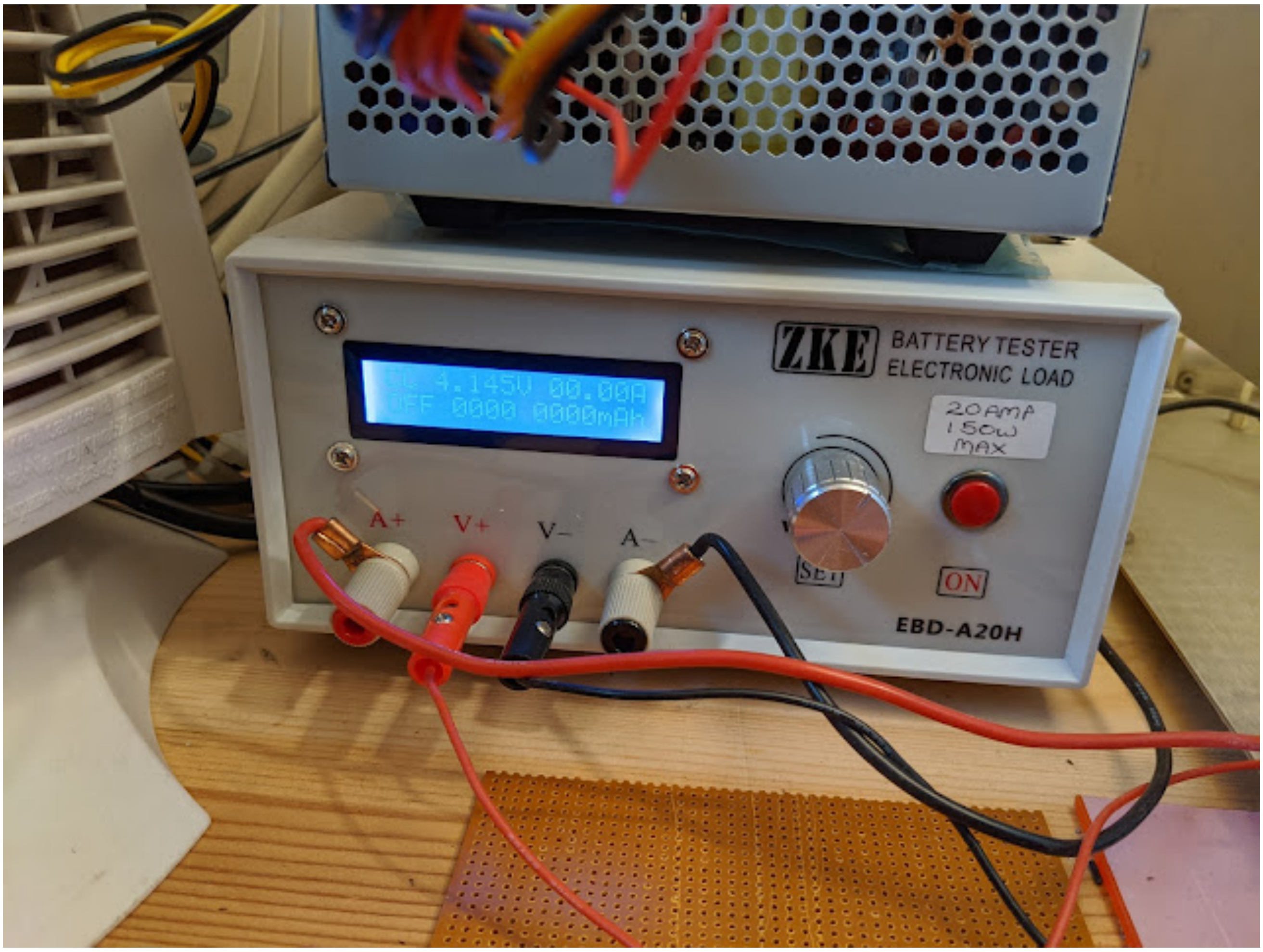
+8vdc line also looks good.



Hard to read, but now running at +8.68vdc output, on 110vac input.

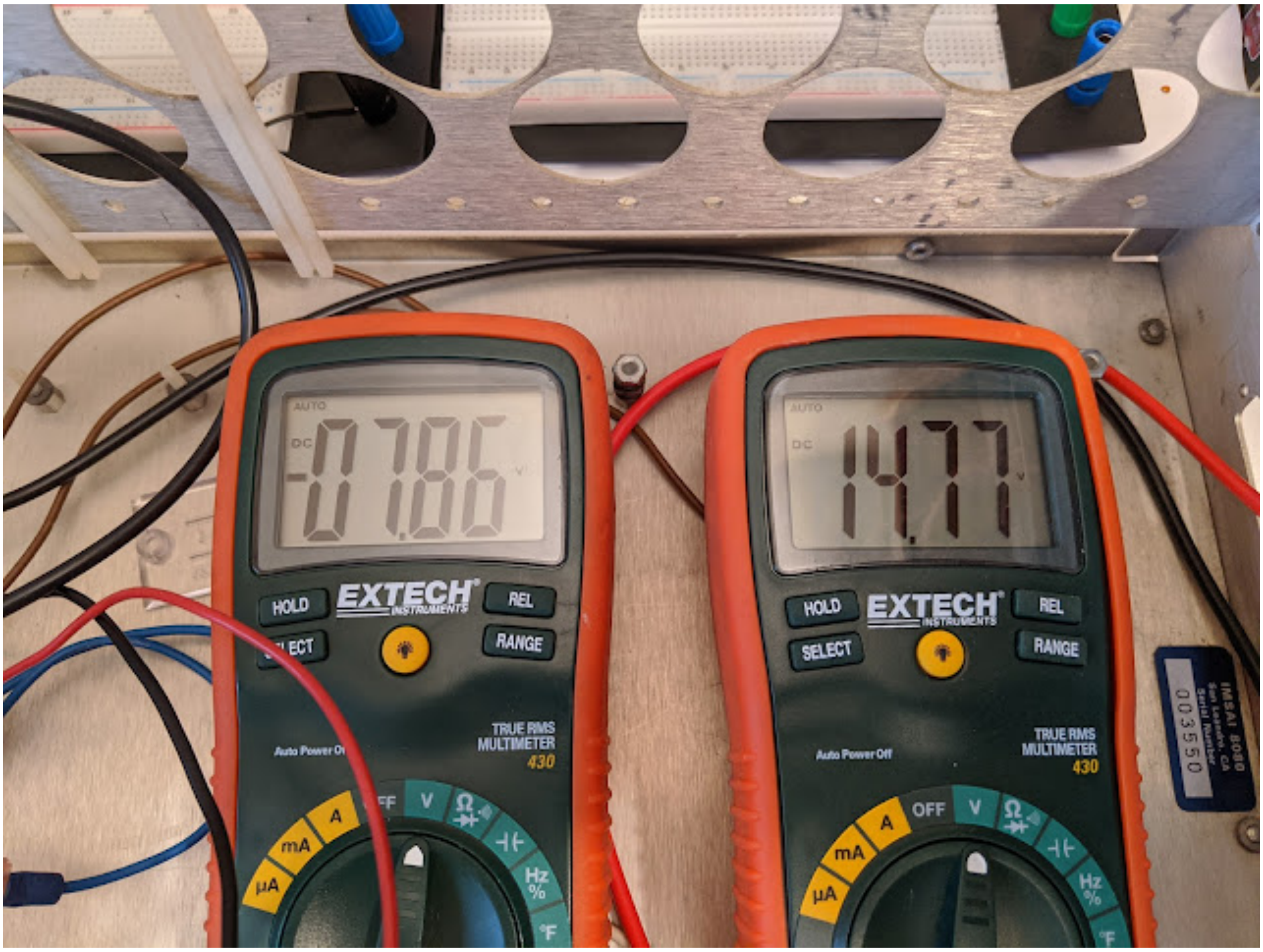
So far, all had gone well. However, when the Variac was wound down and the supply turned off, we would expect the bleed resistors for each DC output to slowly but surely reduce the voltage in the large capacitors to zero, over a period of a few minutes, rendering them safe.

What we saw, was a problem. The +8vdc output voltage had dropped to about half, in a couple of minutes. The -16vdc output voltage had also halved. However, the +16vdc output voltage was not moving.....



+8vdc line.

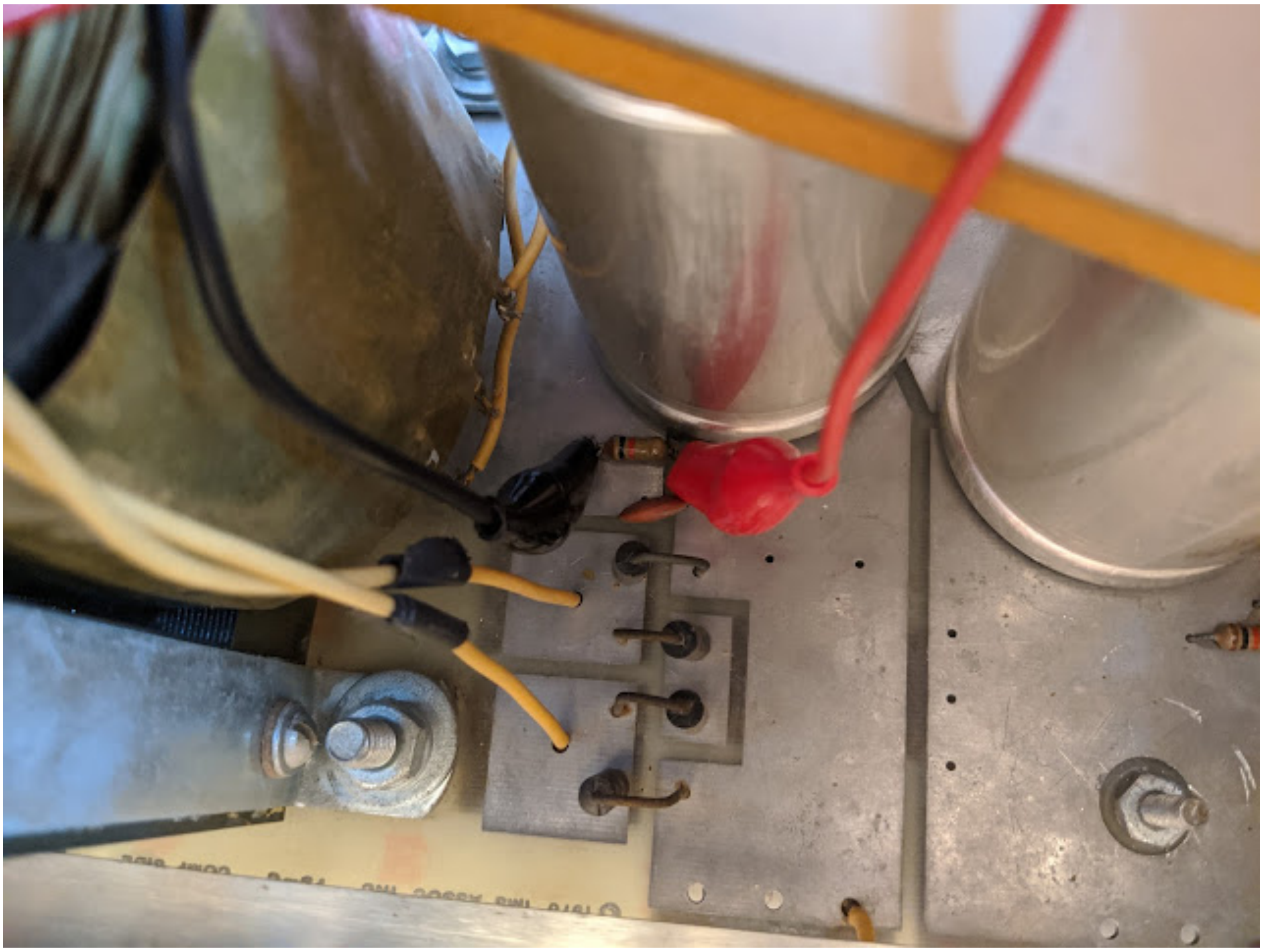
The +16vdc line was still sitting at nearly 15vdc.



-16vdc and +16vdc lines.

Some investigation soon located the cause.

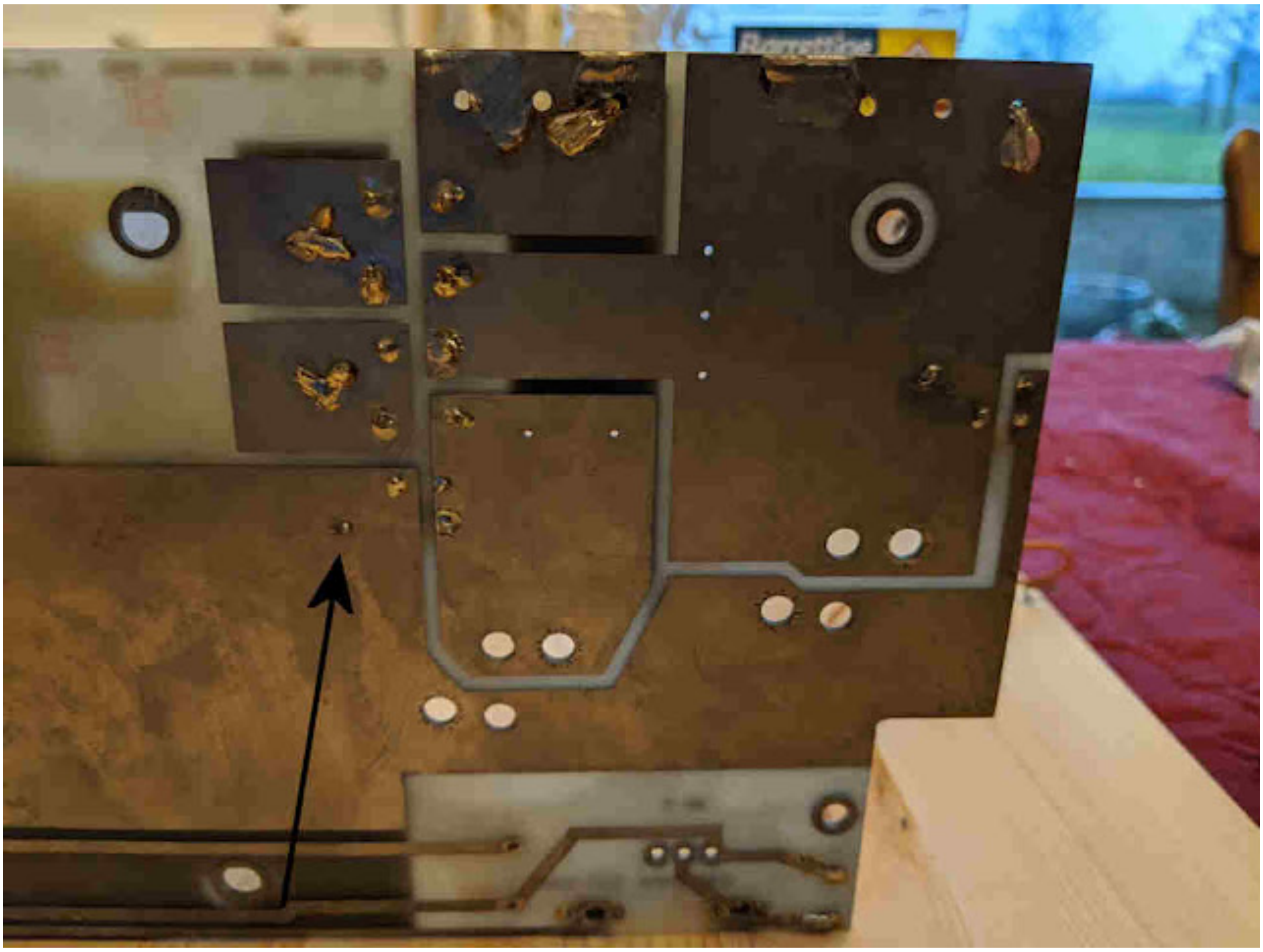
At first, measuring the resistance across the 1k Ohm bleed resistor on the +16vdc line showed the correct reading, which was a puzzle. However, when the test lead on the ground side was moved off the leg of the resistor and onto the ground plate, the resistance rose to infinity. The same did not happen if the test lead on the capacitor side was moved off the leg of the resistor and onto the live plate.



Measuring the resistance of the +16vdc Bleed Resistor

This issue may well have always been present, as it won't stop the machine working properly. It merely leaves a fully charged 10,000uf 25v Capacitor lurking in the PSU, to catch the unwary person who might be working in that area.

This proved that the problem lay with the ground leg connection of the resistor. Going back to the previous day, when we had checked the connections on the underside of the pcb, we could see that the connection looked okay, visually. That said, the leg of the resistor cannot be seen poking through the solder, so we could not be sure it was connected.

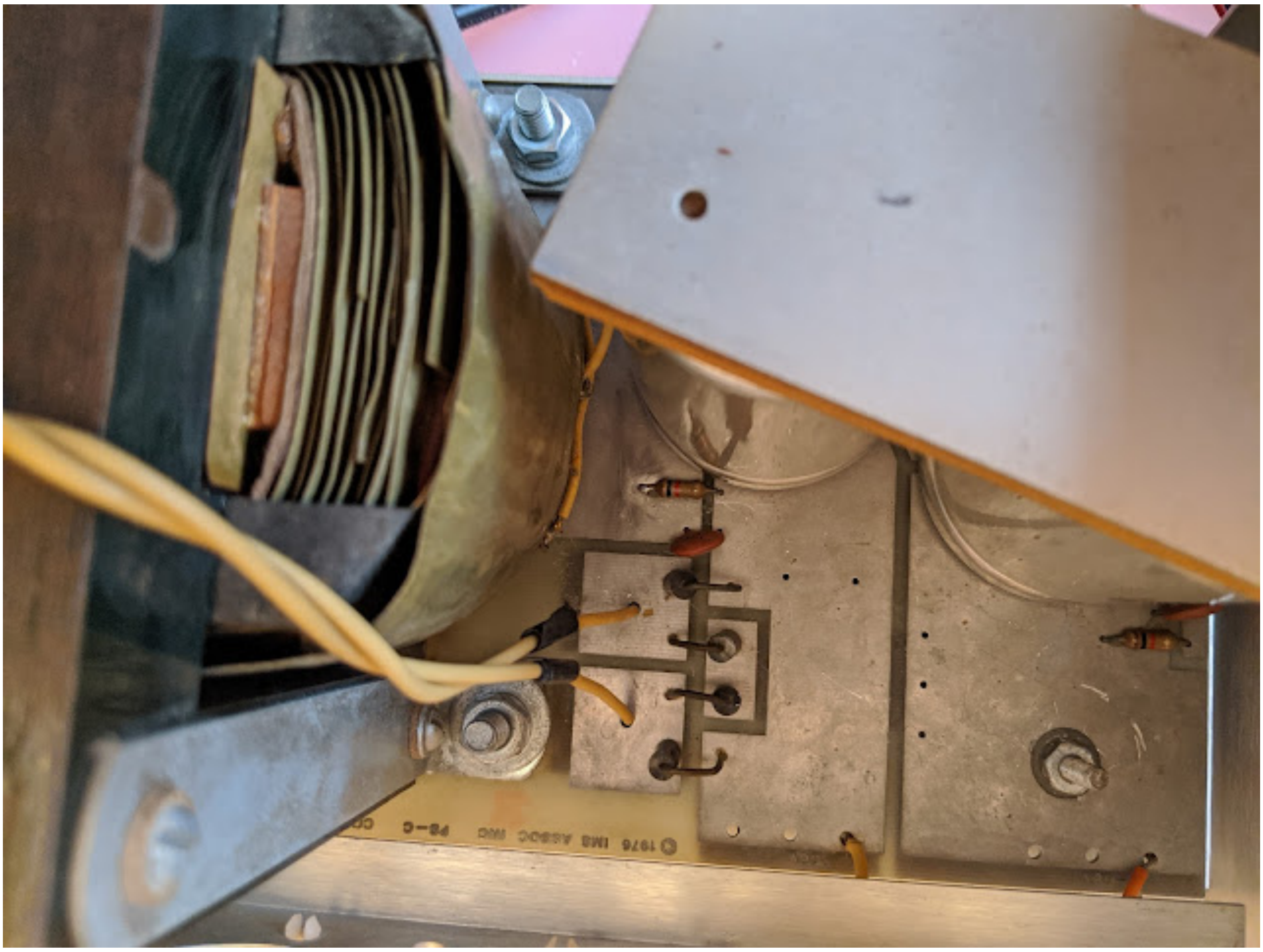


+16vdc Bleed Resistor connection.

It could be a bad joint, or the through-hole plating could be faulty at that spot. We were faced with removing the entire PSU from the Chassis, in order to gain access to the connection or, alternatively, applying a small amount of solder to the leg of the resistor from above and soldering it to the top ground plate instead of the one underneath.

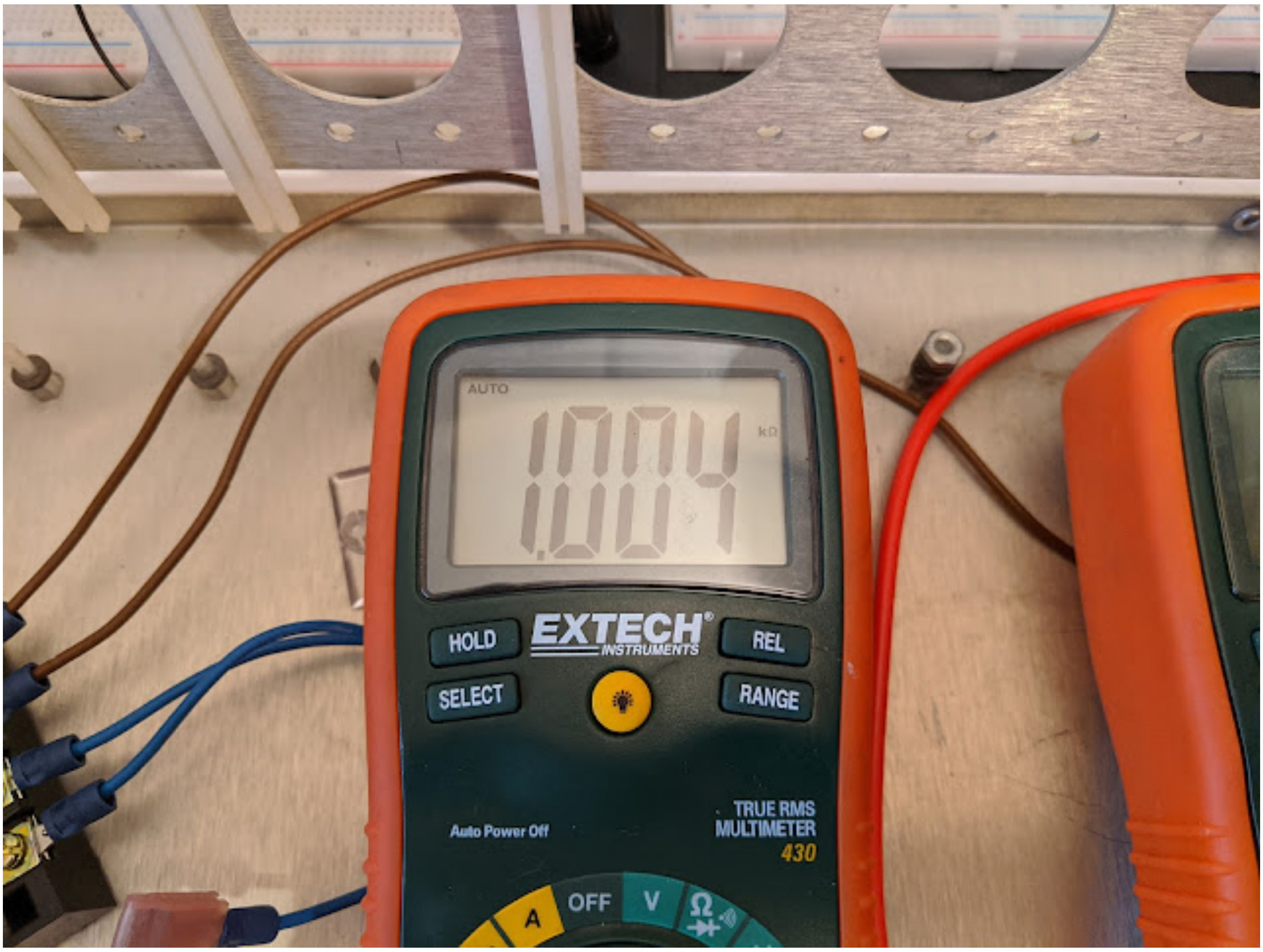
Common sense said to try the latter, without making too much mess. However, it was felt to be worth trying something else first. By applying heat from the soldering iron to the leg of the resistor for slightly longer than normal, with a very small amount of new solder plus flux, there was a chance it would make/remake the connection underneath.

Cleaning around the area with a fibre pen, this was tried.



Left leg of resistor at the top.

Success! The connection was formed and now the Bleed Resistor could do its job at last.



+16vdc line 1k Ohm Bleed Resistor measurement.

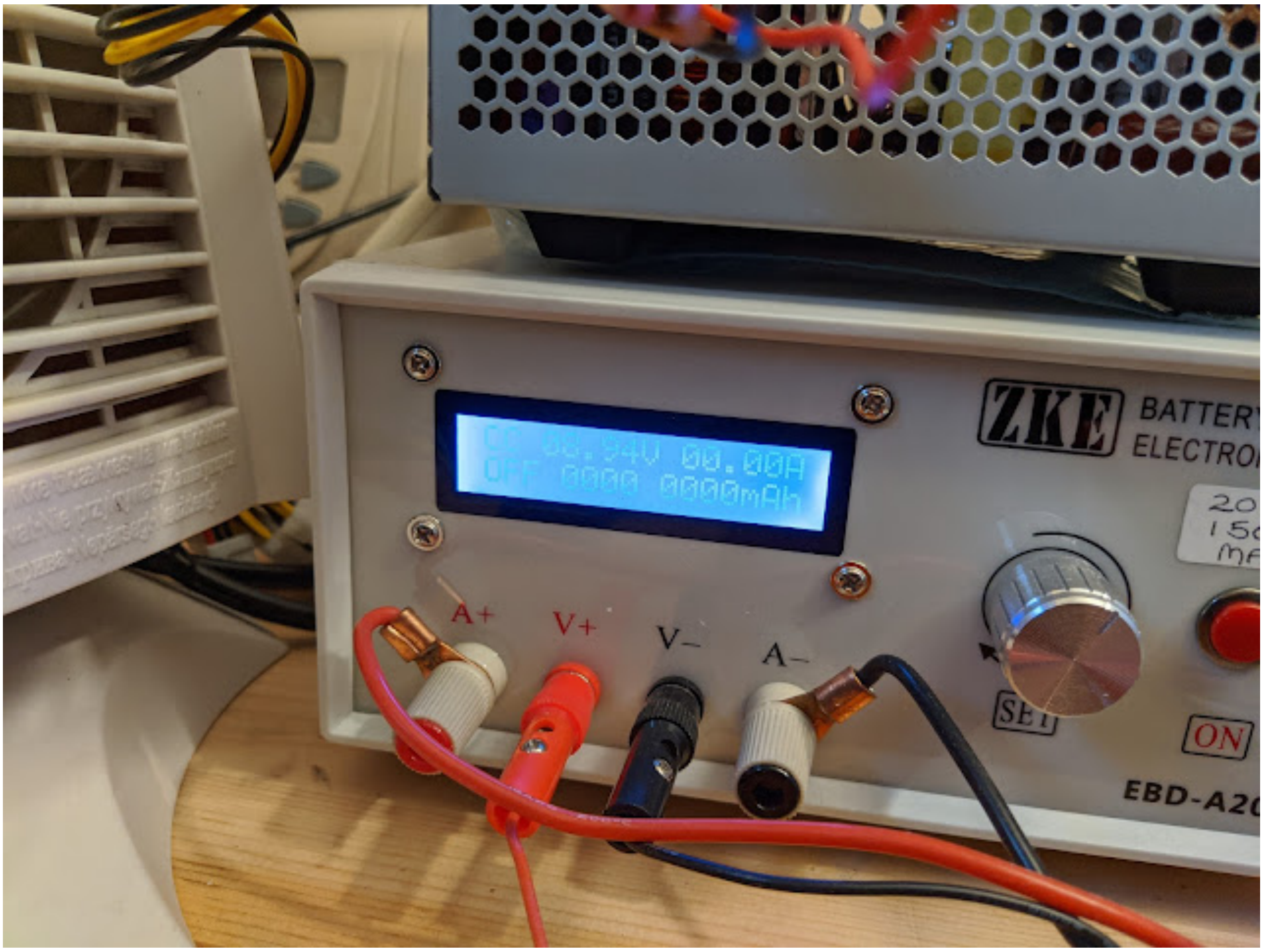
Time to repeat the test, bringing the machine up to 110vac and then allowing the capacitors to discharge.

+16vdc and -16vdc voltage readings after 1 minute.

Problem solved, and a safer PSU for future users.

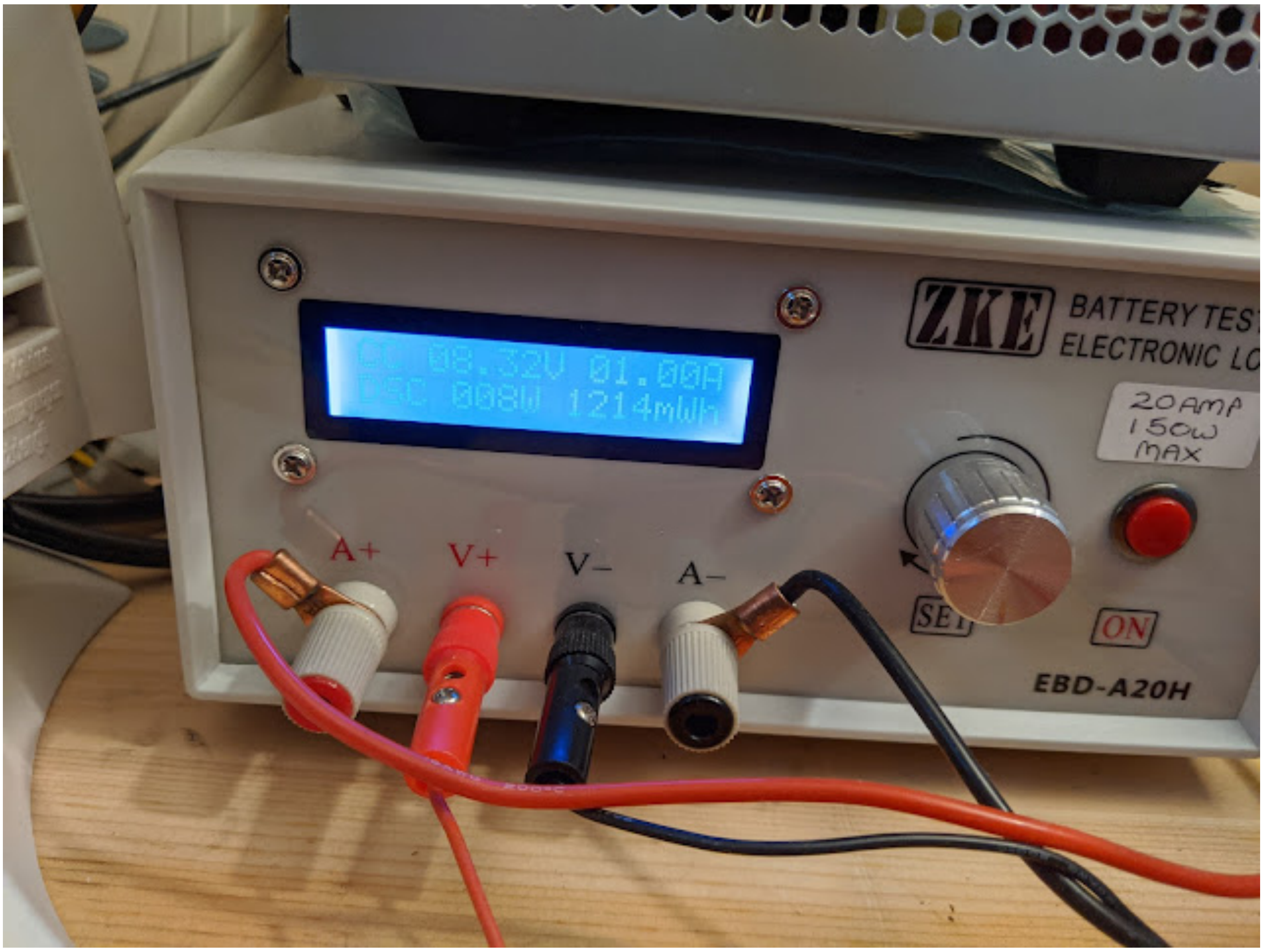
Time to move on to putting the PSU through its paces, with a load test on each DC output.

The mains voltage is ramped up to 110vac and the +8vdc line measured with no load.



No load attached on the +8vdc line.

Next, we run a nominal 1 amp load on the main +8vdc rail for 5 minutes, and check there are no unexpected issues.



1.0 Amp test load on the +8vdc line.

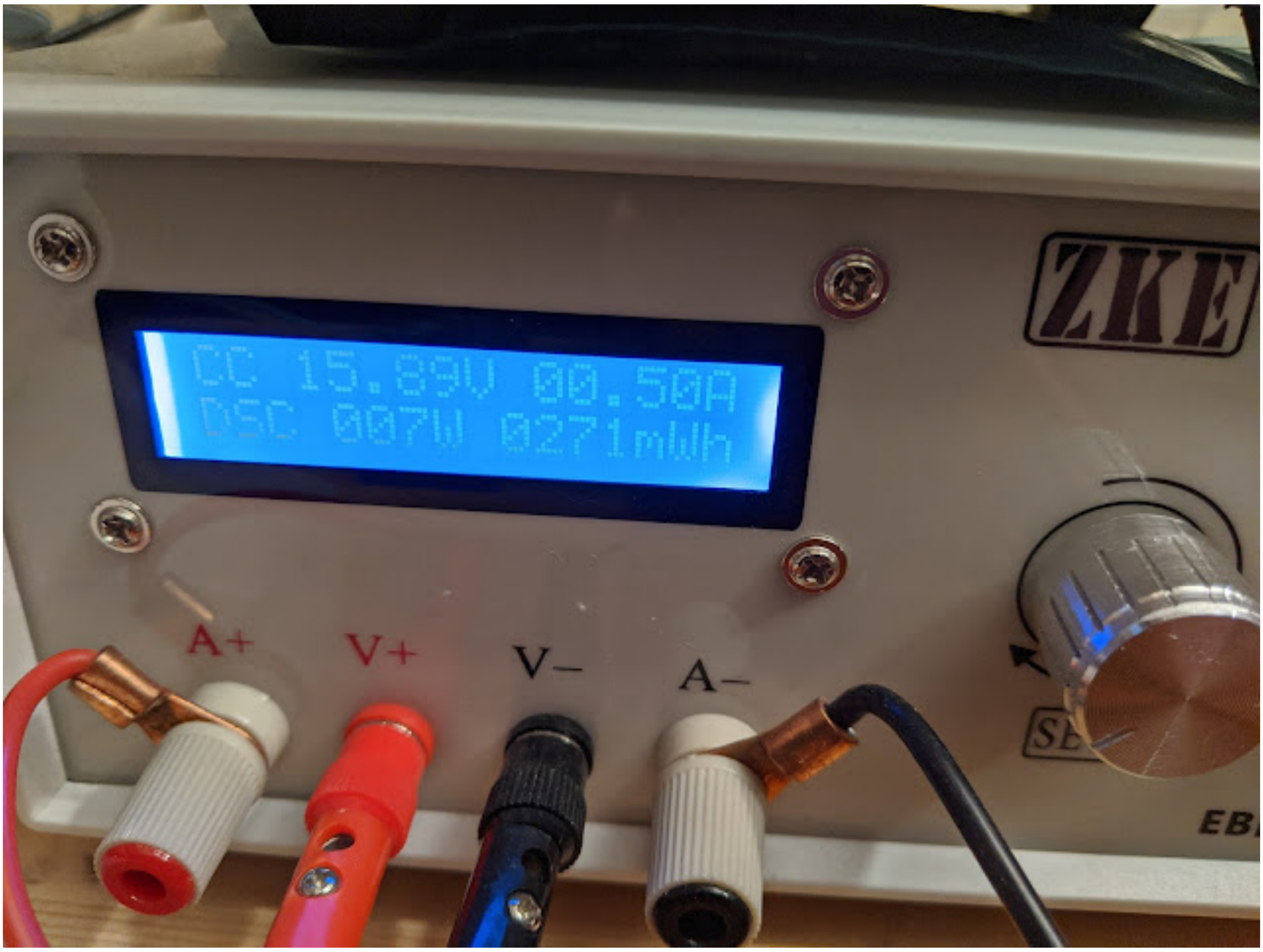
After 5 minutes, all appears well, so the load is increased to 5 Amps for 5 minutes.

The voltage has dropped to 7.47vdc at 5.0 Amps, which is well within the specification of 7.0vdc at 28 Amps. The S-100 boards all have onboard 7805, 5vdc voltage regulators fitted, to take the +8vdc raw supply and provide the regulated +5vdc need for their circuits. The 7805 will work from +7vdc to +30vdc, so 7.47vdc is fine.

5.0 Amp test load on the +8vdc line.

No issues have appeared, so we turn our attention to the +16vdc line.

0.5 Amps is run through it for 5 minutes with no problems.



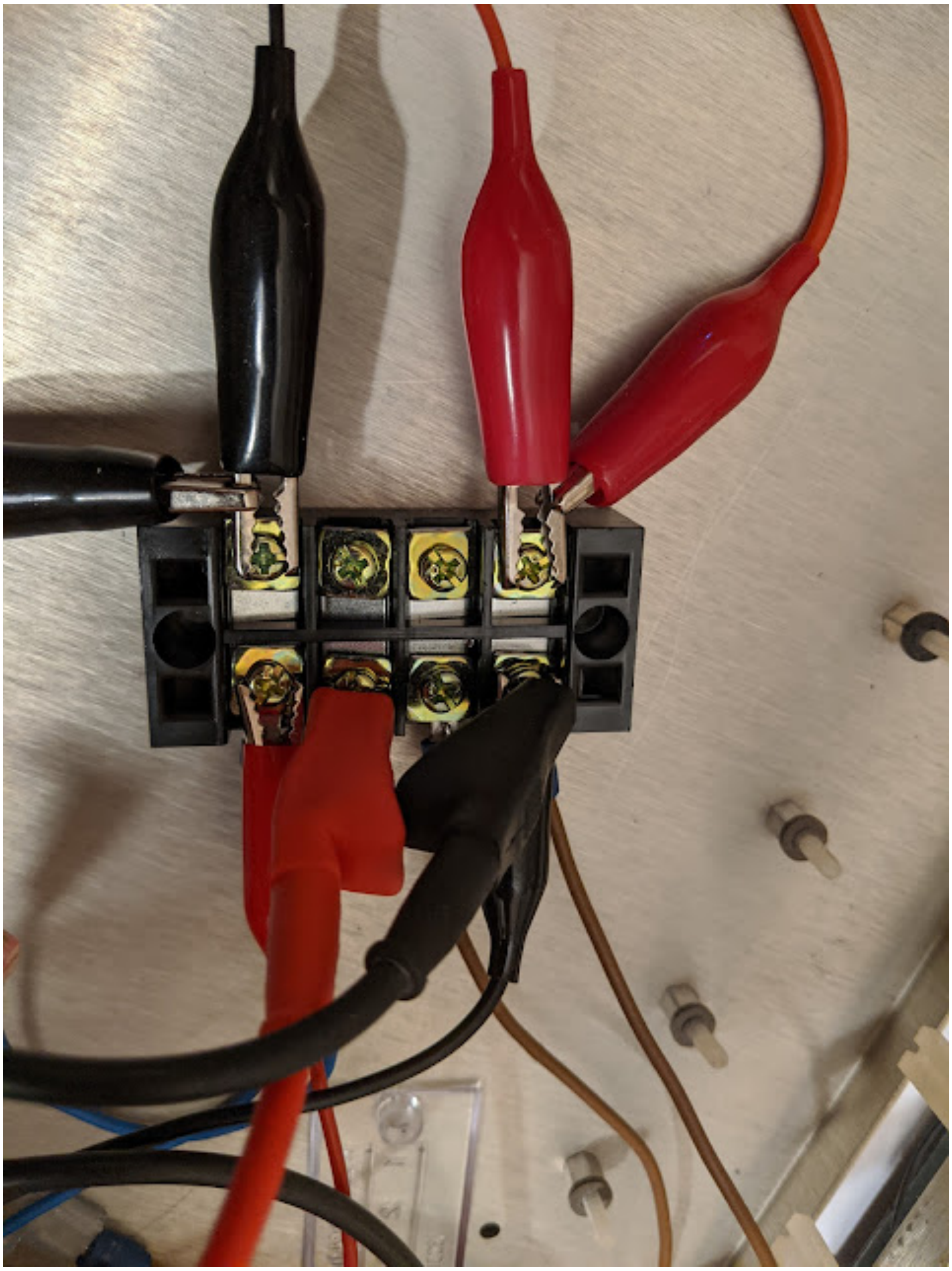
0.5 Amp test load on the +16vdc line.

Finally, we move to the -16vdc line. In order to test this, we have to reverse the polarity of the test, as the ZKE will not normally handle a negative voltage. Although very simply a case of reversing the normal cable attachments from the ZKE, care must be taken to get this right, because an incorrect polarity on the capacitor will quickly ruin it.

All we have to do, is put the positive A+ and V+ cables from the ZKE, onto the Ground connector, and put the negative A- and V- cables from the ZKE onto the -16vdc output line from the PSU.

The -16vdc output line is bottom left. The Ground is bottom right. Ignore the two largest crocodile clips on the bottom row, they are for +16vdc.

The top row of cables are from the ZKE. The top left are the A- and V-, and the top right are the A+ and V+.



Reversing the normal connections from the ZKE, to handle negative voltages from the PSU.

This test was then successfully run at 0.5 Amp for 5 minutes.

We can now say that the PSU is running as expected, under average load conditions.

On that basis, the next Blog will move on to restoring the Wunderbuss Backplane, before fitting it into the chassis, connecting it up to the PSU, and testing it.

We can finally start building a working computer...!

I hope that this has demonstrated to some degree why so much time and effort should be expended checking the PSU on vintage computer equipment, before we are ever tempted to plug it in and switch it on.

BLOG PART 8: The Thinker Toys Wunderbuss Noiseguard and IMSAI EXP-22 Backplanes.

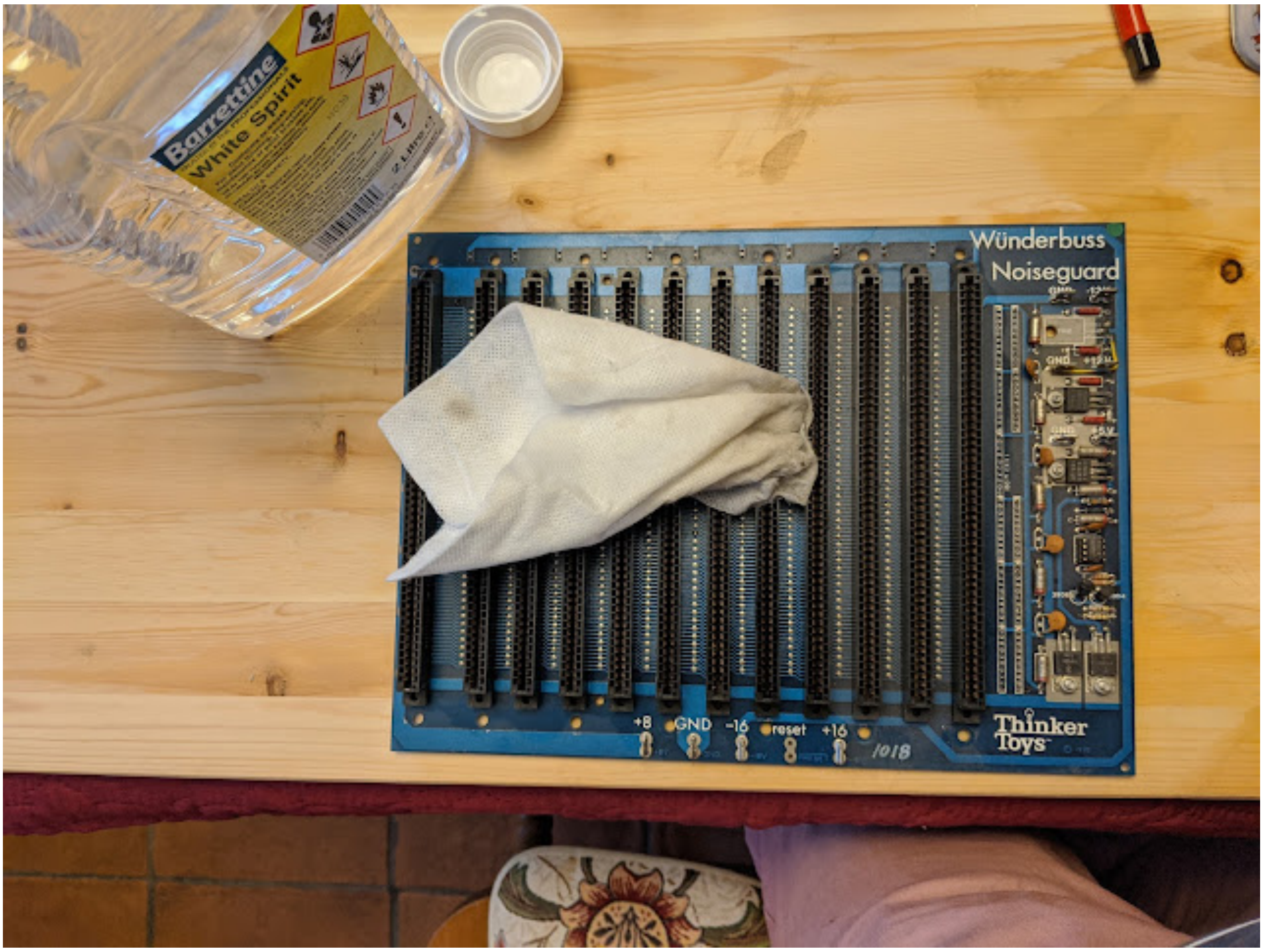
25/11/2019

We have already established that this Backplane is not contemporary with the chassis. More than likely, it was a replacement, designed to facilitate an upgrade to a Z80 CPU Board.

Our first job is to clean it with nylon brushes, to dislodge dust and grime.

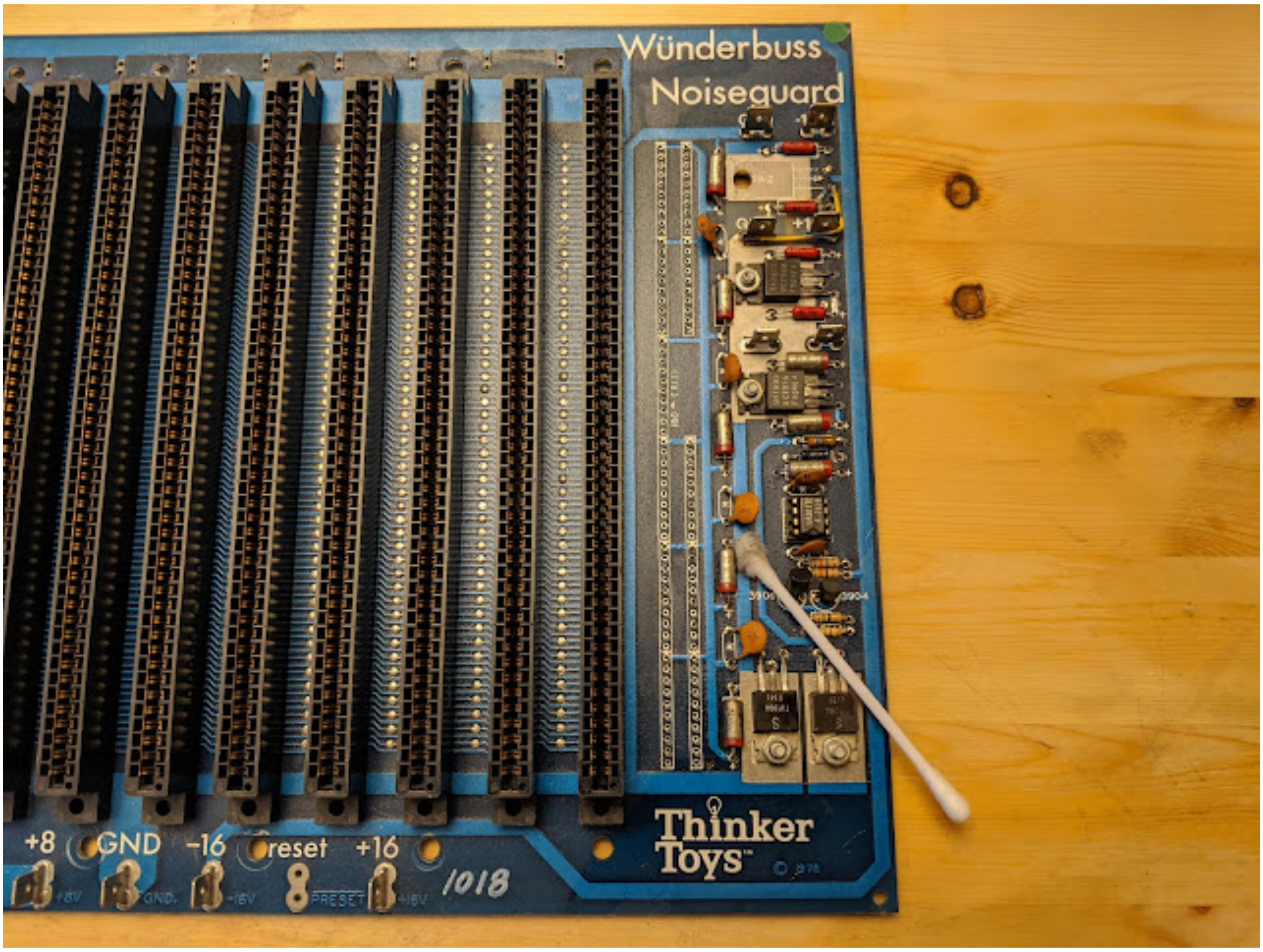
Nylon Brushes

Now wipe down with White Spirit using a Safecloth.



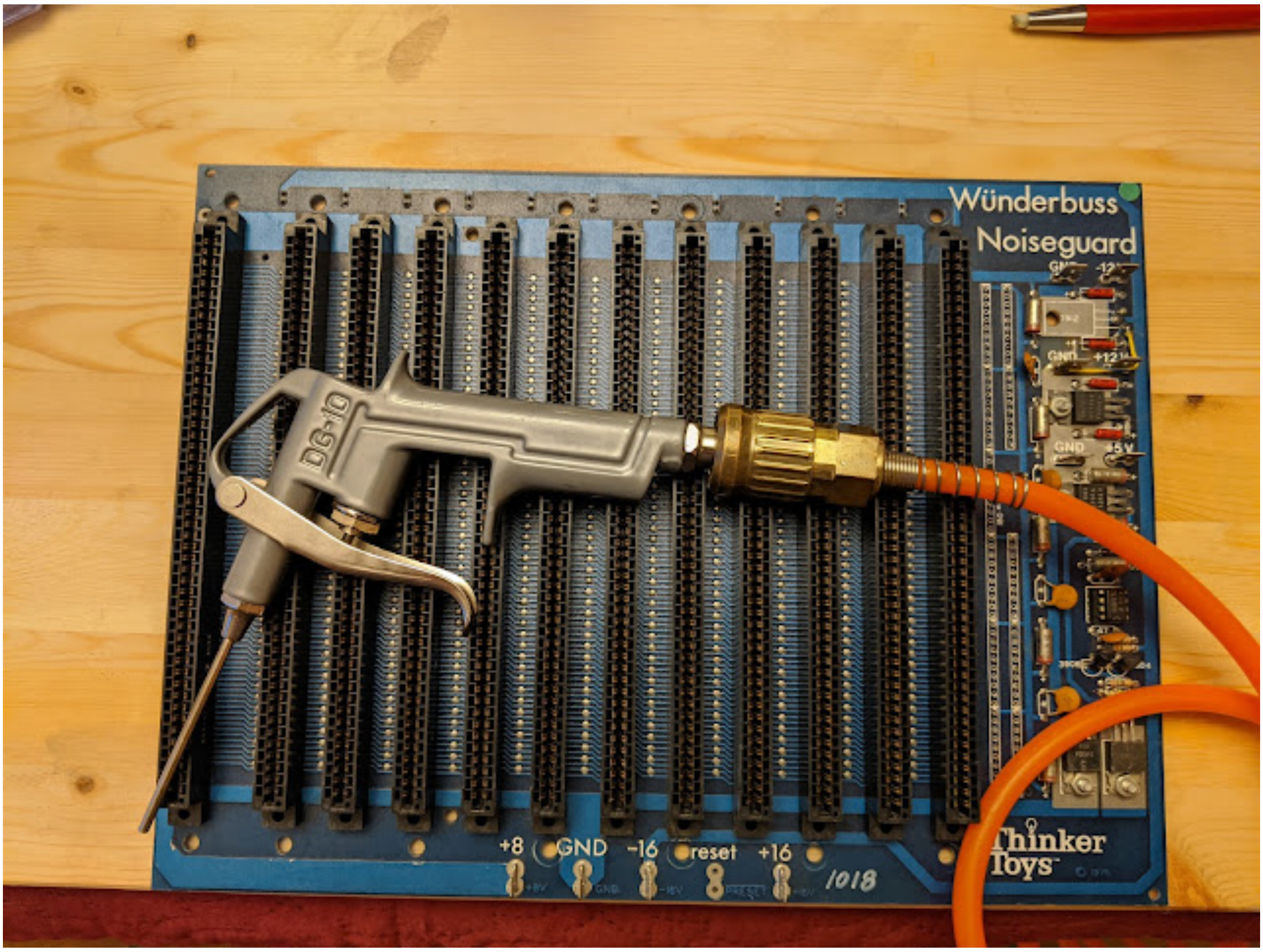
Thinker Toys Wunderbuss Noiseguard Backplane.

To get in-between components, a cotton bud comes next.



White Spirit and Cotton Buds.

Air dusting the S-100 slots can be done with a canister, but a compressor is better.



Air Compressor with fine nozzle fitted.

A 24 Litre unit works really well for this type of job.

24-Litre Electric Air Compressor.

Dangerous marketing in my opinion, but WD-40 make a great contact cleaner that we can us on the S-100 slots. Not to be confused with their famous WD-40 lubricant....!

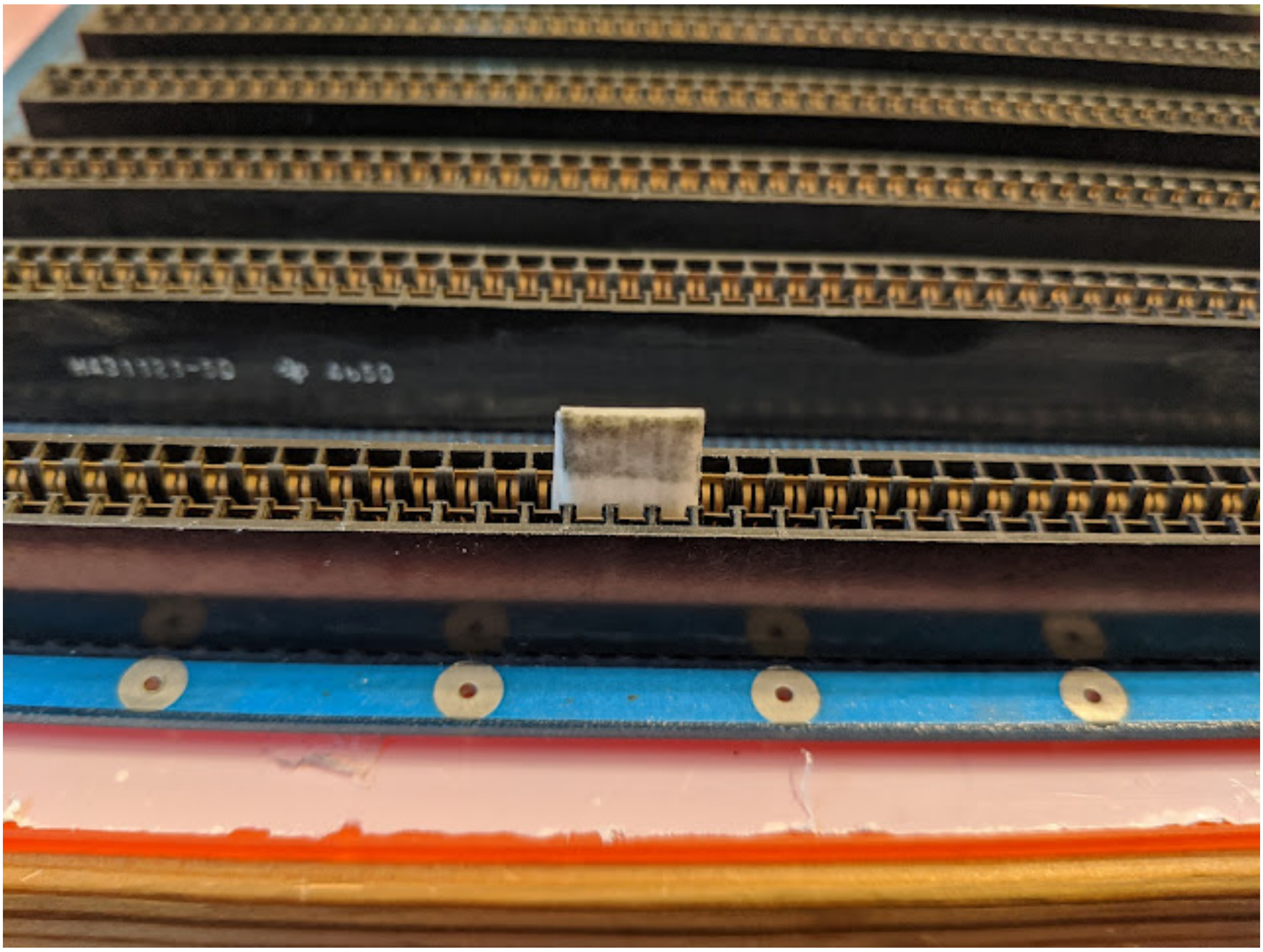
Not your normal WD-40....!!

The cleaner is sprayed into a slot and then contact cleaner strips are used vertically, working along the slot a little at a time. The strip has to be folded into four, so that it is thick enough to push on the contacts at each side of the S-100 connector. A short up-down motion, pushing slightly toward each side in turn, will do a good job.

It will cover 3 pairs of contacts at a time. After 24 pairs have been done, turn the strip upside down to get to fresh cleaner surface. After 48, open the strip up and reverse it, to give access to another two areas that can cover another 48 pairs. Finish the last 4 pairs off and move to the next connector. You will now be able to find the other 50% of the cleaner strip to use on that connector.

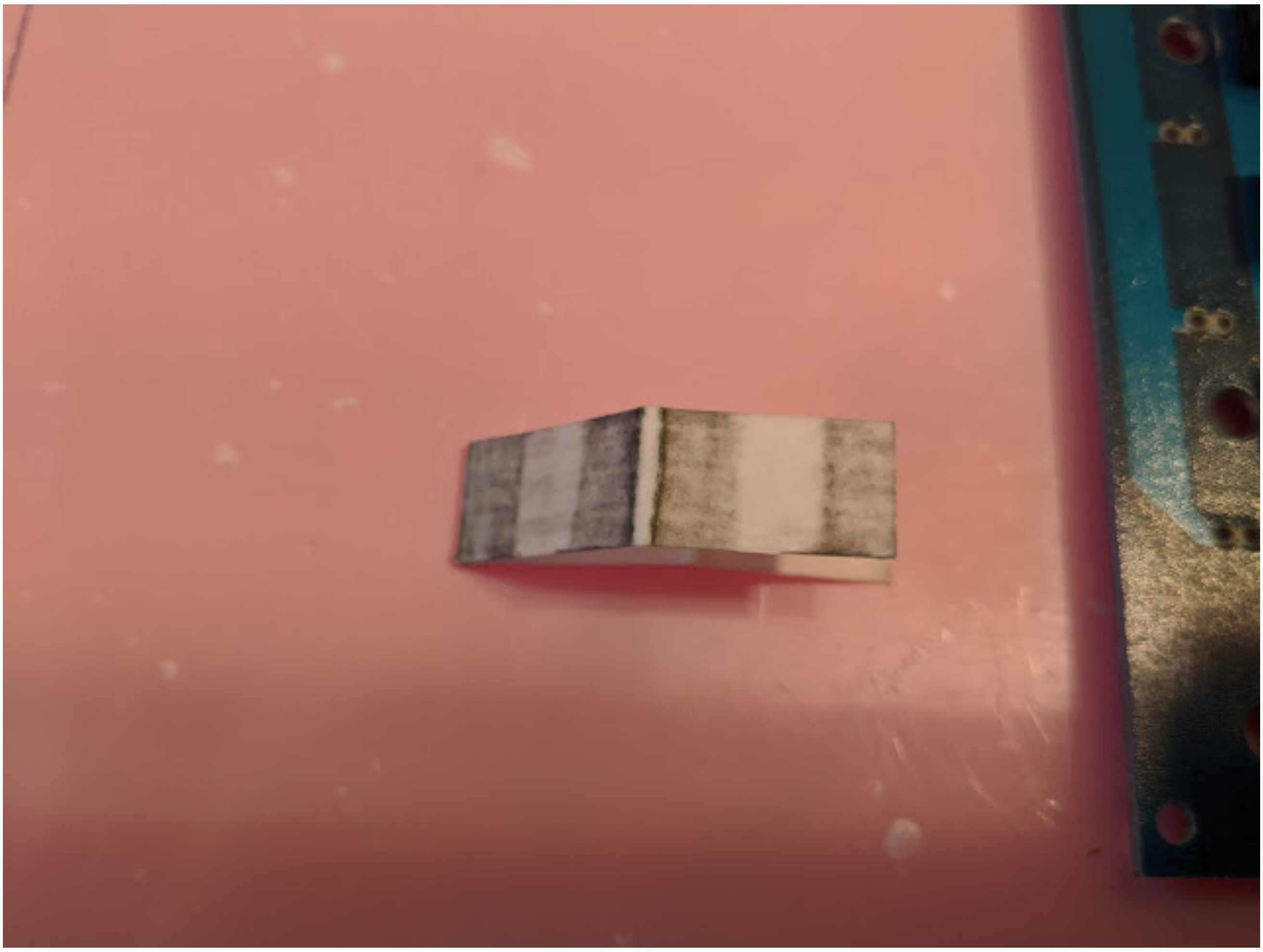
Contact Cleaner Strips.

Carefully fold the strip over on itself twice, making it four layers thick. This is needed in order to push the contact apart and apply enough pressure to clean them effectively.



Cleaner Strip folded to 4 layers thick. It is now about 2cm long.

It is a fairly time-consuming job, but well worth doing, as can be seen by the amount of grime that is removed.

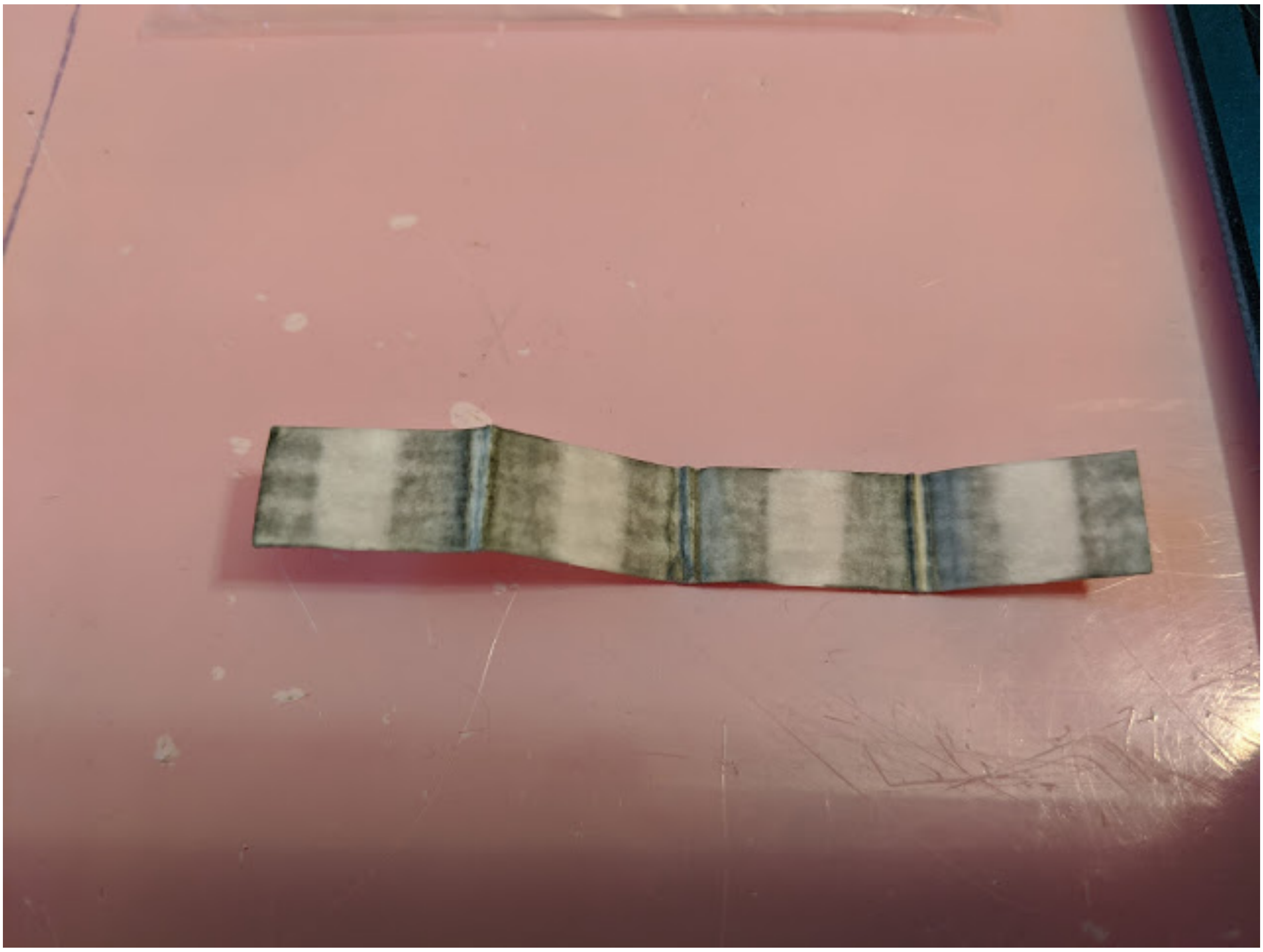


After 24 contact pairs have been cleaned.

Now turn the strip over, and do the next 24 pairs. After that, repeat to finish the connector.

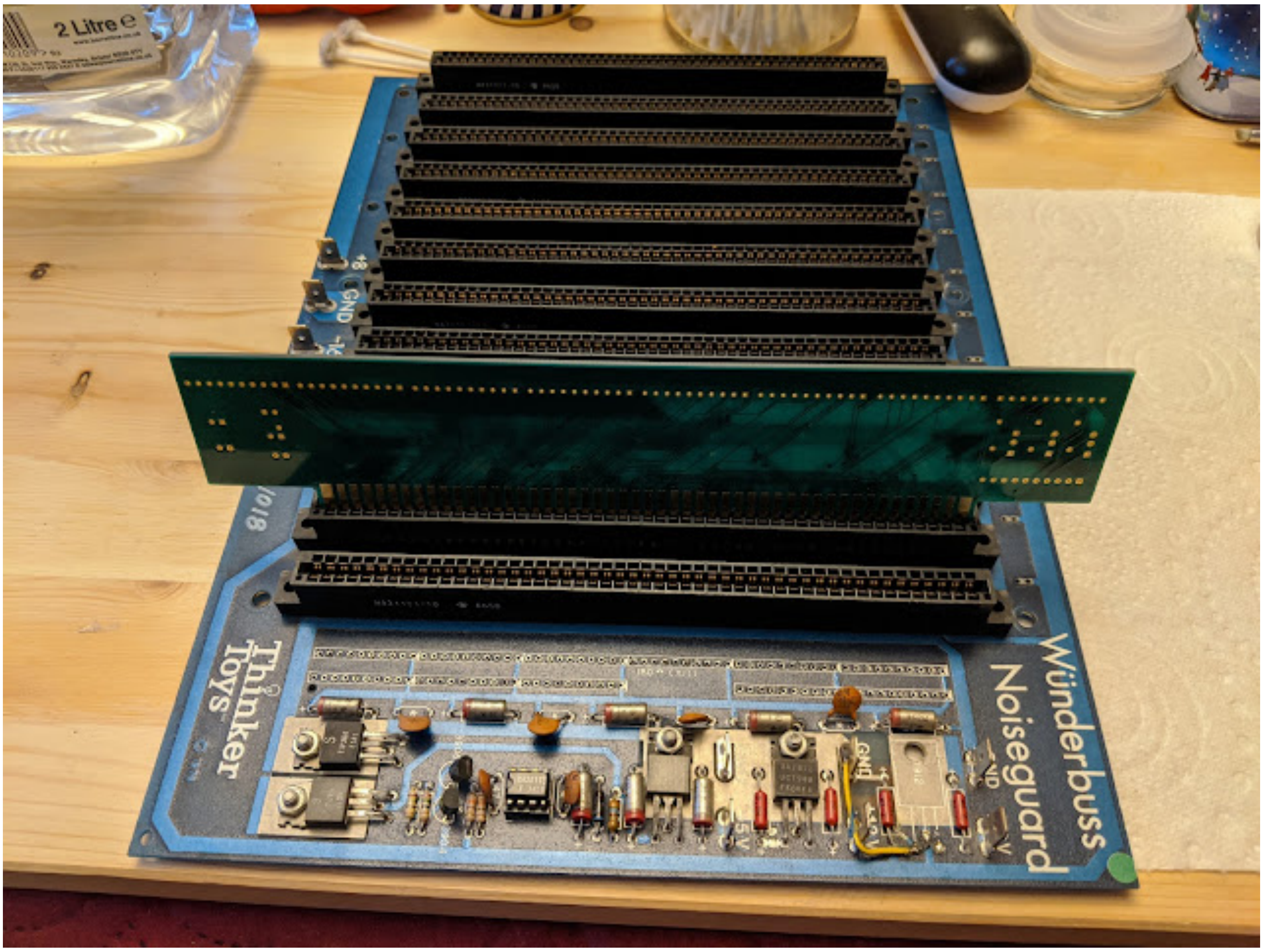
This is what it looks like after one S-100 connector has been done. The strip can now be turned over to do another connector. In this way, a pack of 20 strips can do a couple of 22-slot Backplanes.

I am not aware of any better way of cleaning S-100 slot contacts. At £5.00 a pack, or £2.50 per Backplane, it is money well spent.



One side used up on a single S-100 Connector.

Finally, a spare, unused, PCB is used to check that the slots all accept cards, and we have no bent connector pins.



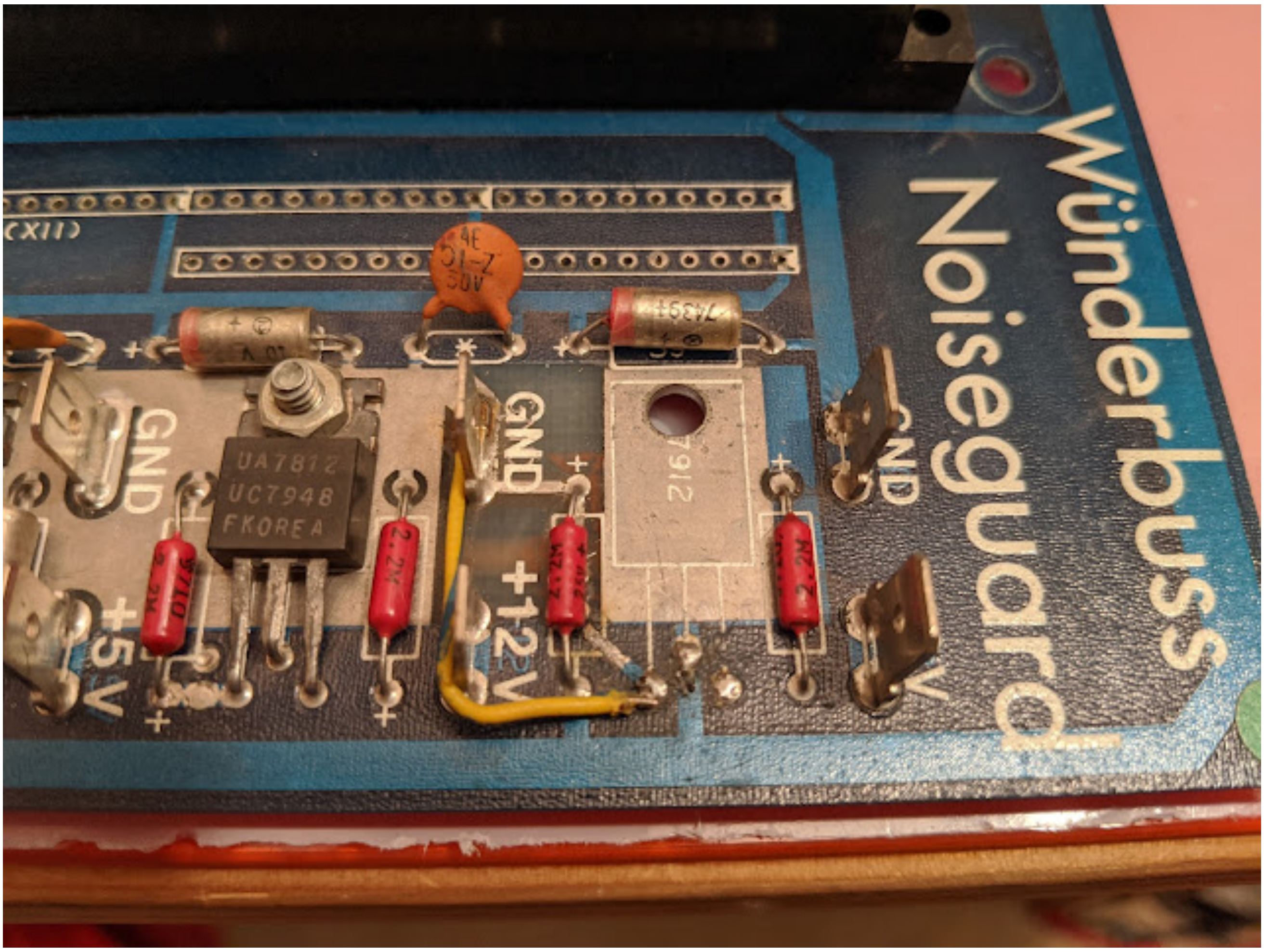
Checking the S-100 Slots.

The initial clean is finished, so we can turn out attention to examining the board and its active termination circuitry.

Upon first glance, two issues are discovered. Firstly, none of the 96 terminating resistors are present and, secondly, the -12vdc Model 7912 regulator is missing altogether!

Closer examination shows that there has been a short circuit in the past and the ground trace from the regulator has been 'fried'. A simple repair, soldering a piece of wire in place of the PCB trace can be seen. However we don't know if any other components were affected by this failure.

It looks as though the board has been abandoned halfway through building the active termination circuitry, which is of concern.



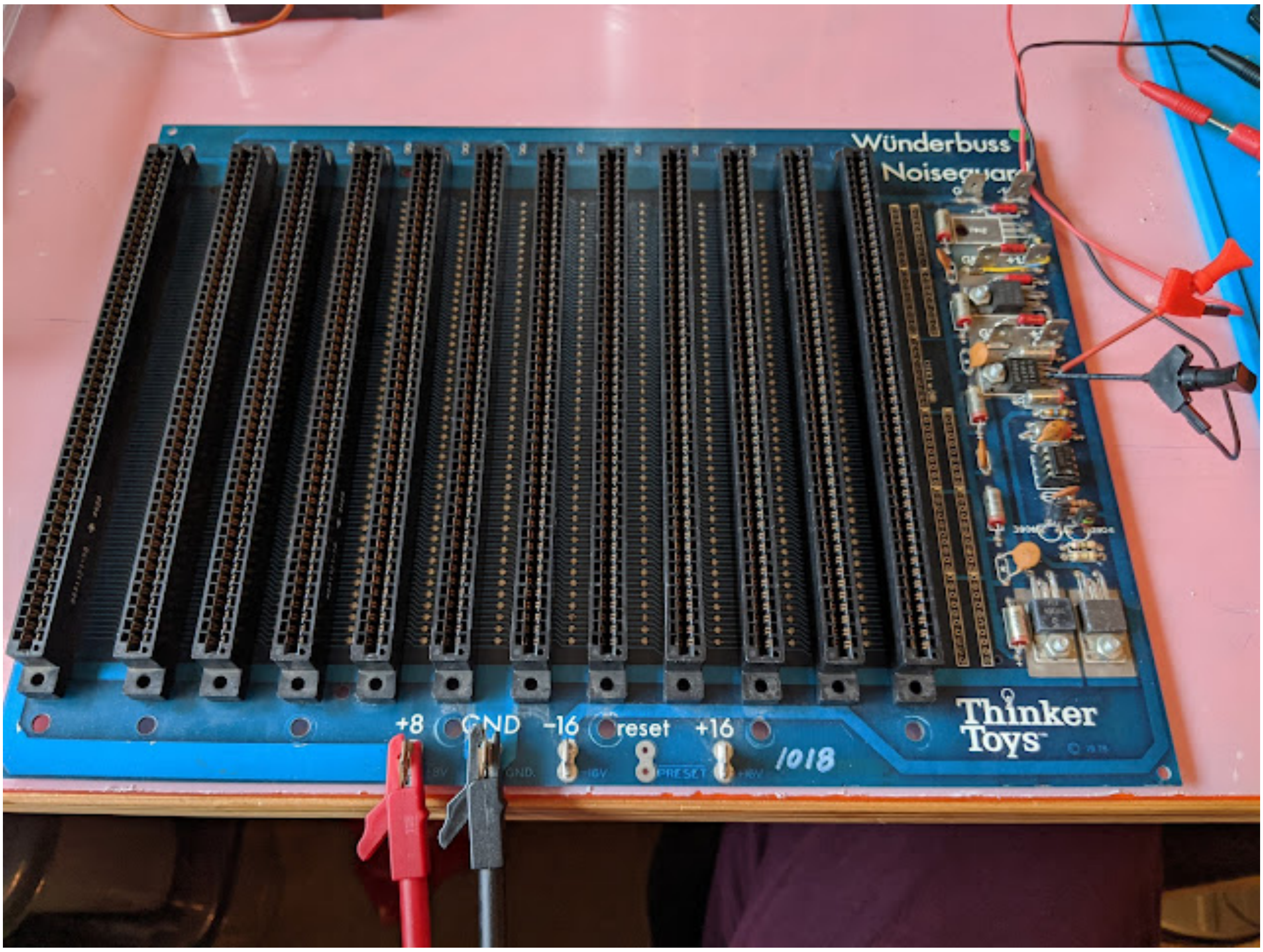
Missing regulator and terminating resistors.

The required eleven x 10-pin, 9-resistor, bussed, 180 Ohm Resistor Packs are ordered, Not very easy to find them at a reasonable price today.

In addition, a 7912, -12vdc regulator is ordered. We might as well try to finish the job.

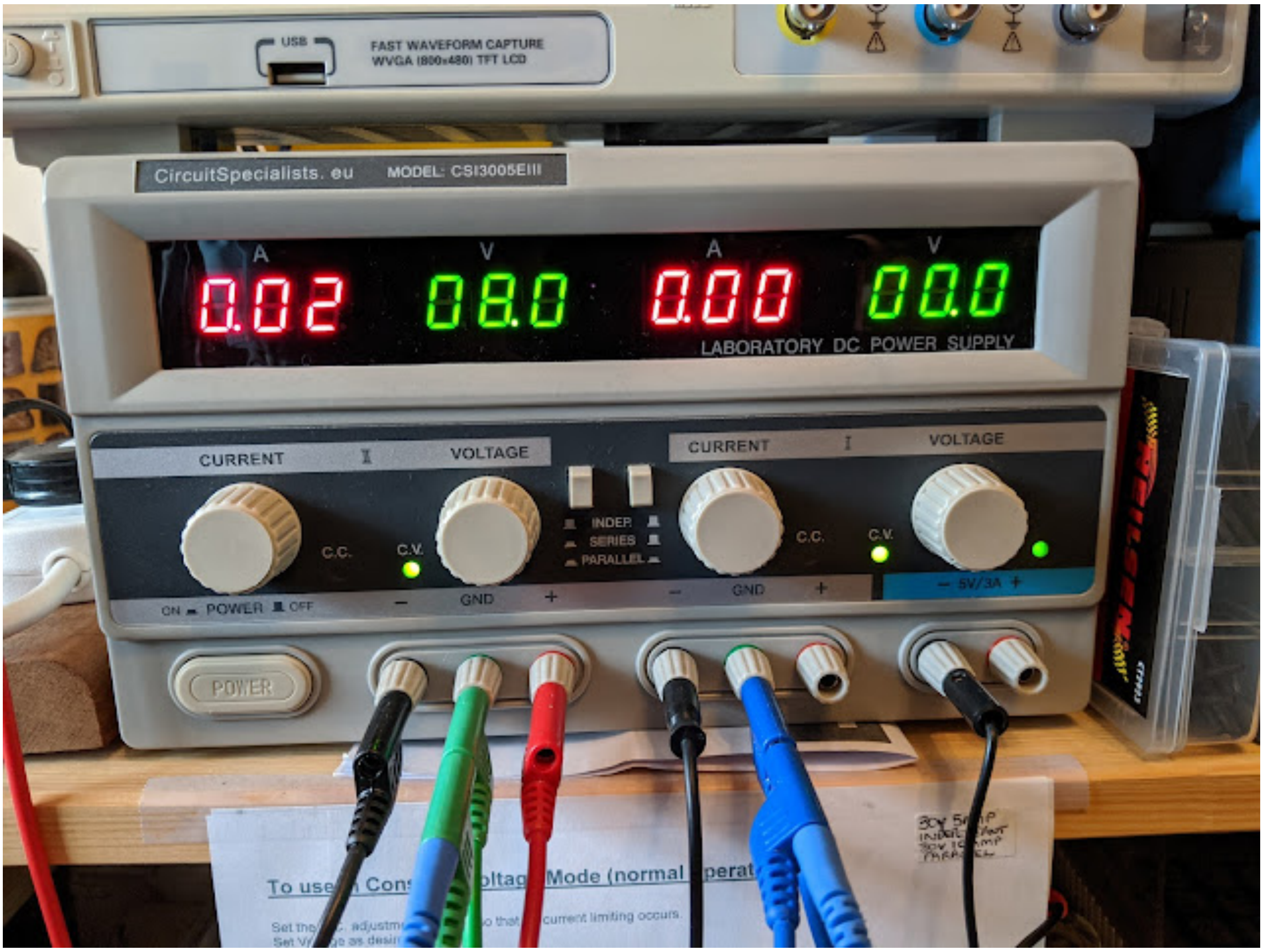
While waiting for them to arrive, we can at least check the +8vdc and 12vdc regulators, and as many components as possible on the board.

The input and output on the Model 7805, +5vdc regulator is checked.



+8vdc Input.

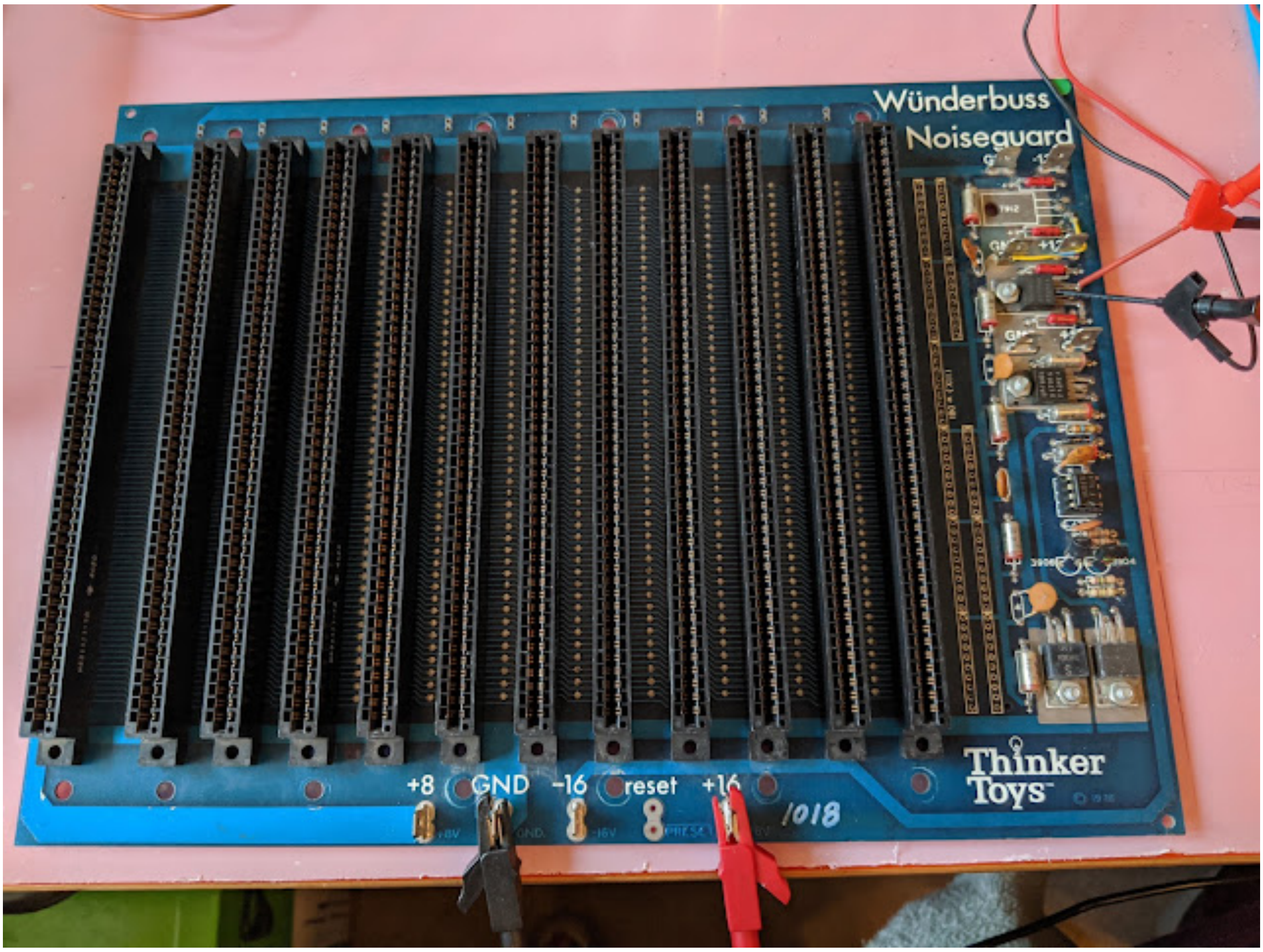
+8vdc supplied, consumes 0.02 Amps, which appears to be okay.



Output voltage is right on target.

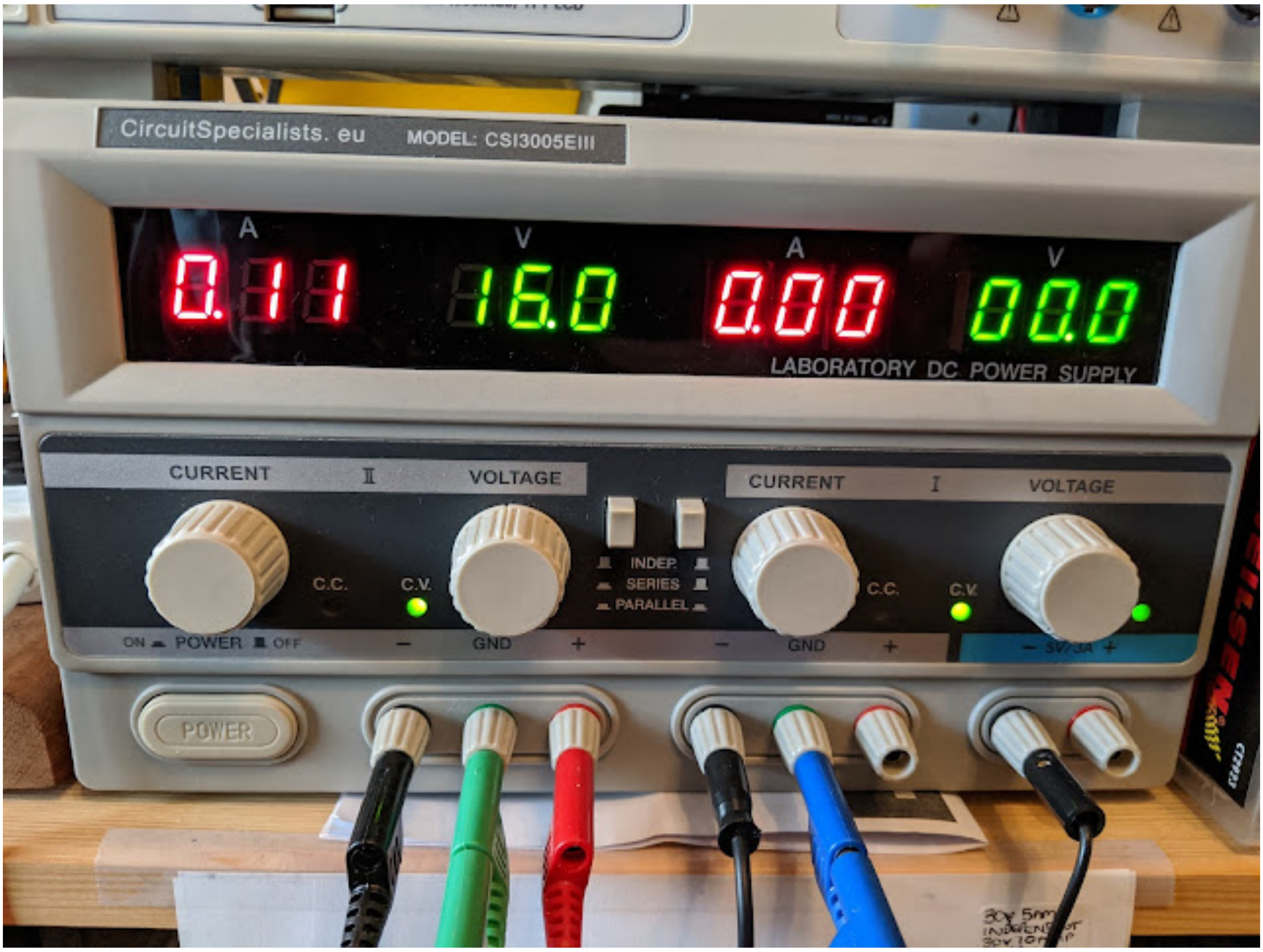
Output from 7805 Regulator.

The input and output on the Model 7812, +12vdc regulator is checked.



+16vdc Input

+16vdc supplied, consumes 0.11 Amps, which appears to be reasonable.



Add caption

Output voltage is 2.25% below target.

Output from 7812 Regulator.

There is a slight smell of 'electric components', which is a bit of a concern.

The values of all resistors onboard is checked and found to be okay.

The ESR of all electrolytic capacitors is checked and found to be within acceptable limits.

IMPORTANT NOTE:

The Wunderbuss employs crimped spade terminal connectors for attaching power. This is not really a good idea.

Typically, crimped spade connections are rated at: Red = 12 amps; Blue = 16 amps; and Yellow = 20amps.

In addition, a professional, calibrated, crimping tool is needed to use the correct force when attaching the cable ends. If you solder the wires, then you can overcome that problem, but you are still limited to the current ratings of the spade connections themselves.

The terminals on the Wunderbuss are 16 amp spade connectors, which are not sufficient for running at the intended maximum of 20 amps on the +8vdc line, or the potentially even higher current on the Ground line.

It could be argued that, with the Backplane only having 10 slots for boards, we are unlikely to ever reach a current draw of 20+ amps, but it would be better to be safe.

It would be best to solder the cables to the terminals and accept the overhead of desoldering them if we ever need to disconnect the Backplane from the PSU.

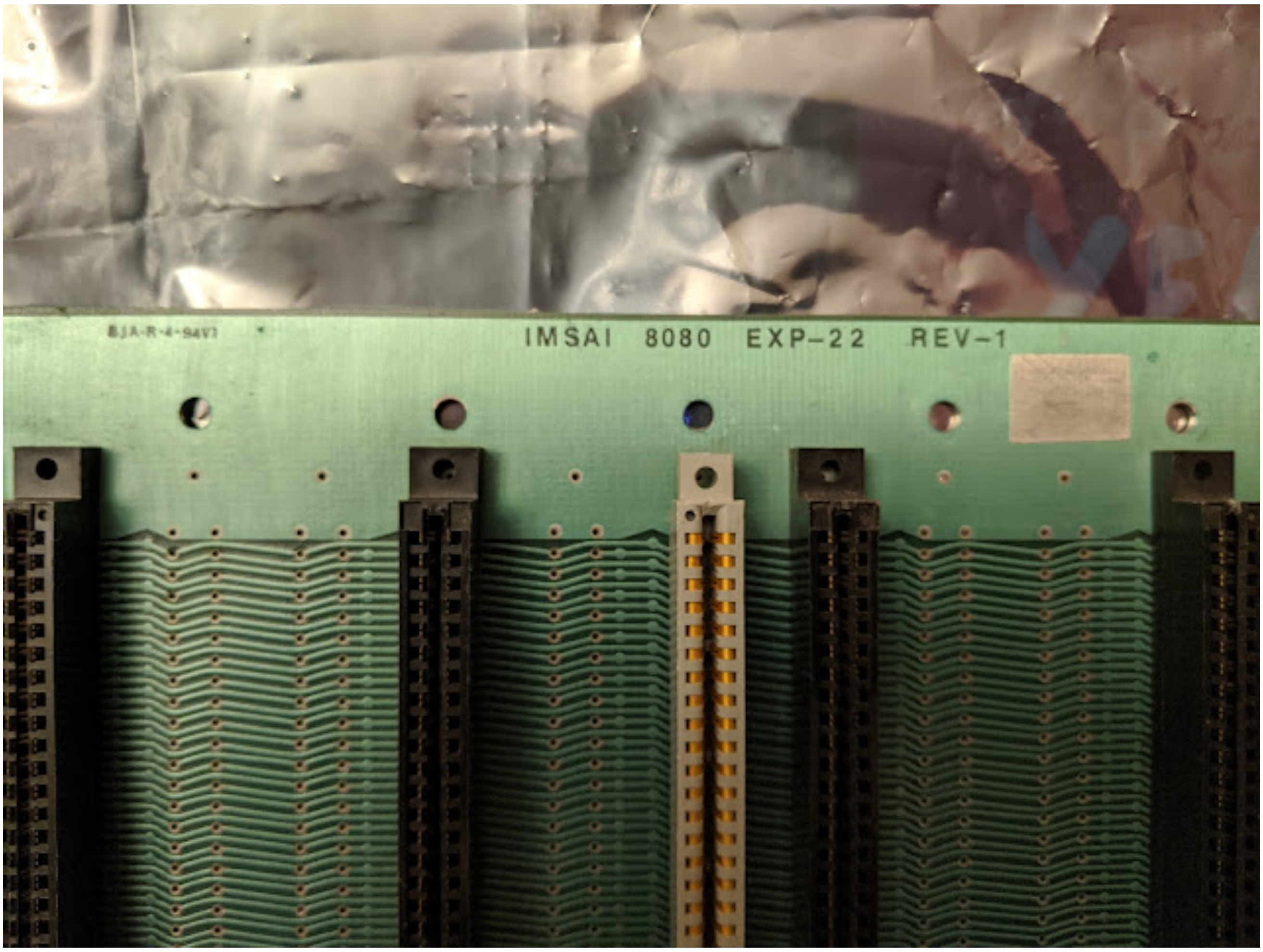
END OF IMPORTANT NOTE.

While waiting for delivery of a 7912 Regulator and the 180 Ohm resistor packs, we have rummaged around the spares stock and located an original IMSAI EXP-22, 22-slot backplane.

This has clearly been built by a hobbyist, as it uses one blue, high-quality, type of S-100 connector for the Front Panel slot, then 6 standard quality black connectors, well spread out across the 22-slots. This must be how it was originally set up. Later, 4 high quality beige connectors have been added, date coded for 1978.

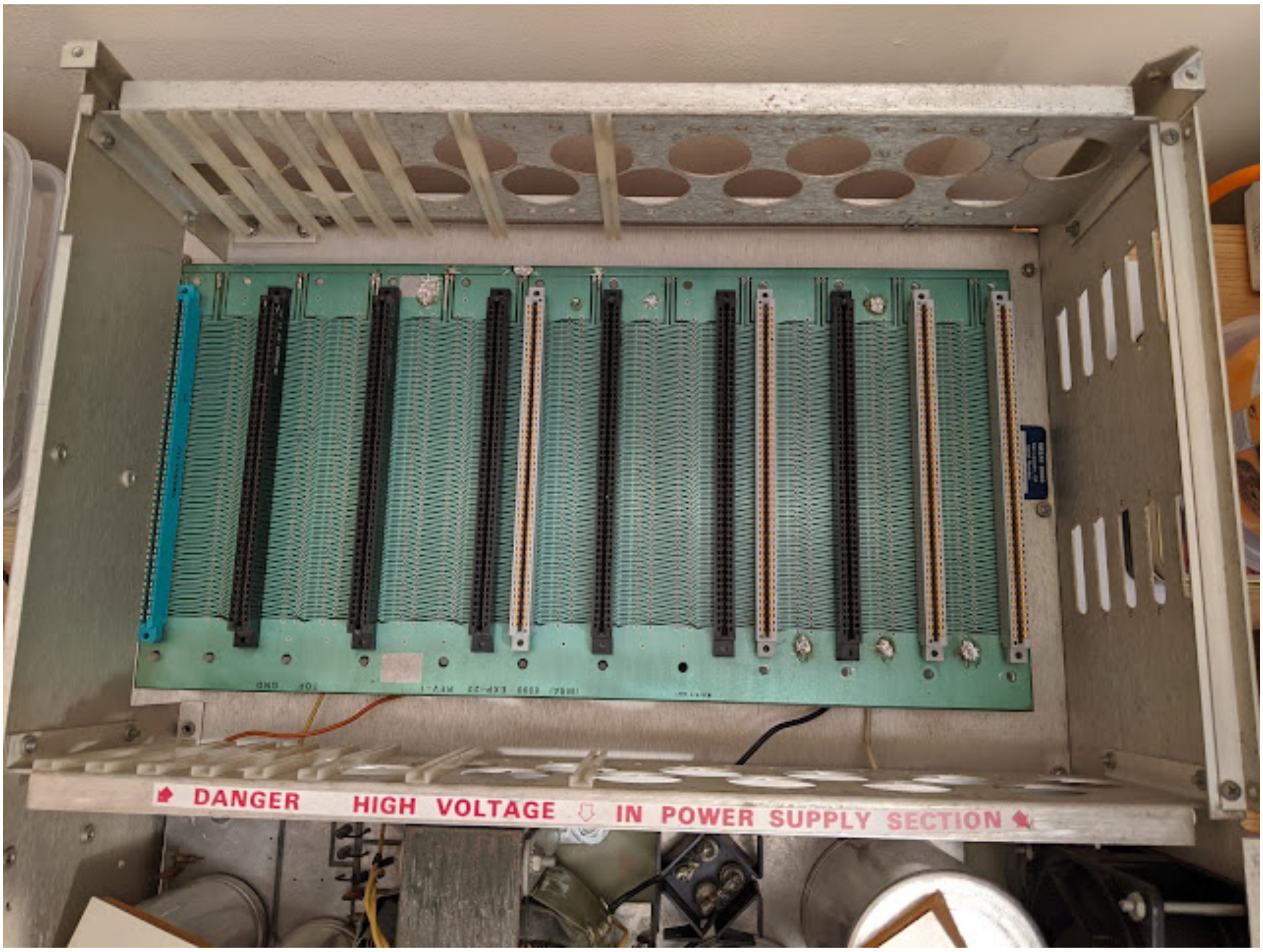
With it not being 'professionally' put together, it is in keeping with the rest of the machine. Given that the Wunderbuss is incomplete and a later addition, a decision has been made to replace it and retro-fit this unit instead. Attempts will still be made to complete the Wunderbuss and keep it as part of the machine's history.

After proper cleaning, as already described for the Wunderbuss, cables of the required amperage will be soldered to the board, and terminated with appropriate connectors, ready for hooking up to the PSU for testing. We have chosen 30 amp cable for the Ground and +8vdc DC supply, and 14 amp cable for each of the +/- 16vdc supplies.



Original EXP-22 Backplane.

This gives an idea what it will look like in place of the Wunderbuss. The plastic card guides will need to be moved, to sit alongside the connectors.



IMSAI backplane before cleaning and fitting.

In addition, in-line Fuse Holders will be added to each of the DC lines, with fast-blow fuses fitted that closely match the measured current draw with the boards we will be running in the machine. This will serve to further protect matters in the event of faults developing.

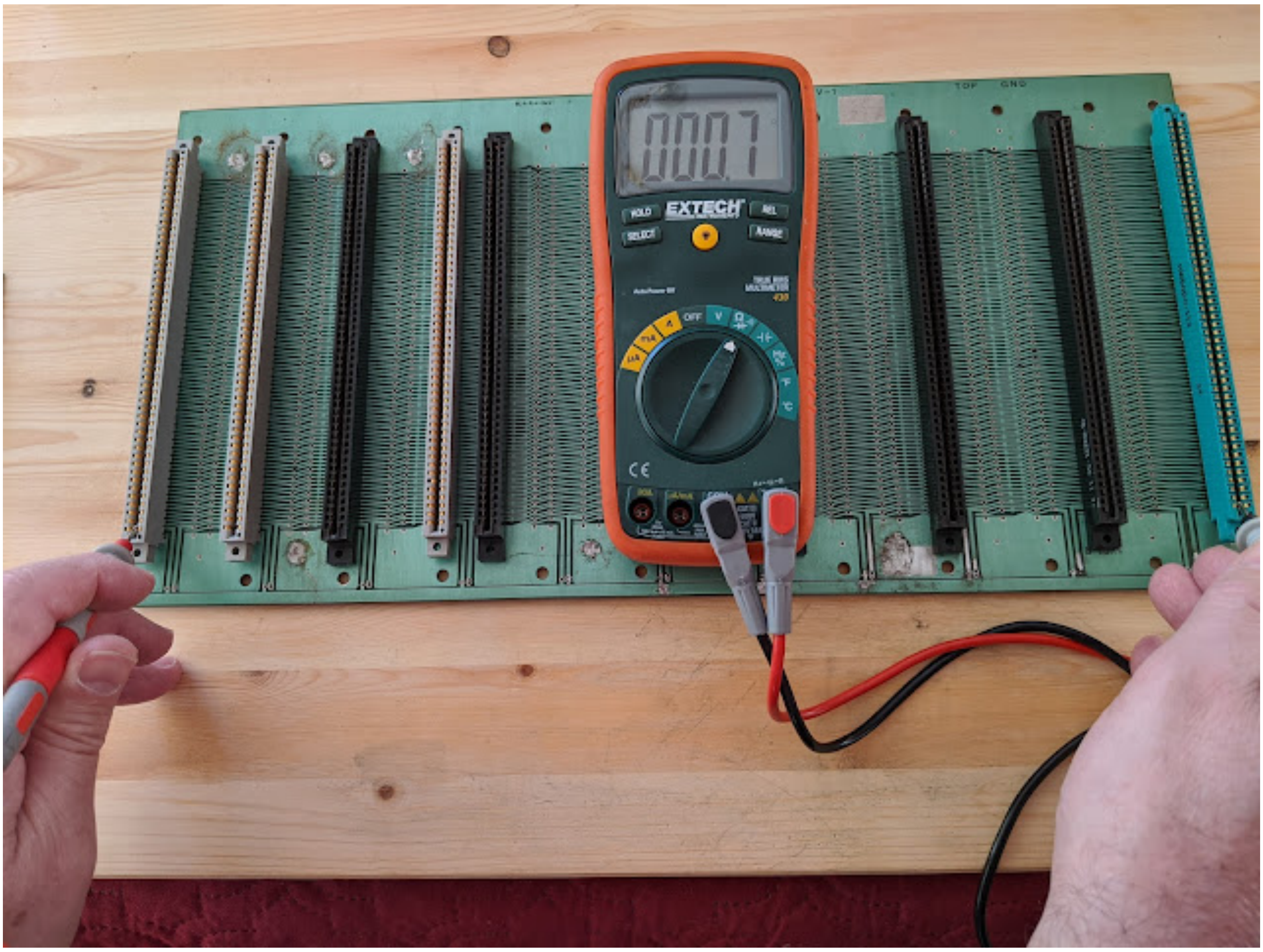
It also means that we can control the maximum current that we ever want to allow on each of the lines. In our case, that would be 20 amps on the +8vdc line and 3 amps on each of the +/- 16vdc lines. In reality, however, it is likely to be fused at 3 amps and 0.5 amps respectively, with the minimal number of boards we plan to run.

20A in-line fuse holder.

Connections will be to a 25A Terminal Block, using crimped and soldered ring connectors, to allow for easy future disconnection of the backplane from the PSU.

25A Terminal Block.

At this stage, a continuity check was carried out on each of the 100 connections on the Backplane, from end to end. In addition, by testing the lines above and below for any given line, we can check that there are no accidental shorts across lines.

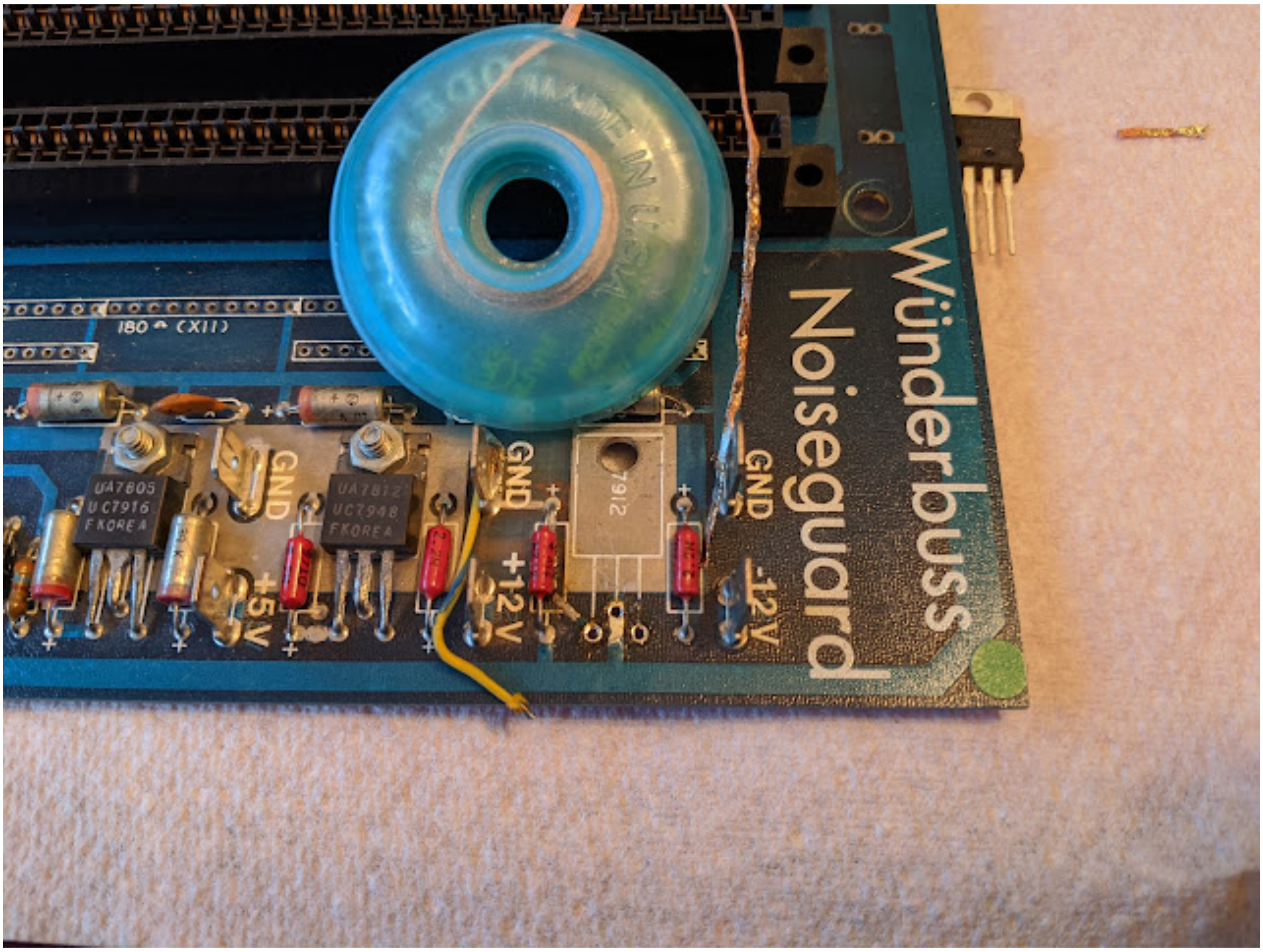


End to end continuity check on each S-100 line.

All was good. We will be ready to install, once the connecting cables have arrived and been soldered into position.

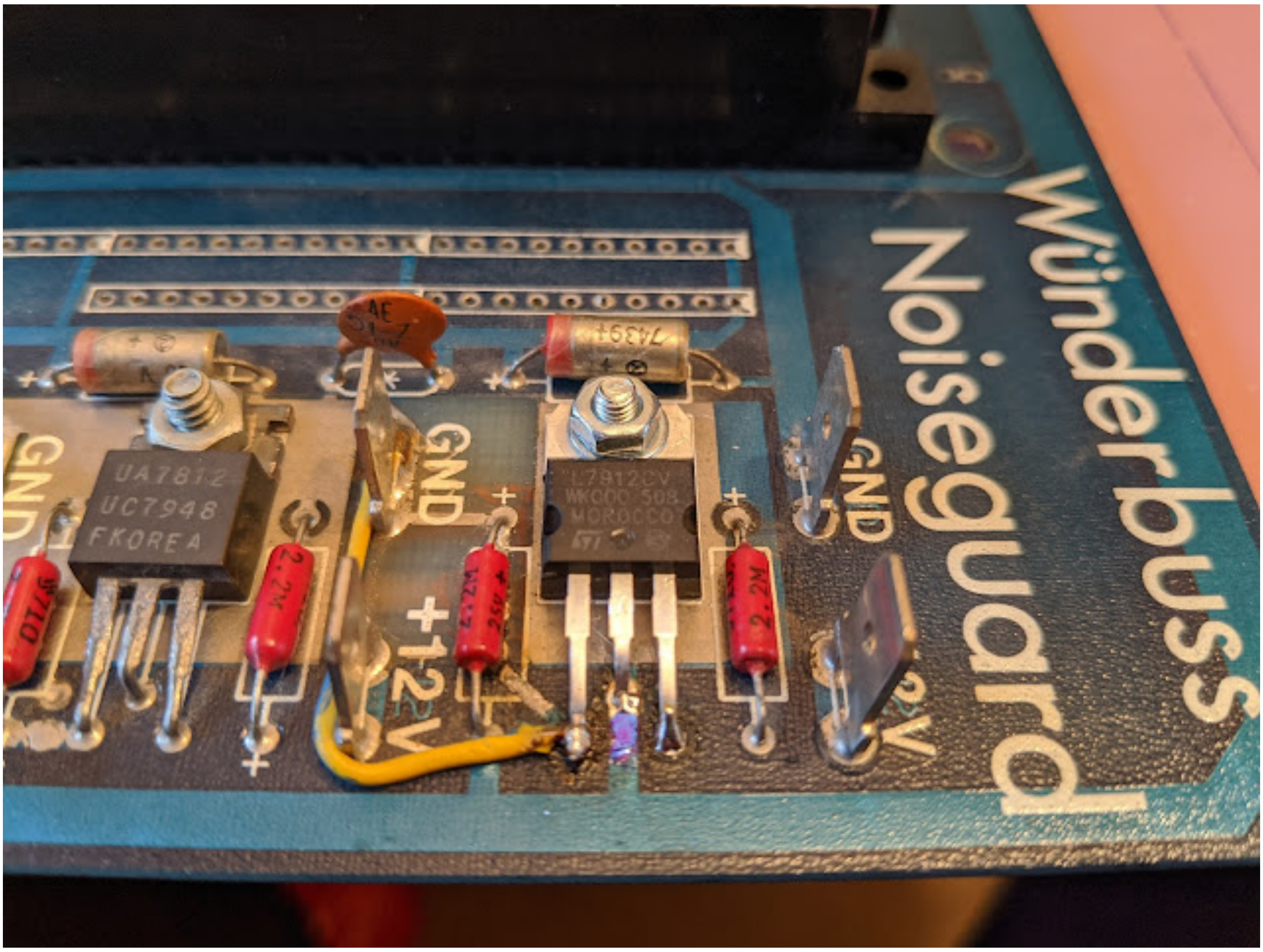
30/11/2019

Desolder braid is used to clean up the site of the old 7912 Regulator that had been removed.



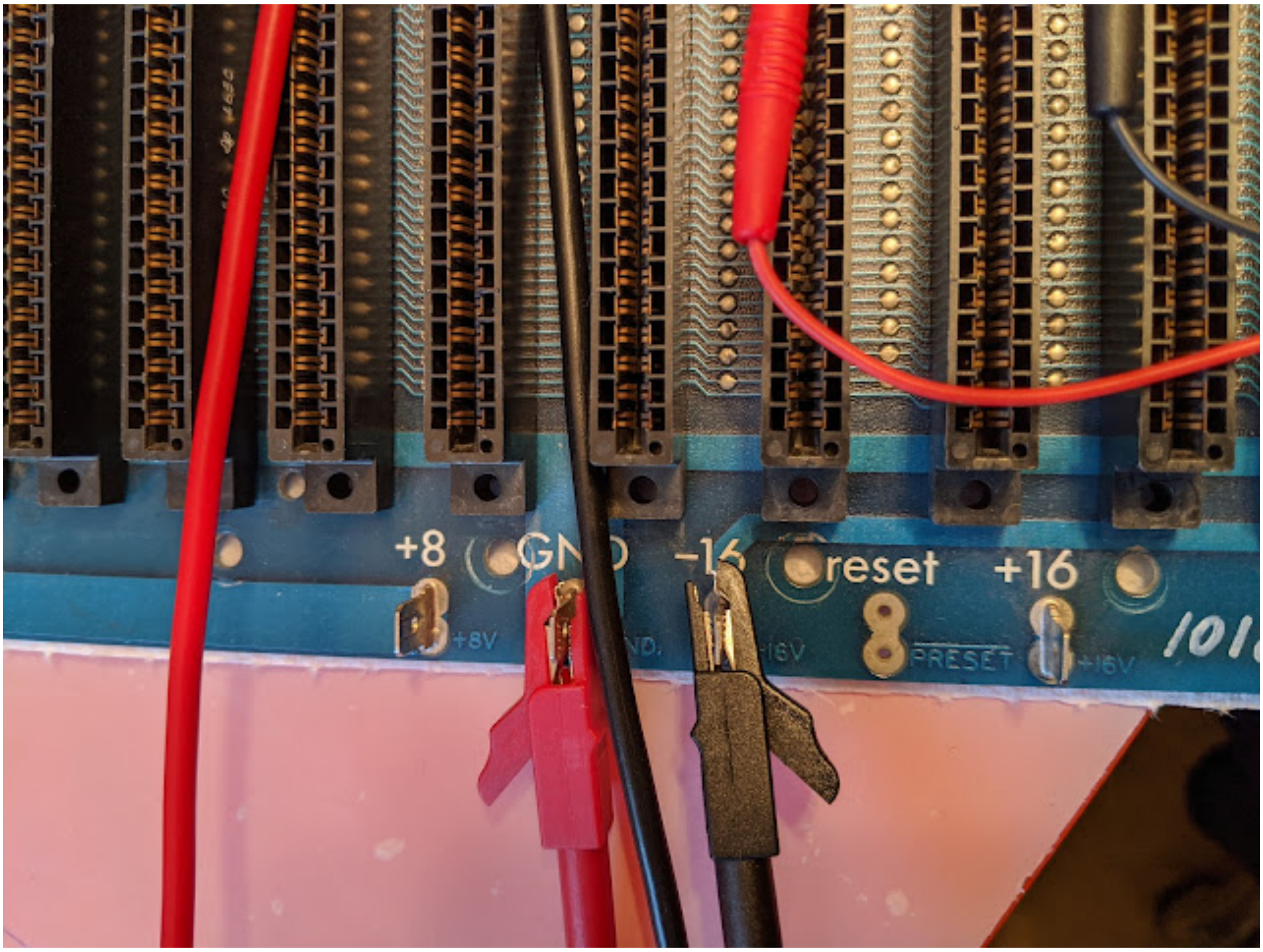
Old solder removed.

The new 7912, -12vdc regulator is fixed in place, and the old Ground repair cable re-attached.



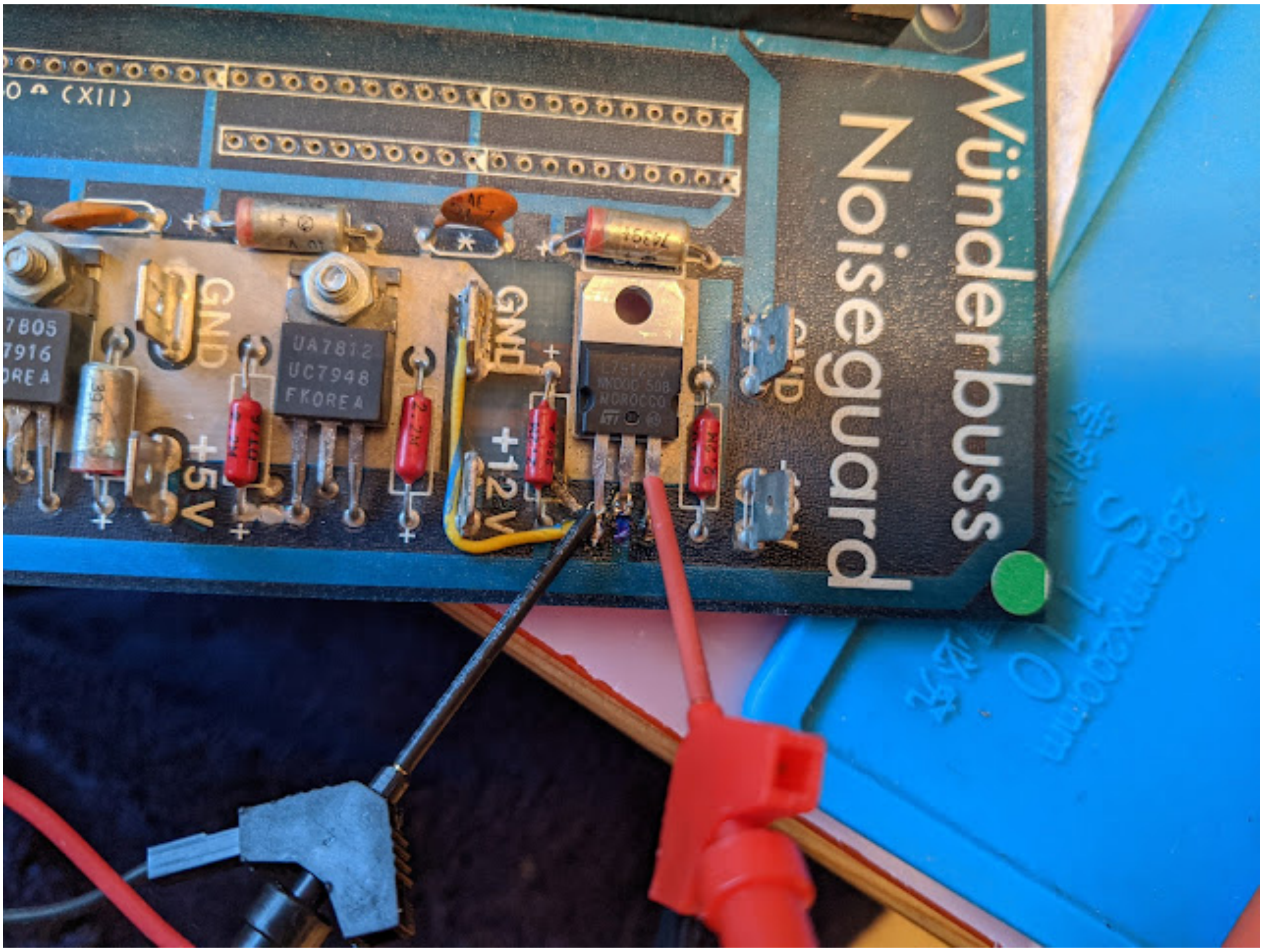
7912, -12vdc regulator.

Polarity is reversed for the -16vdc supply.



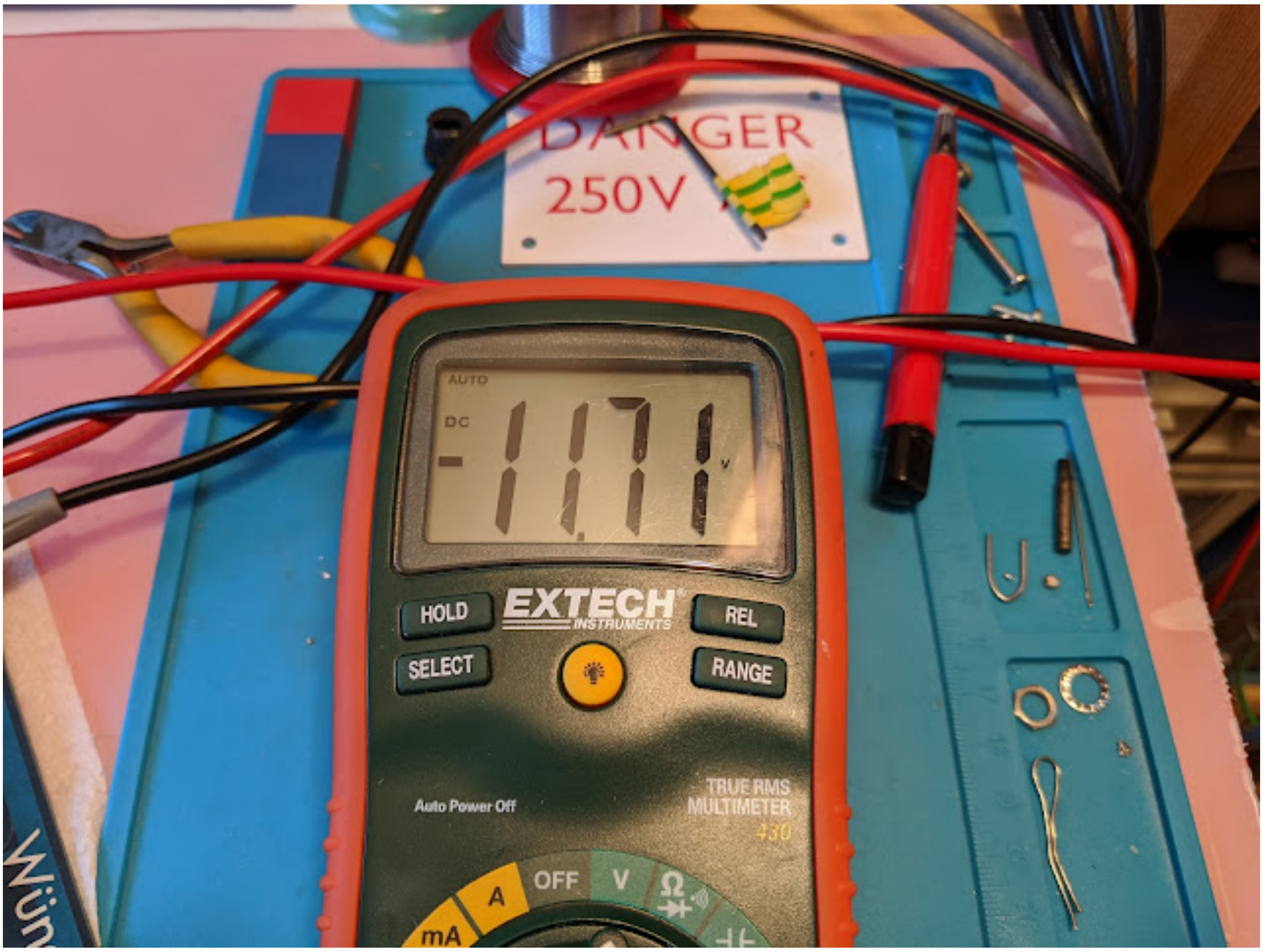
Input for -16vdc supply

Now to test the output voltage.



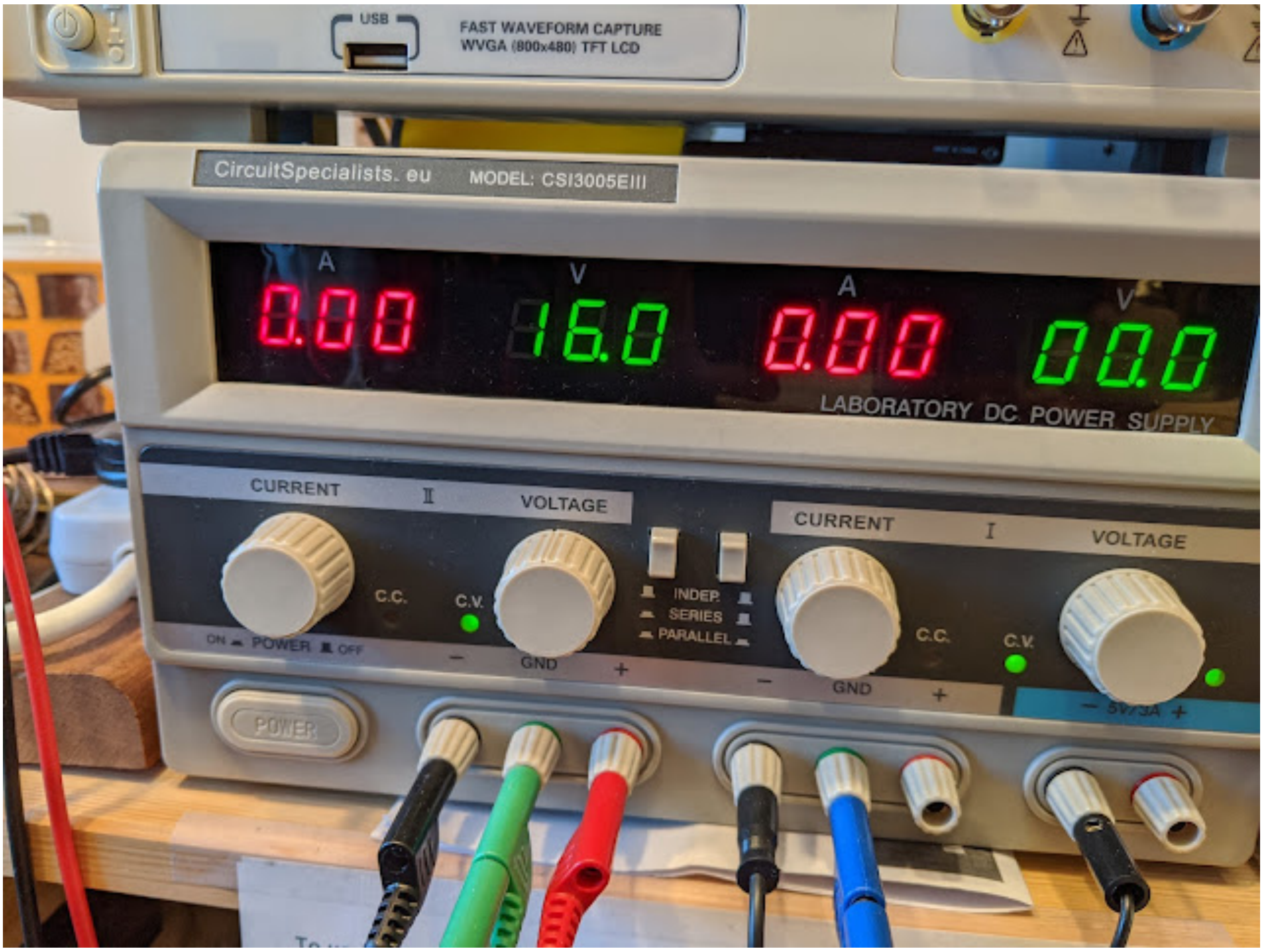
Ground is the left leg on a 7912 and output is on the right.

The output voltage is 2.4% low, but acceptable.



Output voltage from the 7912, -12vdc regulator.

The Bench Supply provides -16vdc just by reversing the polarity at the Wunderbuss.



Input voltage set at -16vdc.

The only locations we found for the 180 Ohm resistor packs were the USA and Australia. The latter were relatively expensive, so the items in the USA were purchased. Unfortunately, it will be some weeks before they arrive back here in the UK, so no further work will be done on the Wunderbuss for the time being. That said, we are in no hurry, now that it has been decided to use the IMSAI EXP-22 instead.

BLOG PART 9: The MPU Board + IMSAI EXP-22 Backplane (Part 2).

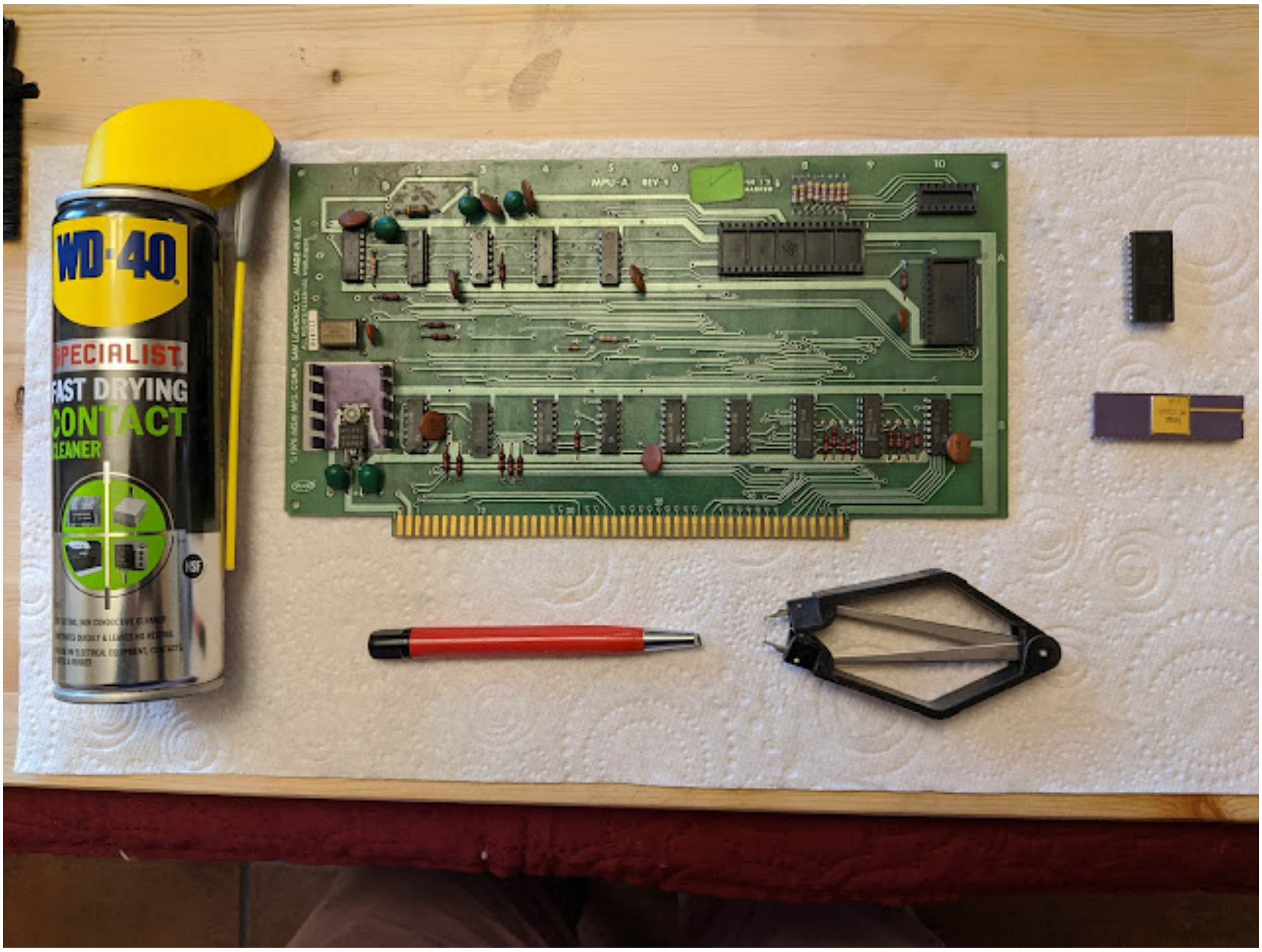
29/11/2019

While awaiting the arrival of the required amperage cable for connecting up the IMSAI EXP-22 Backplane, we are taking a look at the main CPU board for the machine: the MPU-A Rev 4 from IMSAI.

We have already established that this board is not the original but, although made a couple of years

later, is the same in every respect.

First of all, we need to clean it up.



MPU-A Rev 4 IMSAI Processor Board.

IMPORTANT NOTE:

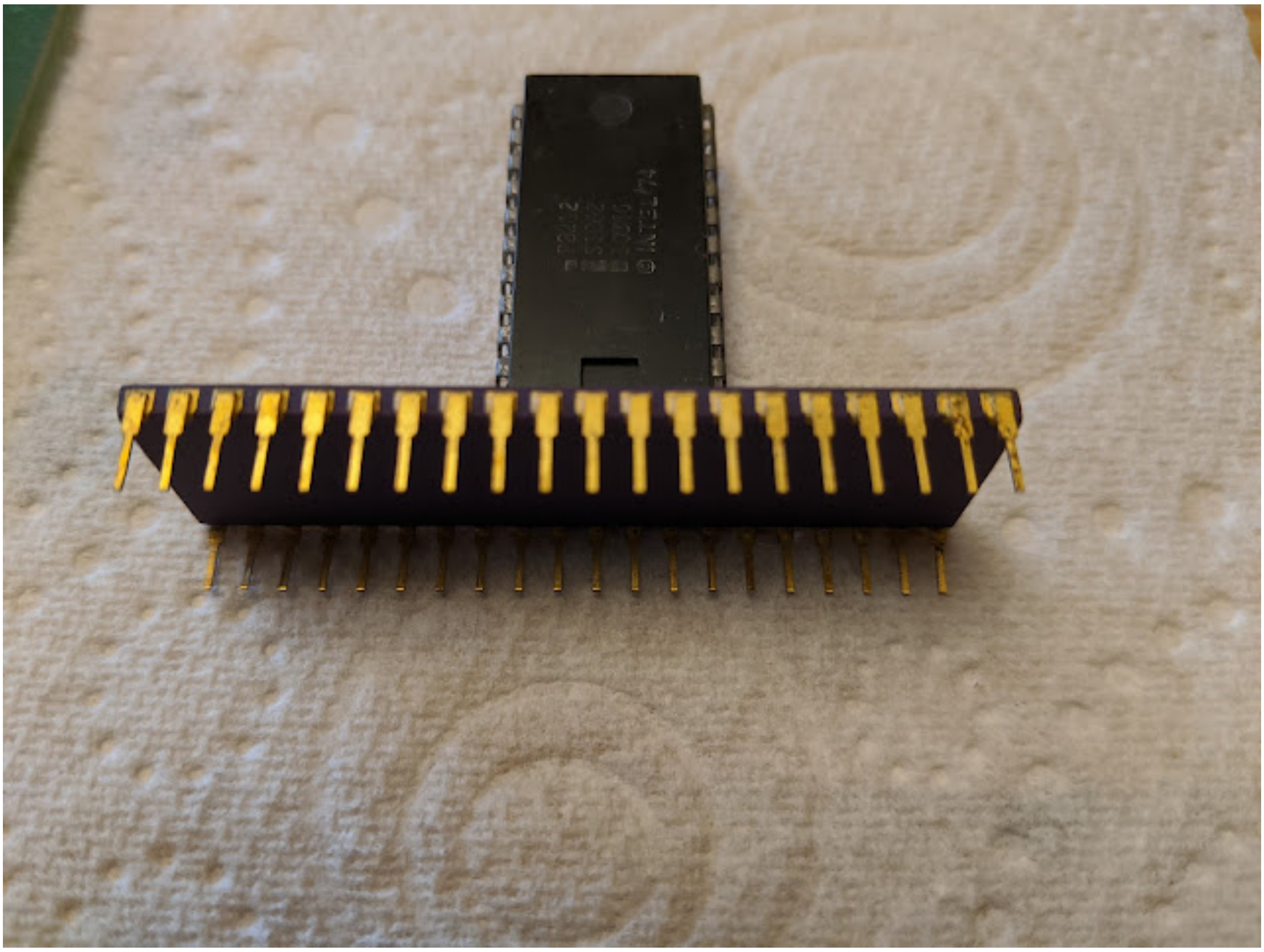
The CPU is a ceramic 8080A with gold plated pins. These are notorious for having very weak legs. Under normal circumstances, if you can avoid it DO NOT TAKE IT OUT OF THE SOCKET. By doing so, you will often find it will not go back in again without damage, and may have to resort to installing it into a Zif socket first. If possible, avoid using them altogether, in favour of normal plastic CPUs with normal metal legs.

END OF IMPORTANT NOTE.

In our case, we can see that there is corrosion on some of the legs at one end and we need to remove the CPU to check this out. Done very slowly and carefully, it was removed and examined.

As suspected, two of the end pins are showing bad signs of fatigue and probably will not go back into the socket without breaking. The Texas socket that has been used is the worst type to deal with in that respect, as they have the hardest grip.

The corrosion has made matters worse, so some very careful, painstaking, cleaning with a fibreglass pen was carried out, with each leg fully supported during this delicate operation.



Bad corrosion on the end pins at both sides.

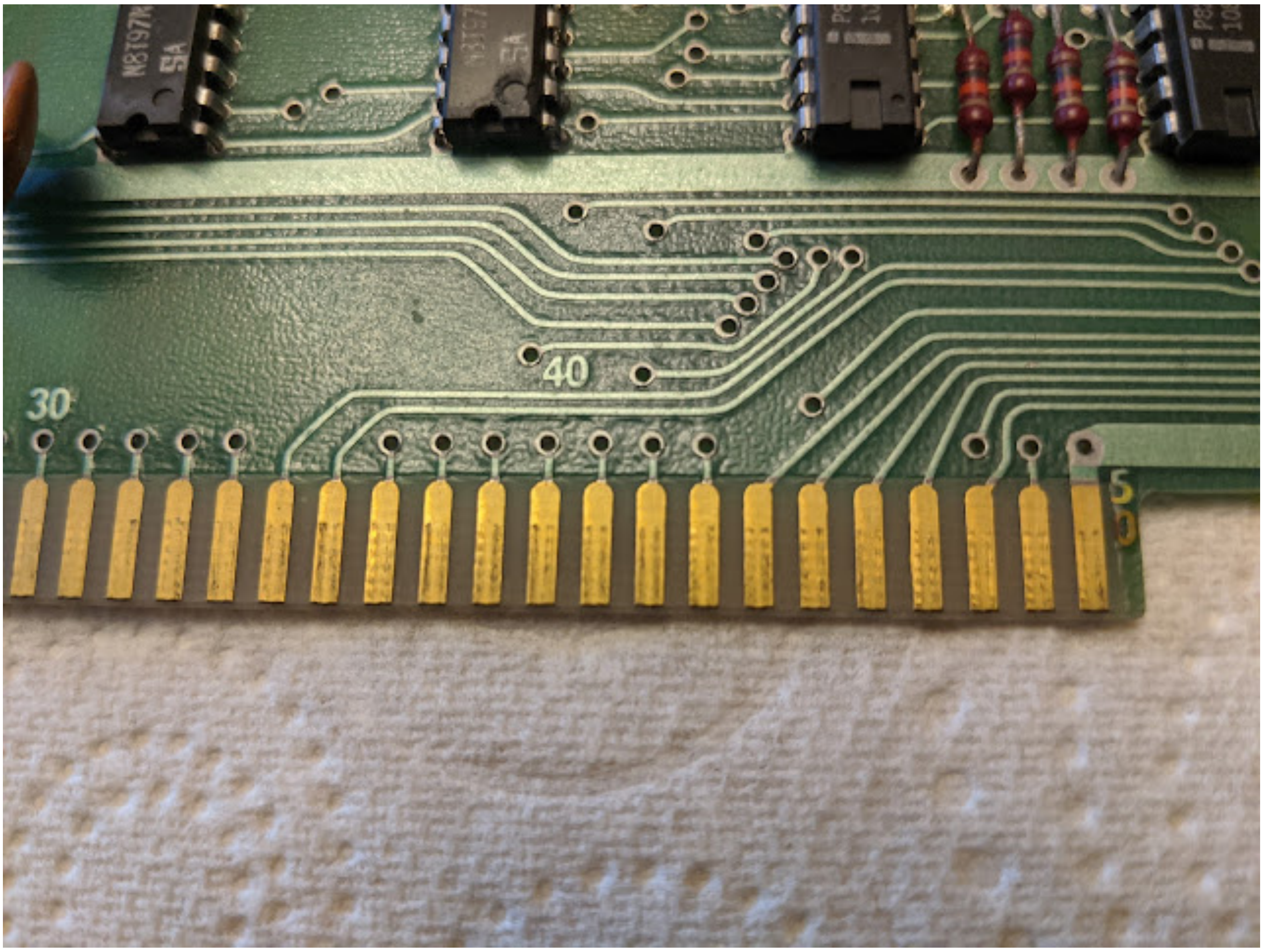
A tiny amount of solder was then applied to the inside top of the two weak legs, at their weakest point, which is always near the top where they widen out.

The Texas socket was sprayed with contact cleaner, then great care was taken in putting the CPU back and using a continuity checker to make sure we had good contact with the socket on these two pins especially. The solder had been just enough to get them back into the socket. A label was then put on the board to advise against any further removal.

The 8212 IC is the only other one that can be removed, so it was taken out, the socket sprayed with contact cleaner, and the pins cleaned before re-instetion.

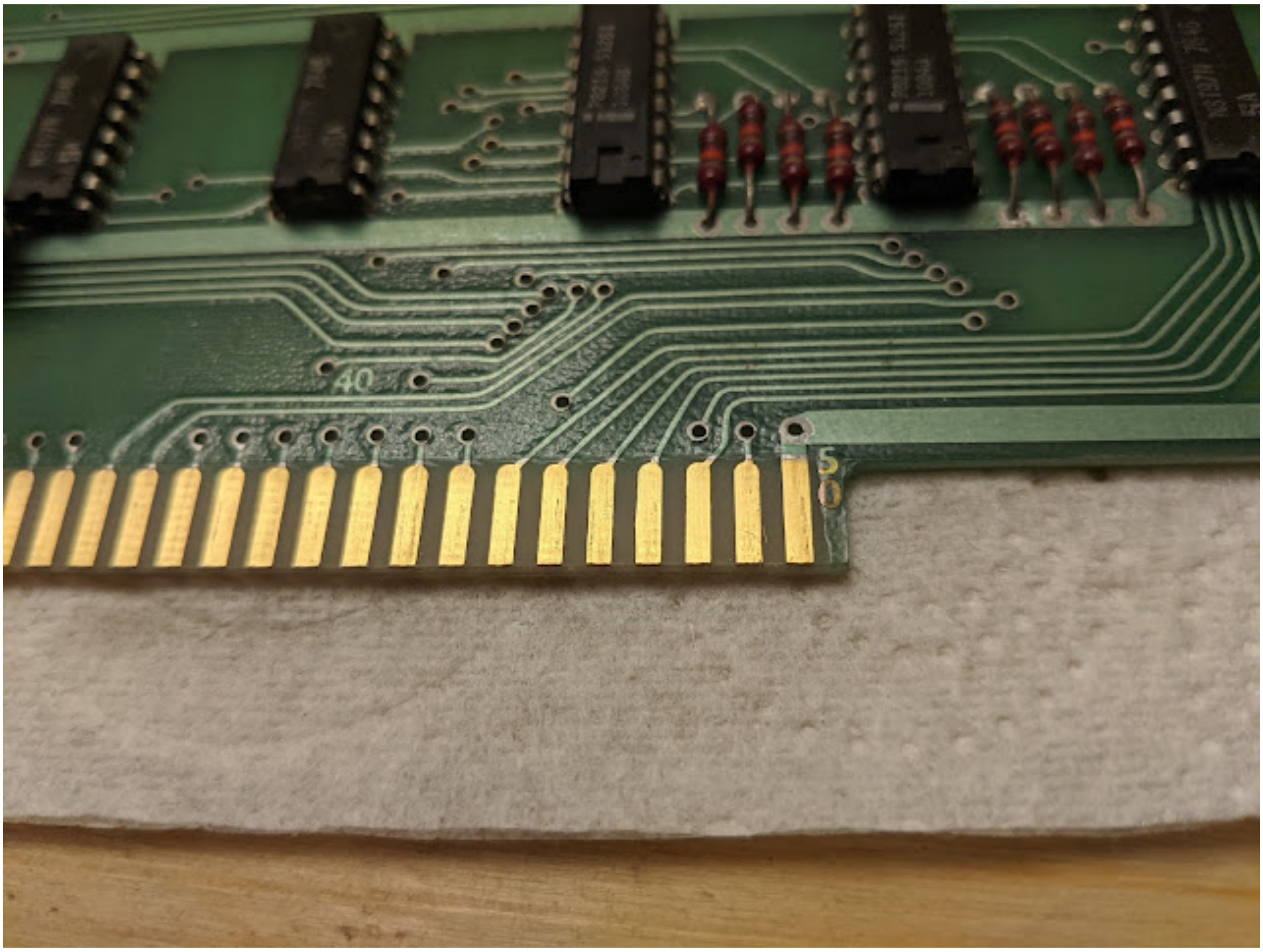
Finally, the gold plated edge S-100 connector was cleaned with the fibreglass pen. Here you can see the before and after images:

Before......



Gold-plated Edge-connector before cleaning.

After......



Gold-plated Edge-connector after cleaning.

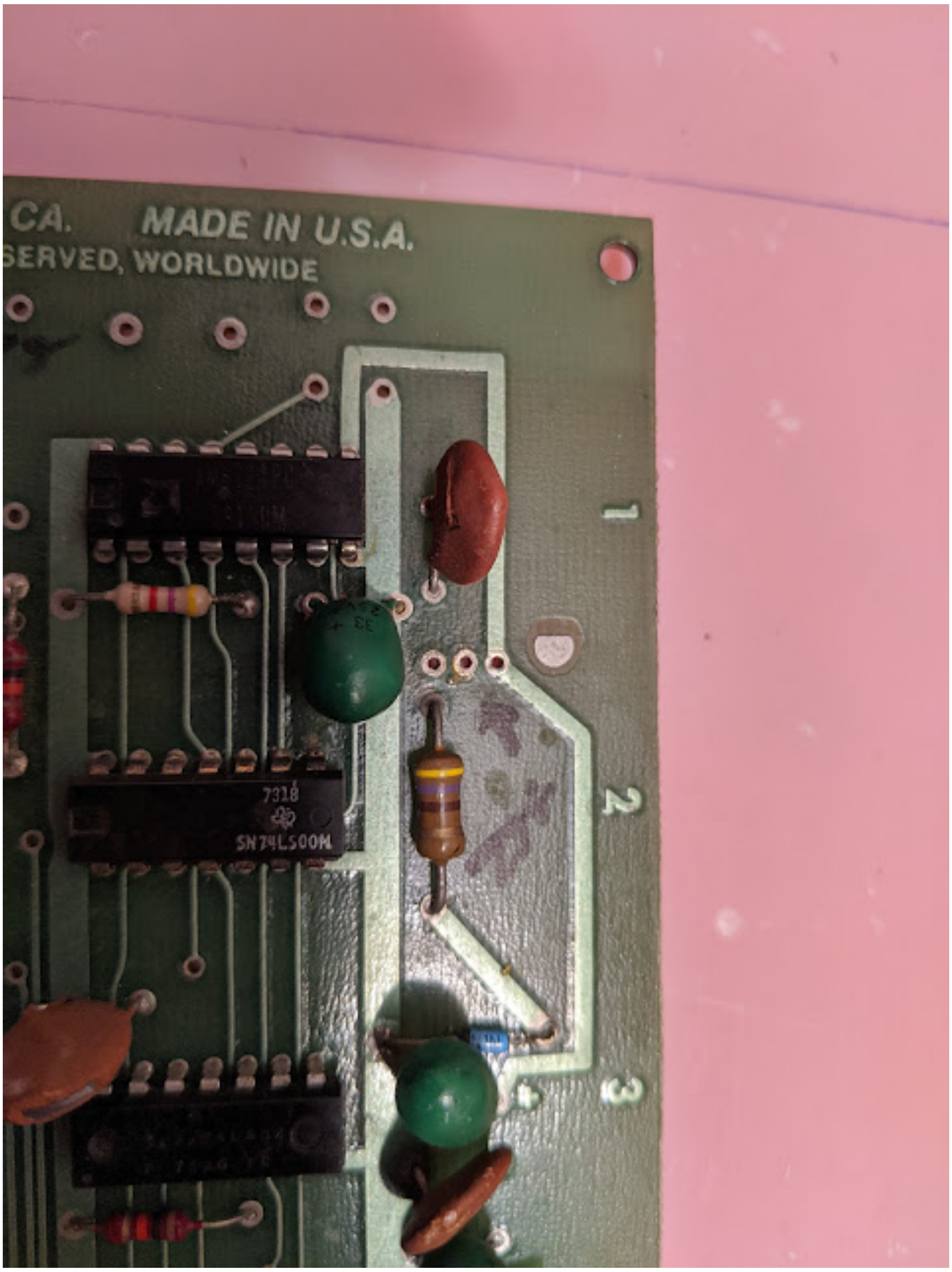
In cleaning the board with White Spirit, cloth and Cotton Buds, it was noticed that a component was missing. The 78L12, low-current +12v Regulator had been removed for some reason, and a small note in felt-tip saying +12 was written beside it saying +12.

Clearly this is not a working board and something has gone wrong in it's past that has not been fixed.

A 78L12 has been ordered, so that we can fit it and find out what other problems may be lurking.

In the meantime, the Tantalum capacitors were checked to make sure none were short circuit: a common problem. Some people automatically replace them given their age. Personally, I prefer to not to, and take my chances.

By bringing the voltage up slowly with a Variac, I have never had one fail. The only time one did, was when connecting a Floppy Disk Drive directly to a +5v supply and switching on without winding the voltage up. Maybe I have just been lucky........

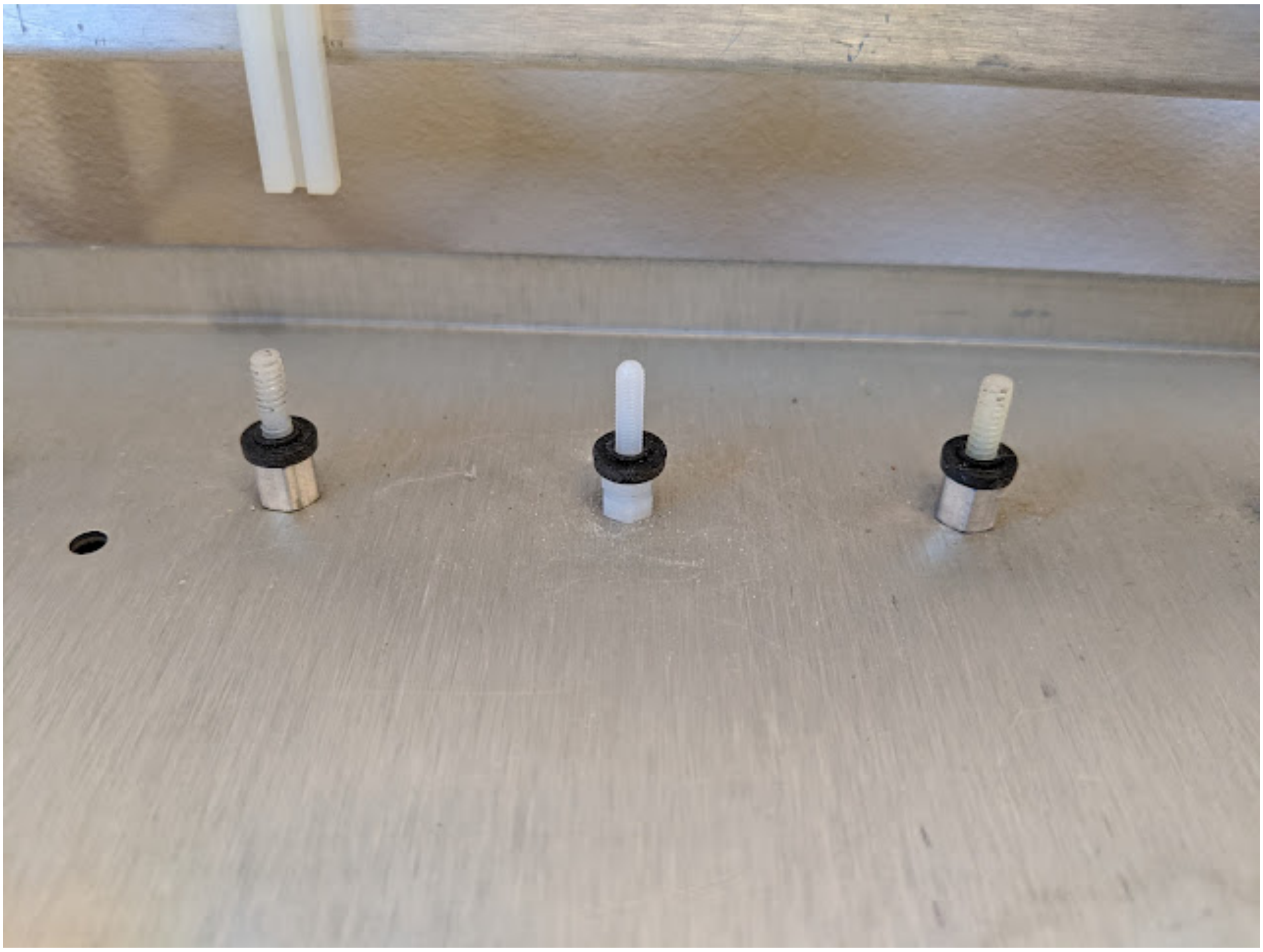


Missing +12v Regulator.

01/12/2019

The day has been spent preparing and fitting the IMSAI EXP-22 Backplane.

First of all, we had one pair of nylon bolts missing, so used a modern replacement, with two nuts that would allow us to create the same height for the washer.

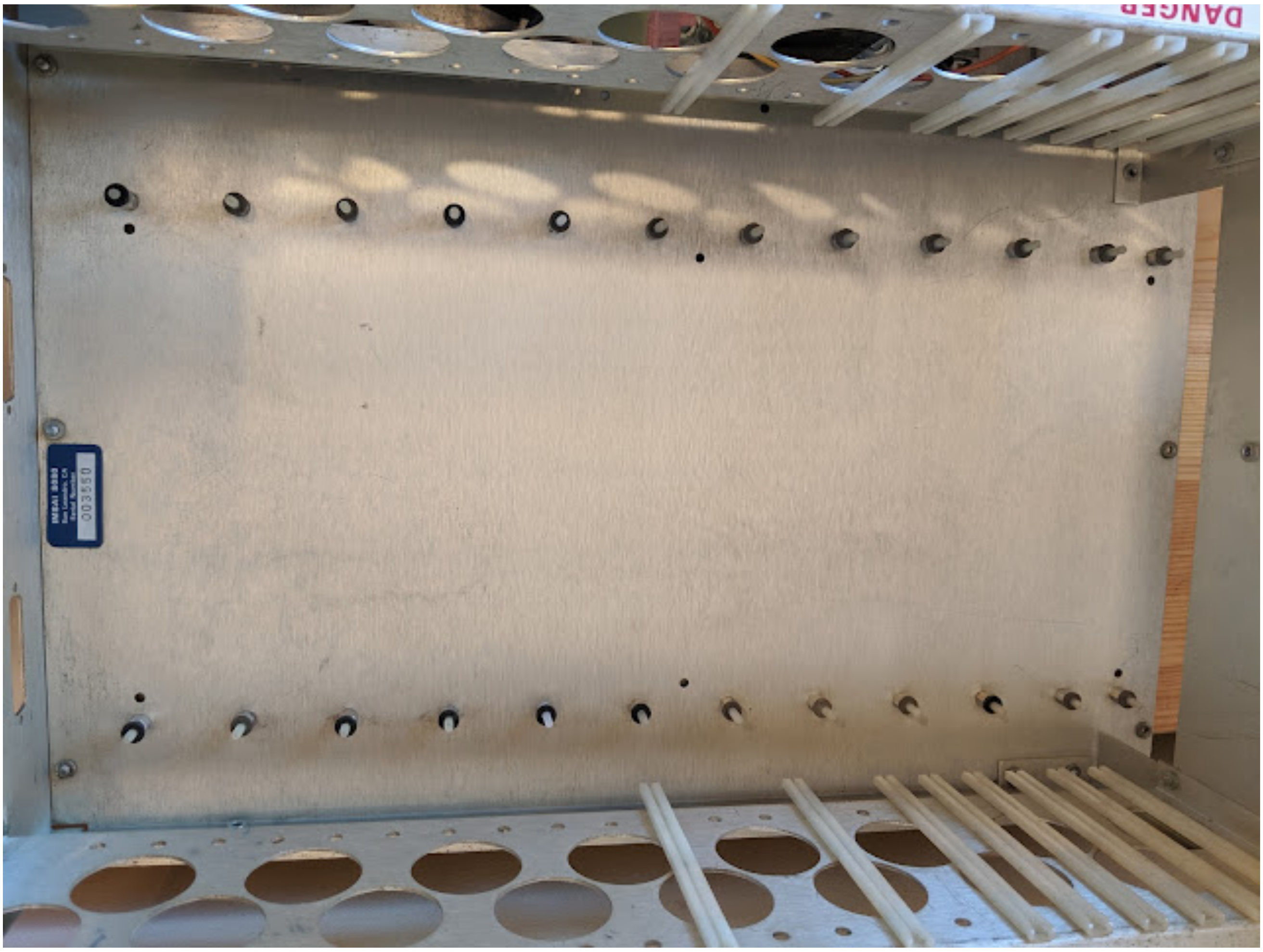


Missing nylon bolt replaced.

It is important to note that the washer underneath the Backplane, and above it, both need to have the ridge pointing into the hole. Many that we took off were installed incorrectly.

Ridge on washers.

The chassis is ready to accept the Backplane.

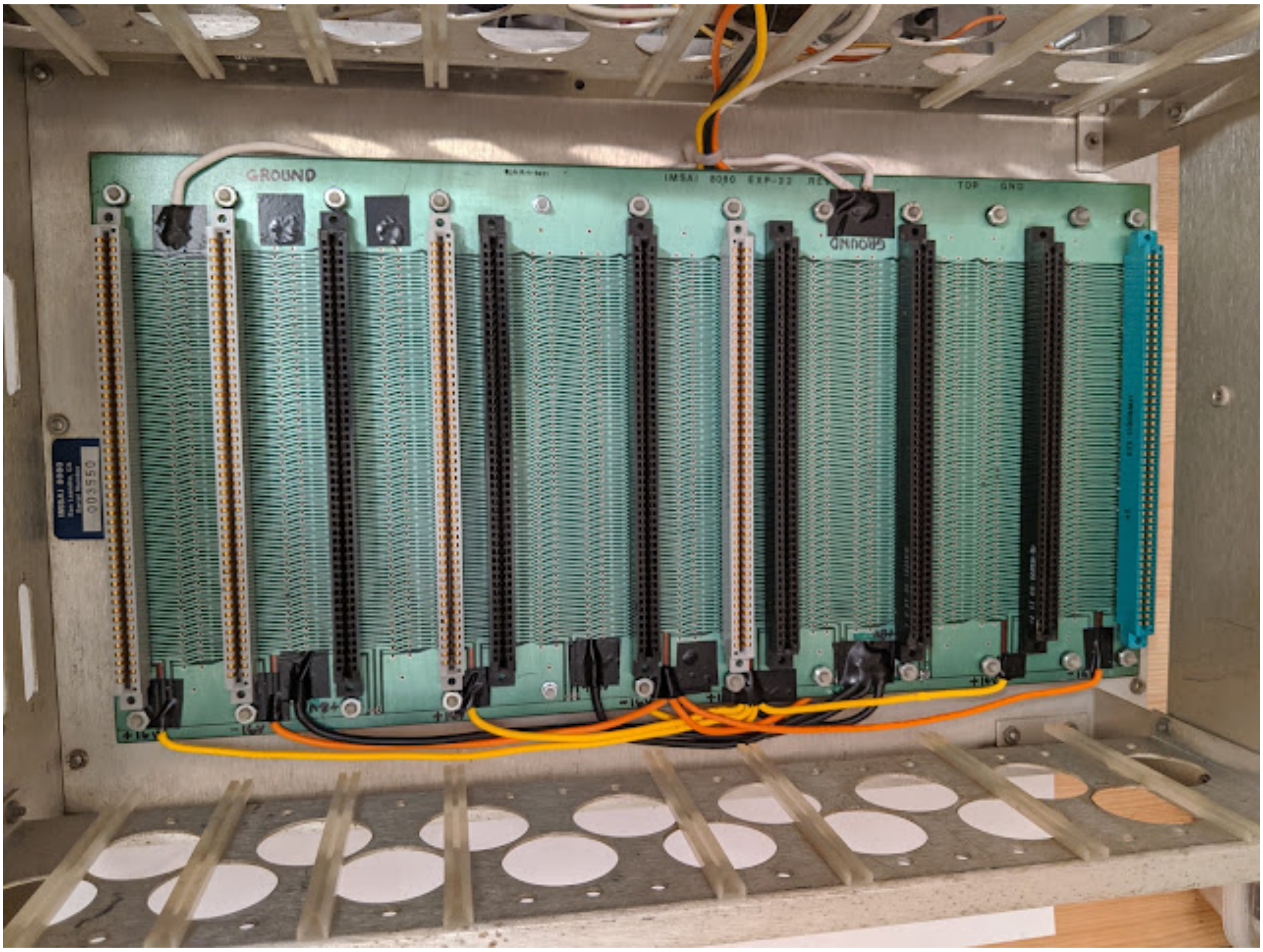


Backplane mountings.

The board has been tidied up as best we can, and the required gauge of wires has been soldered to the backplane, in a number of places for each voltage, which is designed to spread the load in the event that we run with significant amps on the DC lines in the future.

The wires for +8vdc, +16vdc, -16vdc and Ground, have been brought over to the PSU, where we will fit in-line fuses, before hooking up to the PSU outputs.

The limited number of Guide Rails that we have are now re-positioned to make best use of them with the available connectors. In particular, we want to make use of the four high quality heavily gold-plated connectors.



Backplane installed.

Before connecting the Backplane to the PSU outputs, we want to insert an extra layer of protection for the S-100 boards and safety for the operator by reducing the risk of fire.

As the equipment being installed is circa 45 years old now, the likelihood of board failure from shorted tantalum capacitors and other components reaching end of life has probably increased significantly.

The use of in-line fast-blow fuses on the DC lines, where the values of the fuses are selected to closely match the known configuration's normal current draw, will disable the circuit where any abnormal load is detected.

A harness to achieve this has been made up using 20 Amp wire and 20/25 Amp Connection blocks. We have taken the decision previously not to run the +8vdc part of the system above 20 Amps, so this will suffice.

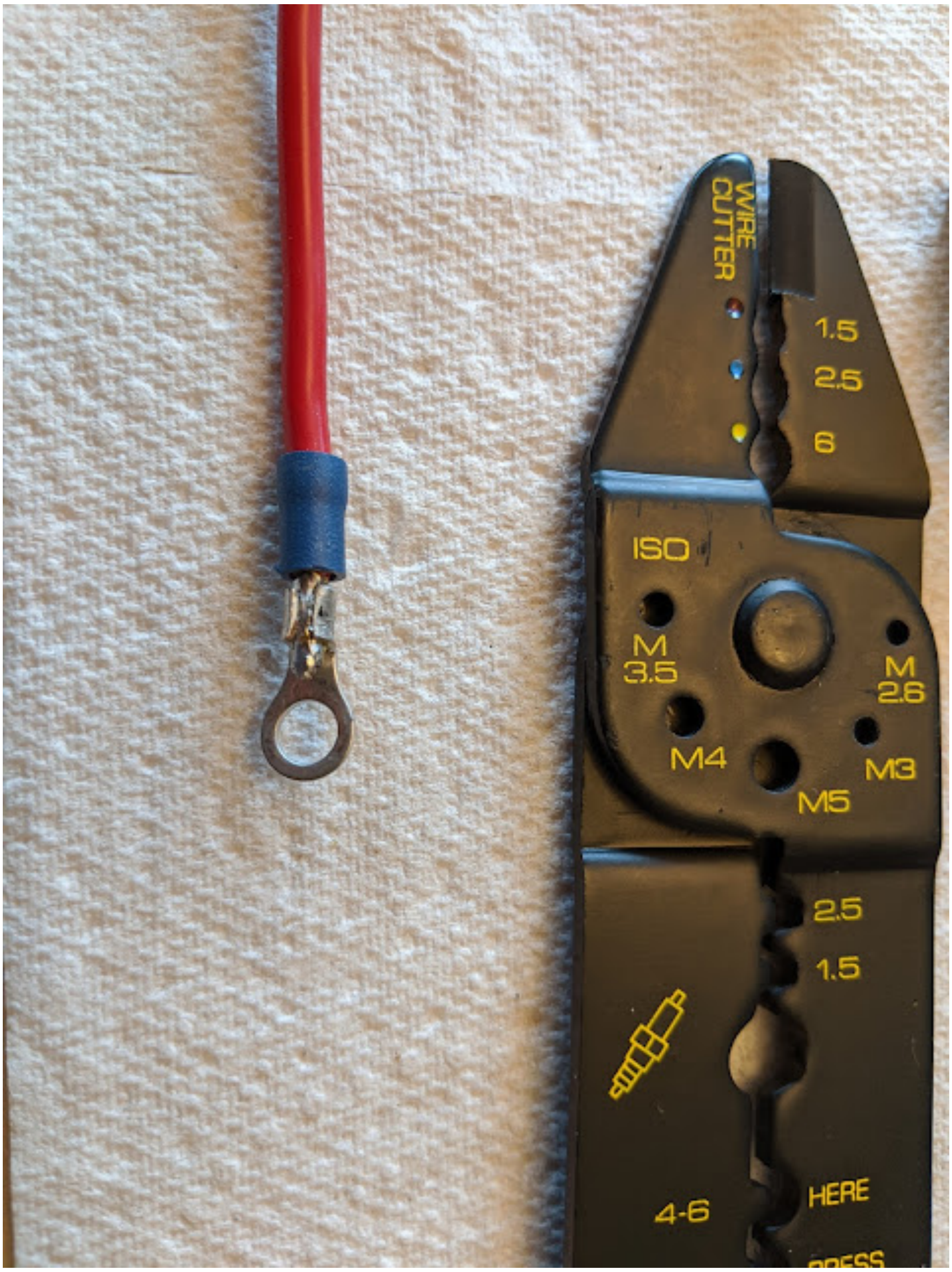
To make this up, the cable ends are tinned with a 40 watt Soldering Iron, then crimped, before finally being soldered to the connectors. We are unlikely to be able to achieve a connection capable of supporting 20 Amps with a normal crimper, so soldering is essential.

Cable ends ready to be tinned.

The crimp connector is easily opened up with a pair of wire cutters.

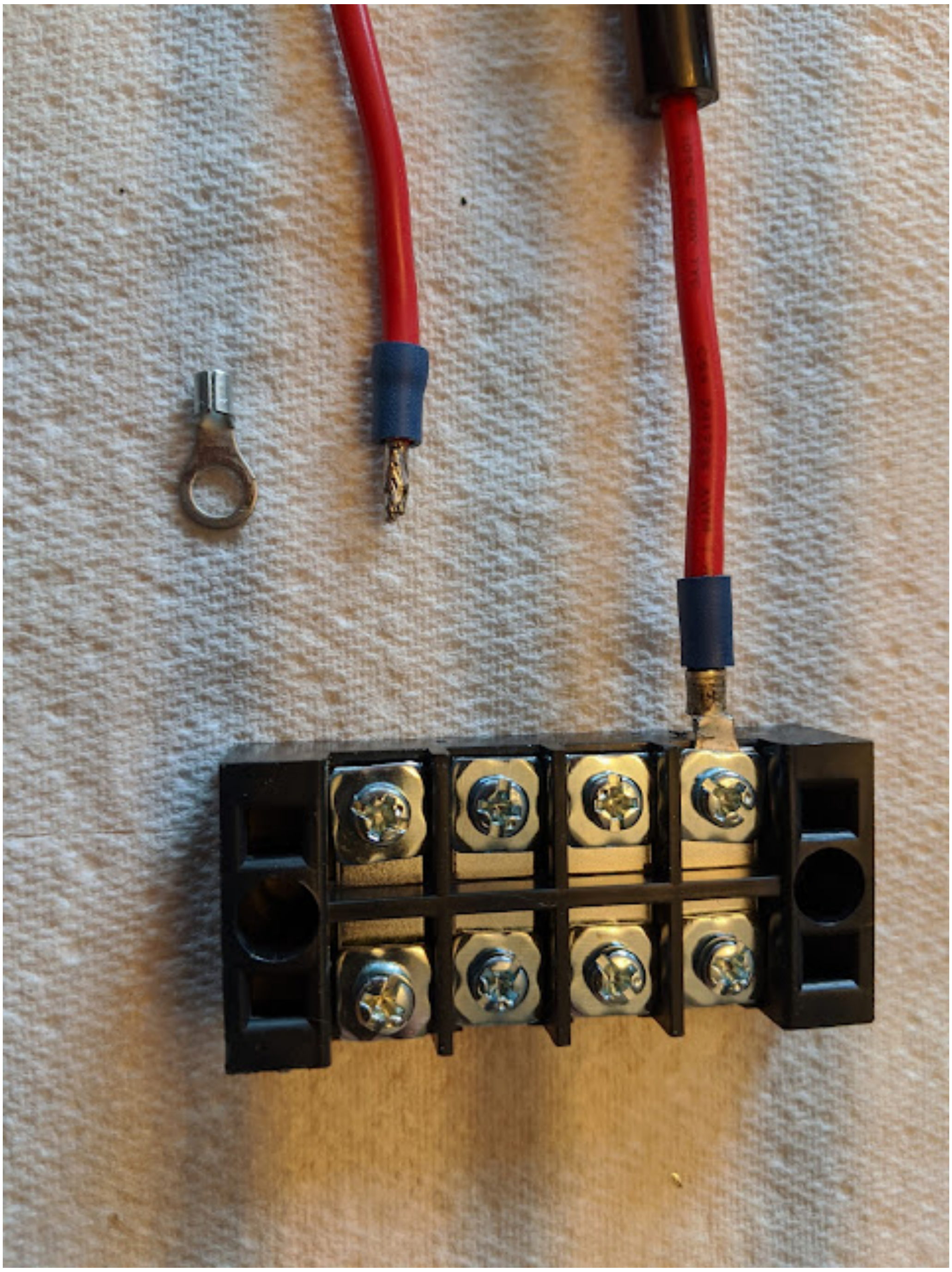
Crimp connector opened up.

Next, we crimp the connector onto the tinned end of the cable, not too hard: just enough to hold it in place while it is soldered.



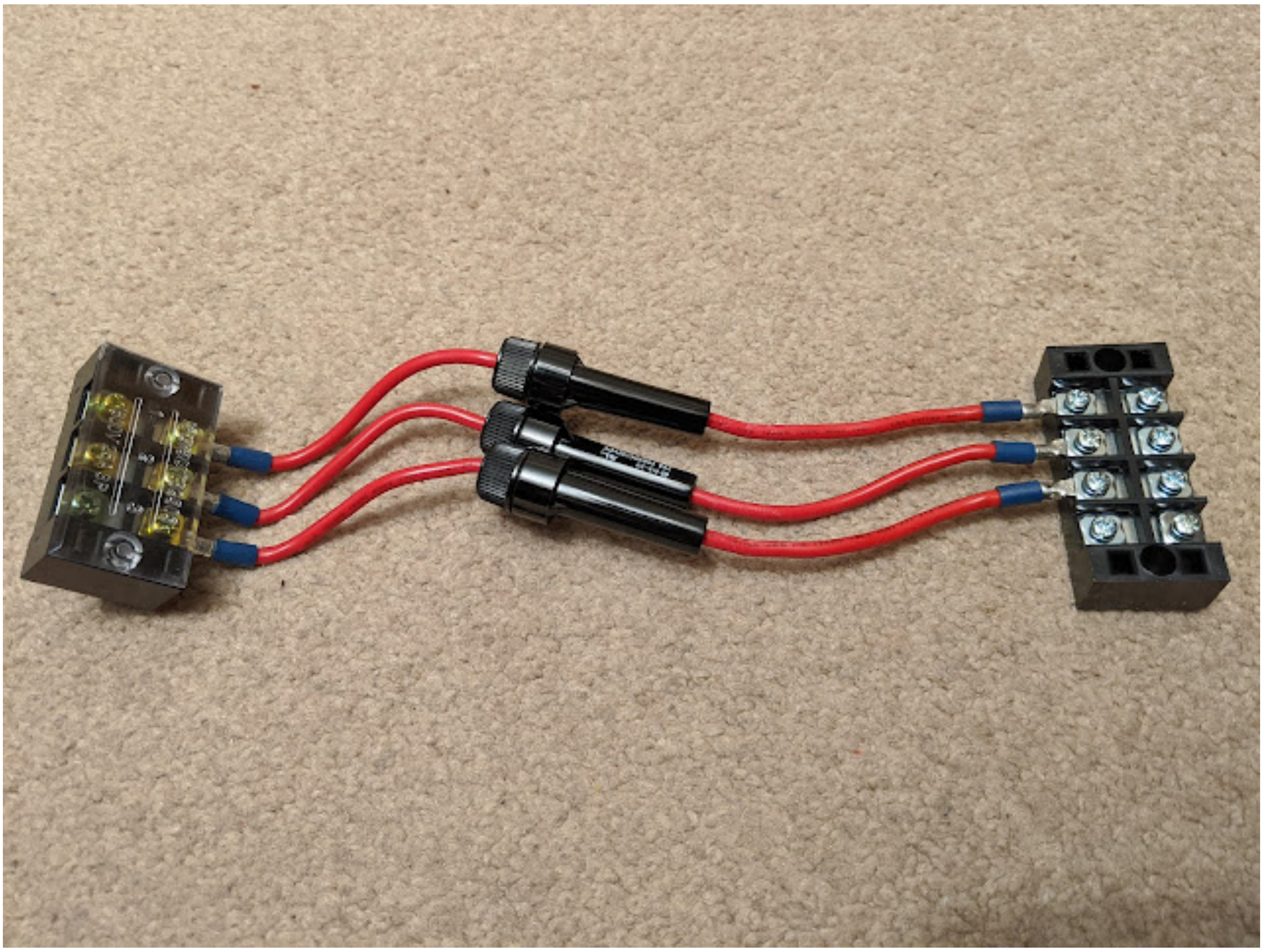
Connector crimped onto tinned cable end.

Finally, the soldered connector is screwed onto the connector block. This will be able to carry the maximum 20 Amp current we are working to. The process is then repeated for all cables.



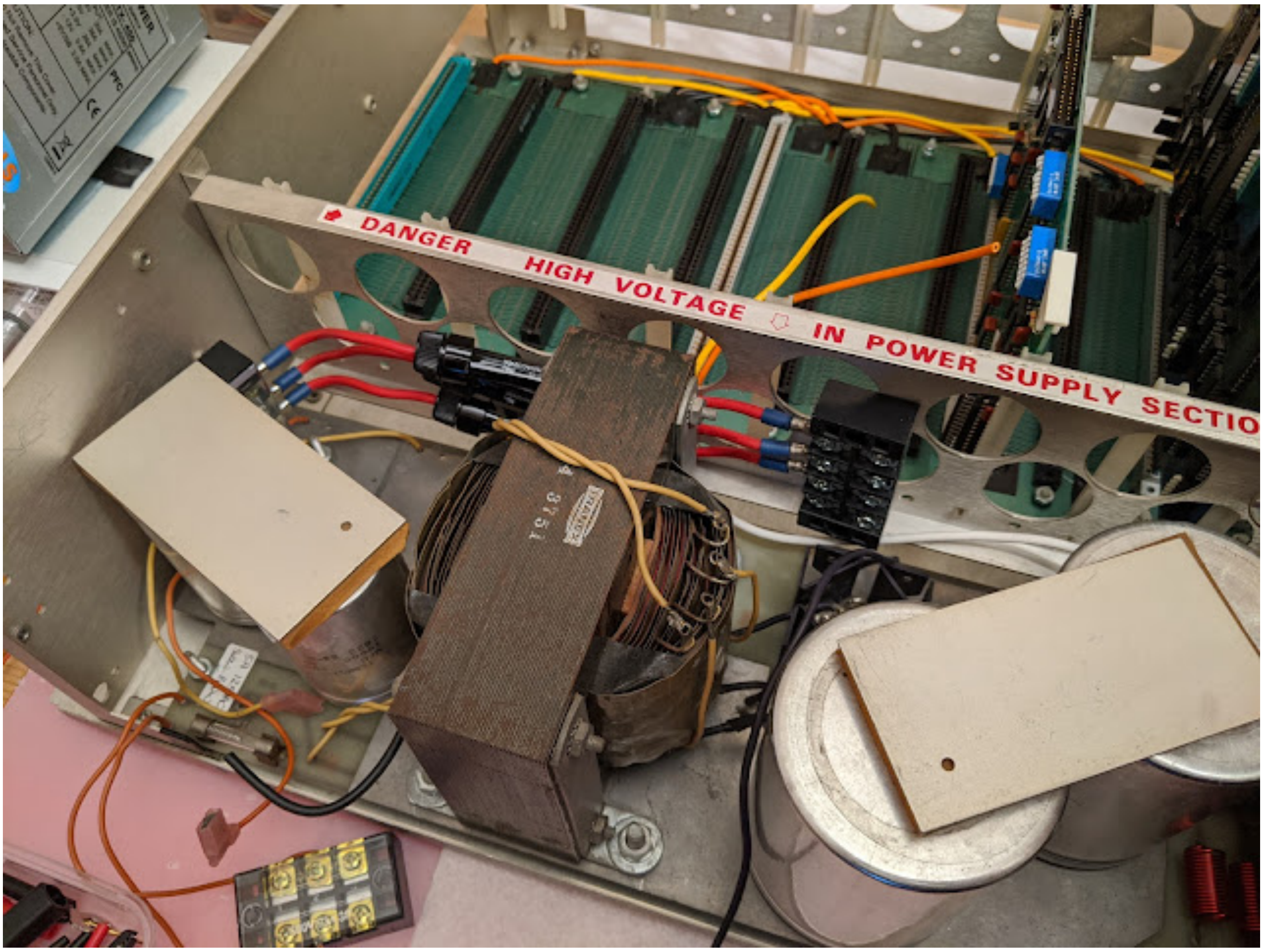
Soldered connector screwed onto terminal block.

The final configuration is now ready to be dropped into place in the PSU.



DC in-line quick-blow fuse harness. 20 Amps.

Positioning within the PSU will vary according to which IMSAI 8080 PSU we are dealing with, but with our PS-28D, it looks like this:



Fuse harness ready to be fixed into position.

The fuses are readily accessible in case they need to be replaced, yet the harness does not detract from the original look too much. The cable ends from the Backplane can be seen, ready to be cut to length and the connectors soldered to the ends before hooking them up to the fuse harness.

We are now going to turn our attention to the Front Panel Board in the next blog......

BLOG PART 10: The Front Panel Board.

05/12/2019

We now turn out attention to the Front Panel Board. We are going to take a sneak preview here by placing the board into a test rig, bringing it up slowly, and seeing what works and what doesn't. If you do not have a test rig then don't despair, it is not essential.

Tests show that the 7805 on-board regulator is outputting 4.95vdc, so we next check the function of the switches.

The results are not encouraging:

1. Examine not working in terms of displaying address

2. Examine Next not working in terms of displaying address

3. Deposit not working in terms of displaying data, possibly not actually depositing

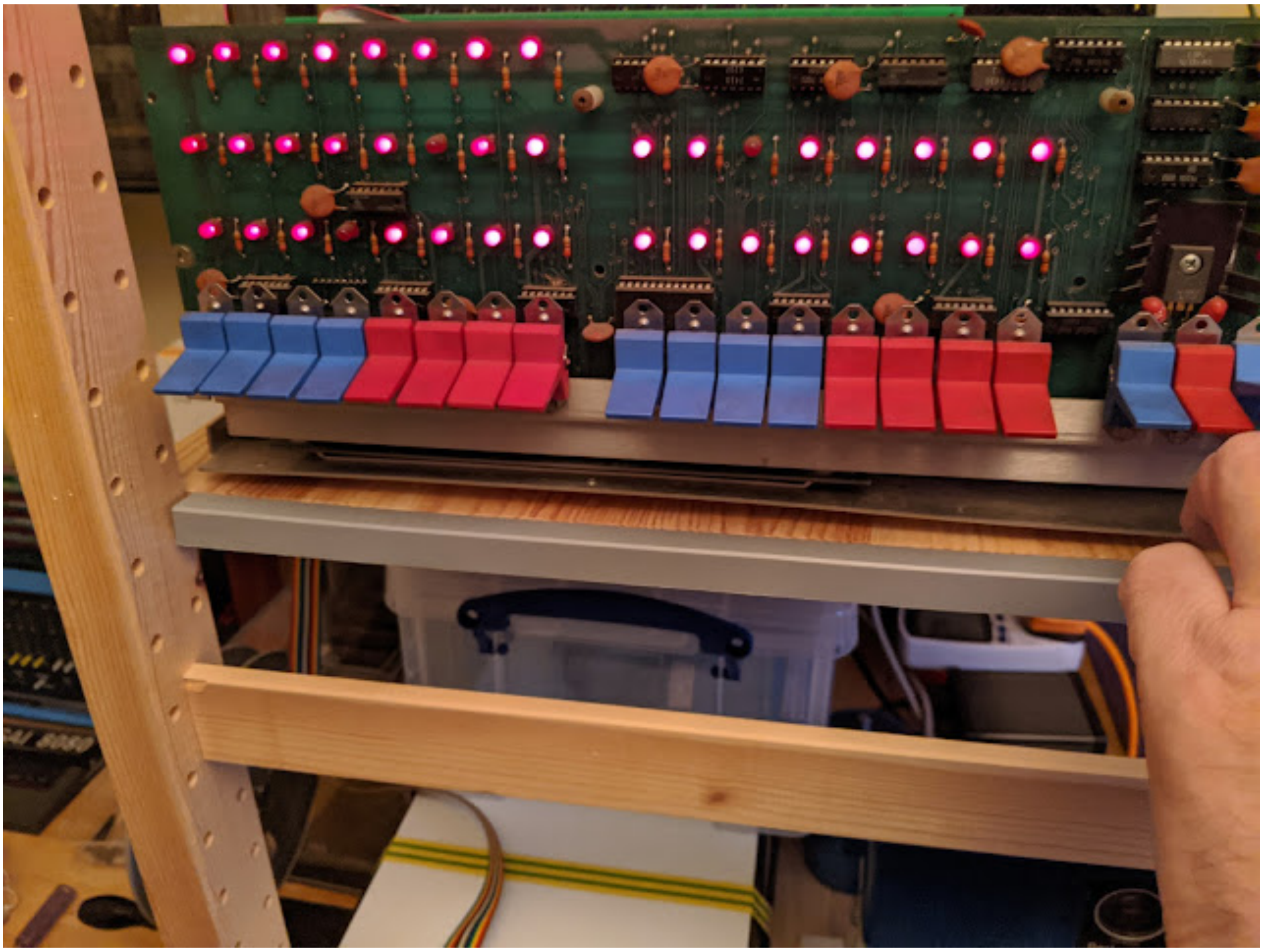
4. Deposit Next not working, in terms of displaying data, possibly not actually depositing

5. Single Step (Up and Down) not working in terms of displaying address

6. 3 LEDS not working: Address 12; Stack; Data 5; (unable to test HOLD)

We were able to set the address to F800 with the switches and then performed STOP+RESET and then Examine. This worked, even though the address was not displayed. We know, because hitting RUN launched ALTMON in the installed EPROM, as expected, and displayed the * prompt on the terminal.

The only keys that appear to work are: STOP; RUN; RESET. By holding STOP + RESET, which should light up all the LEDs, we can see that there are problems with three of them.



Holding STOP + RESET to see which LEDs don't light up.

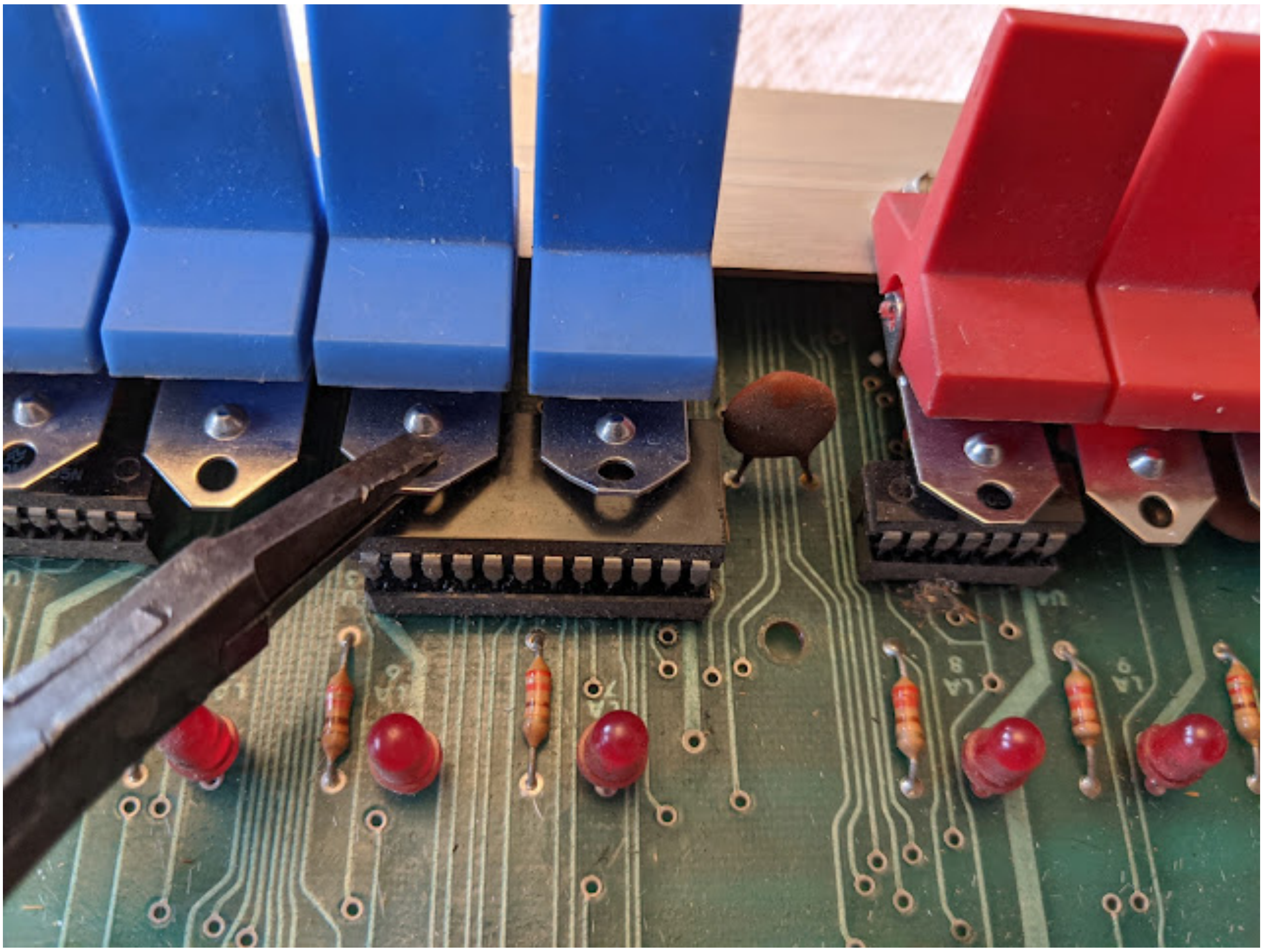
As the restored chassis is now ready for accepting S-100 boards, we could have performed these tests on the machine itself in due course. Using the test rig just short-cut this process because it already has a proven setup with CPU Board, Serial Board, RAM, Terminal, etc. which helps to eliminate other issues that have nothing to do with the Front Panel Board.

This has given us an insight into the state of the board, before we move to deep cleaning it and testing the components.

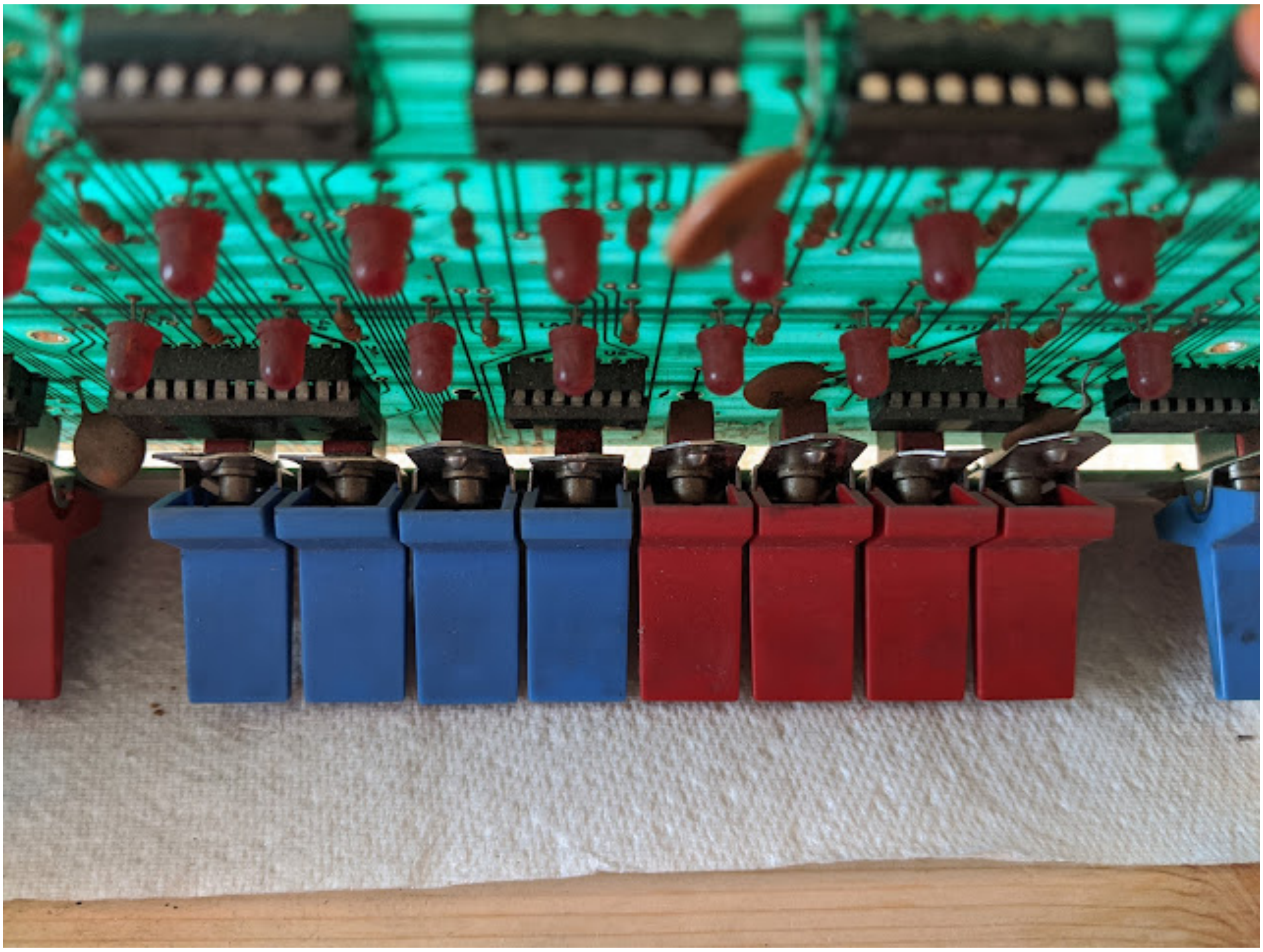
To begin with, we need to remove all ICs and clean and test them.

Some of the ICs are impossible to remove without carefully bending the switch backing plates to create enough room.

A small flat-faced pair of pliers are used to gentle ease the plates up to create enough room, above those IC's where space is too tight. After cleaning and replacement of the IC, the plate is only bent back just enough to allow the switch to operate. This makes any removal easier in the future.



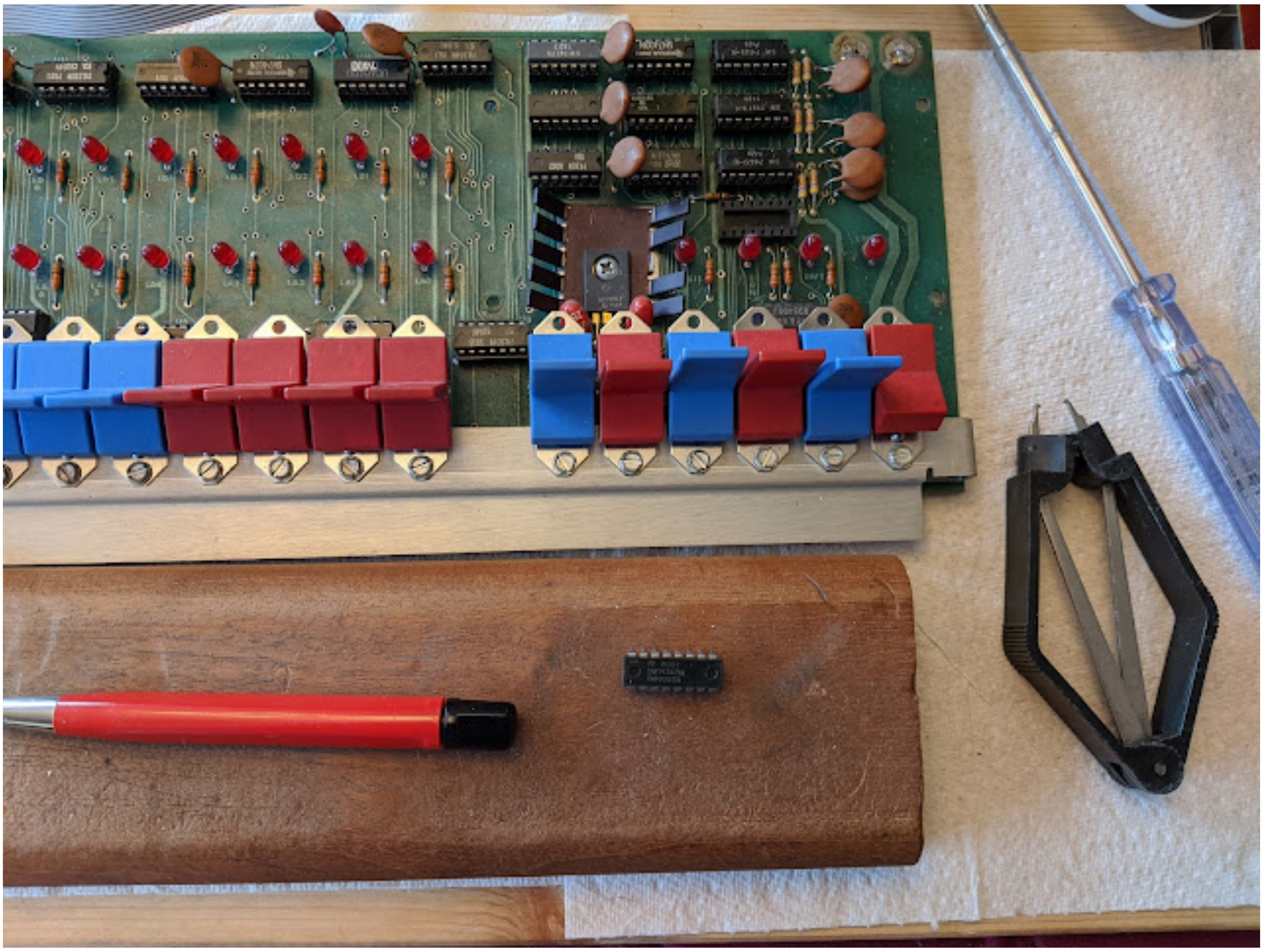
Bending switch backing plates.



The ICs are all now accesible.

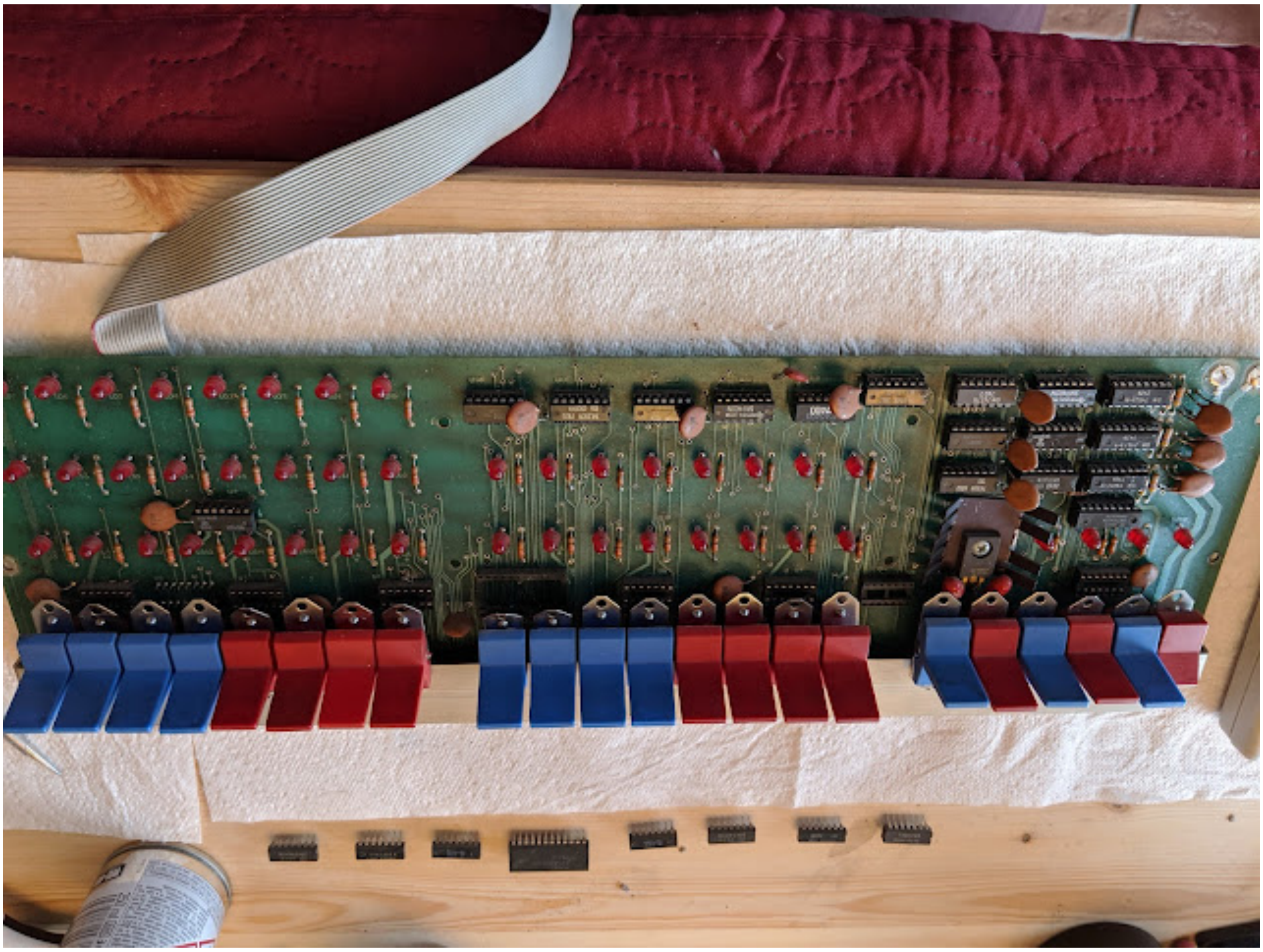
It is usually easier to use a small screwdriver to loosen the ICs a little, before the IC puller is applied to them and they are rocked out of the socket. A small piece of hardwood allows the IC pins to be held flat against it for cleaning the inside of the legs.

Use vinyl gloves and a face mask to avoid the glass fibres from the cleaning pen. Laying everything onto paper kitchen roll catches the fibres and allows them to be easily wrapped up and disposed of in the bin.



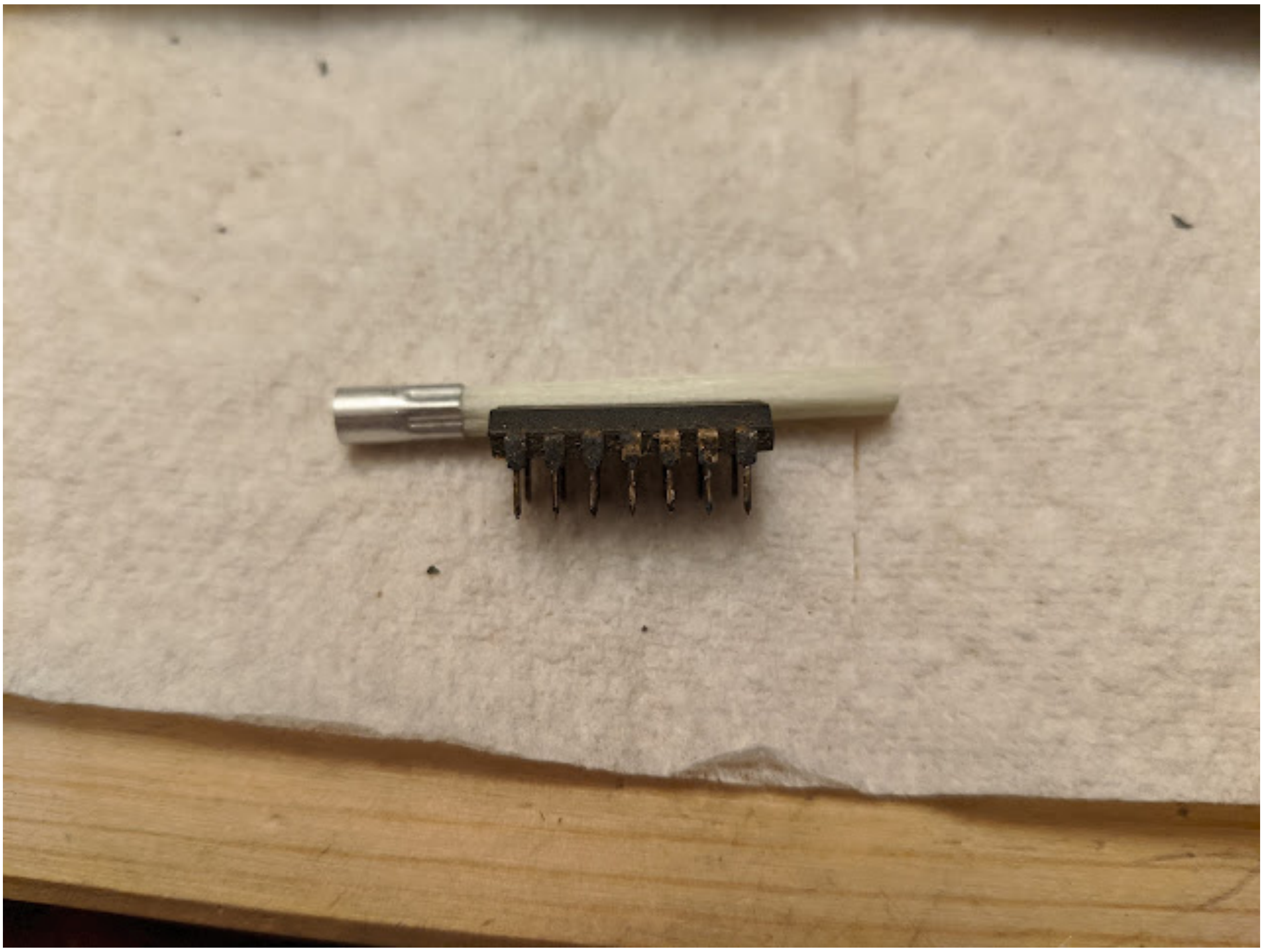
IC removal and cleaning tools.

The hardest part by far is dealing with the ICs behind the switches.



The bottom row of ICs removed for checking and cleaning.

Some of the ICs are badly clogged with the 'gunk' of ages......



Fibre pen used for cleaning legs of ICs.

After using a fibre pen to carefully clean the pins, we need to test the functionality of each.

The first tool used is a low-cost, generic IC tester. Nearly all of what we are going to deal with are 7400 series ICs.

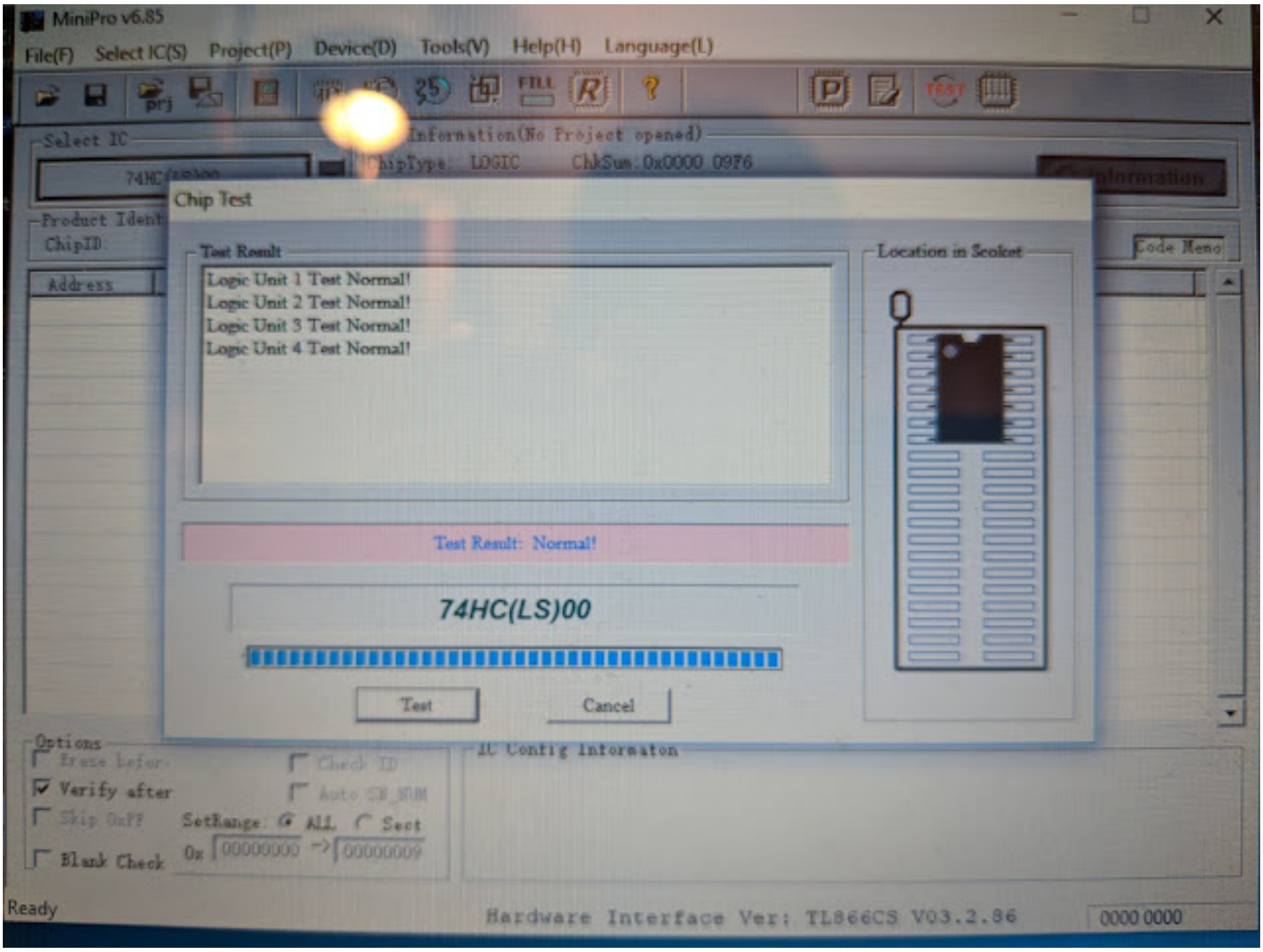
Generic IC tester.

Unfortunately, the above tester is unable to deal with some common 7400 series ICs and, in fact, gives false 'Faulty' results for others. Nevertheless, once you have learned to avoid these, it is a quick and easy way to check the majority.

For the remainder, we resort to using a seemingly little known feature of the Minipro EPROM Programmer, hooked up via USB to a laptop/PC.

Minipro EPROM Programmer.

The software that comes with the Minipro allows us to select 'Logic Units' (aka ICs) and test them. This deals with most that the generic tester can't manage.



This highlighted a number of problems:

Firstly, U25 was a Fairchild chip, that uses a different numbering system. To make identification easier in the future, it was replaced with the equivalent 7400 series IC.

U9, U14 and U16 were so badly clogged that it was felt best to replace them as, even after cleaning, they did not look too good.

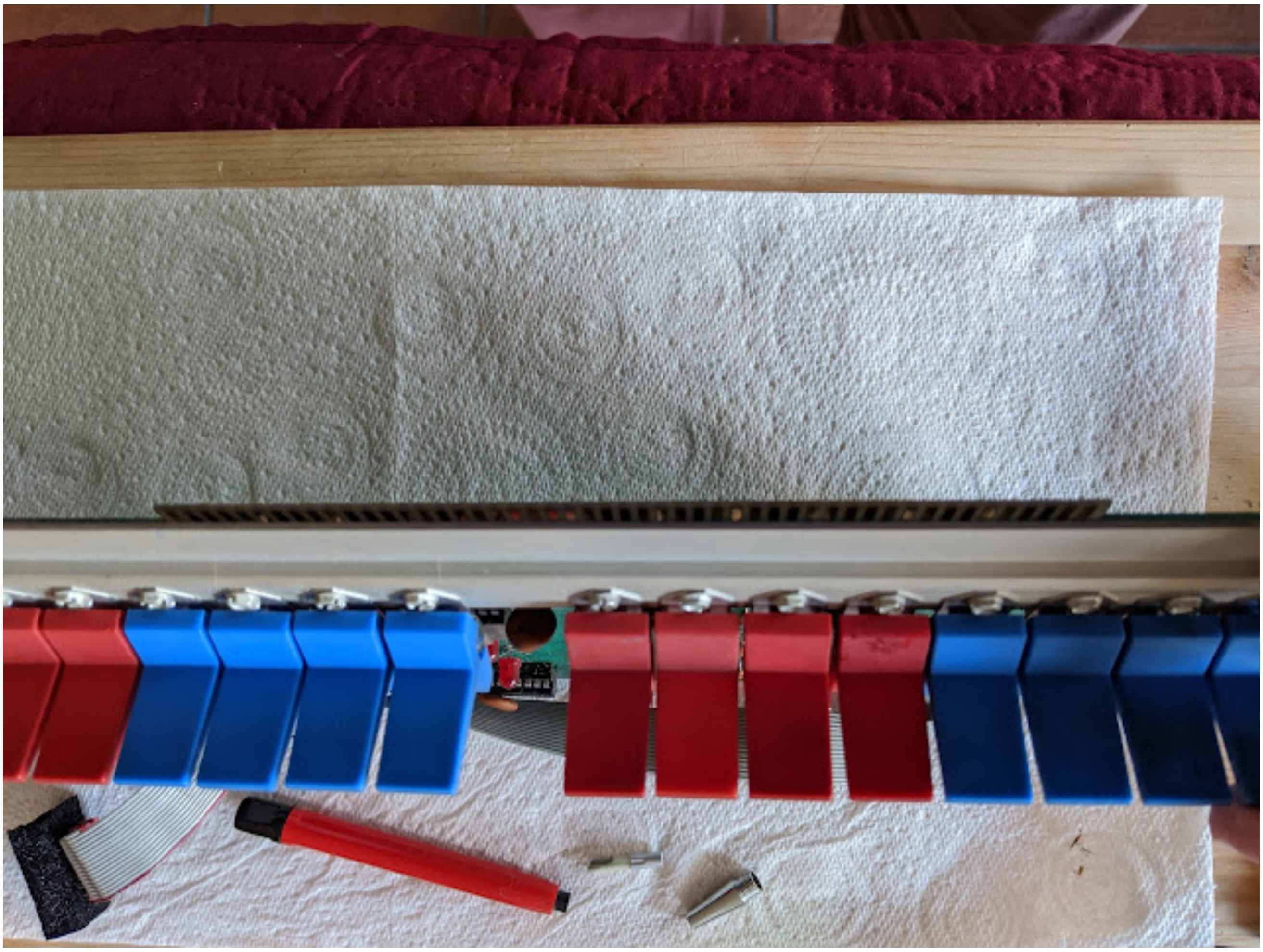
U11 had already had a broken leg soldered back onto it, so it was replaced.

U11 and U12 were the wrong way around. U11 should have been a 74LS10 and U12 a 7410. An easy mistake to have made originally that would probably have caused intermittent problems.

Our testers could not deal with 74107 ICs, so all three at U18,U19 and U22 were replaced with new. The same was true for the larger 8212 IC at U5.

After careful cleaning, all sockets were sprayed with WD40 Contact Cleaner prior to insertion of the IC.

It is important not to forget to clean the S-100 edge connections. One side is hidden behind the switch support bracket and is tricky to clean.



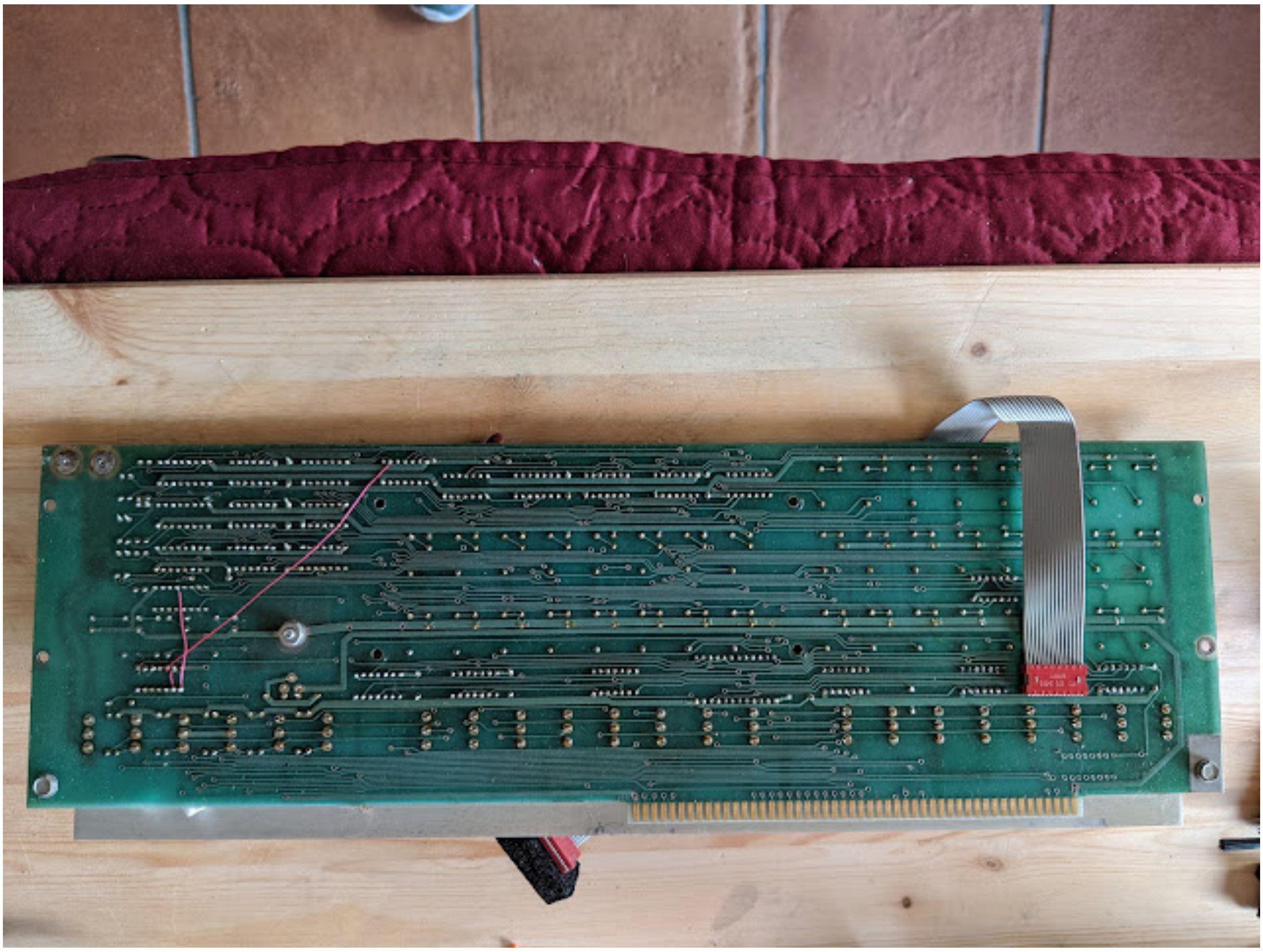
One side of the edge connector hidden behind the switch bracket.

The best approach is to extended the Fibre Pen tip and rub it sideways along the contacts, slowly.

Effect of rubbing tip sideways along contacts.

Now to find out what difference it had made. The unit was put back in the Test Rig and the results looked much better! All functions were now operational and all LEDs were working.

We have what appears to be a fully working Front Panel, which helps a lot. However, when we look at the back of the board, we can see that some modifications have been applied. A number of essential and optional engineering changes were recommended over time, and we will need to see what has and has not been applied out of this list. They are set out at the foot of this Blog.



Engineering modifications on the rear.

Having closely examined the board for changes, we can see that the only one of those listed below that has been applied, is ECO 76-0061 (Early 1976). This is very commonly the case.

Although the modification: ECO 77-0098 (September 1, 1977) appears to be important, we will wait to see whether we have any problems in practise before choosing to apply it. After all, it was nearly two years after production started before it was issued.

IMSAI Board Engineering Modifications:

CPA Programmers Front Panel rev.4 Engineering Change

Manufacturing Corporation Engineering Change Orders (ECOs)

The IMSAI CPA revision 4 Programmer's Front Panel was introduced in December of 1975 as a component of the IMSAI 8080 Microcomputer. It was also sold as a separate item in kit or

assembled form for those individuals wishing to utilise its diagnostic capabilities for troubleshooting,

monitoring, and modifying data in S-100 bus computers lacking such a convenience. It could be run in an extender board in any S-100 socket position.

Four IMSAI ECOs were released during the product life of the CPA rev.4. They are listed in their order of release.

See the addenda following, regarding several schematic errors and some useful “unofficial” modifications that allow greater compatibility with other manufacturer’s boards.

Note: The original IMSAI CPA REV.4 Schematic incorrectly shows the SOUT signal at U15 pin1

connected to U25 pin 5. This should be changed to U15 pin 2 (/SOUT) as noted below:

ECO 76-0061 (Early 1976) Modification to prevent generation of MEMWRITE signal during

1. On the COMPONENT SIDE of the CPA circuit board, CUT the trace from U25 (7400) pin 3

2. On the SOLDER SIDE of the board, CONNECT U15 (74LS04) pin 2 to U25 (7400) pin 5

3. On the SOLDER SIDE of the board, CONNECT U25 (7400) pin 3 to U25 pin 4

4. On the SOLDER SIDE of the board, CONNECT U25 (7400) pin 6 to U25 pins 9 and 10

5. On the SOLDER SIDE of the board, CONNECT U25 (7400) pin 8 to U24 (8T97) pin 4

ECO 77-0035 (March 5, 1977) Modification to always allow the Front Panel to come up in a STOP mode at POWER UP time :

1. On the COMPONENT SIDE of the CPA circuit board, CUT U22 (74107) pin 11 free from the

board near the surface and gently lift it free from the connecting trace

2. On the SOLDER SIDE of the board, CONNECT U18 (74107) pin 13 to U16 (7402) pins 11

3. On the COMPONENT SIDE of the board, carefully solder a small piece of wire (30 gauge

wire-wrap wire works best) from the free lead of U22 (74107) pin 11, through a feed-through

hole (via) to U 16 pin 13

ECO 77-0039 (April 22, 1977) Modification to allow use with IMSAI Dynamic RAM boards (This change makes the S-100 bus RUN line (71) agree with the bus definition):

1. On the COMPONENT SIDE of the CPA circuit board, CUT the trace extending down from

2. On the SOLDER SIDE of the board, CUT the trace from U24 (8T97) pin

10 and feed-through

(via) "A" (see diagram on CPA SOLDER side drawing)

3. On the SOLDER SIDE of the board, CUT the trace from feed-through (via) "B" near S-100

4. On the SOLDER SIDE of the board, REMOVE the entire feed-through (via) pad connected to

5. On the SOLDER SIDE of the board, CONNECT U22 (74107) pin 5 to U24 (8T97) pin 10

6. On the SOLDER SIDE of the board, CONNECT S-100 bus pin 71 to U24 pin 9 7. On the

SOLDER SIDE of the board, CONNECT feed-through (via) "A" to feed-through (via) "B"

ECO 77-0098 (September 1, 1977) Modification to prevent spurious triggering of "one-shots

during RUN mode, causing unpredictable program execution:

1. On the COMPONENT SIDE of the CPA circuit board, CUT the trace from U23 (74123) to

2. On the SOLDER SIDE of the board, CUT the trace from U17 (74123) pin 2 and its feedthrough (via)

3. On the SOLDER SIDE of the board, CUT the trace from U20 (74123) pin 11 and U19

4. On the SOLDER SIDE of the board, CONNECT U20 pin 11 and U22 (74107) pin 6

5. On the SOLDER SIDE of the board, CONNECT U 19 (74107) pin 8 and the LOAD side of

6. On the SOLDER SIDE of the board, CONNECT U17 (73123) pin 2 to U17 (74123) pin 3

Compatibility Modifications (after-market)

(Note: asterisk character * following a function indicates active low or "false", per IEE 696 standard notation)

(a) Modification to run with IMSAI MPU-B (MPU-B uses XRDY2 (S-100 bus pin 12) instead of XRDY (S-100 bus pin 3)

1. On COMPONENT SIDE, ADD jumper between S-100 bus pins 3 and 12

(b) Modification to cut EXTERNAL CLEAR* (S-100 bus pin 54) free from the S-100 bus. Note that this bus pin becomes "SLAVE CLEAR* in the IEE 696 specification:

On COMPONENT SIDE, CUT trace leading from bus pin 54 to via

(c) Modification to eliminate hardware memory protect (S-100 bus pin 20) from bus. Note that this

bus pin becomes "GROUND" in the IEEE 696 specifications:

On COMPONENT SIDE, CUT trace leading from bus pin 20 to via. Note that this modification

requires removing the switch bracket to gain access to the bus pin. As an alternative, it may

possible to insulate bus pin 20 with a piece of tape or similar insulating means

(d) Modification to derive FETCH status (SM1) from S-100 bus pin 44 instead of S-100 bus pin 39

(DO5, a status bit unique to timing and flags derived from the original Intel 8080 microprocessor):

On COMPONENT SIDE, CUT trace leading from S-100 bus pin 39 to U11 pin 9. Connect a

jumper between S-100 bus pin 44 (SM1) and U11 pin 9. The recommended technique is to cut

the original trace just above the bus pin, then jumper from the remaining trace leading to U11 pin

9, to bus pin 44. Note that this modification requires removing the switch bracket to gain access

The ¼″ spacers used between the front panel assembly and the chassis mounting bracket can be a pain to keep on when removing and replacing the front panel group. Simply "crush" the spacers slightly with pliers to distort their diameter and they will stay with the mounting screws. Avoid excessive crush.

A small dab of RTV (silicone rubber), available at your local hardware store) works great for tacking

modification wires in place. If you're inclined to want to smear the RTV around with your fingers, wet them with some dishwashing detergent first to avoid messy fingers after the job is done.

Do NOT use alcohol or glass cleaner-type substances to clean the acrylic front plate or switch handles. Use a mild solution of dishwashing detergent and a soft cloth (never paper towels, because they'll scratch the plastic) instead. Afterwards, a good plastic cleaner formulated for acrylic can be used (but be sure to wash the surface FIRST!)

The original IMSAI CPA rev.4 schematic has several errors as follows:

1. (Lower Left corner): S-100 bus pin 37 leading to U11 pin 9 is mis-labeled. It should be S-100

2. (Center Upper Left): U15 pin 1 (SOUT) is shown going up to U25 pin 5. Change the drawing to

show U25 pin 5 connected to U15 pin 2 (SOUT*)

BLOG PART 11: Pulling things together.

06/12/2019

We can see that things are starting to come together now. Outstanding jobs include:

The Front Panel can be fixed into place and the fascia can be added.

The three other S-100 boards, that still need to be tested, are shown in the positions they will take up once that is complete.

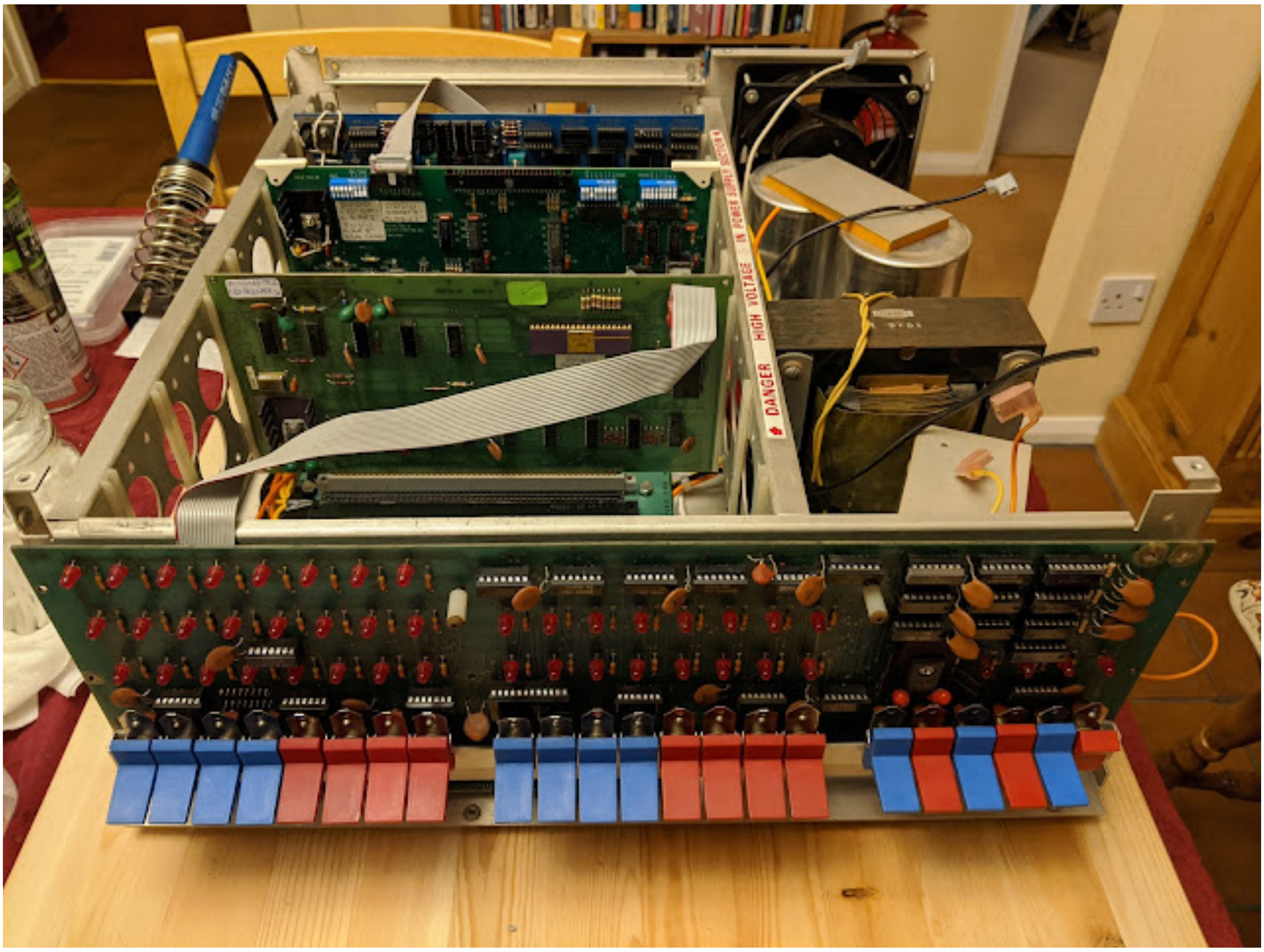
Two serial cables need to be added and fixed to the Backplate, along with a diagnostics cable from the FDC+ booard.

A Floppy Drive cable needs to be added to the FDC+ board.

The PSU needs to be connected to the Backplane.

The mains power switch needs to be hooked up with spade connectors and the mains cable grommet added.

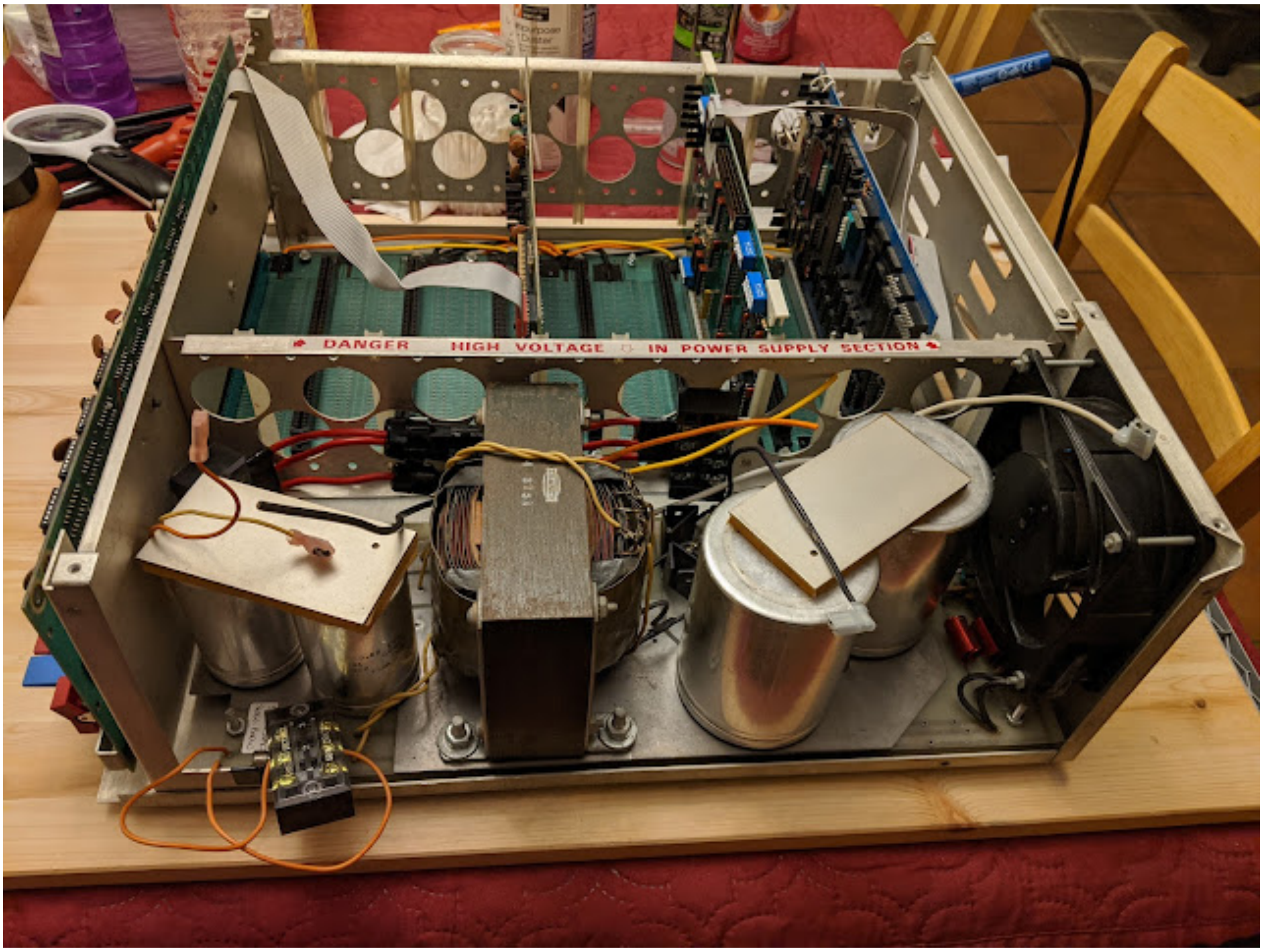
By that point, we hope to have a running machine.



Starting to look like a computer at last.

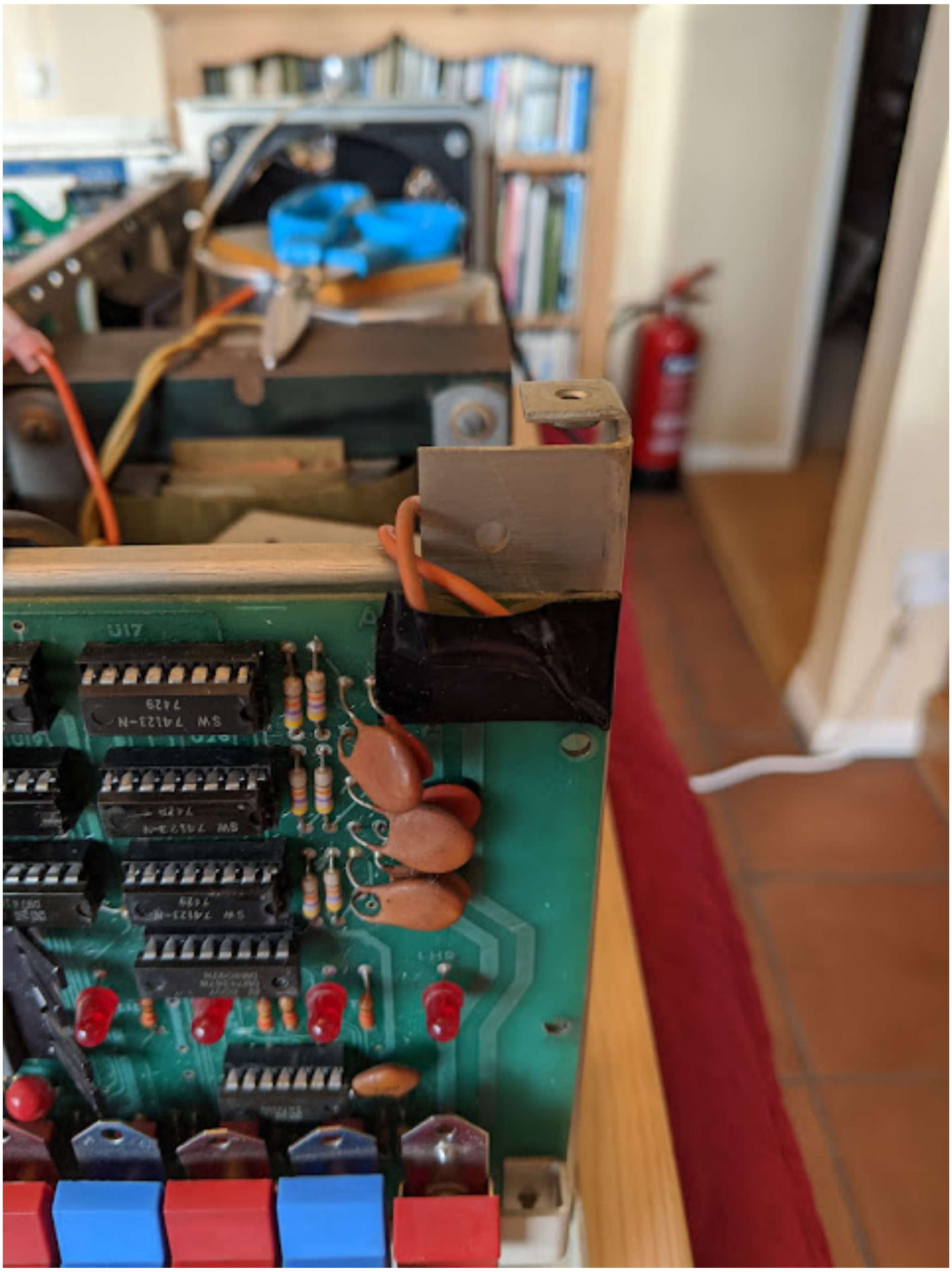
07/12/2019

Next, we need to deal permanently with the on/off mains switch that we temporarily connected via a terminal block.



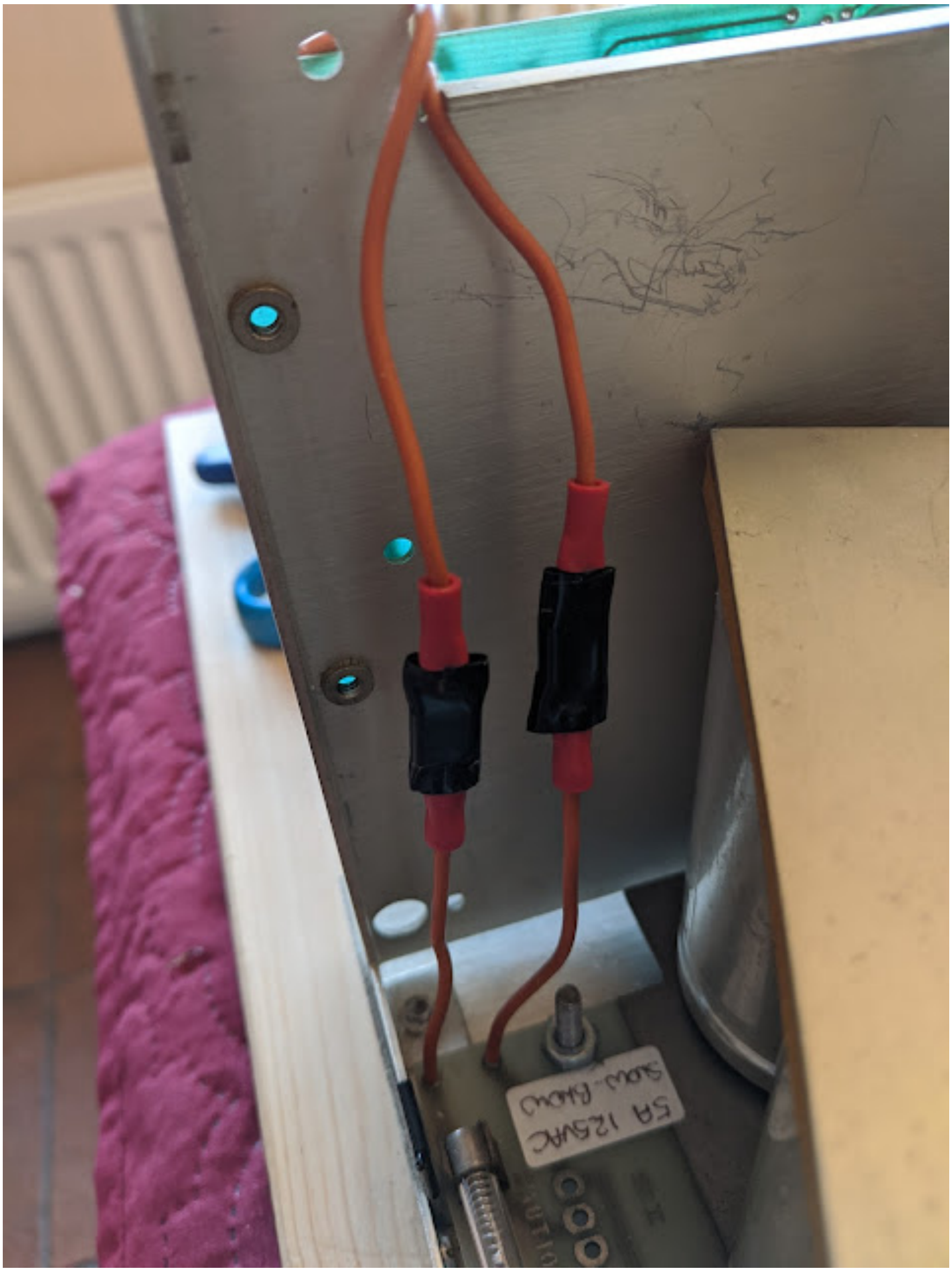
Temporary wiring to force mains switch to ON.

The two cables are soldered to the Front Panel and then Vinyl Tape applied to stop them being a shock hazard for the unwary.



Vinyl Tape covering the two mains supply cables.

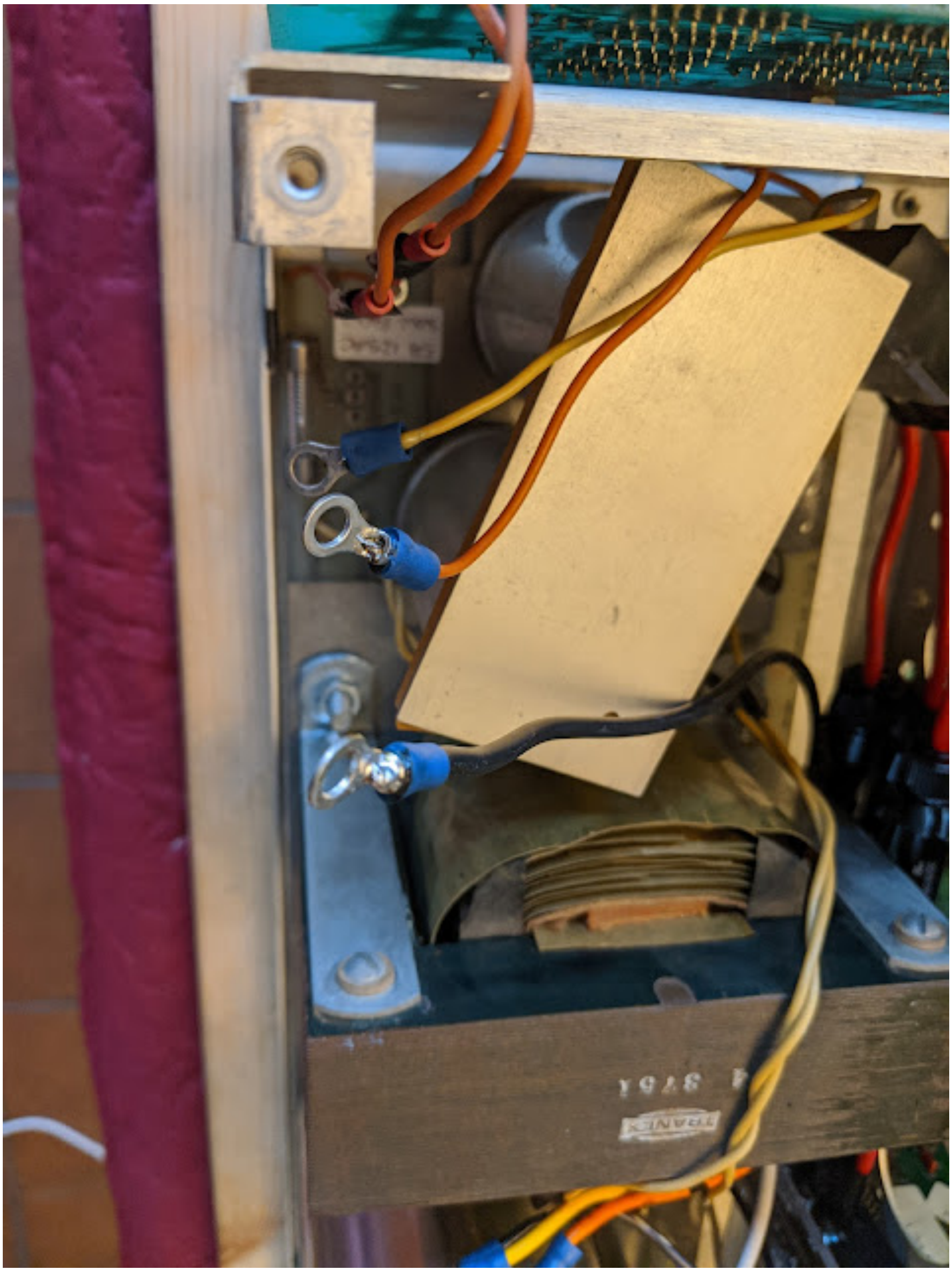
The cables are cut, tinned, crimped and then soldered to the crimp connectors. This will allow for quick and easy removal of the Front Panel in the future, where required.



Mains supply to ON/OFF switch cut and crimped.

The next item is the DC supply cables from the PSU to the Backplane, carrying +8vdc, +16vdc, -16vdc and the Ground. The cable ends are tinned, before round connectors are crimped then soldered to each.

DC cables crimped and soldered.

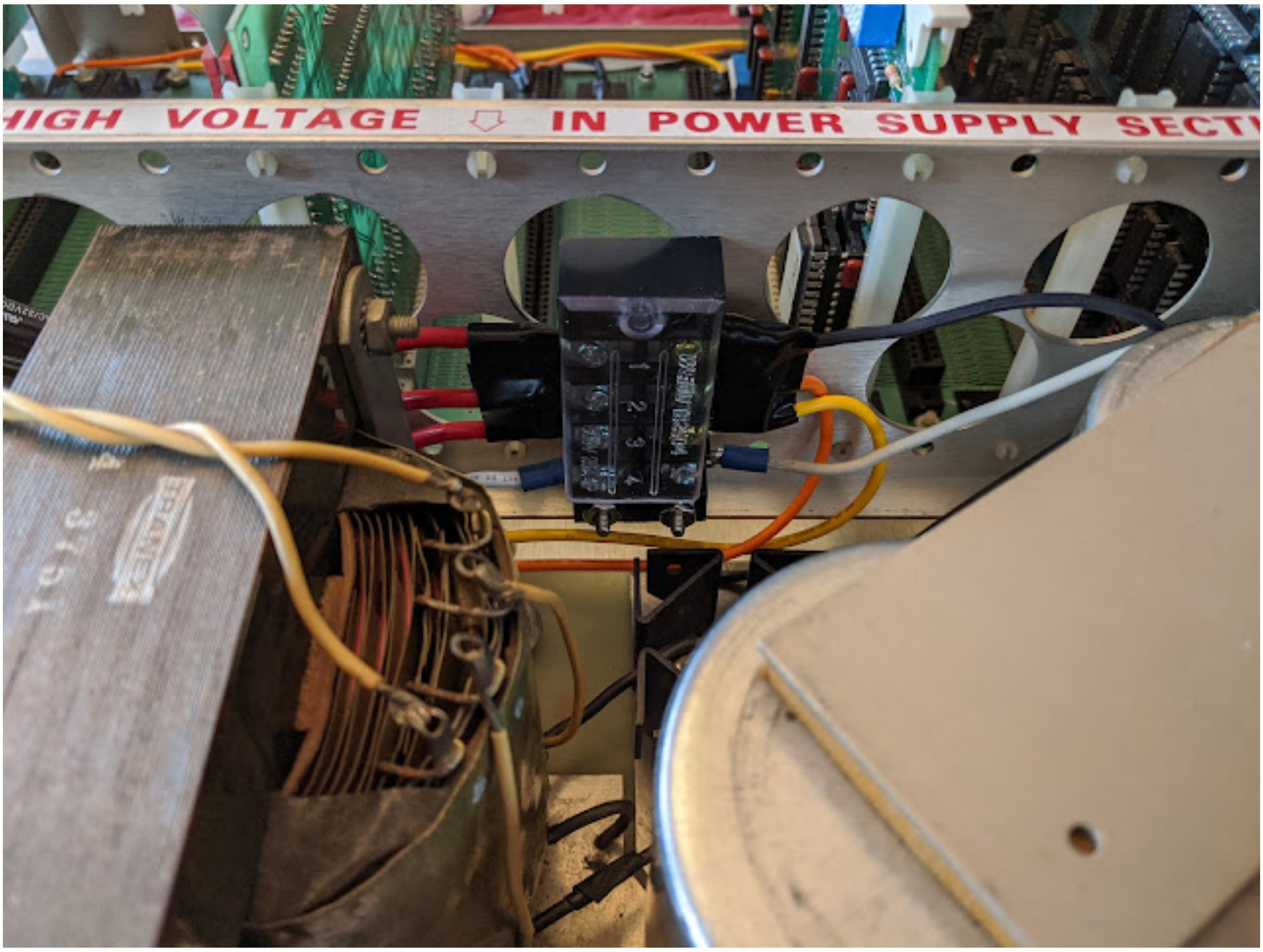


DC cables crimped and soldered.

The Fuse Harness we prepared earlier is now brought to bear.

Fuse harness ready for fitting.

The four-connector end of the Fuse Harness is bolted to the chassis guide rail.



One end bolted to the chassis.

The other end is tucked away behind the +16vdc/-16vdc, 10,000uf, 25vdc capacitors. This allows us to easily access the fuses, while keeping the harness reasonably inconspicuous.

The other end is tucked away.

08/12/2019

The Front Panel Fascia components are now cleaned and prepared for refitting.

Front Panel Fascia components.

Foam Cleaner and some furniture polish are carefully applied. The black plastic sheet with the white legends is cleaned using warm water with little washing up liquid/mild detergent. The plastic degrades over time and great care should be taken not to rub it, should it become sticky, otherwise it will lose its shine.

Foam Cleaner and Wax Furniture Polish.

When refitting the Fascia, make sure that you apply two nuts on the bottom left mounting, as shown, instead of plastic spacers, as this is a grounding point for the Front Panel.

In our case, on the other mounting points, we are using nuts on the innermost part, instead of the small plastic spacers. This is because those supplied with this machine are too small, and a non-standard size, for some reason.

Two nuts on a grounding point for Front Panel.

The Fascia is now cleaned and installed once more.

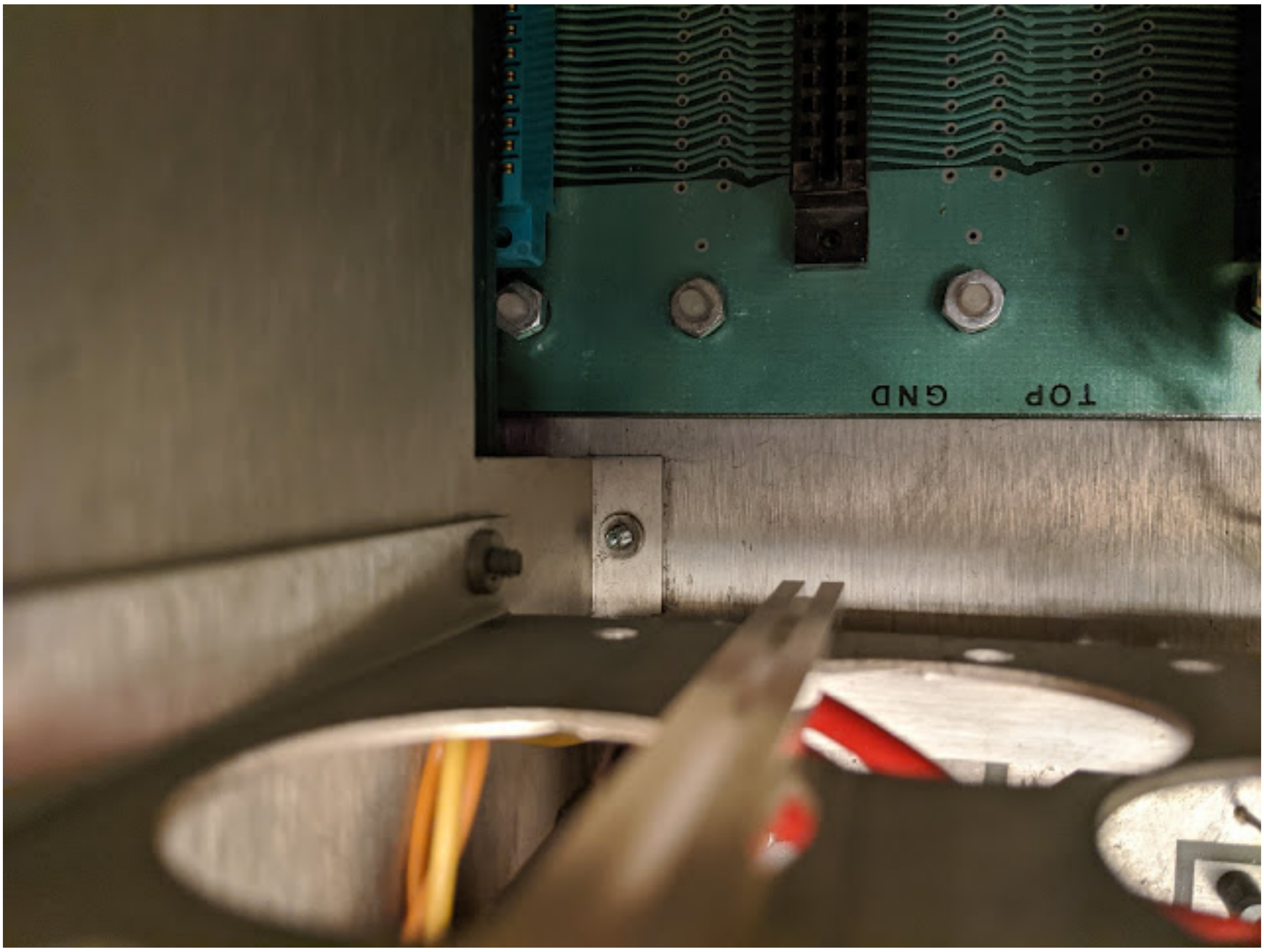
Cleaned Fascia re-installed.

The machine is now brought up slowly, using a Variac, and the DC voltages carefully monitored, along with their current draw. We immediately start to have a rather strange, intermittent, problem, with the Front Panel lights going 'haywire' when we attempt to use various keys such as Deposit and Examine.

A lot of time is then spent troubleshooting this, with varying amount of success. For example, if you enter a value on the switches that takes less than 6 switches set to on, all is well. Then, if you try adding a larger number with more switches deployed, it goes 'haywire' again.

After doing extensive tests on the electrical component side of things, a physical examination is undertaken, almost as a last resort. What is discovered has a huge impact. A screw that bolts the right side card guide rail to the chassis is missing. We did not remove this, so it has been absent for a long time. It allows the rail to move around, and that could be causing all sorts of connection problems on the S-100 cards.

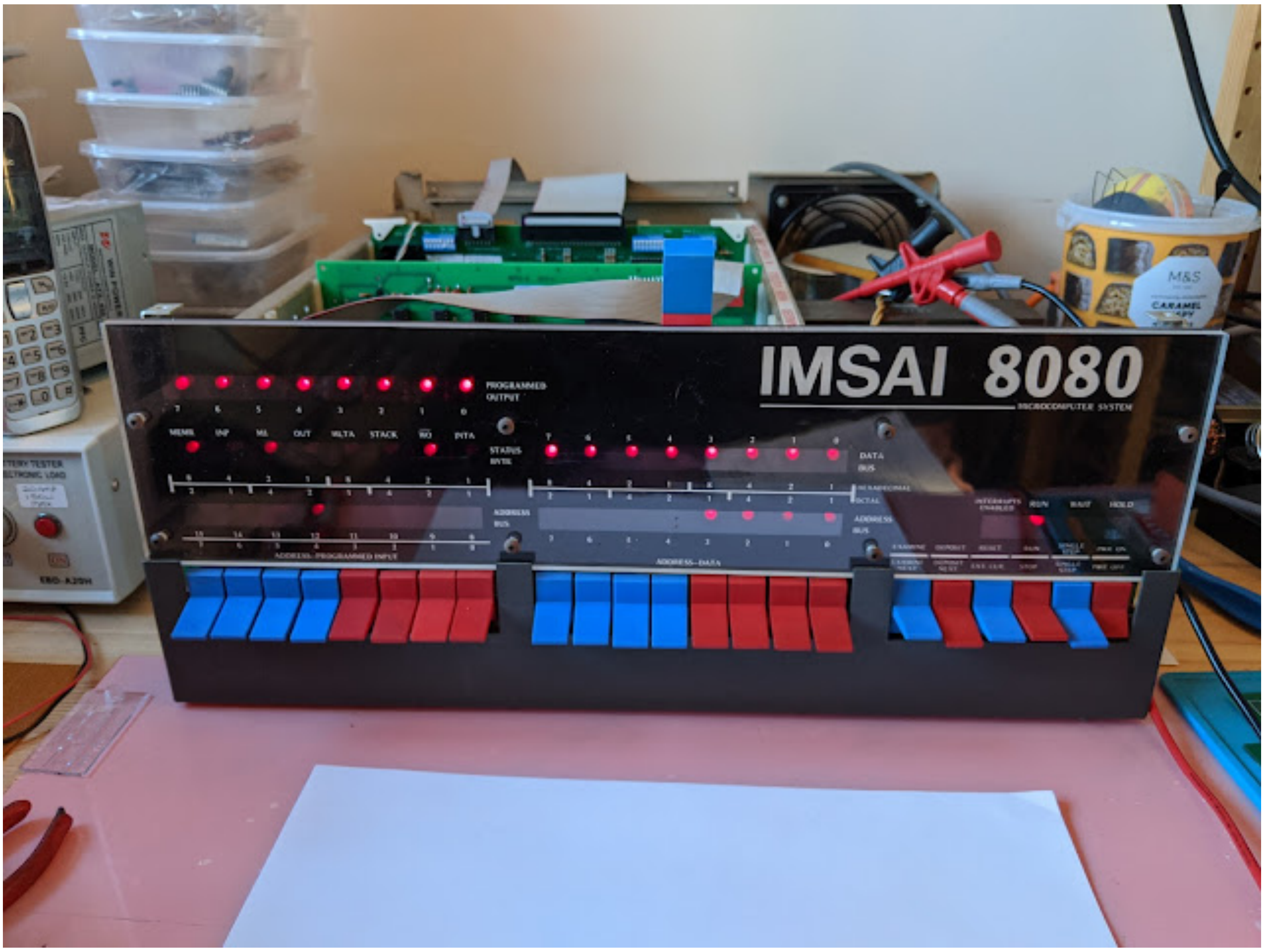
A correct size screw is located (6/32), and the machine suddenly becomes completely stable. Don't you just love those moments? Whether this screw was acting as a grounding point, or just stopping anything moving at all is not entirely clear. It doesn't really matter!



Missing bottom mounting screw for Card Guide Rail now fitted.

All now appears well, despite all the changes. At 110vac, the +8vdc line is showing 8.25vdc with just the Front Panel, CPU Board, FDC+ Board, and SSM IO4 Board installed.

We now enter and run 'Kill the Bit', which runs fine.



Running 'Kill the Bit'.

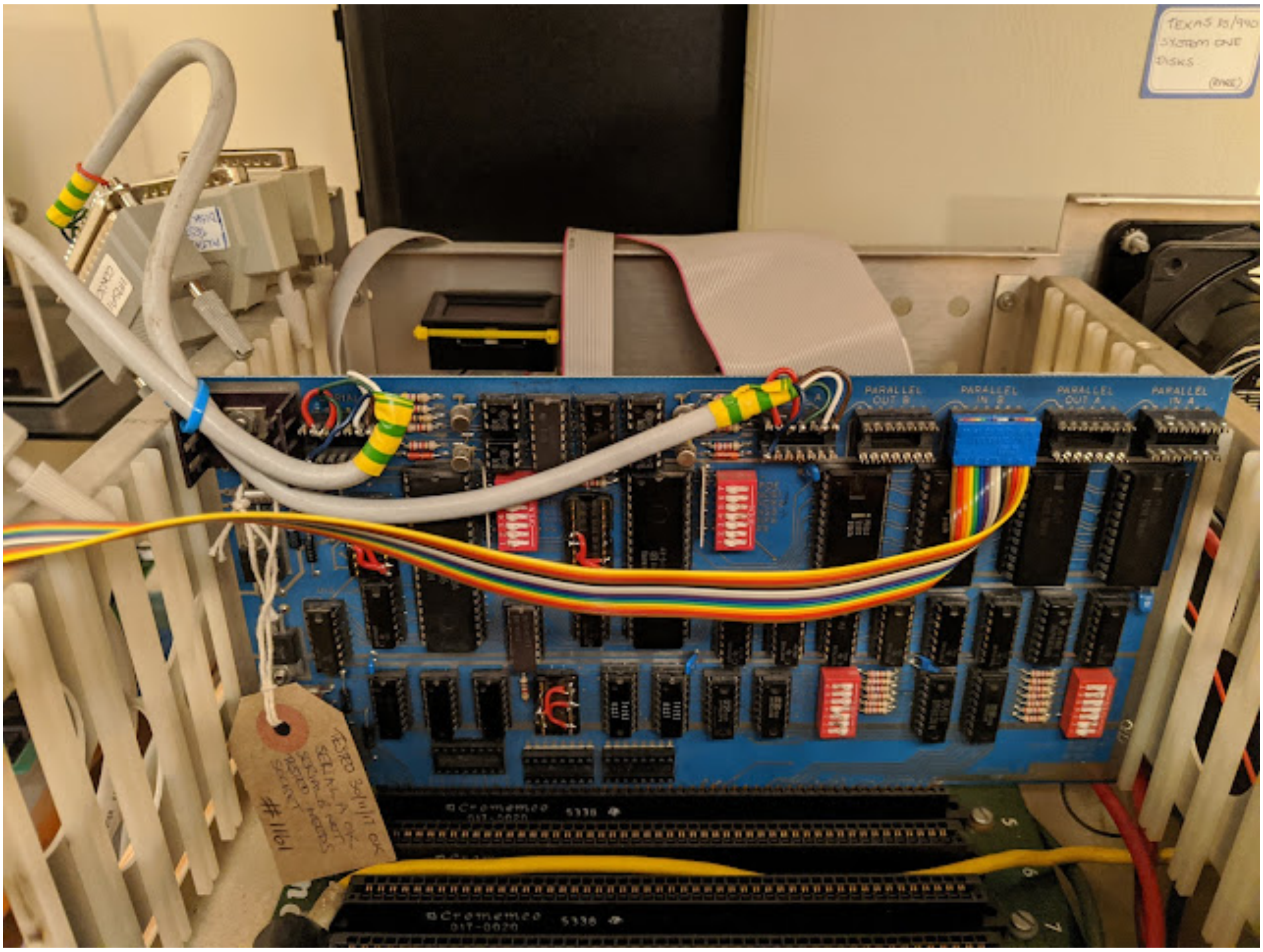
BLOG PART 12: Fitting the other S-100 boards.

09/12/2019

A working SSM IO4 S-100 board, with two serial ports and two parallel ports, will be removed from our 'Test Rig', and fitted to the machine.

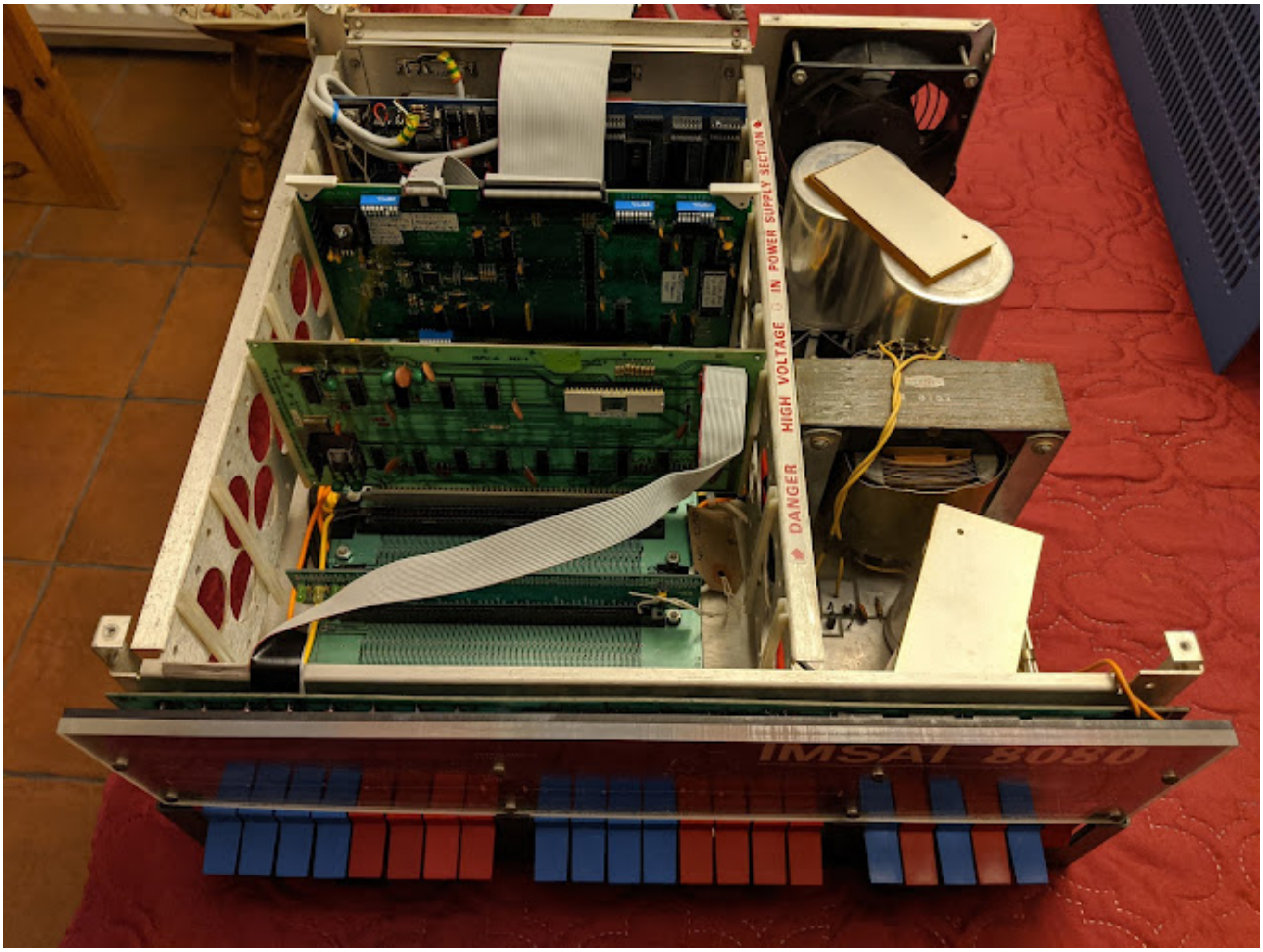
As can be seen here, it has ready-made grey serial cables that can be bolted to the Back Panel.

The parallel cable is a multi-coloured ribbon.



SSM IO4 S-100 Board.

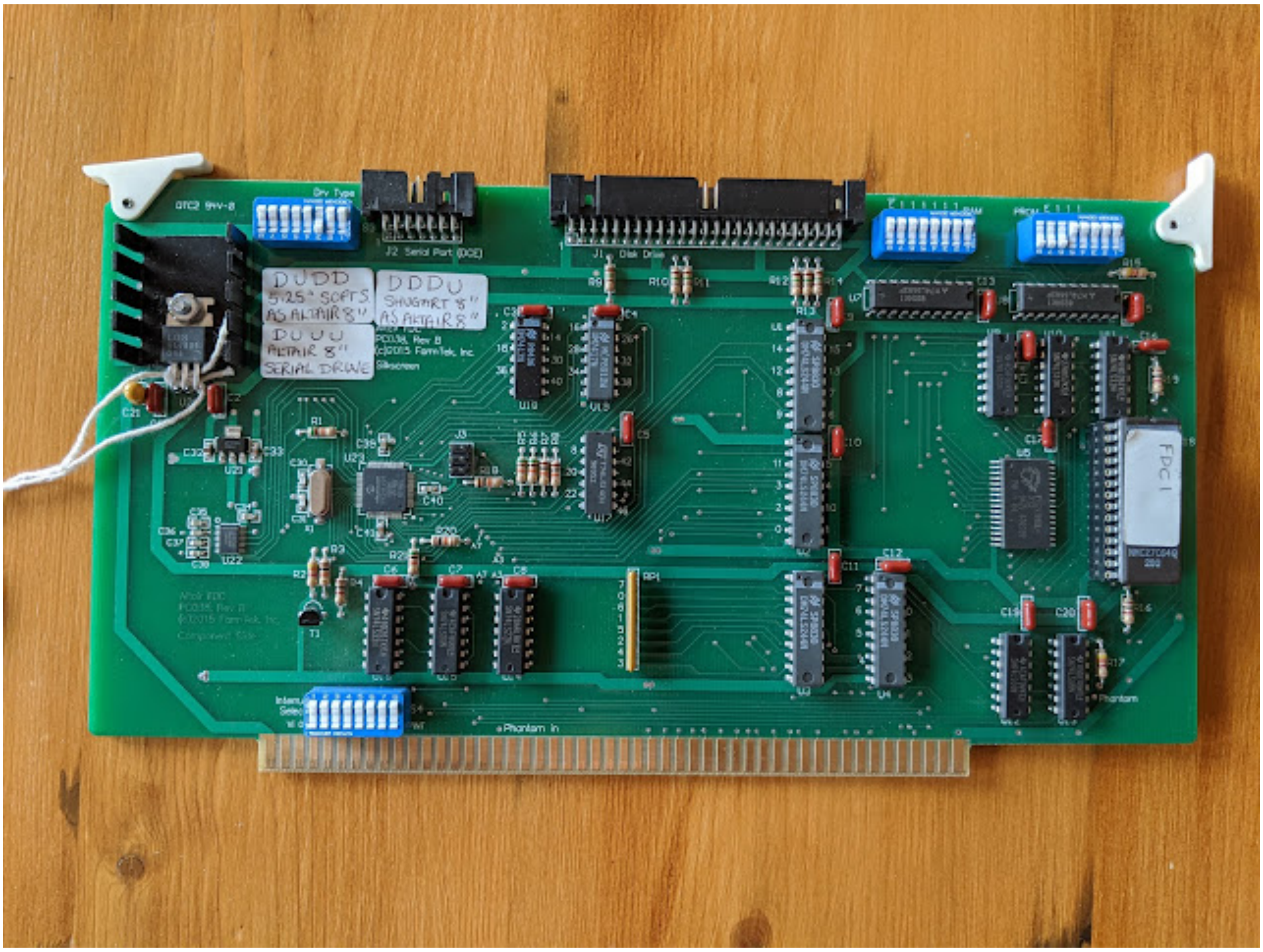
The middle of the three larger S-100 boards seen here, in front of the SSM IO4 S-100 Board, and behind the CPU Board, is an FDC+ S-100 Board.



FDC+ S-100 Board in the middle of three.

This is an incredibly useful modern S-100 board, made by Mike Douglas. More details can be found at:

https://deramp.com/fdc_plus.html

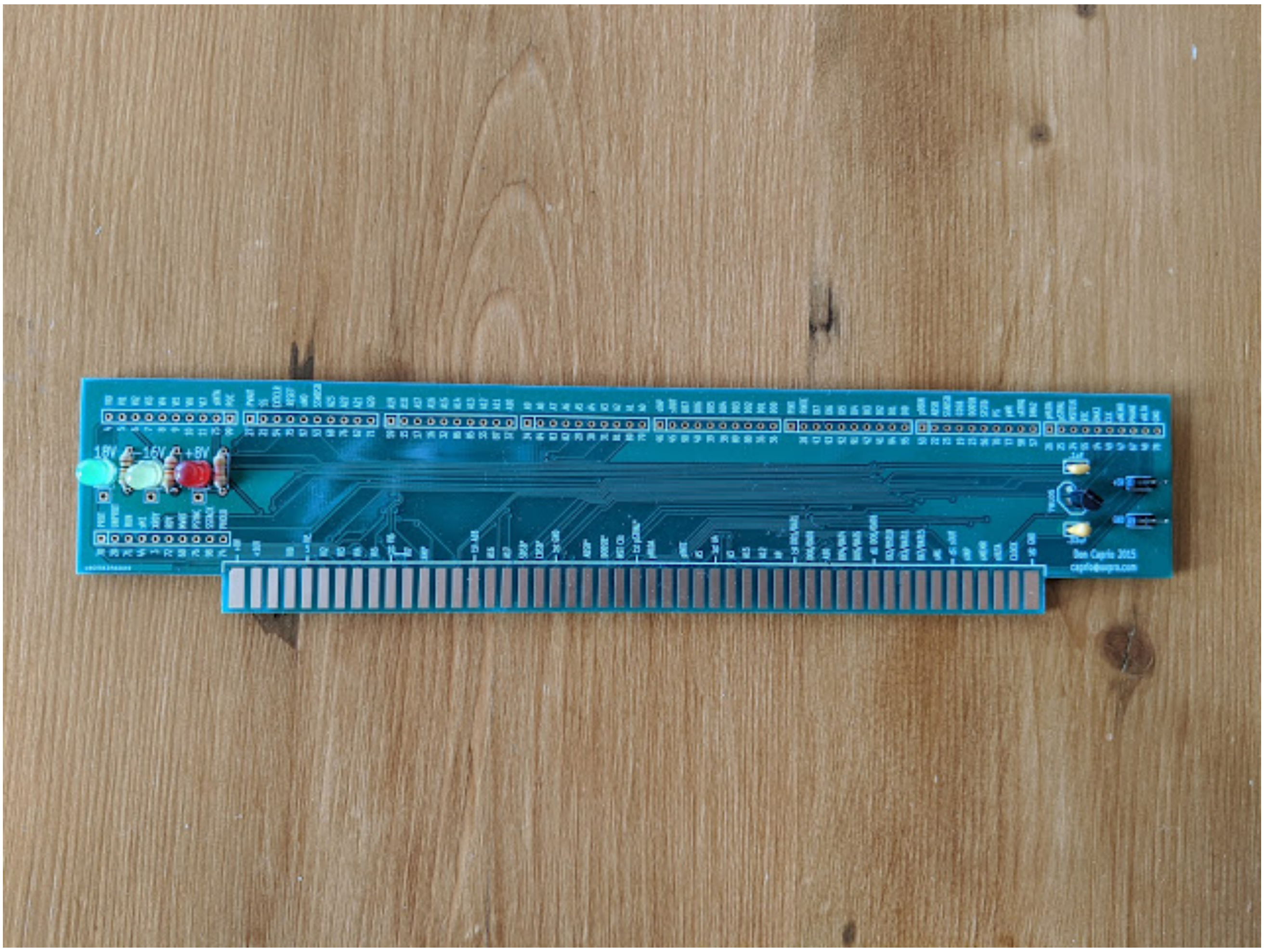


FDC+ S-100 Board

The board contains up to 64K usable RAM, up to 8K user-programmable PROM pre-programmed with some of the standard Boot and Monitor programs. It also emulates a set of the most common Floppy Disk Controllers used at the time, including 8" and 5.25" drives.

Amongst other things, it allows us to quickly get a machine 'up and running' without worrying about troubleshooting multiple other S-100 boards at the same time. The functionality of the FDC+ can be replaced, bit by bit, with working original S-100 Boards, over time, if we so desire.

At the front of the Backplane, we can also see a small S-100 board. This is a modern 'breakout' board, that enables us to attach to any of the S-100 signals, and also has LEDs to show whether or not we have all three of the DC voltages present: =16vdc, -16vdc and +8vdc.



S-100 Breakout Board

The initial test of the machine presented a fairly serious looking problem, as can be seen in the following video clip. The machine was running out of control.

Click play button twice to run then [ ] in bottom right to view full screen.

A good deal of troubleshooting and investigation was carried out to pin it down. Fortunately, we had a test rig available that enabled us to quickly rule out the individual boards being the source of the behaviour. However, removing and replacing the boards, to test them in another machine, caused the behaviour to change.

At one point, it remained stable enough to allow for the entry of the 'Kill the Bit' program from the Front Panel, which ran without problems.

Click play button twice to run then [ ] in bottom right to view full screen.

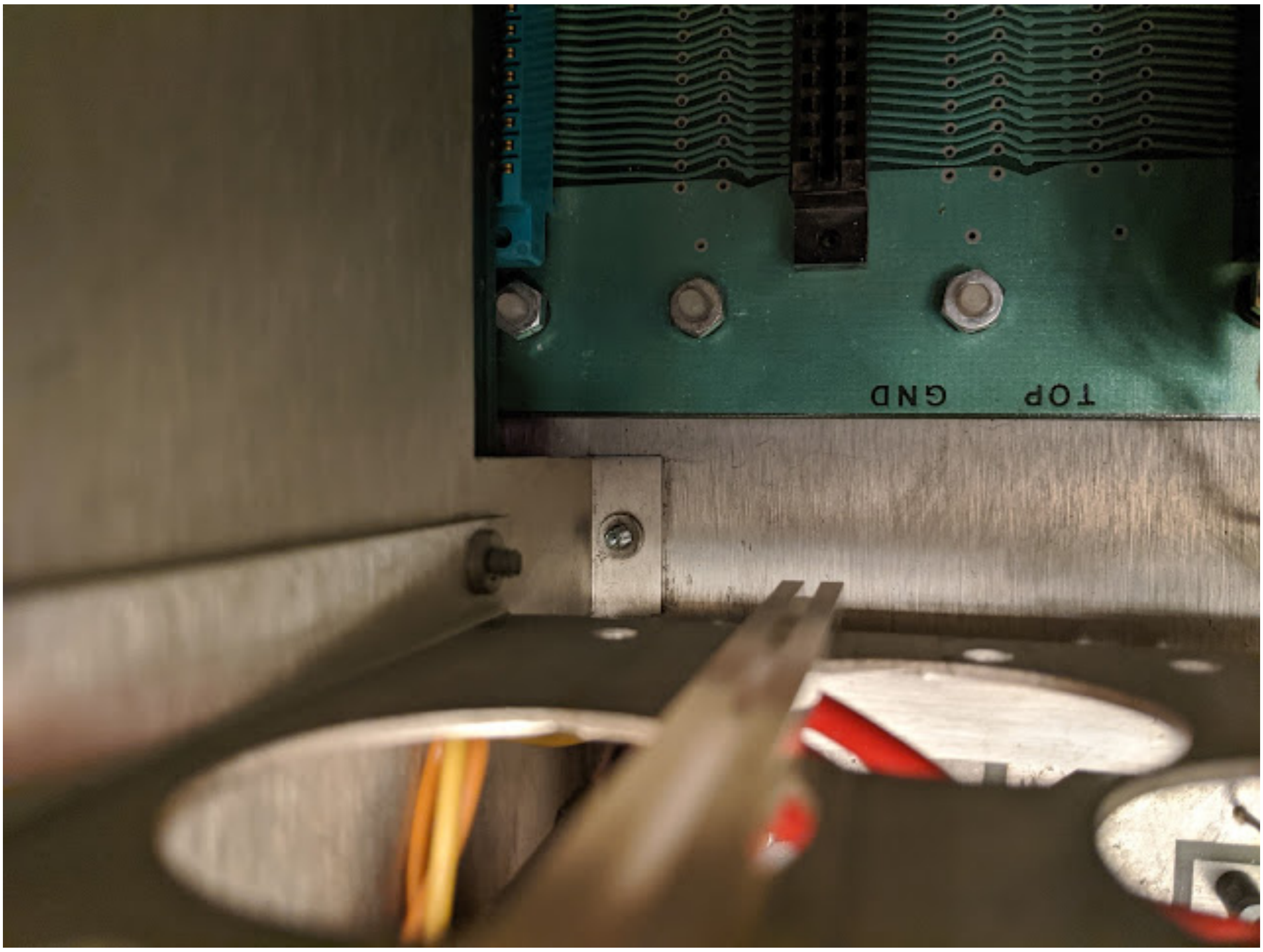
However, it soon reverted to erratic behaviour. At one point, you could enter data values of up to 32 using the Front Panel, but anything higher, involving extra switches, failed.

This was frustrating, to say the least.

10/12/2019

Then, while carrying out a physical examination of the machine, it was noticed that a screw was missing. This was not one that we had removed. It fixed the right-hand Guide Rail to the bottom of the chassis.

A suitable #6/32 screw was located and fitted. Immediately, the machine started to work properly, and remained that way through a variety of tests. Problem solved!



Missing screw fitted, securing Guide Rail to Bottom Plate.

It is not certain whether the issue was a grounding problem, because the Front Panel has a few grounding points, and this rail forms one of them, or whether the lack of screw was allowing the cards to move in their S-100 connectors and cause intermittent connectivity issues. Perhaps it was both. It is highly likely that the previous owner had similar problems, but had failed to find the fault.

A variety of tests were then carried out. Here, the machine is shown running a short program displaying square roots, using Microsoft BASIC 4K V4.0.

Click play button twice to run then [ ] in bottom right to view full screen.

BLOG PART 13: Finishing Off.

10/12/2019

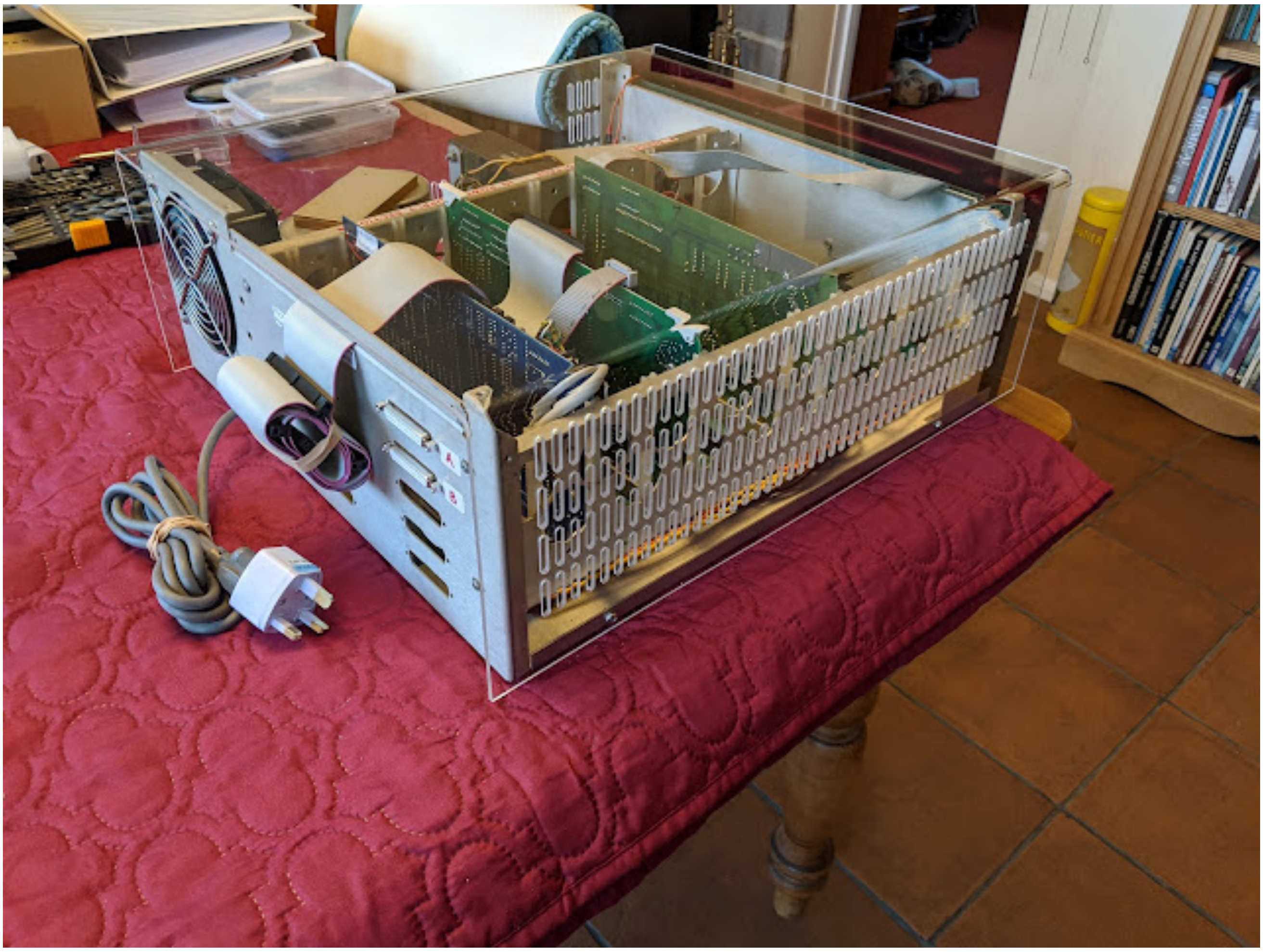
All that remained, was to put the machine back together and deliver it to the Centre for Computing History at Cambridge.

First, the renovated lid was tried out.

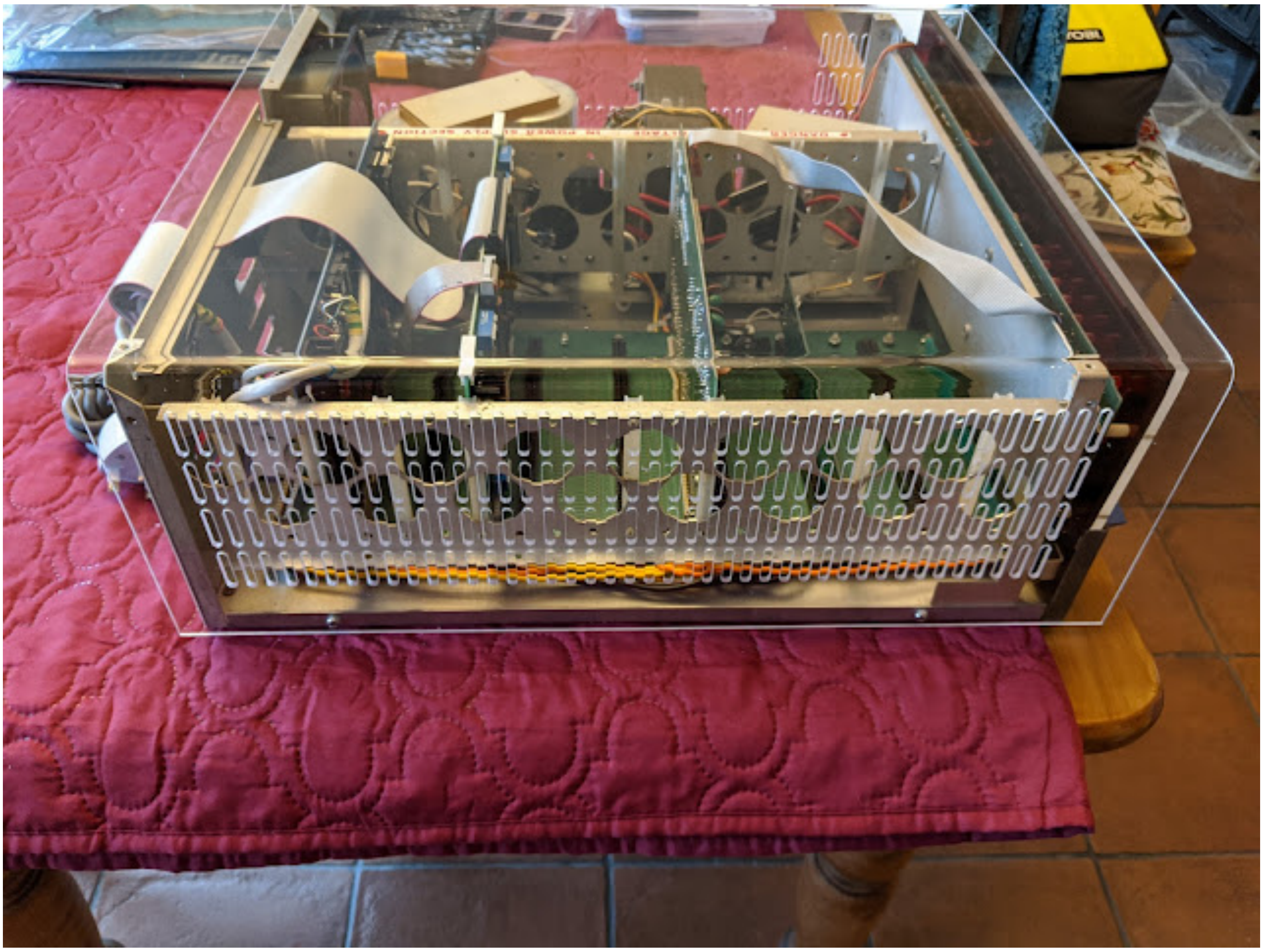
Renovated lid fitted - Front View.

Renovated lid fitted - Rear View.

An acrylic lid was manufactured to the same specification as the original aluminium one. This allows the contents to be viewed when running, safely, yet retains the same airflow for cooling purposes.

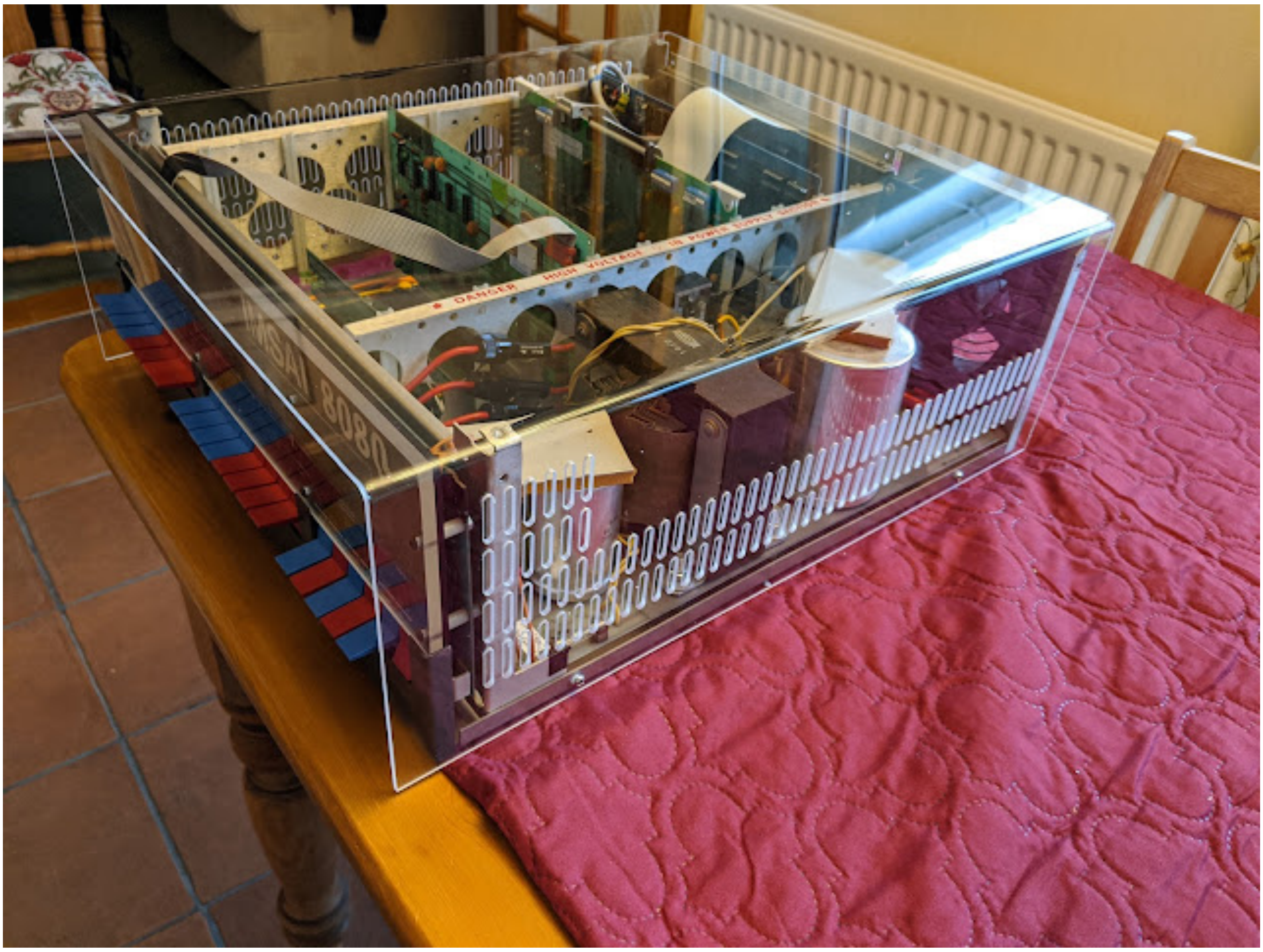


Acrylic lid - rear view.



Acrylic lid - side view.

Acrylic lid - front view.



Acrylic lid - perspective view.

The museum now have a fully restored and tested machine, with the ability to display it as originally constructed, or with a see-through lid, for those who want to see the inner-workings - for example, as it was run in the film War Games. If you prefer a blue front view, you could paint the front couple of inches of the acrylic lid, up to the first air vent.

It is fully compatible with both of the Altair 8800b machines at the museum, that we have previously restored. It can, therefore, be used to run the same demonstrations using all of the associated peripheral equipment, such as: Lear Sigler AMD-3A Terminal; Twin Teac 55-GFR 5.25" Floppy Drives; TREND Paper Tape Reader/Punch; Sony Vaio Laptop; and AM Radio.

Here is a picture of the machine, installed at the museum, which brings this Blog to an end.

It is now ready to be demonstrated to the public, along with the two MITS Altair 8800b machines. A full reading copy of the IMSAI manual is also provided alongside the machine, for the public to view.

IMSAI 8080 at the Centre for Computing History - Cambridge