

The 12V SLA Battery De-Sulphation Machine:

Dr. H. Holden. October, 2026.



The photo below shows a typical 12V SLA (sealed Lead-Acid) Gel Cell battery. These batteries are used in many applications, typically for emergency lighting backup, computer UPS devices and as backup batteries in home alarm systems as well as many other applications for mobile equipment.

lives in hot climates when float charged at 13.8V. Some manufacturers advise de-rating that by $-18\text{mV}/^{\circ}\text{C}$, for example down to 13.62V at 35°C . However, inadequate charging can also result in plate sulphation too. Other failure mechanisms include water loss and active material degradation. For example, excessive over voltage and over current charging can result in gas evolution and water loss. And with sealed batteries, the water is not easily replaced.

In a nutshell, the Machine design presented here is offered up to other experimenters in this field to experiment with aged and sulphated 12V SLA batteries. Your results may vary compared to those presented here. The results will depend on the condition of the battery to start with. The results of treating two aged and sulphated 12V SLA batteries with this machine are presented in this article.

Of particular note: This Machine is not intended to be applied to any new 12V SLA battery, or to be used as a general battery charger for one. And clearly, very aged batteries which have issues such as swelling and splitting of their housings, or other obvious gross abnormalities, should not be subjected to any treatment by this Machine. The result of applying this machine to a new battery, as a brief experiment only, is described below. The behaviour here is quite different to that of treating an aged and sulphated battery.

SLA Battery Chemistry and Sulphation:

The basic chemistry in the discharging process of the Lead-Acid cell is that porous or spongy metal Lead on the negative plate combines with Sulphuric Acid and porous Lead Dioxide on the positive plate and gives up electrical charge in the process. The products are Lead Sulphate and Water. The Lead Sulphate is deposited out as fine crystals on both the Positive and Negative plates of the cell. Charging reverses the process, removing Lead Sulphate from the plates. This sort of sulphation can be referred to as “soft sulphation” because it is generally reversible by the normal charging process.

If the battery is left too long in a discharged state (low individual cell terminal voltage) then crystals of Lead Sulphate coalesce into a hard mass blocking the pores in the plates and inhibiting the movement of ions. This is called “hard sulphation”

Lead Sulphate itself is an electrical insulator. This is the reason the battery’s internal resistance also increases somewhat when it is in a low state of charge. However, with hard Lead Sulphate deposits on its plates, this is not reversed by normal charging methods. It effectively insulates the plates from ionic interaction with the electrolyte. This significantly raises the cell’s internal resistance, renders it resistant to normal charging as well as limiting the battery’s maximum storage capacity and Ah capability.

Everybody who has owned a 12V SLA battery, or the earlier Wet types such as the types used in motorcycles & cars and neglected them by letting their terminal voltage fall to a low voltage for a period of weeks and months knows the consequences well. The battery sulphation becomes excessive, the internal resistance rises and it becomes very difficult to get the battery to accept any charge from the charging source.

Many electronically controlled charging systems are constant voltage types in the range of 14.2 to 14.4V. They apply the fixed DC voltage to the battery's terminals and the battery takes from that what it requires in the way of charge current. The charge current slowly reduces over time as the *emf* of each cell in the battery increases with its state of charge. The charge current in this situation is affected significantly by the battery's overall internal resistance and the state of charge of each cell in the battery.

The more primitive automotive style Line powered battery chargers, based on half wave rectified and unfiltered pulses from a line transformer secondary can sometimes be more successful on getting initial charge into a sulphated battery on occasions, than a fixed DC supply. This is because of the pulse's peak voltage value exceeding the 15V region. This can allow some charge to more easily enter the sulphated battery.

This De-Sulphation Machine Project:

This project began when I found that I had accidentally left two identical 12V SLA cells for some 12 to 18 months or more, in storage, in the shed, without checking their terminal voltage.

In one case the battery's terminal voltage was only 2.86V or less than 0.5v per cell. Call this one Battery B. In the other case, for a second identical age and brand battery it was 7V, or just over 1 volt per cell. Call this one Battery A. On checking the battery's date codes I was somewhat surprised to find they were both 6 years old.

On applying the constant voltage charger with a 14.4V voltage to the battery's terminals, the charging current draw from each battery was very low at around 15mA, the battery's terminal voltage simply jumped up to 14.4v on the DC charger and I realized that they had sulphated and that their internal resistance was badly elevated. Typically on this particular charger, the current for a discharged battery could be in the range of up to 2 Amps when connected initially, and with a fully charged battery, in the range of 100mA to 300mA.

Hard sulphation has been seen to be at least partially reversible with pulsed currents for brief periods, generated from 1kHz to 3kHz pulsed source voltages which are significantly higher than

the battery's terminal voltage. Commercial de-sulphation machines have been built for the purpose, though I have not seen such a machine up close.

The basic operating theory is of high peak currents being responsible for causing local disruption of the Lead Sulphate crystals and better ion migration and electrolyte contact with the plates. Although theories of "molecular resonance" have been proposed to break up the Lead Sulphate crystals, these seem less plausible mechanism, as mostly those effects occur in the MHz not the kHz region.

Some de-sulphation devices use the collapsing field from a previously energised inductor, to deliver a short high voltage burst and an associated peak current pulse to the battery. I saw a few internet projects using devices such as 555 timer IC's and a Mosfet and and an inductor to "pulse the battery".

For my Machine design, I wanted to be able to meter (measure) the peak current delivered during a pulse and also control the pulse width with a Duty Cycle controller (also metered) but also have a fixed operating frequency that was independent of the duty cycle controller.

Also I wanted to measure the battery's **average** terminal voltage during the de-sulphation process. This value, especially for low duty cycles of 2.5% or less, is very close to the voltage between the current peaks when no charge injection is occurring during the process of de-sulphation. This voltage level, between the episodes of current injection is called the "**baseline voltage**" in this article. This is one reason I selected Analog DC voltmeters for the task, because their moving coil movements average out the result of DC waveforms with superimposed pulses.

A brief note about the *baseline voltage* versus the *average battery terminal voltage*:

As an example, measuring the voltage directly across the battery's terminals with the Oscilloscope during the de-sulphation process: Consider the baseline voltage is 14V between the voltage peak and there is a 2V peak voltage rising from that baseline to a 16V level, for a time of 50uS. This represents a 2.5% Duty cycle with the fixed operating frequency used in this Machine of 500Hz, or a 2000uS period. Then the waveform on the battery's terminals, seen with the Scope, has an average voltage of $((50/2000) \times 2) + 14 = 14.05v$. This is what the Analog voltmeter would read, if it had that resolution. The main point being, that for a low duty cycle pulse of 2.5% or less and the pulse amplitude being a relatively low proportion of the baseline voltage, the difference between the baseline voltage seen with a scope and the average battery terminal voltage seen by the meter is negligible at that low duty cycle. At a 15% duty cycle, the maximum the Machine is designed to provide and using this 2V amplitude pulse example, the average voltage would be 14.3v with the 14V baseline)

In addition, by designing a building the machine, I was able to inspect the voltages across all of the circuit elements in the current pathway during the current pulse, because the secondary low voltage side of the power supply was deliberately left floating, allowing easy connection of the scope's Earth clip to any circuit point.

The Machine with a New Battery versus a Treated Battery:

It is not recommended to apply the Machine to a brand new 12V SLA battery.

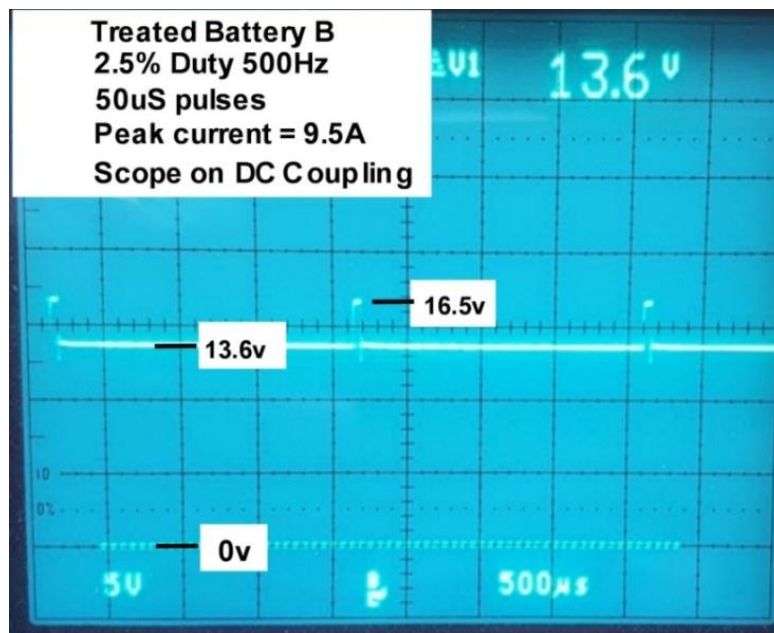
I had a new battery on hand to test. It was not a brand match with the two other aged and sulphated batteries. It consisted of two series 6V 4.5Ah cells I had recently bought for another application. As a brief test on the machine, the result was quite different to the two sulphated batteries at the end of their treatment.

The peak current profile with the new battery at a 2.5% duty was initially 15A. After less than one minute it settled on a 9A peak current (during the 50uS pulse) in an equilibrium condition with its baseline terminal voltage increasing from around 13V open circuit, to 16v under the influences of the brief current pulses. The pulse voltage peak on the battery's terminals seen with the Scope was only 0.6v higher than the baseline of 16v, peaking to 16.6V. This indicated a very low internal resistance of this new battery arrangement, in the very approximate order of $0.6\text{v}/9\text{A} = 67$ milli-Ohms. After less than 3 minutes the new battery was disconnected as it was not appropriate to leave it connected to the Machine.

Clearly, if a battery behaves in this manner, initially on the Machine, it should not remain connected to the machine for any extended period. It is not wise to apply an average terminal voltage of greater than 14.6V to the terminals of the 12V SLA battery because it exceeds its maximum specifications (despite 15V being mentioned on my other battery's labels) it can result in gassing and loss of water. I prefer the 14.6V limit.

On the other hand, with a near fully treated Battery B, the worst case of the two batteries I started with, near the end of the de-sulphation process, the result is shown on the Scope recording below. The baseline voltage was 13.6V, the voltage peaked to 9.5A during a 2.5% Duty (50uS wide pulse) to 16.5v. The approximate estimated internal resistance being the pulse amplitude of 2.9V divided by 9.5A present only during the pulse = 305 milli-Ohms.

This is shown in the scope voltage recording below, taken directly across the battery's terminals, in the late phase of the treatment:



The results with Battery A were a little better than with Battery B. Battery A's internal resistance dropped to 240 milli-Ohms and the peak current during pulse time was 10A.

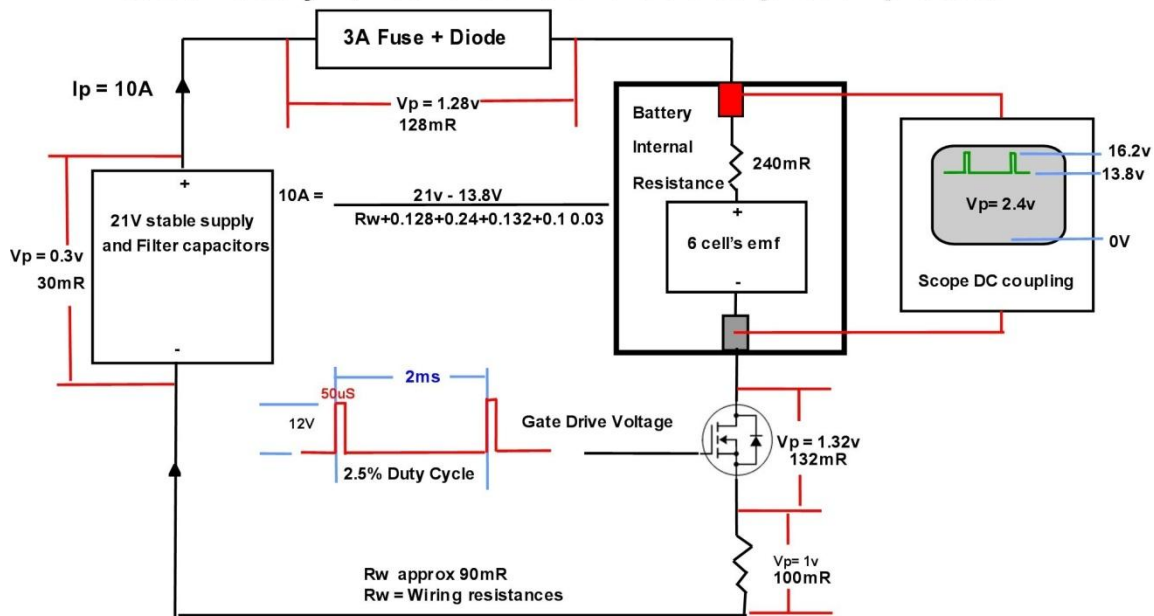
The diagram below shows the circuit voltages seen after treating Battery A over a course of 3 days.

The six circuit elements which all have an effective internal resistance are:

- 1) The PSU as a whole including the large filter capacitances.
- 2) The 3A Fuse and the 6A10 rectifier taken as one object for simplification.
- 3) The battery with its internal resistance.
- 4) The fully enhanced Mosfet's resistance.
- 5) The 100mR Current Sensing resistor.
- 6) The 10A rated hook-up/Appliance wire resistance, estimated, since all of the voltages around a circuit add to zero.

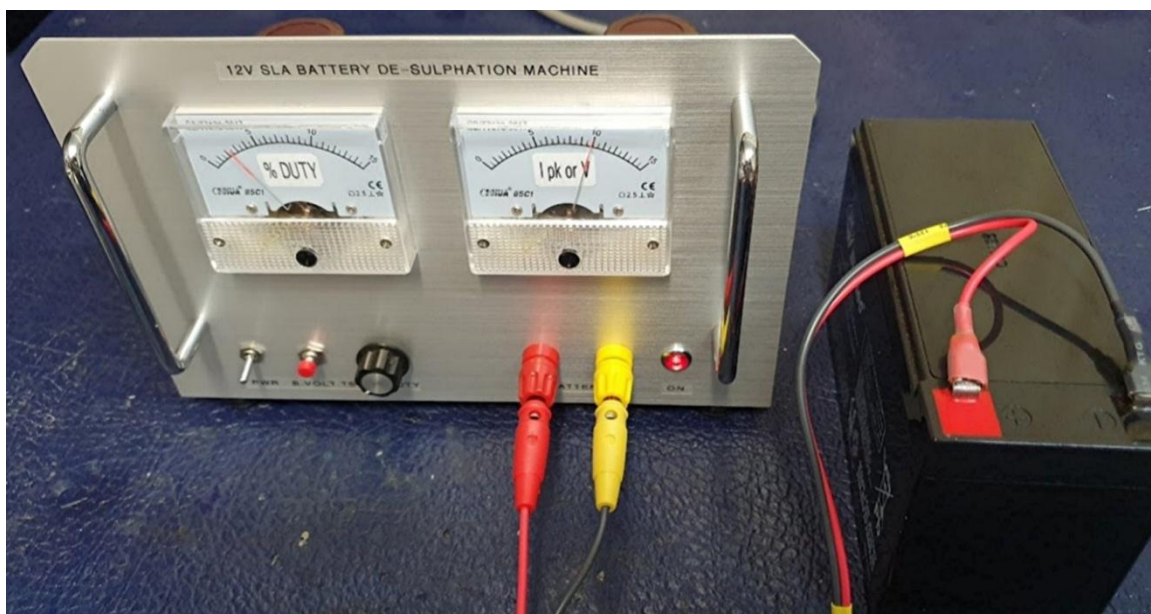
The transient voltage drop across the power supply terminals for a 10A 50uS wide pulse was only in the order of 0.3V, on account the large value filter Electrolytic Capacitors and possibly some active regulation by the supply over that time, suggesting that the 21v supply's internal resistance, dynamically at least, over the 50uS time frame of a current pulse, was in the order of 30mR.

Treated Battery A, near the end of the de-sulphation process.

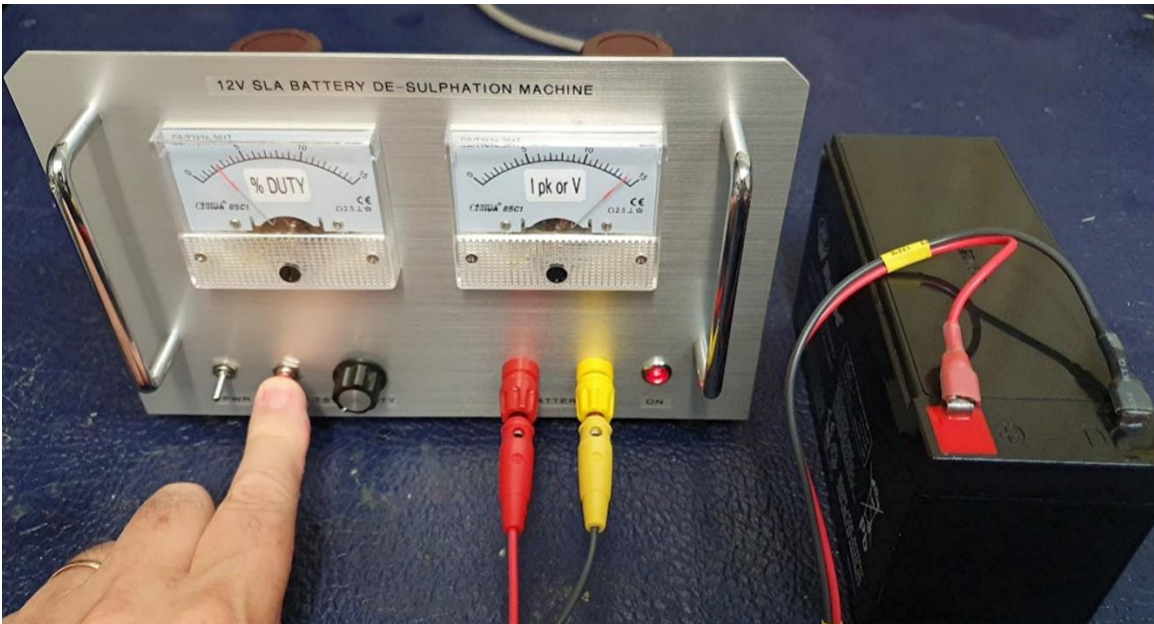


The total values of the approximate internal resistances of objects around the circuit came to a value lower than the calculation suggested for a 10A pulse, because of wiring resistance, including the leads to the battery needs to be factored in. They appeared to be in the range of 90mR but the exact value is not critical.

The photo below shows the unit in conjunction with a Treated 12V SLA battery in the final stage of the treatment with a 2.5% duty cycle and a 10A peak current, where no further improvement was observed over 8 hours:



On checking the battery voltage the value was just a little under 14V on the Analog meter.



What protocol and duty cycle should be used to treat a sulphated battery ?

It is not ideal with a 12V SLA battery to apply an average voltage of more than 14.6V to its terminals. Therefore using the Machine, the meter button should be pushed so the left hand meter displays the Battery's average terminal voltage. The % duty cycle control should be reduced until the voltage reads 14.6V or a value below that. And for the first two or three hours checked and reduced in duty cycle if the terminal voltage rises higher than 14.6V.

After that, the process can be slowed down by setting the duty cycle to 2.5%. It could possibly take 72 Hours or more, for the battery on the Machine, to fully charge and attain a stable steady state where the **peak current** seen on the meter reaches a stable value in the vicinity of 10 Amps and does not alter for 6 to 8 hours. The battery at worst should only be allowed to get a little warm to the touch. If it gets hot, the duty cycle should be backed down.

Given the variability of different batteries in the first place, their state of charge and degree of sulphation, it is a matter of watching over them carefully, especially in the early phases where the duty cycle is set greater than 2.5%.

The battery should never be left unattended, or left overnight without supervision. And the Machine & battery should be in a well ventilated area. If the terminal voltage and charge rate becomes too high the battery can evolve Hydrogen gas. Although the Machine described here

has ample fusing, however fusing mainly prevents wiring fires rather than protecting electronic components. Therefore the presence of fusing is it not an excuse to not supervise the battery while it is connected to the Machine.

When is the de-sulphation and charge process complete?

Part of this answer depends on the condition of the sulphated battery to start with. The basic principle, using this Machine, is that when the plate sulphation is as reversed as it can be, in conjunction with the state of charge of the cells in the battery being as high as that can be with the average terminal voltage 14.6V or below, the peak current value on the 2.5% duty setting will stabilize and not change at all over an additional 6 to 8 hours on the Machine.

Generally, the peak current being measured is the current during the pulse time. This profile has a near perfect rectangular flat top on a 2.5% Duty cycle (50uS) in this Machine as observed with a Scope across the battery's terminals. Although on higher duty cycles of 15%, the current during the pulse time, seen with the Scope, can droop down a little after the first 100uS, to about 80% to 90% of the initial value ,over the following 200uS because the battery acquires charge or some polarization effects over the longer time frame of the pulse. During that longer period the baseline voltage elevates a little. The peak current meter displays the initial peak current value over the first 50uS or thereabouts.

Of note (all else equal) the two processes occurring over time, with the battery on the machine: One of increasing battery baseline voltage with charging **lowering** the peak current because it reduces the driving voltage gradient with respect to the fixed 21V supply. However, with passing time, the decreasing battery internal resistance results in **increasing** the peak current, due to the reduction in total circuit resistance during the pulse. The peak current value globally increases over time with the sulphated battery on the machine, because as sulphation is reversed (be it hard or soft sulphation) the battery's internal resistance drops dominating the process.

In the case of my two aged batteries, after the de-sulphation process was as complete as it could be evidenced by an unchanging peak current and baseline voltage, to be 100% sure I transferred the battery to its usual constant voltage charger for 4 hours and confirmed that the current drain had dropped to the usual less than 300mA region and that the battery warmed up a little in the usual manner it does when fully charged on that charger.

After that I performed a discharge capacity test on the batteries by applying a near constant 600mA load and measured how many hours each battery could support that load while still keeping a terminal voltage of above 10V.

Interpretation of the results and definition of a success using the Machine:

Both Battery A and Battery B which were treated by this Machine likely should not even be operational at all at this point.

The reason being is that both their date codes indicated they are now nearly exactly 6 years old, both made in September 2020. The fact they started out, prior to treatment on the Machine, sulphated with a high internal resistance and were rehabilitated to any practical use at all by the Machine may well be a small miracle.

However as noted, this is not a scientific or controlled study of the process of de-sulphation, merely an experiment with this particular Machine with two aged and sulphated batteries.

Generally small SLA batteries of this nature are regarded at end of life at 5 or 6 years of age @ 25°C and these two batteries have been in a hot shed in Queensland in a grossly discharged state for many months. However for SLA batteries still working and well cared for, without being exposed to excessive temperatures, abnormal charging regimes or without being accidentally neglected and left to sulphate, they could be expected to possibly possess half or less of their original Ah capacity at this age, as a very rough estimate. So we could guess it was plausible if they had not been left to sulphate they might have half of their original rated Ah capacity at around 3Ah.

There is no general formula to predict the loss of capacity with aging which could be applied to a battery. In light of this, the expectations of what this Machine can do with these aged batteries and what it cannot do, must be kept in a realistic range for the particular batteries in this experiment.

It was clear in the early phases of treatment with the Machine that it was highly beneficial in allowing these sulphated batteries to initially start to accept some charge. On the standard charger, the charge current was extremely low. As the batteries gained charge on the Machine and at least some of the soft sulphation reversed on their plates, their internal resistance dropped and as the hours passed by, the the peak current, for any duty cycle increased significantly, ultimately on this Machine levelling out at 10A region for the 2.5% duty cycle pulse.

The Battery, while in the stable late stage condition on the Machine, the move of increasing the duty cycle above 2.5% results in a *reduction* in peak current. The reason for this is that with the higher duty, the battery baseline voltage drifts upwards, reducing the difference between the baseline voltage and the fixed 21V power supply voltage and all else equal, including the battery's internal resistance at that point, this lowers the current during the pulse time.

However, it should be noted, that without cutting the battery open for microscopic examination and using two identical sulphated and aged batteries, one used as a control, it is by no means certain that any specific proportion of hard Lead Sulphate has been removed from the plates. This is because a significant proportion of soft Lead Sulphate has been removed by the charging process itself, allowed by the Machine. However, in all probability, at least some hard Lead Sulphate has been eliminated.

The final test on the battery is to have it in a fully charged condition and apply a load to near fully discharge it to the region of 10V to 10.5V with the load attached. At this point the cells can be thought of as fully discharged to the region of 1.75V each.

As noted one cannot expect that an aged battery or a rejuvenated one will have the same storage capacity of a new battery of the same type. The question really becomes does either battery have any amount of useful Ah storage capacity at all?

I performed a relatively quick discharge test on each battery (fully charged) into a 600mA load. Battery B held the terminal voltage to 10V and above for 2.25 Hours suggesting an Ah capacity of 1.35Ah. Battery A, was almost identical at 1.38Ah. Those figures might have been a little better if I had performed the test at a more moderate discharge rate of 300mA rather than 600mA.

Although these results might seem disappointing, in light of the original 6.5Ah capacity on the battery's label, a 6 year old battery would likely, for other reasons, be expected to have half their original capacity possibly less if in perfect condition and well cared for. So, in light of that, the results with these aged and neglected batteries may well be quite impressive, considering the condition the two batteries started out in before the treatment.

At least now, the battery's A & B have a useful capacity and do not need to be discarded or recycled just yet.

Building the De-Sulphation Machine:

I had seen a few designs where the philosophy of applying a brief high voltage pulse to an inductor was done with a 555 oscillator, a Mosfet and an Inductor. The problem I found with the concept was mainly that the duty cycle was not independent of the operating frequency and the the current pulses depended on the inductor's energy storage properties at the operating frequency.

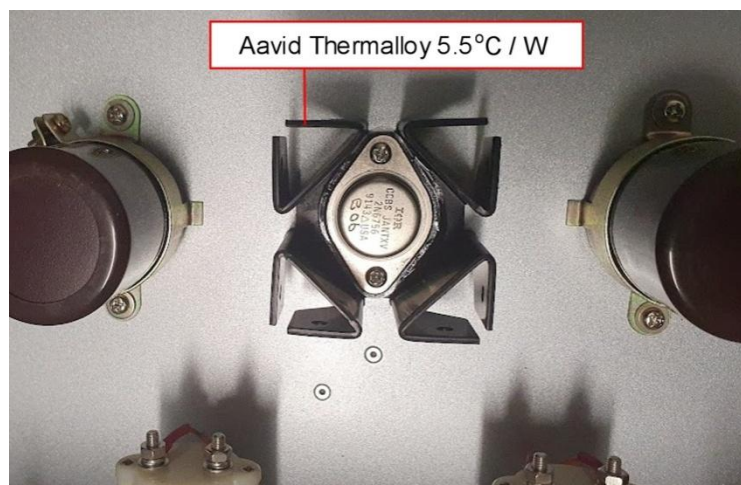
I decided on a design which used a crafted low internal resistance 21V power supply. A 24V Mean Well 3.2A supply with its output dialled to 21V on its preset pcb potentiometer was used,

along with a large filter capacitance applied to its output. This is to support brief high currents without the power supply detecting that and going into a current limiting mode. This supply specifies that the adjustment range on its pcb preset potentiometer has a minimum value of 21.6V. The one I used dialled to 21V without difficulty. If the particular unit does not, it is of no concern and it can be set for 21.6V.

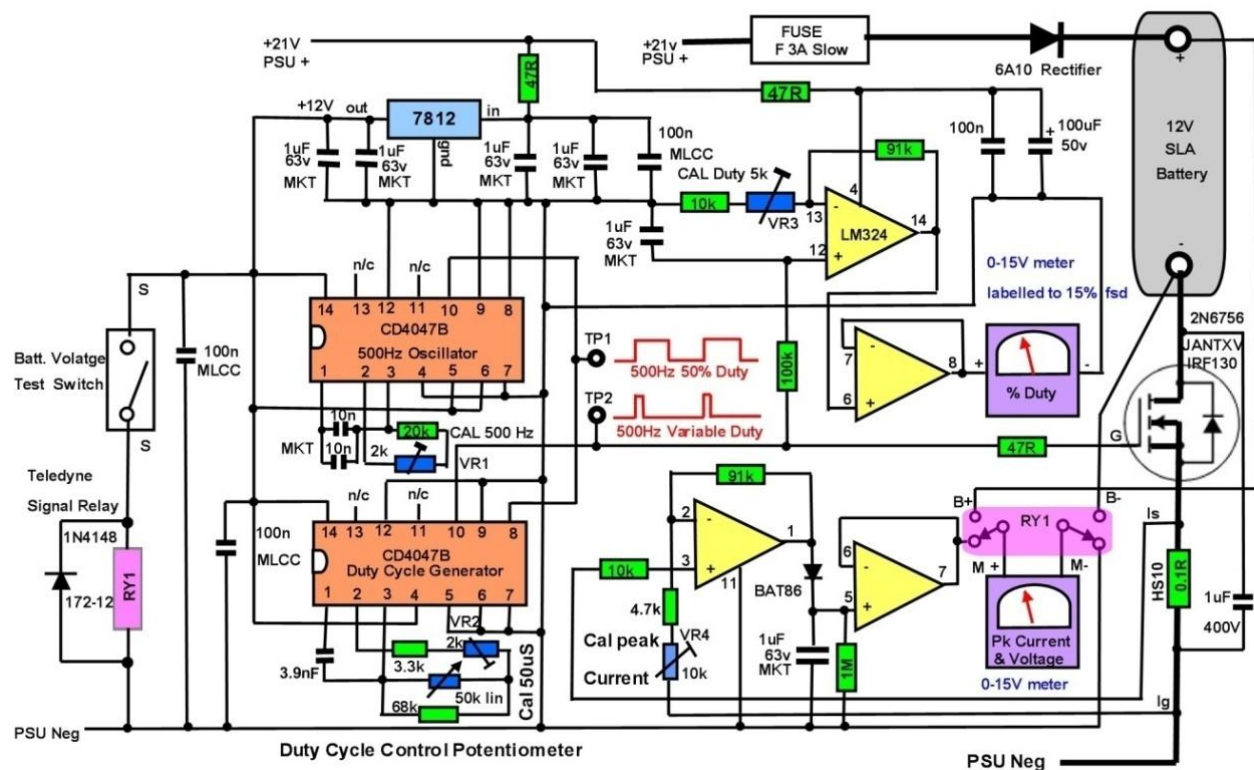
Due to the brief nature of the current pulses (in this case in the range of 50uS to 300uS) and the large value of support capacitance added to the power supply's output, close to 9,000uF, on practical testing the supply droop, at the supply's terminals during a 50uS 10A current drain pulse was in the order of 300mV. This arrangement synthesized a supply with a dynamic internal resistance of around 30mR. In my unit I used two 18,000uF 16V capacitors in series, with 390R balancing resistors, as these are what I had on hand in my parts stock, but a typical single 10,000uF 35V capacitor would be fine. If that is used, a 820R 1W or 2W resistor should be placed in parallel with the capacitor's terminals to discharge it in a reasonable time frame after the Machine is switched off.

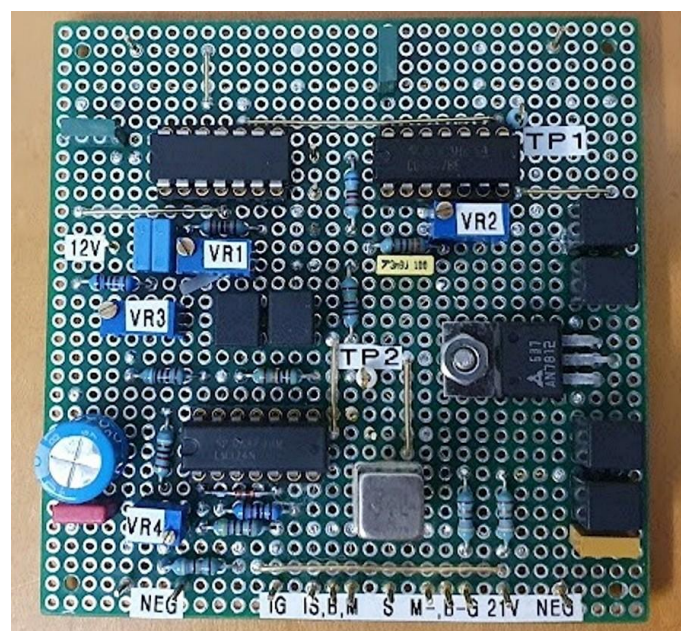
The control PCB in the unit consists of a separate 500Hz oscillator and a duty cycle generator, both based on the CD4047B Cmos Monostable/Astable multivibrator IC's. These are readily available if now somewhat vintage parts. The entire design is free of firmware. The drive pulses from a CD4047 feeds the gate of an IRF130 power Nch Mosfet (this is equivalent to the 2N6756 JANTX mil-spec International Rectifier part I used) These are very rugged TO-3 body Mosfets with a Rds on (fully enhanced) in the order of 200mR or less.

The Mosfet has significant heat sinking applied, by way of a finned heat sink thermally bonded to the lid of the die cast housing. The Mosfet does not warm up noticeably at all in use. However the heat sink helps to protect the Mosfet's junction in the event of abnormal conditions such as a failure to enhance due to a drive circuit anomaly, or gross continuous over Drain current. That is protected with a 3A fuse. However, if desired, the Mosfet (with insulators) can be screwed to the Metal lid of the diecast housing alone, without the attractive Thermalloy Heat Sink with no concern.

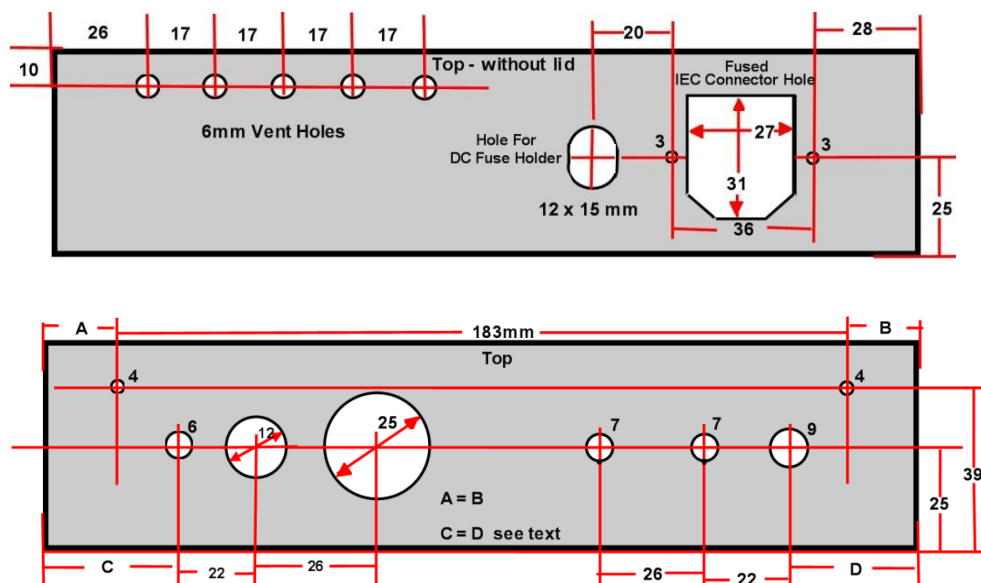
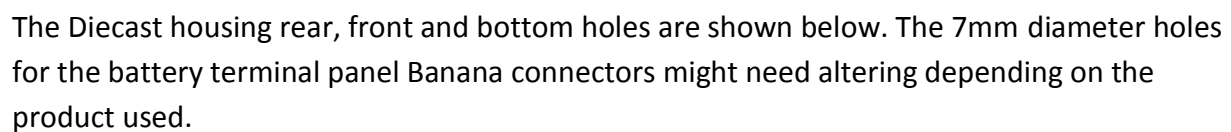


The duty cycle is monitored and metered with the technique of R-C integration and an OP amp driver circuit. The schematic and general wiring diagram:



[illegible]

The 2mm thick front panel hole layout is shown below. This is more than adequate thickness because the two handle's lower mounting holes help fix the handle to the diecast chassis and the upper handle mounting supports to the top panel, the whole arrangement being very rigid.



The 12mm and 25mm diameter clearance holes are required for the Potentiometer and Push Switch because the diecast material of the case is 3mm thick and the total threaded length of the sections on these parts were too short to accommodate a total of 5mm thickness and their securing nuts.

The array of holes and specifically the hole centers in the diecast enclosure' front vertical surface matches the front panel. Due to the tapered sides on the diecast enclosure, the side measurements A,B C,D shown in the diagram etc are less meaningful. Therefore the hole array must be centred correctly A=B and C=D. The front panel can be created first with 1.5mm pilot holes and it can then be used as a template for the holes in the diecast housing.

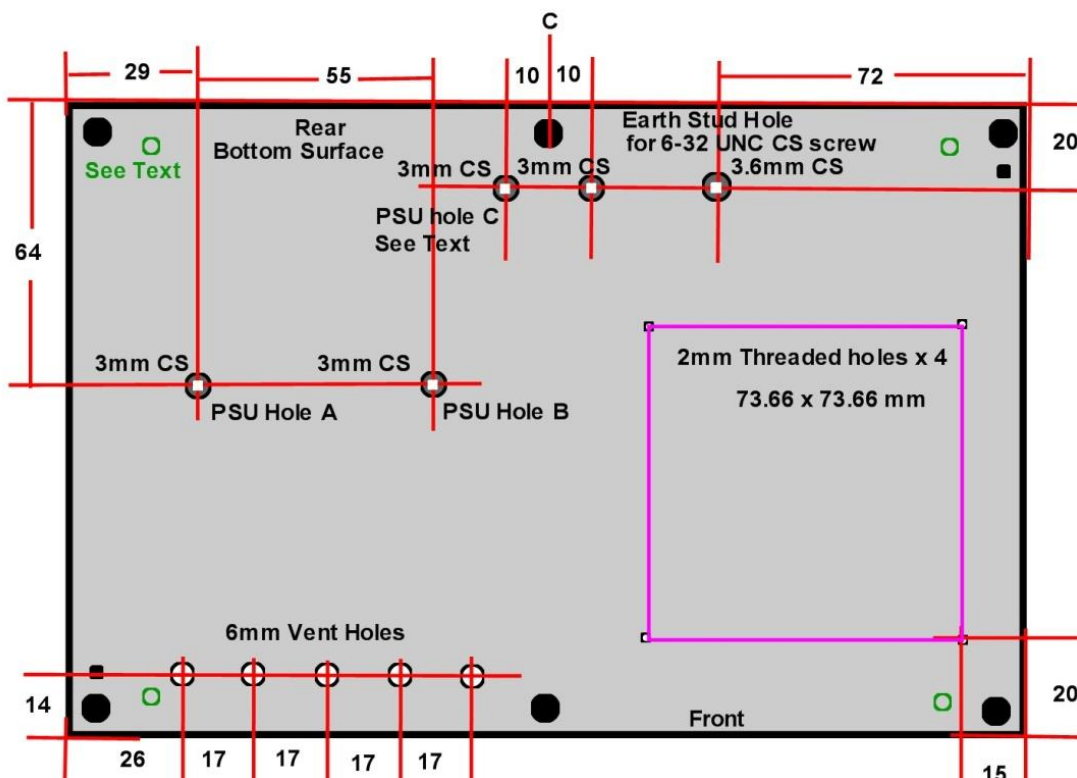
The particular handles used had a 91mm hole spacing. This may need to be adjusted, depending on the product used, many types have a 100mm spacing.

Diecast enclosure bottom view:

The holes marked in Green are already partially present on the inside of the enclosure and are drilled through with a 1.5 mm drill (sleeved to make sure it stays on the hole centre) Then tapped with a 2mm thread for 2mm machine screws and bushes to retain the 4 rubber feet.

Rubber feet are better screwed down with an internal metal bush & washer. Stick on rubber feet nearly always fall off especially in a hot climate when the adhesive fails.

2mm holes are also threaded to take the 8mm tall standoffs for the pcb.



TOP LID

Dimensions: 70 (width), 60 (height), 45 (corner radius), 50 (internal width), 40 (internal height), 70 (bottom width), 20 (bottom height).

Features: Rear, Front, TO-3 outline, 25 (hole diameter), 3 (hole diameter), 4 (hole diameter), 2 mm CS (cutout), 11.3 mm (cutout width).

A photograph of a rectangular metal plate, likely aluminum, with a brushed finish. The plate features several circular holes: four small holes at the corners, two larger holes on the left and right sides, and a central octagonal hole with four small circular holes inside it. The plate is set against a dark background.

During construction it is wise to fit the power supply first and attend to the Line wiring side of things and make sure all of that is normal secure and checked with a working power supply, before fitting the pcb & other components.

It is important to use lugs on all of the wires leading to the PSU's terminals. These are soldered to the wires and with added heat shrink insulation. Jaycar HP1350 4mm lugs are suitable. Never be tempted to screw the bare wires directly under the PSU's terminal screws.

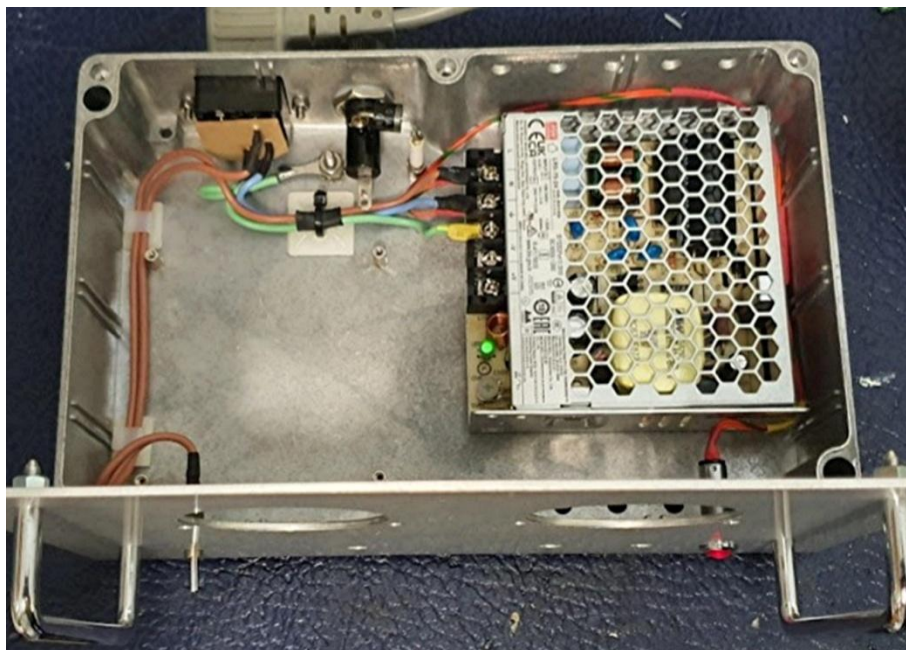
Also there are two Earth connection cables, soldered to the rear panel mounted Line power IEC connector's Earth pin, one passes to a 6-32 CS screw & chassis nut previously fitted with lock washer prior to the case being painted, then a nut is used to secure the Earth lug which is an internal Star style lug. An additional nut & lock washer added for more security. 10A rated appliance wire is used.

The second Earth wire from the IEC's connector's Earth pin, connects to the the Earth Terminal on the PSU. This Earth terminal on the PSU is also connected to the PSU body and when the PSU is screwed down to the housing by its 3 fixing screws, the housing then acquires two solid Earth connections from two conductors with a high current carrying capacity and the failure of a good chassis Earth inside the unit is mitigated to near zero.

It is also wise to put additional insulation over the rear of the IEC connector as shown.

The additional rear panel fuse is for the low voltage DC circuit.

The photo below shows early stages in the construction with the power supply wiring done and the power supply being tested:



When wiring the Line power switch, which is often a 3 terminal changeover switch, it is always a better proposition to connect the live (Phase) connection to one of the outer terminals, not the switch centre. If it is on the switch centre, then in the OFF position, Phase gets switched to the other outer terminal. And having no wire attached to it, it is more difficult to insulate that terminal without the heat shrink insulation falling off, or having to put a boot over the whole switch.

One trick that is helpful, while assembling or servicing and adjusting instruments built into diecast housings, with screw on top lids, is to offset the lid on two of its mounting holes as shown in the photo below. This allows good access and helps to determine the required lengths of the hook-up wires between items mounted on the lid and the inside of the case.

Temporary offset Lid position during construction or calibration:



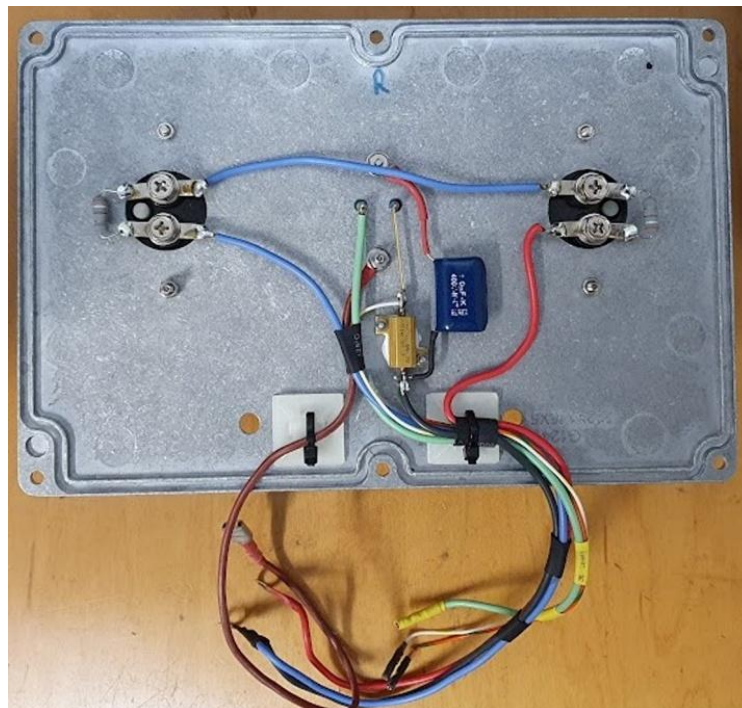
All the wiring which links the top panel assembly to places in the enclosure should be on connectors of one kind or another, so that the lid and everything on it can be fully disconnected.

In this case the connectors are a female spade terminal on the flying wire to the Mosfet's drain, to a male spade terminal fitted on the rear of the negative battery Banana connector.

A 4mm lug terminal Jaycar HP1350 on the the black wire to the PSU's negative supply terminal and a 4mm lug on the Red and Blue wires from the main filter capacitor's terminals and this wire is also 10A rated appliance wire. The socket pins on the smaller sized wires which carry signal information to and from the pcb use Jaycar socket pins, part number HP1260. The 0.9mm PCB pins they plug on to are Jaycar part number HP1250.

(Of note the pin-socket HP1260/HP1250 assemblies can be a very tight fit from new. Once the socket is fitted to the flying wire and heat shrink insulation added, better two layers of heat-shrink, as it gives a better hand grip later, it pays to add a tiny drop of machine oil to the socket and use a spare pin held firmly in toothed pliers, to exercise the socket at least 3 times. This makes them a better fit when they are finally applied to the pcb's pin. Also they are better soldered to the flying wire than connected with a crimping tool due to variation in the wire sizes used. The end crimp area is still folded over to support the wire's insulation. It takes some practice to use the correct amount of solder without it running into the socket area where the pin slides into it)

The photo below shows the assembled top panel. The application of the 1uF capacitor on the Mosfet's Drain to the Negative supply terminal is to remove high frequency transients in the edges of the switching pulse which occur due to inductance of the wiring and the rapid rise & fall time of the current pulses.



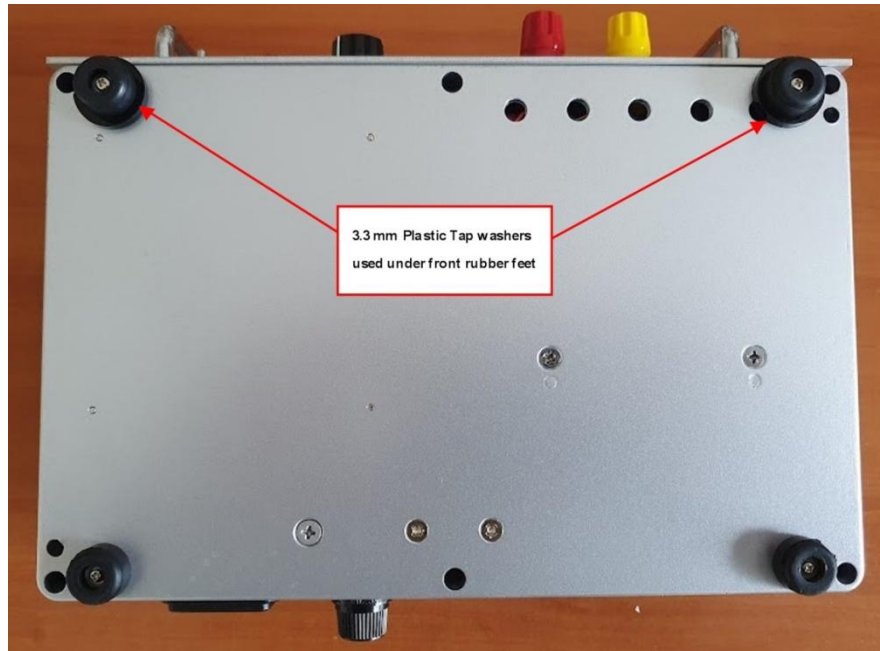
The photo to the below shows the unit in a condition just prior to complete assembly, where the pcb has been fitted and the the lid remains offset to allow for access to the calibration potentiometers.



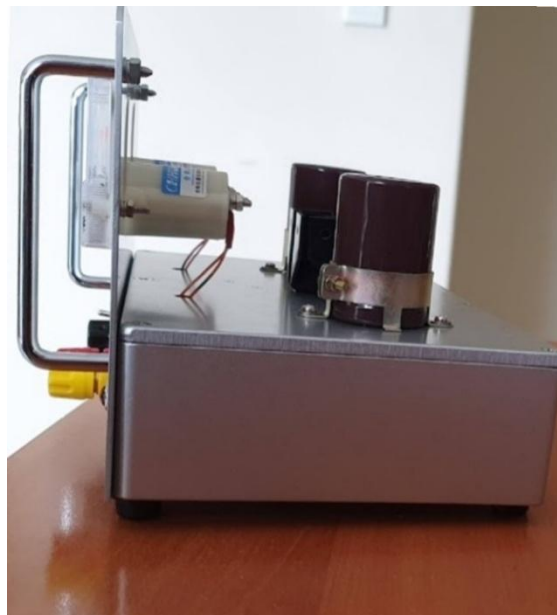
After calibration the meter leads are unscrewed from the meters (the wires have 3mm lugs to suit the meter terminal) they are threaded through the two holes in the top chassis plate and then the chassis top is slid across and attached with its usual six screws. Then the wires/lugs are reconnected to the meters terminals.

The photo below shows the bottom of the unit to draw attention to the rubber feet (a part available from Clarke Rubber). These are screwed with 2mm machine screws to 2mm threaded holes cut in the housing as previously described.

The feet screws have a spring washer and flat washer and an internal Brass Bush placed in the hole in the rubber foot. This is so that when the screws tighten up, they stop on a metal-metal interface but at the same time the rubber is just a little compressed to tighten the foot. The rear feet have a 3mm tall spacer placed inside them with a 4mm OD and a 2mm central hole.



However, the front feet (nearest the front panel) have a 6mm long metal bush with a 2mm hole and a 4mm outer diameter, because a 3.3mm thick plastic tap washer was added under each front foot to lift the chassis off the bench surface at the front. The reason for this is that the Jaycar diecast housing has tapered sides. This tends to tilt the front panel top edge toward the user. By increasing the height of the two front feet, as the photo below shows, this renders the front panel to an angle close to the vertical plane.



Calibrating the finished Machine:

There are 4 calibration presets.

VR1 is set with a scope or frequency counter attached to TP1 to attain 500Hz or a period of 2mS.

VR2 is set while monitoring TP2 on the scope so that when the front panel control (a 50k Lin part) is in its full Anti-clockwise position corresponding to its minimum resistance. The width of the drive pulse to the Mosfet is set at 50uS, corresponding to a 2.5% duty cycle.

Due to the fixed values in the potentiometer control circuit, when the control is rotated fully clockwise the pulse width should extent to just over 300uS so that the % Duty cycle meter can be pushed a little past "15" = 15% on the meter. If it did not reach 300uS the 68k resistor in parallel with the control could require increasing, but that is unlikely needed. Then the panel control is set manually to give exactly 300us width on the scope, corresponding to a 15% duty cycle.

At this point VR3 is adjusted so that the % duty cycle meter reads "15" = 15% on the meter.

VR4 is set by disconnecting the terminal the terminal Is on the pcb and applying +1.5V from a power supply to the Is pin on the pcb and negative of that supply to the Ig pin. This simulates a 1.5V drop across the 0.1 Ohm current sense resistor corresponding to 15A. VR4 is then adjusted so the peak current meter reads "15" = 15A, on its scale.
