

The C64 PSU Project

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Introduction

To keep it short: Read the “Setting R2” Chapter and you can skip the rest of this document if you don’t want to read a lot.

My goal was to create a PCB that can be a single solution to the Commodore 64 Power Supply problem what the community is having. Right now, there are only a few off-the-shelf solutions you can buy. One of them is the [Ray Carlsen PSU](#). The other one is [a Polish made](#), lower current device.

If you need a decent PSU that can deliver 3 or 4 A, you need to order it or build one for yourself. In my case, the postage would cost more than the actual thing. So, I set out to design a simple PSU that combines the [C64 Saver circuit](#) with a regulated, safe power supply.

Your C64, without cartridges or a Datasette, will need max. 1.5A from the 5VDC line and 1A from the 9VAC line.

Pros:

- I made 2 versions. The “Original C64 PSU Replacement” uses off the shelf components. Most electronics shops will have these. You choose your brand and price point. This will deliver only 3A of current maximum!
- The “Higher Current C64 PSU” contains a Mean Well branded part. Now, you will have to buy that particular device from Digikey, Mouser, etc. You have a lower part count but less freedom. However, it delivers up to 4A on the 5V line which allows you to use the 1541 Ultimate II cartridge or similar.
- The “Adjustable version” is the best because you can set the output voltage to 5.2V to compensate for the 0.1V drop in your wire (and the almost 0.1V drop at the LM2576 under full load) but you need to make a resistor (2.2k + 330 ohm)
- “Higher Current C64 PSU” can be made with just one tantalum cap so it is good as a backup PSU (no electrolytic cap leaks over time, HOWEVER IT’S NOT MY FIRST CHOICE)

Cons:

- You probably will not be able to fit these boards back into the original power supply case. So, you will need to buy a new enclosure.
- For R2, I used a resistor instead of a variable one (potentiometer) because this will not drift over time or due to vibration. However, it requires you to try one out between 330R and 510R.
- “Higher Current C64 PSU” cannot be used with a longer cable because the voltage will drop to 4.8V at 4A and a 1m long cable. So, it can be a low part count “Replacement PSU”

Setting R2

Why is this section at the beginning? Because you can skip all other chapters, you still need to do this step.

The “C64 Saver” part of this circuit (top of the board with a ground plane) sets the maximum allowed voltage passed to your C64. This should be no more than 5.35V (and not less than the 5.23V that the voltage regulator is producing)! Simply select a value of the resistor which will work the best for you.

You need to solder in C5, D3, R1, R6, D4, R3, C6, Q1, Q2 and RL1. Do NOT cut off the legs of C5! Hook your variable power supply’s positive and negative output respectively to C5 at the bottom of the board. Take the 470 Ohm (metal film) resistor and gently put it in place and bend the leads to surely make connection (while making sure they are not touching anything or shorting something out). It is easier to remove it this way later. Now, raise the voltage from 0. Between 2.5V and 3.5V, you will hear the relay clicking. If not, make sure your R2 is making contact. Keep raising the voltage slowly. You will hear the second click. That is your cut off voltage. Depending on your 4.7V Zener diode, it is between 4V and 6V.

Because there could be differences between the Zener diodes (D3) and how they perform in real life, you might need to change your R2 resistor. I tried 2 different diodes and I got these results:

ZPY4.7 (BZX85C4.7)	Cut-off voltage		XY4V7 (XY4.7)	Cut-off voltage
470 Ohm	5.35V		470 Ohm	5.0V
510 Ohm	5.2V		390 Ohm	5.36V
			430 Ohm	5.17V

The higher the resistor’s value, the lower your cut-off voltage will be. I set mine to 5.40V because the voltage regulator is producing 5.23V and due to the Bopla case (no ventilation holes on the top) the C64Saver circuit gets too sensitive. I recommend you to use the 3D printed case (or similar design), set your voltage at 5.2V and the cut-off voltage at 5.35V.

Please, only use METAL FILM resistors (1% tolerance) everywhere on the board with 1/4W, up to 0.6W rating.

Now, you can solder the rest of the components, add a fuse and enjoy your board!

The components

LM2576T-5.0 and LM2576T-ADJ Voltage regulator

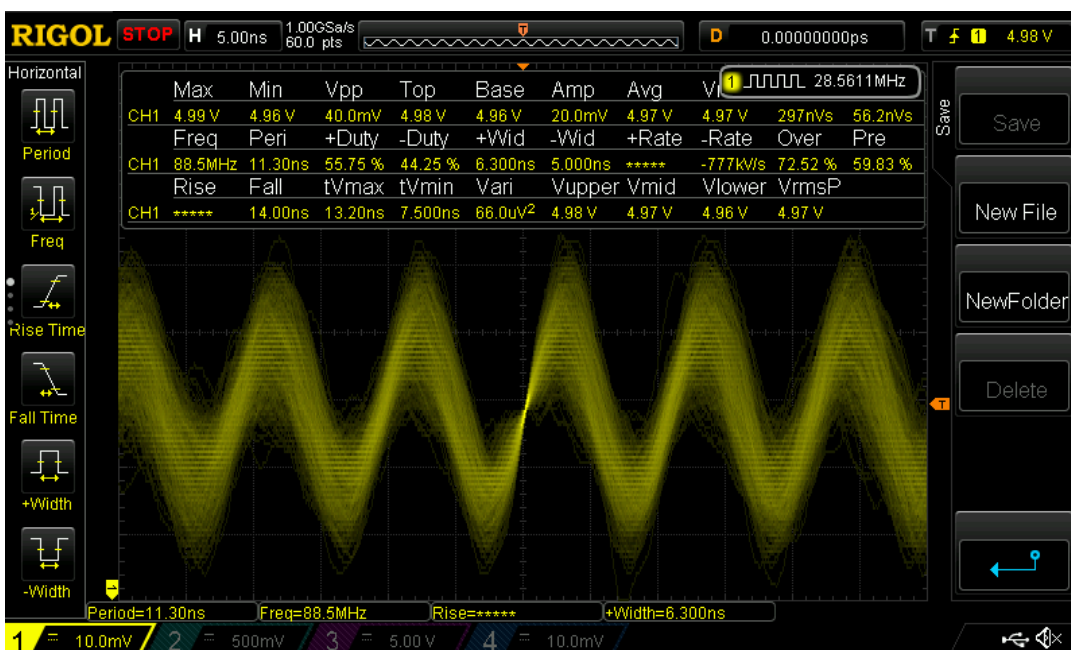
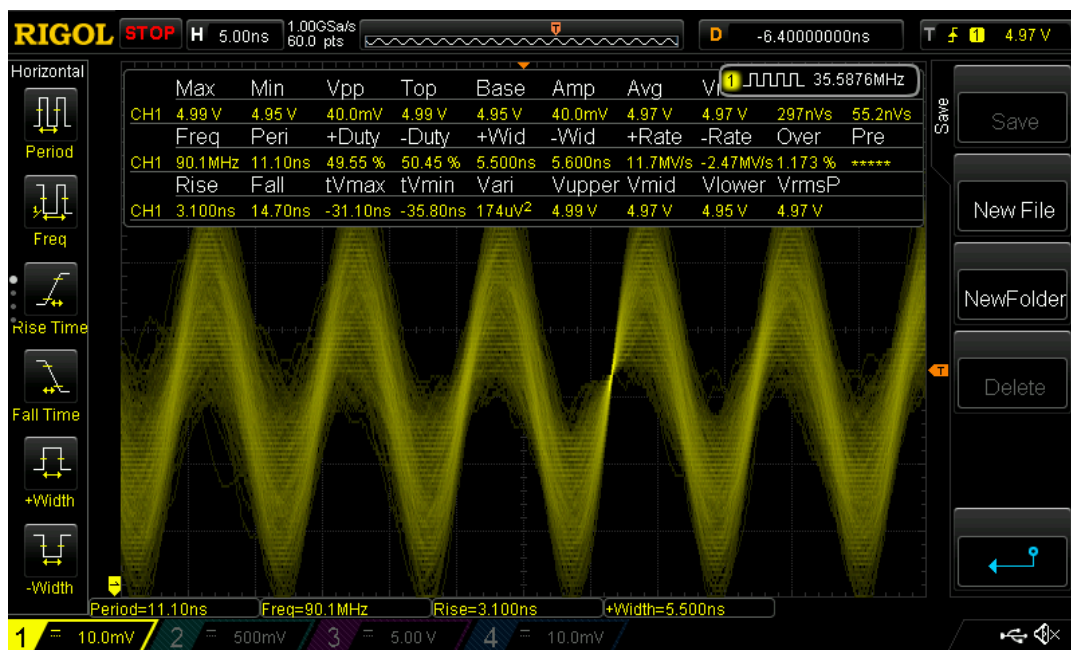
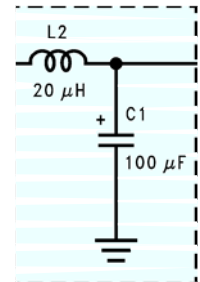
LM2576T -5.0 provided 4.98V regulated output with 20-50mV ripple. That is perfect for the C64. In the datasheet, they also recommend a low pass filter on the output to reduce noise.

This did not yield any meaningful improvement, according to my measurements.

I got 20-50 mV of ripple but this time, it stayed around 40 most of the time.

If you choose to have a 1m long cable, you will have an extra 0.1V drop. So, I recommend the ADJUSTABLE VERSION.

(Zoom in for larger pictures)



Capacitors

The 2200uF and 1000uF ones are electrolytic caps. LOW ESR is recommended, however it will work with any quality, modern one. Minimum 50V rated ones. The 2200uF has 7.5mm lead spacing while the 100 and the 1000uF have 5mm lead spacing.

The 100uF ones are tantalum or low esr electrolytic. For tantalum (recommended by me), you need 25V rated ones.

The 0.2uF (or 0.22uF) cap is MLCC (multilayer ceramic disc) but a ceramic disc is also effective. They are generally rated for 50V.

Resistors

Please, only use metal film resistors with minimum 1/4W rating. My choice was 0.6W rated ones but larger ones might not fit through the holes.

The Relay

I tried both. They are identical in their characteristics. The LEG-5F is on eBay and tme. The Sun hold is also available from many places.

According to their datasheets, you should be able to use: Finder 36.11, Relpol RM50 or Omron G5LE-1.

By now, you have probably realised that this is an overkill. If it's worth doing, it's worth doing right.

They are all rated for a few million operations so you won't need to replace them anytime soon.

AC CAP

I used a 4.7nF capacitor (X2 rated because it is over the two AC lines). The lead spacing is 10mm. The material is metallized film. If it fails, it fails with a short so be sure to use a fuse! Feel free to go up to 47nF for C7.

Bridge rectifier

KBPC 610 and KBPC 608 are physically the same size. Choose the one you can purchase easier.

They are 15mm x 15mm in dimensions. I watched Adrian Black's video [where he recommends 14mm x 14mm heatsinks](#). They are cheap and one is enough to keep it cool.

Above 1A current draw, they get pretty warm. This is why I placed a hole on the PCB. Even if you don't put a heatsink on it, the hole should aid the cooling. They are very robust and will last decades despite their higher temperatures during operation.

It's recommended that you raise it from the board by at least 5 millimeters when you are soldering it in place.

LED1 and LED2

I used 3000mcd rated LEDs which are bright enough for the purpose. Any brand and model will do. I recommend the 5mm size.

You can use wires to extend the legs and you can mount them wherever you see fit.

I chose to use 2 LEDs instead of one because if one of them goes out, I still get feedback from the other one. If you used a bicolour LED and it burned out, you would lose all feedback at once.



Inductor, L1

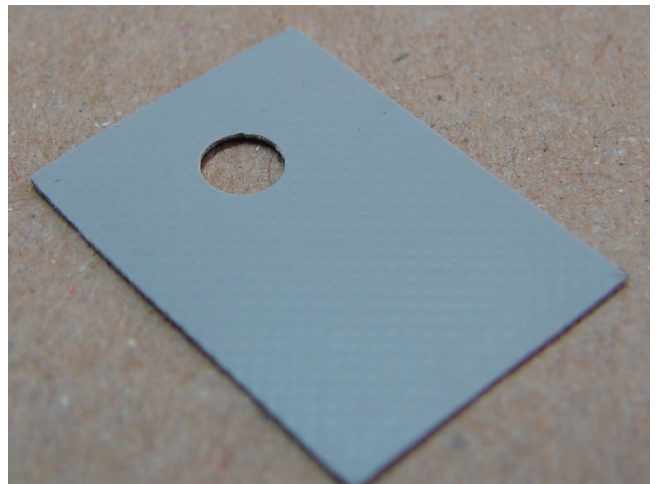
I recommend you one of these. It will fit into L1, which has 6mm lead spacing. Be sure it has a 3A rating.



Heatsink

ASSEMBLE YOUR HEATSINK - VOLTAGE REGULATOR FIRST, THEN SOLDER THEM!

You will need a TO-220 sized heatsink. Mine is 25*34*12 mm. On eBay, you will find this easily. The sellers allow ± 1 mm difference. There are mainly 2 sizes with this shape. There is a slightly taller one (38mm tall) that has the same lead spacing, which is 25.4mm. Be sure, it is threaded on the inside. So you can just use a screw to secure the thermal conducting pad (TO-220 size) to the heatsink.



Fuse and fuse holder

Essential component, cannot be left out!

I used 5x20 fuses in an external (not in line) fuse holder.
Make sure you do NOT connect this across the 2 AC lines.
Break one line and put it in series.
If your country (Switzerland, France, etc) uses polarized outlets and plugs, put your fuse on the “Live” or hot line.



First install your switch (4 blades, 2 connections for each line) then install your fuse holder! The order is power switch, fuse holder, transformer. This way, you cannot open your fuse holder and get an electric shock while your switch is off.

Slow-blow (marked with the letter T) recommended. The rating depends on your transformer. Mine was rated at 1.67A, so I picked a T1.6A fuse for the 9VAC out.
If you reuse the cord and DIN plug from the old power supply, please use a 1.6A rated fuse (such as the [LITTELFUSE 021301.6TXP](#)). For the “Higher Current PSU”, you need to use wires rated for higher current (such as your mains wires).

If you reuse the original (European version, 2 prong plug) power cord from the factory PSU, consider putting one fuse on each AC line behind the switch. [More about Double Fusing here.](#)
Put insulation on your wires! Prevent a possible short!

The Transformer

As I stated in the Introduction, my goal was to enable you to have options.
So right off the bat, you can choose the best option for you.

Power = Voltage x Current

$$P = V \times I \quad [VA = W]$$

You need to know your country’s mains voltage. [Where I live, it is 230V.](#) Then make sure it has 2 x 9V output. The minimum rating you need is 30VA. For the “Original C64 PSU Replacement” I picked the INDEL TSZZ 30/004M/5 (available on eBay) because this is what my local shop imported from Poland. It has 2 outputs with 9V on each and 1.67A of maximum current.

I would go with 35VA or maximum 50VA rated one. Feel free to use PCB mount or chassis mount versions. Whatever you can fit in your enclosure.

The other option is to use 2 separate transformers. If you take one with a 7V or a 7.5V output on the secondary side then the voltage regulator will run cooler. This is a gross overkill because transformers are expensive and large. However, if you disliked the overheating issue of the factory PSU, this will reduce the heat output of the LM2576 (even though it is running very cool compared to the factory one).

For the “Higher Current C64 PSU” with a PCB mounted transformer, I used the INDEL TSZZ 18/003M (9V 2A).

Place 2 washers between the transformer and the PCB to prevent it from warming up your board.

Enclosures

As I mentioned before, the [Bopla E 450VL](#) is a stylish enclosure. Jan Beta used the 440VL [in his video](#). The 450VL is slightly larger (and very expensive), allowing you to manage your cables better or insert a larger transformer. However, I had to drill holes on the top of it for better ventilation.

The enclosure doesn't matter. My first box was plastic and 159x139x59 mm in size.

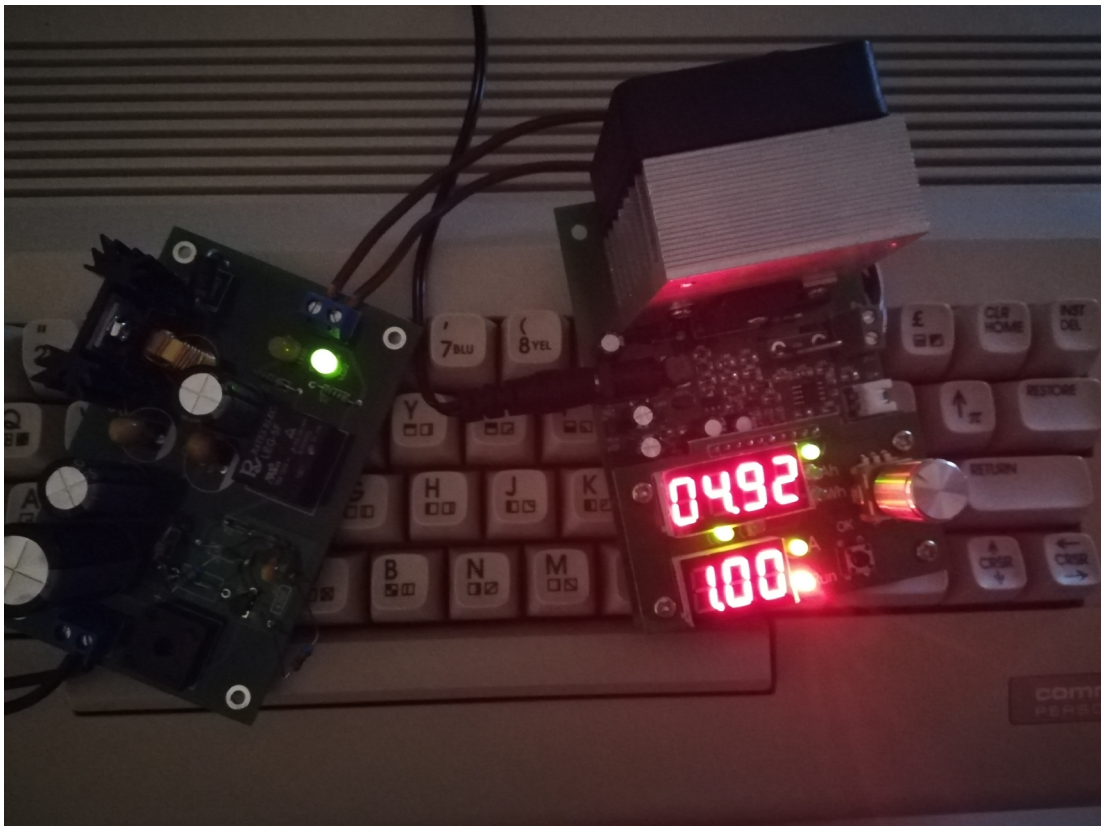
You can just 3D print the recommended box from [thingiverse](#). That one has a better air circulation through the top.



Testing

Voltage under load

The LM2576T-5.0 provides a 4.97V output. Under a 5V 1A load, it drops 0.05V!



My C64C draws around 1A during normal operation from the 5V line. A Breadbin C64 would draw 1.1 A or 1.2 A maximum.



When I measured the output of my factory original PSU inside the C64 (behind the switch), I got a 5.2V reading.

If you choose the version with an LM2576-ADJ then you need to insert R7 and R8. By changing the value of R8, you can raise your voltage. With R8 being 2.7k, the output is 5.04V. With a 2.4k resistor the output was 5.45V without a load. So, if you want other than the default, you need to make your own custom value by adding a 330 Ohm resistor in series with a 2.2k.

I measured (with a 2.7k resistor) 5.05V output of the LM2576T-ADJ voltage regulator and 4.96V under 1.26A load. (Maximum load under normal operation without cartridges). I also took a measurement under 1.6A load and got 4.95V.

A 2.52k gave 5.24V at the regulator and 5.17V under 1.6A load.

$$V_{OUT} = V_{REF} \left(1 + \frac{R_2}{R_1} \right) \quad \text{where } V_{REF} = 1.23V$$

With a 2.2K + 330 Ohm for R8, you will get 5.23V before you turn your C64 on.

With a 2.2K + 390 Ohm for R8, you will get 5.13V before you turn your C64 on.

The IRM-20-5 provides 5.02V and under load it keeps it reasonably well.

- At 1A it was 4.98V
- At 2A it was 4.96V
- At 3.5A it was 4.9V

To connect the load and the PSU, I used a 30cm long, 2.5mm² wire. If you are planning to have a cable with 1m length, calculate with an extra 0.1V drop. This is why I recommend you to create a resistor with a value between 2.5k and 2.6k.

Heat

Under that 1A load (with a 9VAC transformer) the heatsink on the voltage regulator barely got warm! After 30 mins, I was holding the board by the heatsink for a minute. I can safely say that it will not overheat on room temperature if your enclosure has ventilation holes in it.

The KBPC bridge rectifier will get much warmer than the voltage regulator. So, the heatsink is recommended. [As seen in this video.](#)

Under 2A load, the bridge rectifier will get hot (without a heatsink). It is perfectly safe at that temperature but it is the hottest part of this build. They were designed to handle these temperatures. It's recommended that you raise it from the board by at least 5 millimeters when you are soldering it in place.

For the record, according to the KBPC 610's datasheet, it is rated for 3A of current without a heatsink! The "Original C64 PSU Replacement" - ideally- is used only for maximum 1.5A continuous current for the C64 and the 0.1A (100mA) idle current. So, half of what the rectifier is rated for without a heatsink...

Even though the rectifier is close the C1, after an hour I did not feel (by touch) much difference between C1 and C2. It does not overheat it.

Idle current

Due to the C64 Saver and the voltage regulator, this device has 100mA of idle current. So, use a power switch to turn this off when your C64 is not in use.

Reusing the factory cable

When you choose to reuse the cable from the old power supply, you will notice that it is long. Mine ([Part No. 251053-11](#)) was 1.5m (5 feet) long.

So, naturally, I was curious about the voltage drop across it. The supplied voltage dropped to 5.18V on the board under load (I used my own C64C) and I measured 4.99V behind the switch. When I cut it to 1m (3 feet), I measured 5.04V inside the C64C.

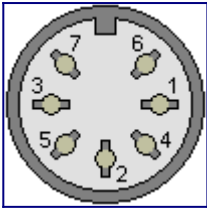
So, I wouldn't have it longer than 1 meter in length! (I, personally use it at 75cm length. Just cut the original in half.)

Total Power Draw

My C64C (Assy NO. 250469, PCB NO.2523II Rev4) consumed 8W.

When I added the Epyx Fastload cartridge and a [SIDFX](#) with a SwinSID Nano, the TPD went up to 11W.

Wiring diagram



Contact assignment

Pin	Voltage	Current	Comment
1	GND	N/A	Ground/Not connected
2	GND	N/A	Ground
3	GND	N/A	Ground/Not connected
4	-	N/A	5V or Not connected
5	+ 5V DC	1.5 A	5 Volt direct current
6	9V AC1	1.0 A	9 Volt alternating current phase 1
7	9V AC2	1.0 A	9 Volt alternating current phase 2

Source: https://www.c64-wiki.com/wiki/Power_Supply_Connector

Note: although only four pins are actually used, the power connector is a 7 pin DIN, as shown. Use pin 5 for +5 volts and pin 2 for ground or minus. The 9VAC output is on pins 6 and 7.

Source: <http://personalpages.tds.net/~rcarlsen/cbm/c64/C64%20PS/pstester.txt>

BOM

C1 : 2200uF - 63V or 50V with 7.5mm lead spacing (maximum 18mm in diameter)

C2 : 1000uF – 50V with 5mm lead spacing (maximum 12.5mm in diameter)

C3: 100uF -min. 25V tantalum or electrolytic

LM2576T-ADJ (if you chose the “Adjustable version”)

TO-220 heatsink (25*34*12 mm) with 25.4mm lead spacing

R7 and R8 optional for ADJ version (8.2k and 2.53k (2.2k + 330 Ohm) metal film resistor)

L1: 100uH 3A

D5: 1N5822 through hole

C4: 1000uF 50V or 35V electrolytic with 5mm lead spacing (maximum 12.5mm in diameter)

C5: 100uF -min. 25V tantalum (recommended in all versions) with 5mm lead spacing

D3: 4.7V Zener diode such as XY4v7 (min 1W, max. 2W rated)

KBPC610 or KBPC608 with [1 piece of 14mm x 14mm heatsink](#)

C7: X2 class AC capacitor with value between 4.7nF and 47nF, lead spacing is 10mm

R2: Metal film 1/4W resistor between 390R and 510R (see Setting R2 section)

R1: 1k metal film through hole resistor 1/4W

R6: 220k metal film through hole resistor 1/4W

D4: 1N4148 diode

R3: 2.2k metal film through hole resistor 1/4W

C6: 0.2uF capacitor (through hole) MLCC

Q1, Q2: 2N3904 through hole transistors

RL1: Sun hold RAS-0515 relay or Rayex Elec. LEG-5F

R4, R5: 470R metal film through hole resistor 1/4W

LED1, LED2: 5mm through hole leds

T2: Mean well IRM-20-5 (optional for the Higher Current C64 PSU)

2 terminal block connectors with 5mm spacing, rated for your mains voltage!

10mm brass spacers (female on both ends) with M3x10 screws (such as [TDYSFF-M3/10](#))

INDEL TSZZ 30/004M/5 or INDEL TSZZ 18/003M depending on your country of residence and which version you chose!

8 washers (to elevate the transformer by 2mm from the PCB) if you chose the version with the transformer on board

Schematics

