The Time Expander Nixie Clock Kit

(in one form or another)

Before You begin

All components in this kit are of the through hole type. Soldering should be pretty straight forward.

In addition to the contents of this kit, you will need the following items to complete assembly:

- Soldering iron.
- Solder.
- Side cutting pliers (for removing excess component leads)
- Cyanoacrylate glue
- M2 Allen key
- M3 Allen key

The following items are nice to have during the build process, but they are not strictly mandatory:

- Magnifying glass (for inspecting solder joints. This is not the project you want to create your first short circuit with...)
- Multimeter (for checking correct polarity and voltages)

IMPORTANT: Before you start soldering. Please note that three of the IC sockets are going to be mounted on the underside of the board.

What's included in the full kit:

- Assembly instructions
- Raspberry Pi Zero W Nixie Shield PCB.
- 100-240 VAC 12VDC wall adapter.
- Raspberry Pi Zero W.
- Sandisk MicroSDHC 16Gb card with precompiled firmware and firmware source code.
- Laser cut acrylic stand.
- Lumos HV-PSU_EXT_V3 high voltage nixie power supply.
- 6 x NOS IN-12A Nixie tubes.
- 40 pin male header.
- 40 pin female header.
- 10 x DIP-16 sockets.
- 6 x K155ID1 BCD to decimal decoder (74141 compatible).
- 1 x ULN2003 transistor array.
- 3 x 74HC595 shift register.
- 80 x tube socket pins.
- 3 x 12k 1/4W resistors.
- 6 x 15k 1/2W resistors.
- Hookup wires.
- 4x 18mm spacers
- 4x 30mm M3 bolts
- 4x 10mm M3 bolts
- 8x M3 lock nuts

What's included in the PCB only kit:

- Assembly instructions
- Raspberry Pi Zero W Nixie Shield PCB.

The BoM is on the last page in this document

A note regarding power supplies.

The full kit contains a 12V CE certified wall adapter and a high voltage power supply from Lumos (https://www.lumos.sk/high-voltage-power-supply-extended). The Lumos supply can be powered from anything from 10 to 18VDC and has 3.3V, 5V outputs (for powering logic) and adjustable 105-182VDC (for powering Nixie tubes).

> *If you only have the PCB and the BoM, you will have to source an external power supply that can step up voltage to approx 170V (delivering up to 2.5mA to each tube) from your own low voltage source. Designing reliable boost converters for nixie clocks can be a tricky process and I highly recommend getting a third party HV supply. The Lumos supply is affordable and has proven to be quite reliable. Several of the cheaper chinese nixie HV supplies you will find on AliExpress or eBay - not so much.*
>
> *If you are using separate HV and 5V supplies, then tie their grounds together and connect HV, GND and +5V to the HCONN terminal on the board*

Health, safety and solder tip hygiene.

IMPORTANT:

1. ***UNDER NO CIRCUMSTANCES SHOULD YOU ATTEMPT TO POWER THESE TUBES USING LINE VOLTAGE (it will end in tears, shrapnel and carbon tracking).***
2. ***Do NOT handle the clock while it is running.***
3. ***The Nixie tubes are operating on approximately 170 VDC. Even though the HV power supply only capable of delivering currents in the tens of milliamp range, touching the PCB or any of the exposed solder pads on the PCB while the clock is operating may produce a nasty shock. Keep it away from children at all times.***
4. ***Keep in mind that this is a kit project - that you have assembled. It is not CE certified. Don't leave it running unattended - you do not want to electrocute curious bystanders. Also - It is not a night lamp.***

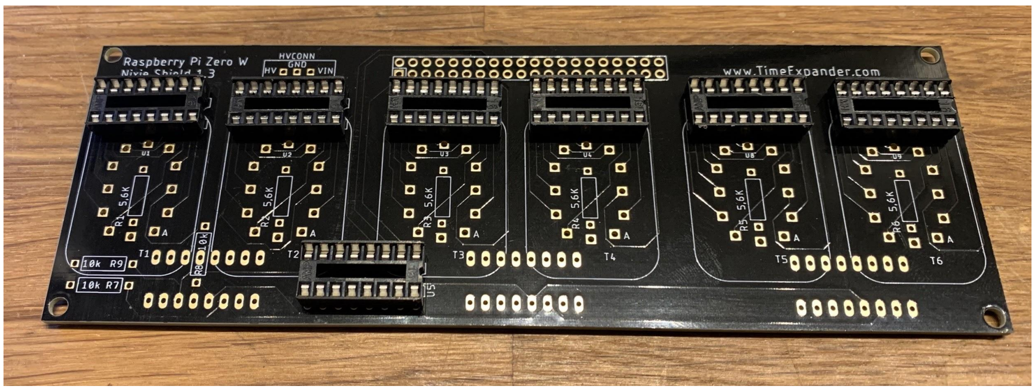
Ok. Having read the previous 4 paragraphs in mind, you now have 293 solder joints ahead of you.

Remember to clean the tip of your soldering iron regularly and work in a well ventilated area. A fume extractor is nice to have, but I realize that not too many hobbyists have them. Use lead free solder if possible. Lead oxidizes in air (this process is accelerated by heat) and the oxides can be absorbed through the skin. The soldering process produces small solder particles as well as smoke from the solder flux. You do not want this stuff in your lungs. Lead is toxic and it accumulates in the body.

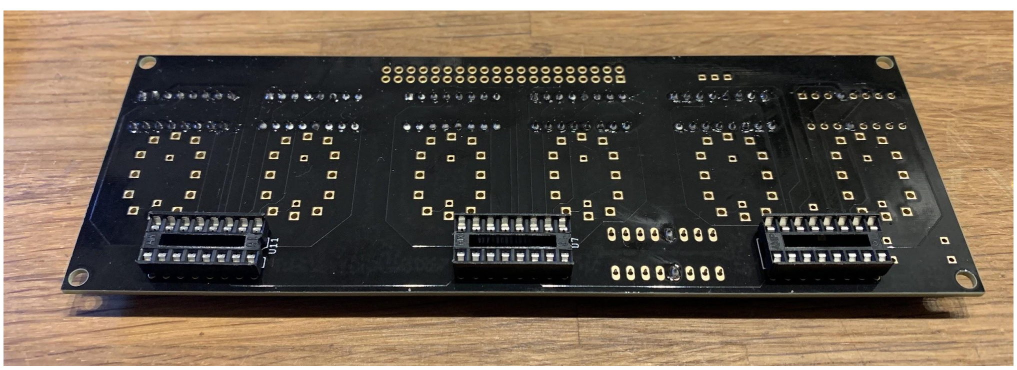
Work in a well ventilated area and / or (preferably) use a fume extractor even if using lead free solder.

Time to power up the soldering iron!

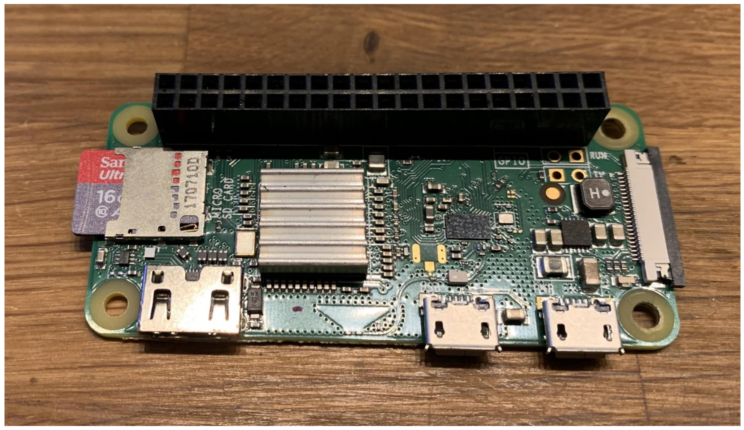
1. Solder the 7 DIP-16 sockets to the top of the board (T1-T6, U5). Make sure that the notch on the socket matches the notch on the silk screen.



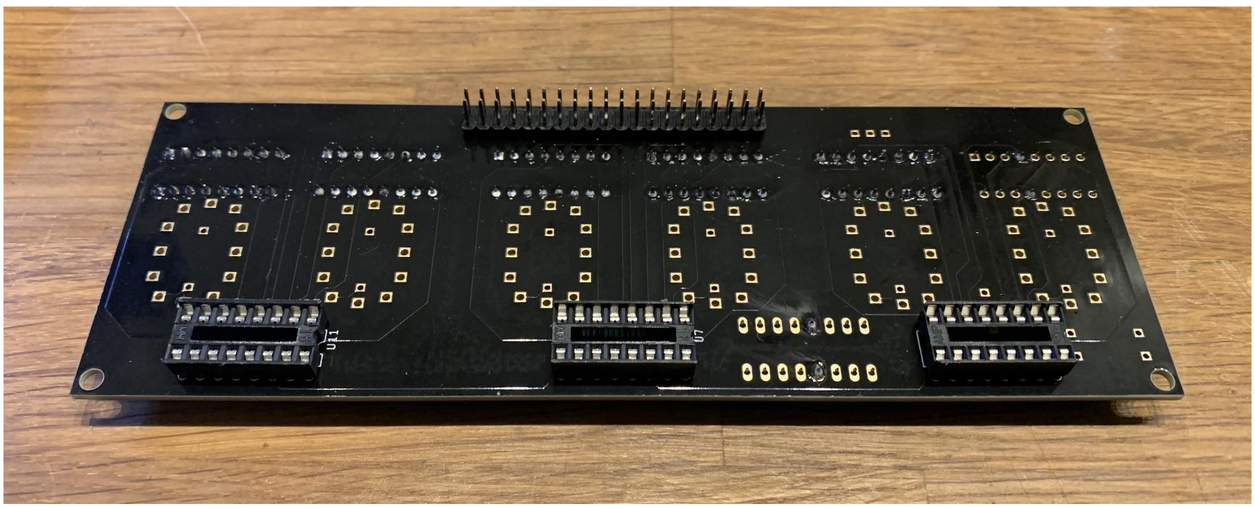
2. Solder the remaining 3 DIP-16 sockets to the back of the board. Make sure that the notch on the socket matches the notch on the silk screen.



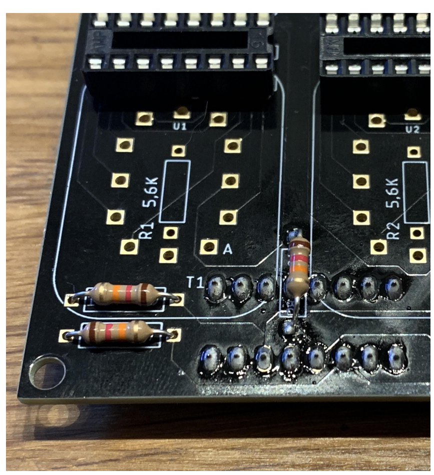
3. Solder the female 40 pin header to the top of the Raspberry Pi Zero W board



4. Solder the male 40 pin header to the back of the nixie board



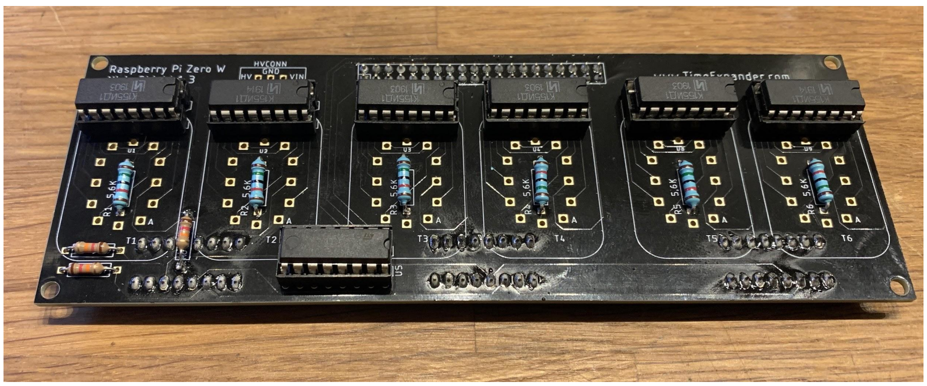
5. Solder R8, R9 and R10 to the top of the board. One of the legs of R8 will have to be soldered from the top side of the board (It seemed like a good idea at design time…). Trim the excess leads with a side cutter.



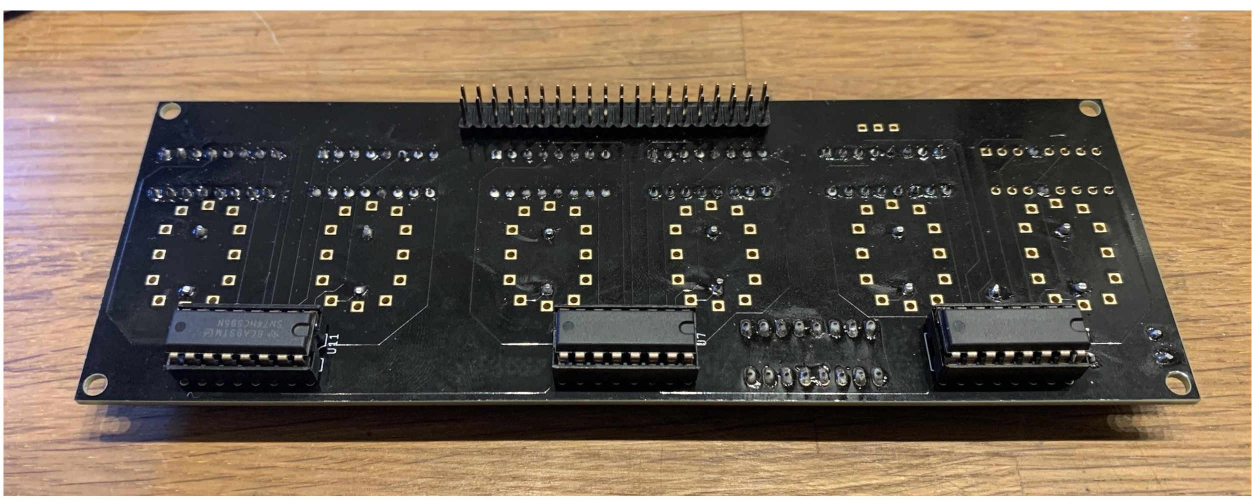
6. The ½ W resistors are a tight fit. Make a sharp 90 degree bend as close to the resistor body as possible for easiest possible assembly. Then solder R1, R2, R3, R4, R5 and R6 to the top of the board. Trim the excess leads from the back with a side cutter.

7. Insert the 6 K155ID1 BCD decoders. Make sure that the notch on the chip matches the notch on the socket.

8. Insert the ULN2003A into the U5 socket. Make sure that the notch on the chip matches the notch on the socket.

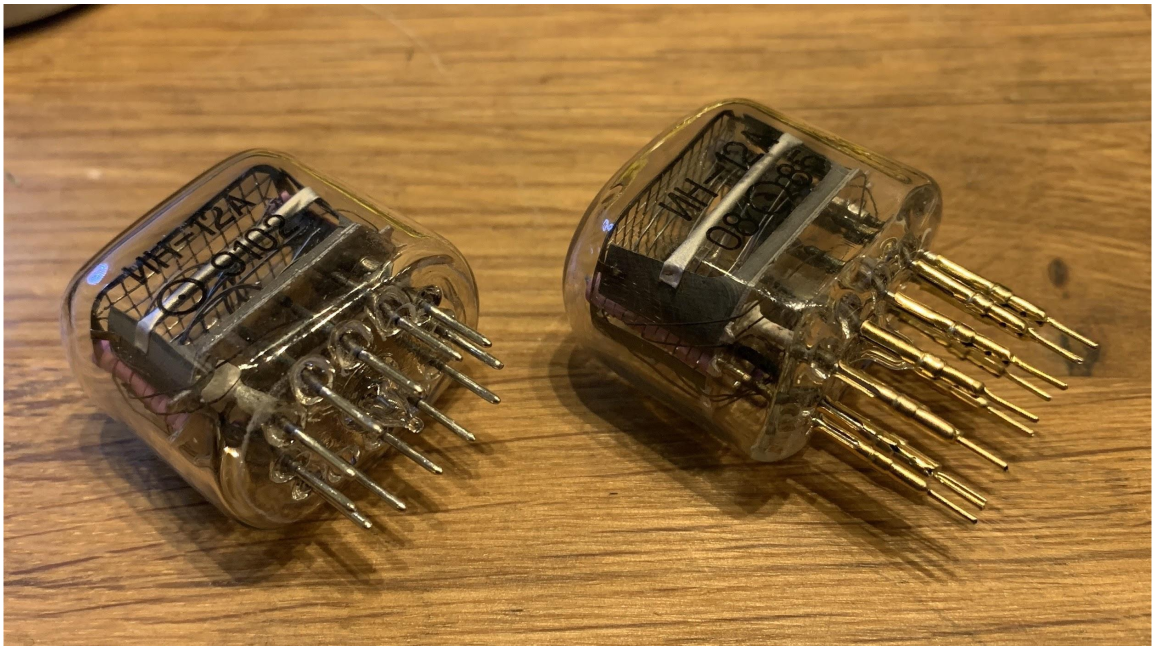


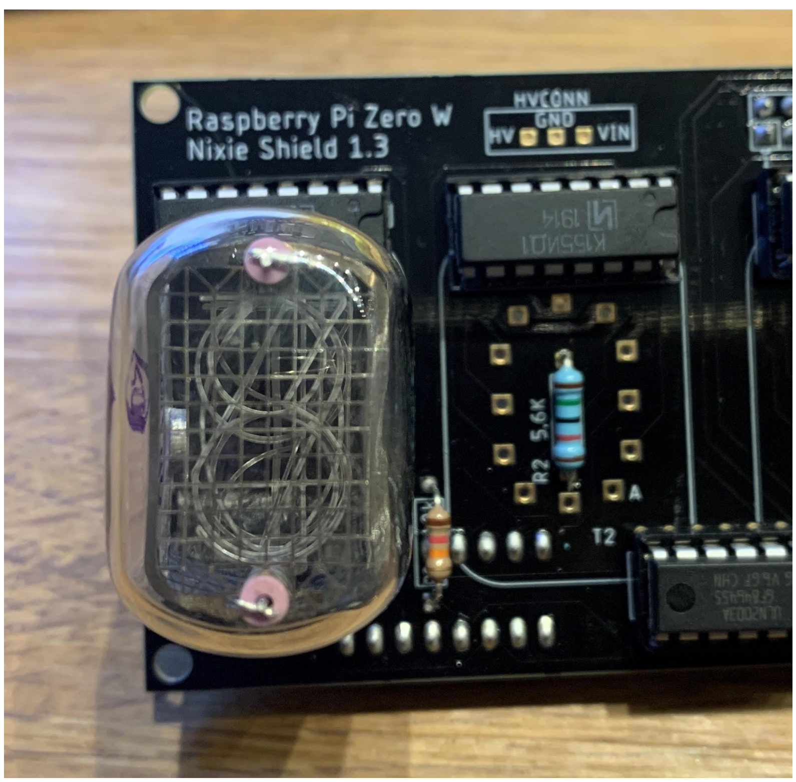
9. Insert the 74HC595 shift registers into the U6, U7 and U11 sockets. Make sure that the notch on the chip matches the notch on the socket.



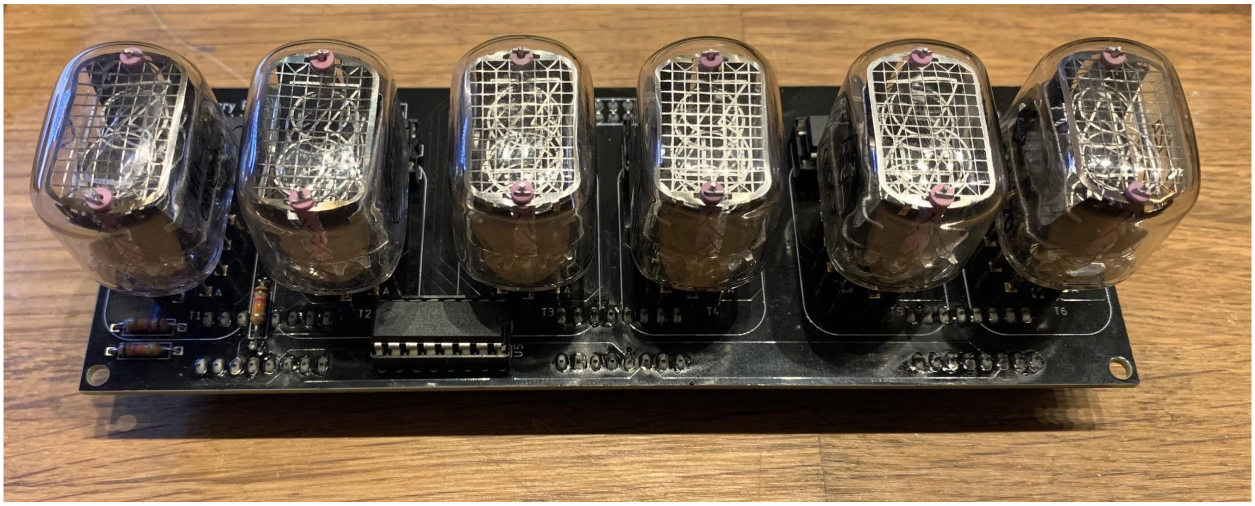
10. Attach pin sockets to all the pins of one of the IN-12 nixie tubes and insert the tube into T1. This can be a bit fiddly. I recommend fitting one pin after another going in sequence,

around the tube. Once the tube is inserted, flip the board around and solder the pin sockets to the back of the board. Make sure that the tube is oriented the correct way. The numbers should have the same orientation as the silk screen text on the PCB.





11. Repeat the process for the remaining tubes

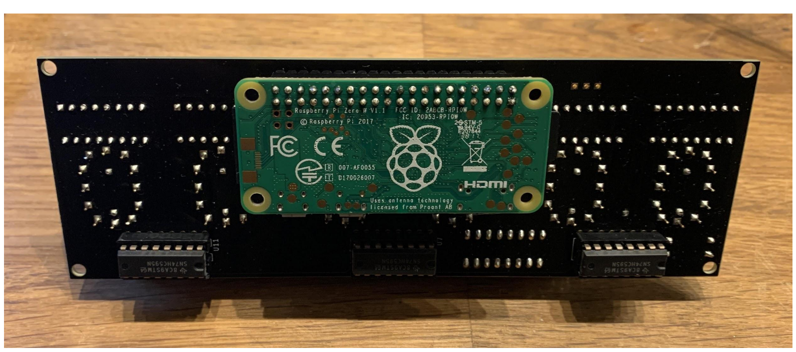


12. Configure your raspberry for headless boot with SSH and wireless network.
    a. Insert the SD card into your computer and create an empty file with the name "ssh" on the boot partition (labelled "boot"). This will enable SSH.
    b. create another file called "wpa_supplicant.conf" with the following contents:

```
ctrl_interface=DIR=/var/run/wpa_supplicant GROUP=netdev
update_config=1
country=US

network={
      ssid="<Your SSID>"
      psk="<Your key>"
      key_mgmt=WPA-PSK
}
```

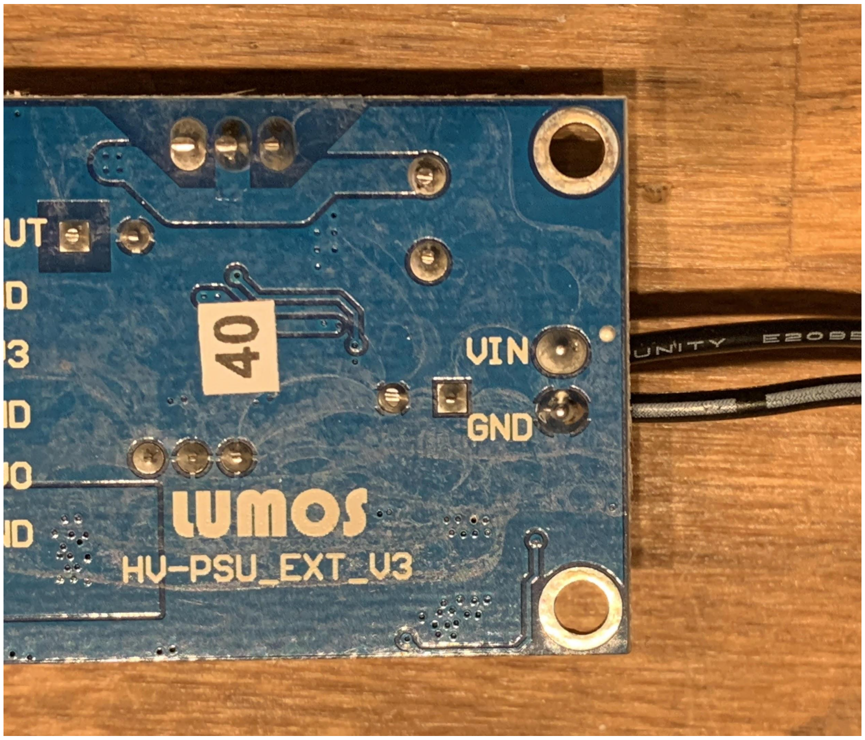
13. Update the ssid and psk parameters. Then eject the SD card from your computer and insert it into your Raspberry Pi Zero W. Attach the Raspberry to the nixie board.



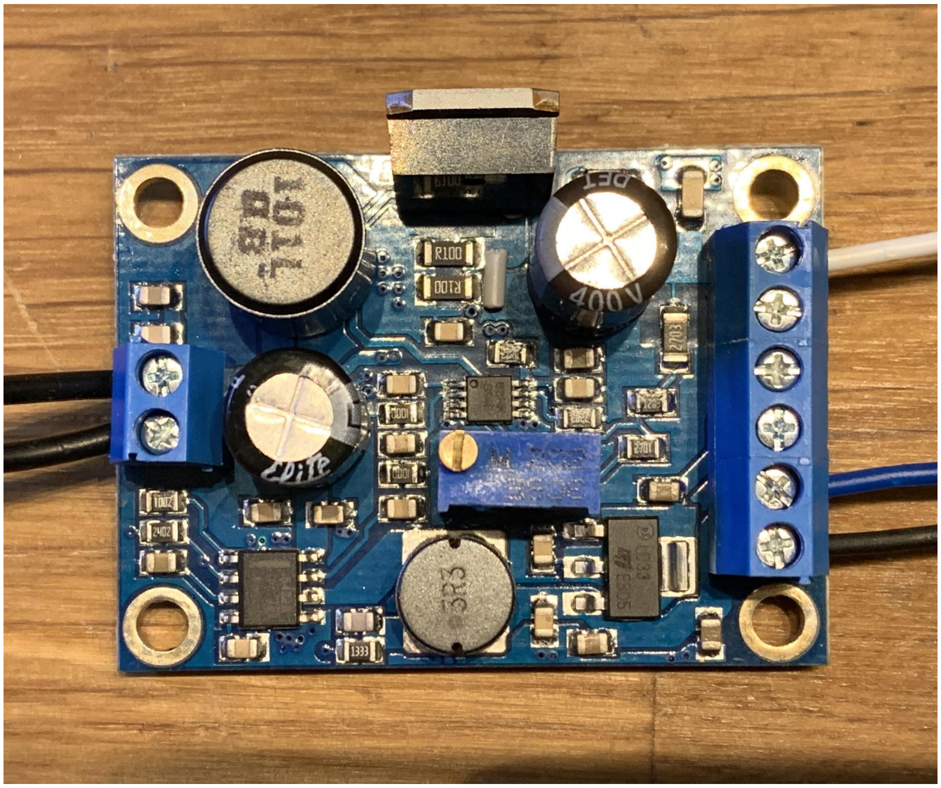
14. Next up: cut the plug of the 12V power supply.

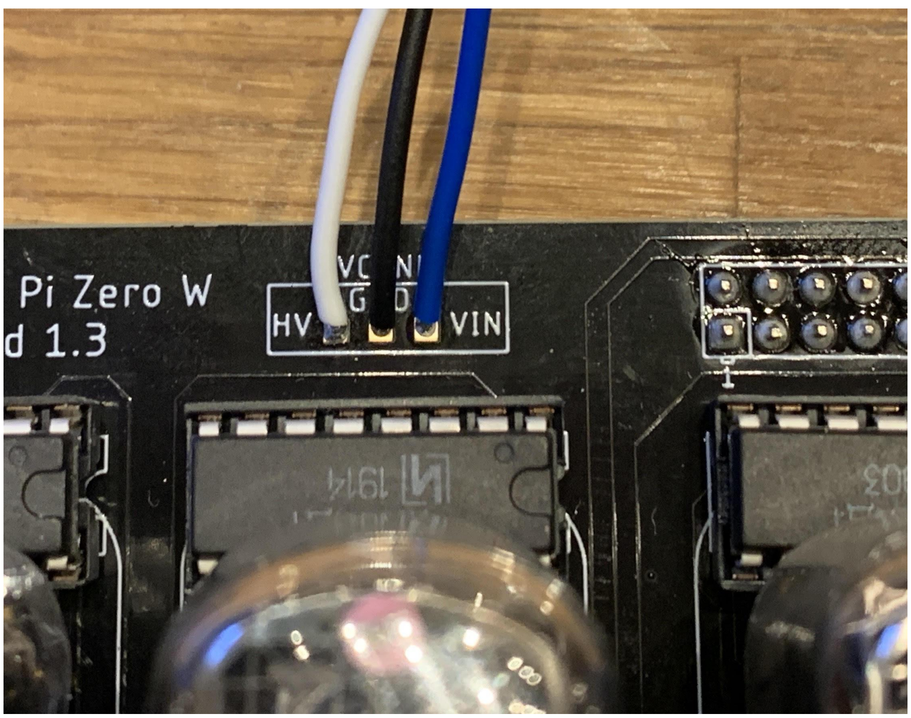
15. Connect the lead with the **WHITE DASHED LINE** to the **GND** side of the HV power and the other lead to VIn (Nothing good ever comes from reversed polarity).

16. Solder the WHITE wire to the HV terminal on the nixie board.
17. Solder the BLACK wiret to the GND terminal on the nixie board
18. Solder the BLUE wire to the VIN terminal on the nixie board.
19. Trim any excess wire on the back of the board. **You do NOT want any short circuits or solder bridges** here, since it will instantly fry both the nixie board and the raspberry pi if you apply power.
20. Connect the BLACK wire to GND on the HV board.
21. Connect the BLUE wire to the 5VO terminal on the HV board
22. Connect the WHITE wire to the VOUT terminal on the HV board
23. Double check the wiring. If you get this wrong, you may fry most of the chips and / or the Raspberry..
24. Triple check the wiring.


UT
D
3
D
0
D
40
VIN
GND
LUMOS
HV-PSU_EXT_V3


VOUT
GND
3V3
GND
5V0
GND
40
VIN
GND
LUMOS
HV-PSU_EXT_V3





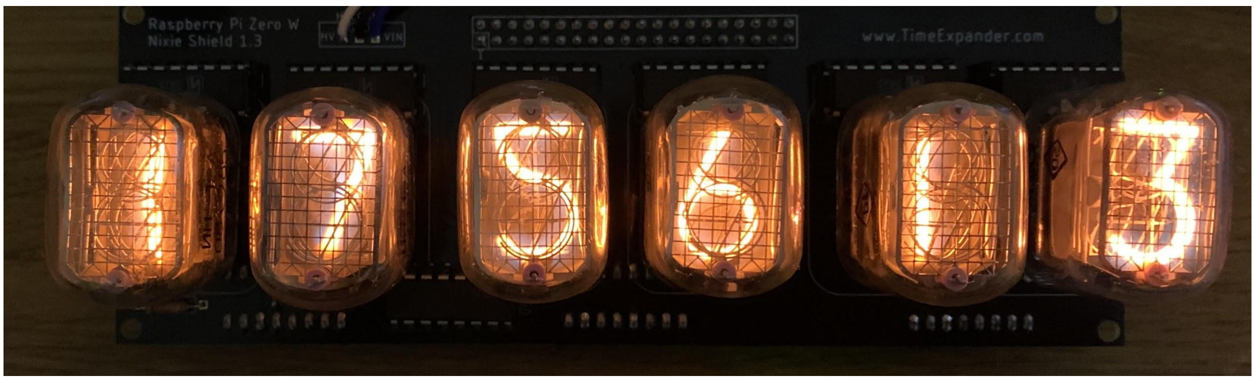
25. Now - After you have done a *thorough* inspection of all your solder joints. And done a final visual inspection, looking for any shorts caused by solder blobs or pieces of wire that has stuck to the board...

26. take a deep breath… and

27. **with the boards on a non conductive surface - and without touching any of the boards** - Insert the 12V adapter into a wall socket.

28. Don't panic when the clock doesn't light up immediately or if you see one or two static digits. The Pi will boot up in 60ish seconds. It will come to its senses shortly :)

For the first 10 seconds, you will see a weird looking number (I'll come back to that). Then the clock will display *a* time. A few seconds later, it will display the correct time.



If the digits appear too bright, then turn the potmeter on the HV board counterclockwise. If the digits appear dim, or only partially illuminated, then turn the potmeter clockwise until you are satisfied with the brightness.

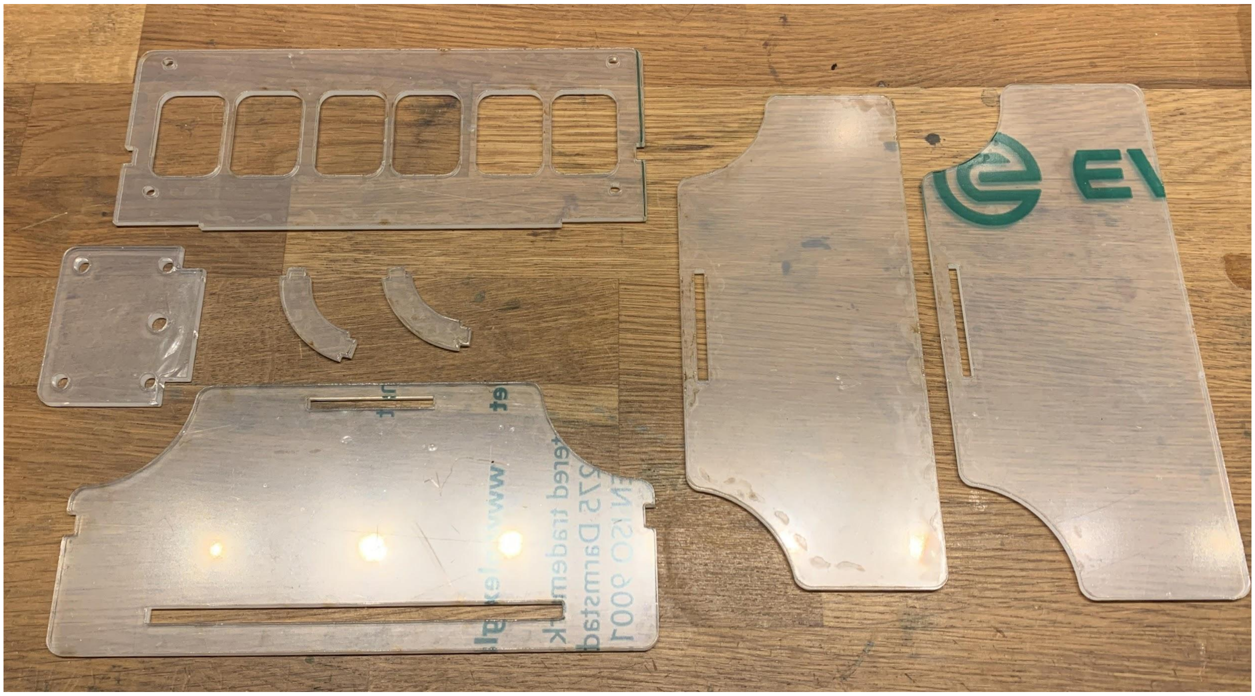
Optimal voltage is in the 160-170V region. This can be measured between VOUT and GND on the lumos HV power supply using a multimeter. **Be very careful not to short the VOUT to GND and do NOT touch any metal on the probes while doing this !**

If the clock displays the correct time, it has successfully connected to the network. It does not take daylight savings time into account, so it may be 1 hour off. I'm a lazy coder. Sue me. (If it counts seconds, but shows incorrect time, it hasn't connected to the network. If this is the case, you will have to revisit your wpa_supplicant.conf. Google is your friend :))

Anyways. Congratulations on successfully assembling the The Time Expander Super Duper Deluxe Edition Nixie Clock kit!

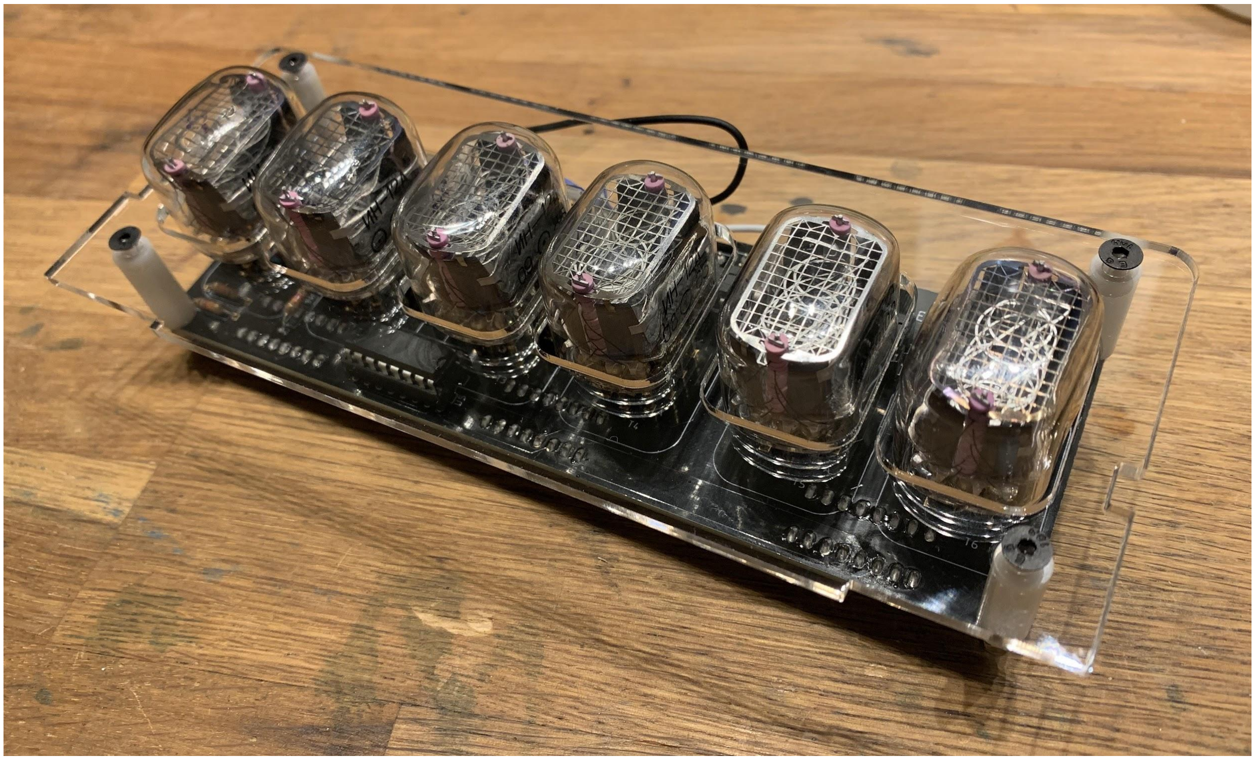
What, You want an enclosure as well ?

The electronics are way too beautiful to be hidden away inside a box. Fortunately, the full kit includes all necessary parts for building a nice stand for the clock.

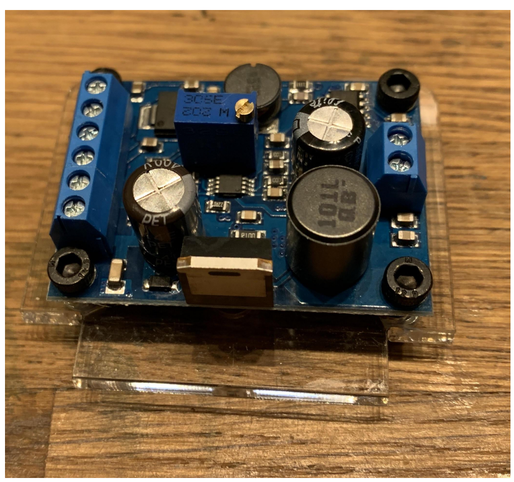


Assembly:

1. Remove the protective film from the laser cut parts.
2. Locate your M2 Allen key and use 4 plastic spacers, 4 30mm M3 bolts and 4 M3 lock nuts to fasten the PCB to the front panel. Disconnect the 12V power supply and pull the 12V cable through the center hole before mounting the board. Reconnect the board (dotted line == GND, Remember ?). Do not tighten the bolts too much, or the acrylic may crack.

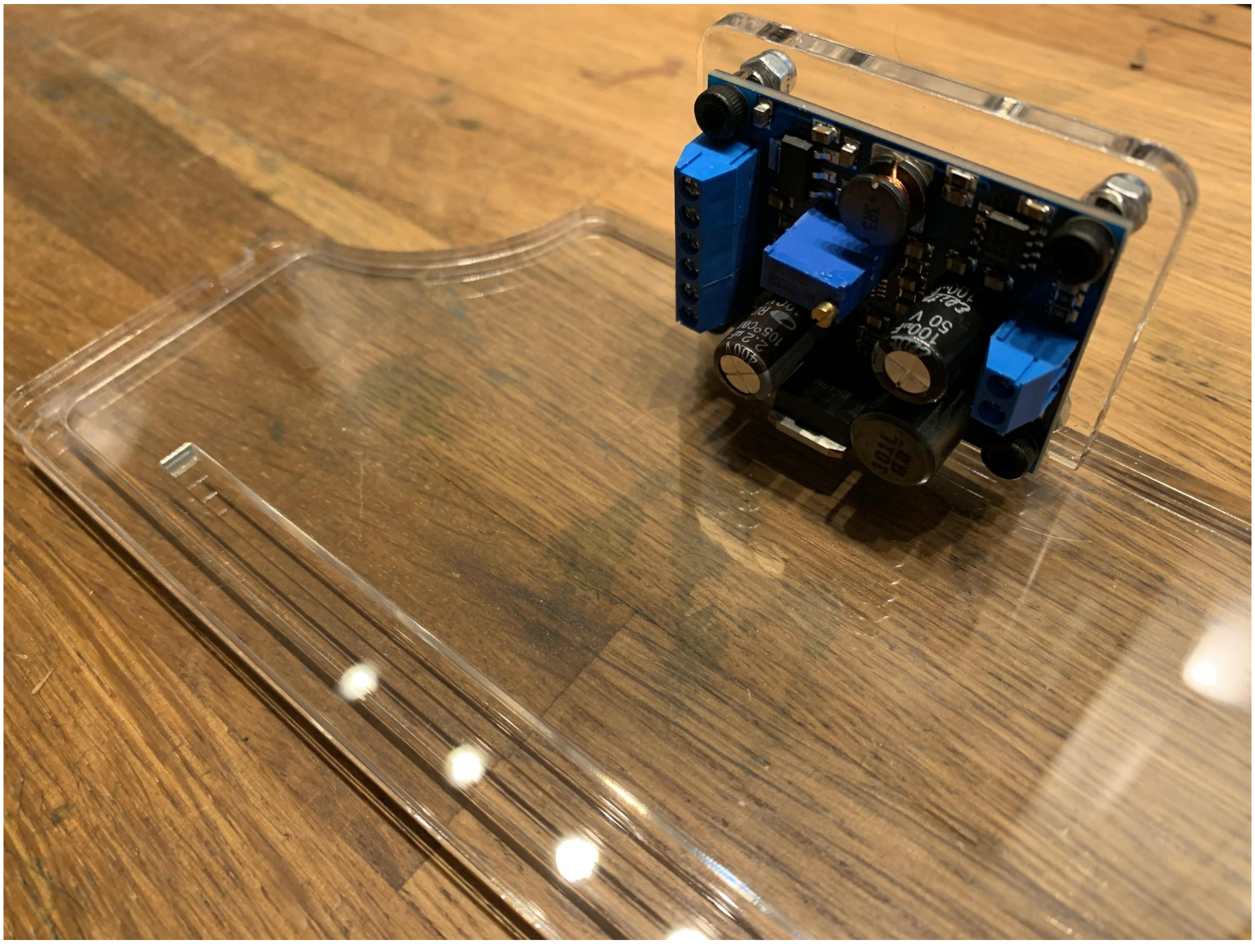


3. Locate your M3 Allen key and use 4 10mm M3 bolts and 4 M3 lock nuts to fasten the HV power supply to the small acrylic part with the 5 holes in it. Do not over tighten the bolts, or you may damage the PCB or acrylic.

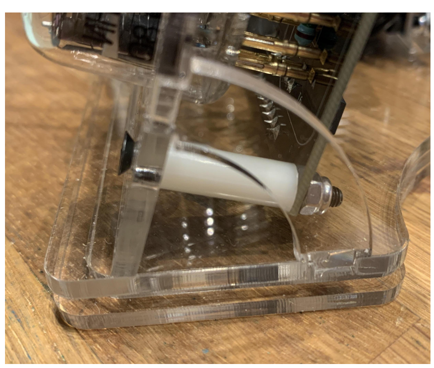


4. The three big acrylic pieces are going to be stacked on top of another. Notice that one piece is slightly smaller than the two others. This will be sandwiched between the other two. The top part has two slots cut in it. And the bottom part has only one slot. Align the pieces along the 37mm long slot.

5. Apply some cyanoacrylate glue to the tab on the HV power supply acrylic and slide it through all three slots in the stack. This should lock the base.



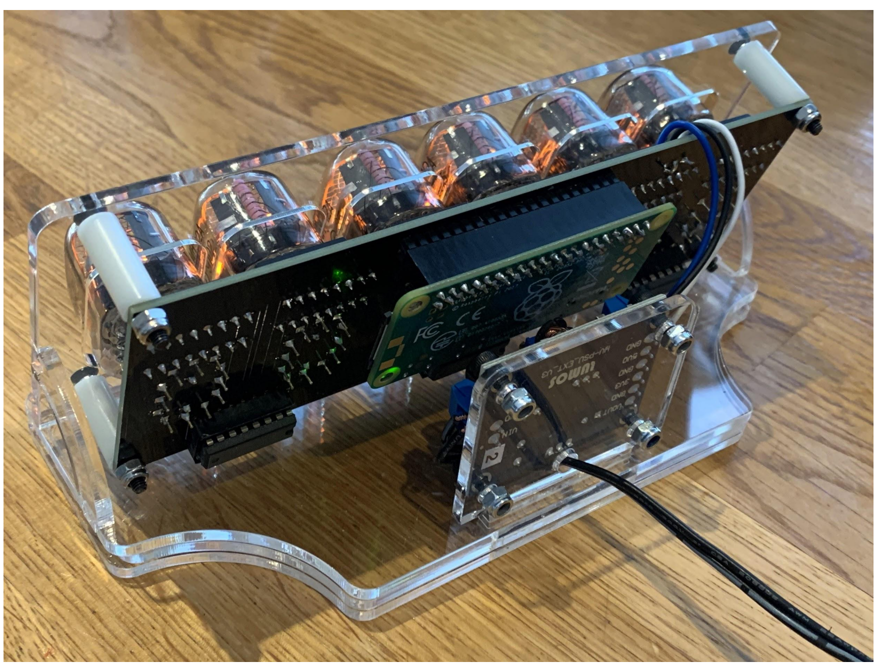
6. Let the front panel rest on the assembled base by inserting the tab near the bottom into the long slot in the top of the base.
7. Locate the two curved acrylic pieces. These will slot in between the front panel and the base.



8. Apply some cyanoacrylate glue to the tabs and insert these into the corresponding slots in the base and front panel.

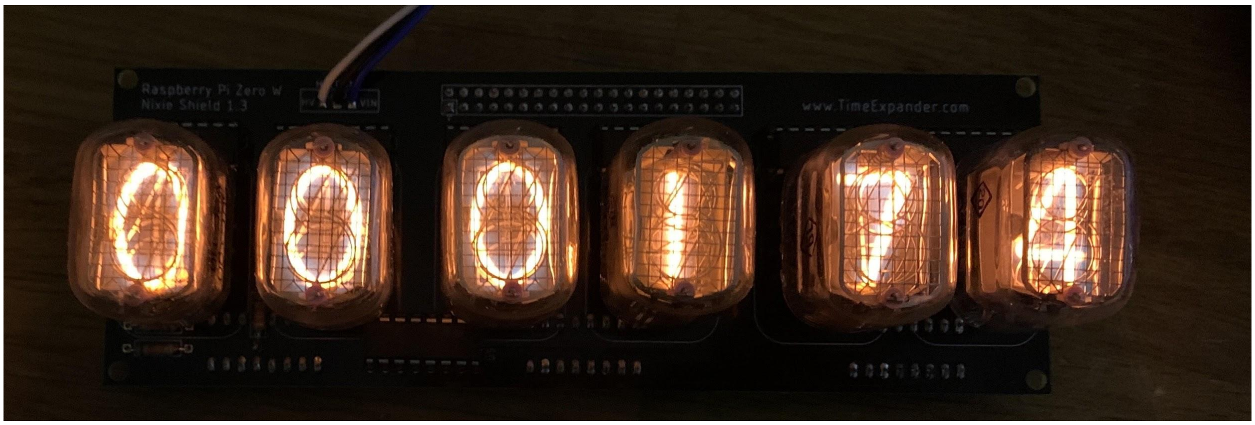
The End Result

Unless smoke is pouring out from the soviet era NOS BCD decoders or you have managed to electrocute yourself in the process, you should end up with something like this:



Now - It is time to hack your clock!

You probably noticed that the clock displayed something weird during the first 10 seconds after power up. The number you saw was the last octet in the clock's IPv4 address on it's wlan0 interface. I could probably have scrolled the entire IPv4 address on the display, but since you're probably on a home network, the last octet should be sufficient to connect to the clock via SSH



All devices on my home network have IP addresses in the range 192.168.10.*. From the image above, we can see that the clock is on 192.168.10.174.

If you are on linux or mac, you will be able to open up a shell on the clock with the command:

```
ssh pi@192.168.10.174
```

If the Pi is running mdns, it will also be reachable with the following command

```
ssh pi@raspberrypi.local
```

The password is "raspberry". I highly recommend changing this - **NOW!**

Navigate to the folder "clock" under your home directory. The executable "clock" is started on boot.

Full source code is available in `/home/pi/clock/clock.c`. and from https://github.com/hansj66/NixieKit/tree/master/firmware. The build script is available in `/home/pi/clock/build.sh` This should be an excellent starting point for creating other applications. Give it a web server and a REST API ? Create a meeting cost calculator ? Go play!

Note: The bundled wiringPi library is compiled with inverted logic for the 595 driver (Because I decided to use the ULN2003 as a cheap-O-rama level shifter).

In case you got the PCB only version.

You will still be able to complete the kit. You will have to download the wiringPi library and patch the 595 driver slightly (just invert the logic for controlling the 595). Firmware and STEP files for the enclosure / stand is available under Apache 2.0 license from:

https://github.com/hansj66/NixieKit

Bill of Materials

1. Nixie Clock PCB.
2. Raspberry pi zero W. This can be sourced from several places. The full kit version includes the Raspberry Pi Zero W with the official casing. Including the camera case. https://www.seeedstudio.com/Seeedstudio-Raspberry-Pi-Zero-W-with-Official-Case-p-2965.html
3. 16 Gb SD card. The full kit comes with a 16Gb SanDisk Ultra SD card that is preloaded with OS, compiler, source code and a patched wiringPi library.
4. Nixie power supply. The full kit comes with the Lumos HV-PSU_EXT_V3 (https://www.lumos.sk/).
5. 5V supply (Unless you use the Lumos HV power supply, you will need a dedicated 5V supply to power the nixie board and the Raspberry)
6. 10 x DIP-16 sockets.
7. Male 40 pin header.
8. Female 40 pin header
9. 3 x 12k 1/4W resistor (R8, R9, R12)
10. 6 x 15k 1/2W resistor (R1, R2, R3, R4, R5, R6)
11. 6 x K155ID1 (ICs for T1-T6)
12. 1 x ULN2003A (U5)
13. 3 x 74HC595 (U6, U7, U11)
14. 6 x IN-12 Nixie tubes
15. 72 x nixie pin sockets
16. 8 x m3 lock nuts
17. 4 10mm M3 bolts
18. 4 x 30mm M3 bolts
19. 4 x 18mm nylon spacers
20. Acrylic stand.

Sockets, headers, resistors, ULN2003A and 74HC595 can be sourced from eBay, AliExpress or via DigiKey, RS Online, Farnell etc.

The Lumos supply, nixie tube sockets, IN-12 tubes and K155ID1 ICs can be sourced from multiple sellers on eBay.

Spacers can easily be 3D printed. You should be able to source M3 bolts and locknuts from a local hardware store. If not, these can also be sourced from eBay or AliExpress

STEP files for the acrylic stand and firmware are available from
https://github.com/hansj66/NixieKit/