VFD Tube Clock with ESP32 DevKit-C Assembly Manual

Revision 4 – released 2018-10-05

This kit is designed for someone who has intermediate experience with assembling electronics. This is not a beginners electronics kit and requires knowledge of soldering, programming Arduino and a good grasp of basic electronics.

Please take your time – it will take approximately four hours to complete this kit. Ensure your work area is well lit (daylight preferred) and clean.

Assemble the parts in the order as stated in the instructions. Read and understand each step before you perform each operation for the best chance of success.

The following tools and materials will be required to assemble the clock:

- A good quality soldering iron (25-40W) with a small tip (2-3 mm).
- Thin solder wire with no-clean flux. Do not use any flux or grease.
- A set of small screwdrivers.
- A small wire cutter for electronics.
- A wire stripper.
- Long nose pliers.
- A hot air soldering station / heat gun / lighter (or alternative).
- A multimeter.
- A computer with the Arduino IDE and Arduino Core for ESP32 installed.

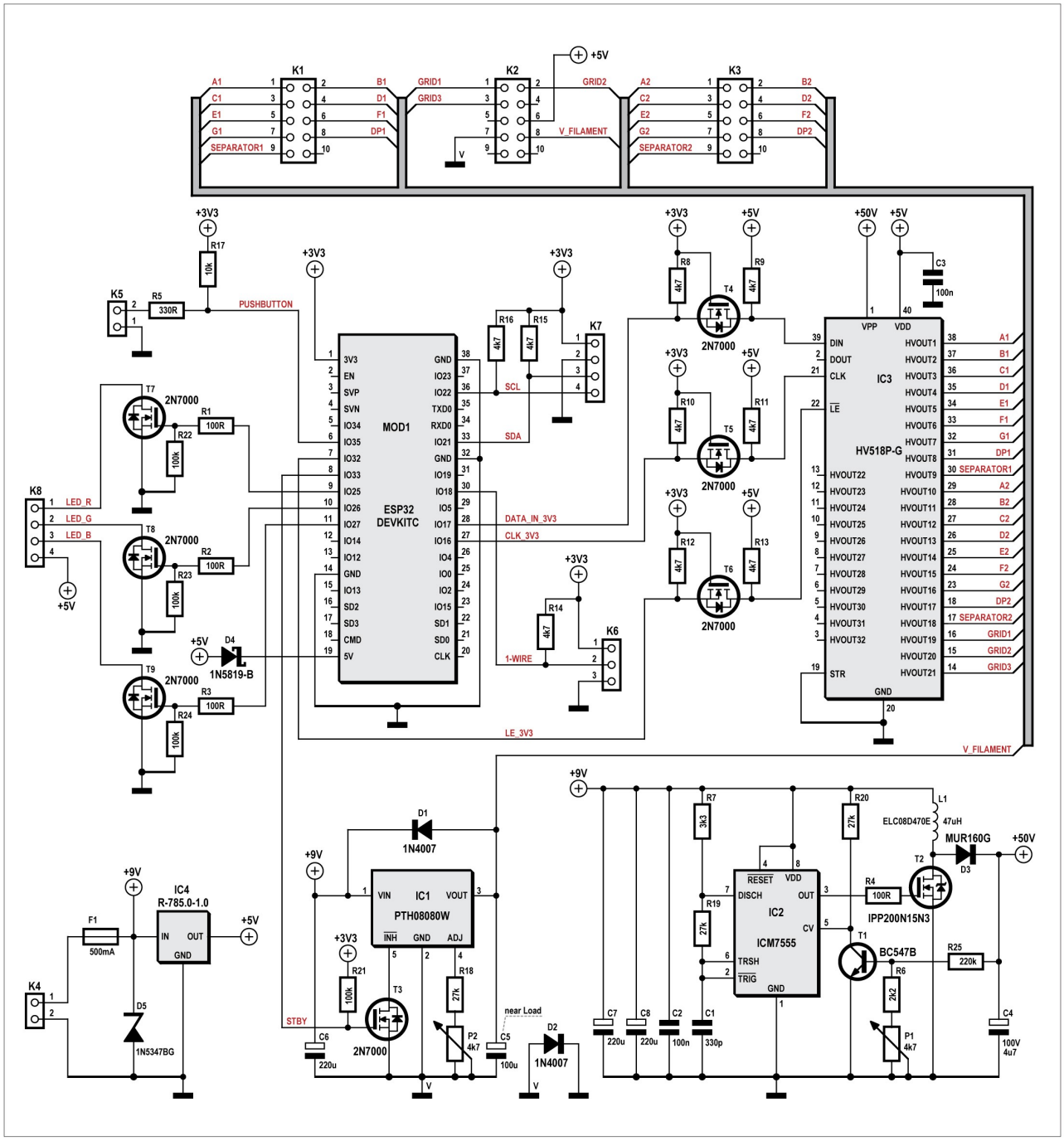
Reading the entire manual before starting the project is highly advised and will help you comprehend the overall project.

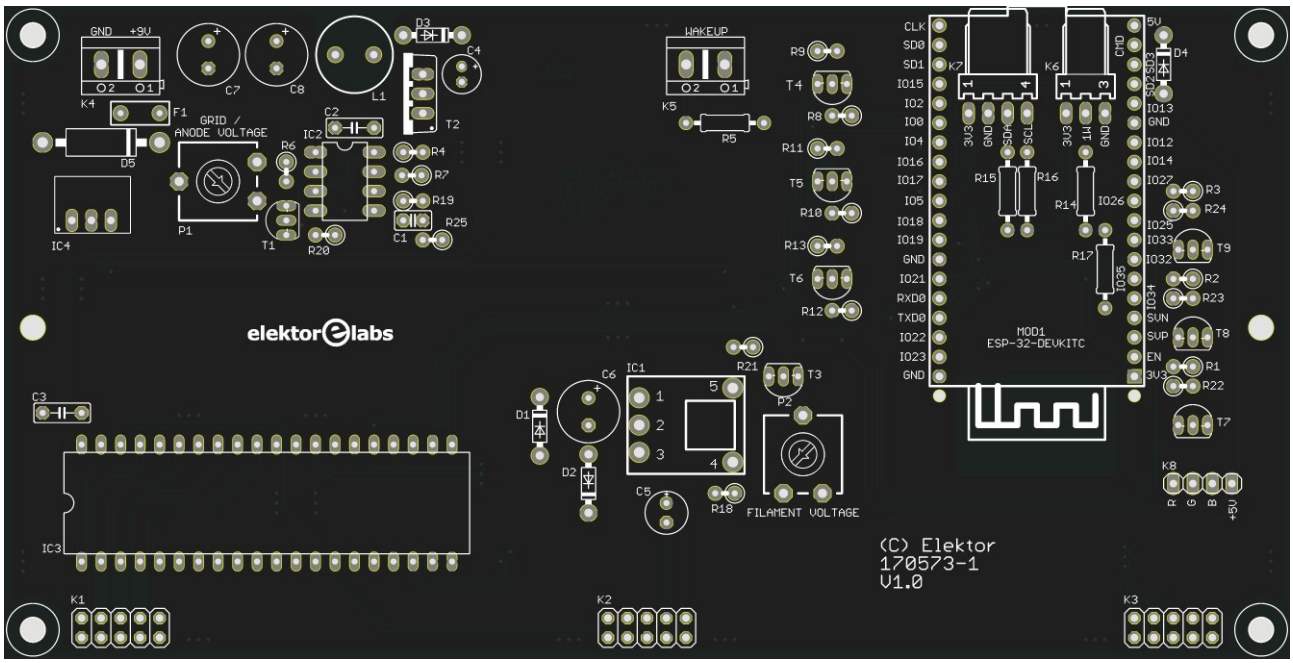
This manual is written for clock software dated 2018-10-05.

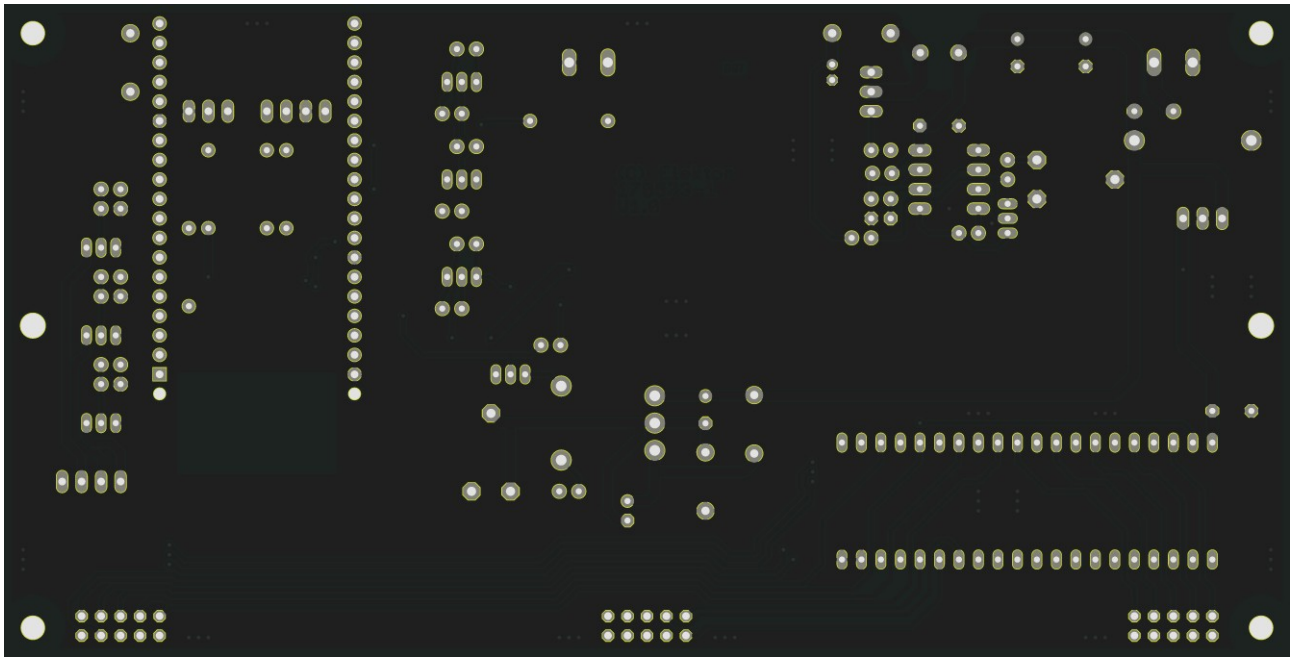
Disclaimer: All pictures are for illustration purposes only. Actual product may vary due to product enhancement.

Schematic and PCB Layout

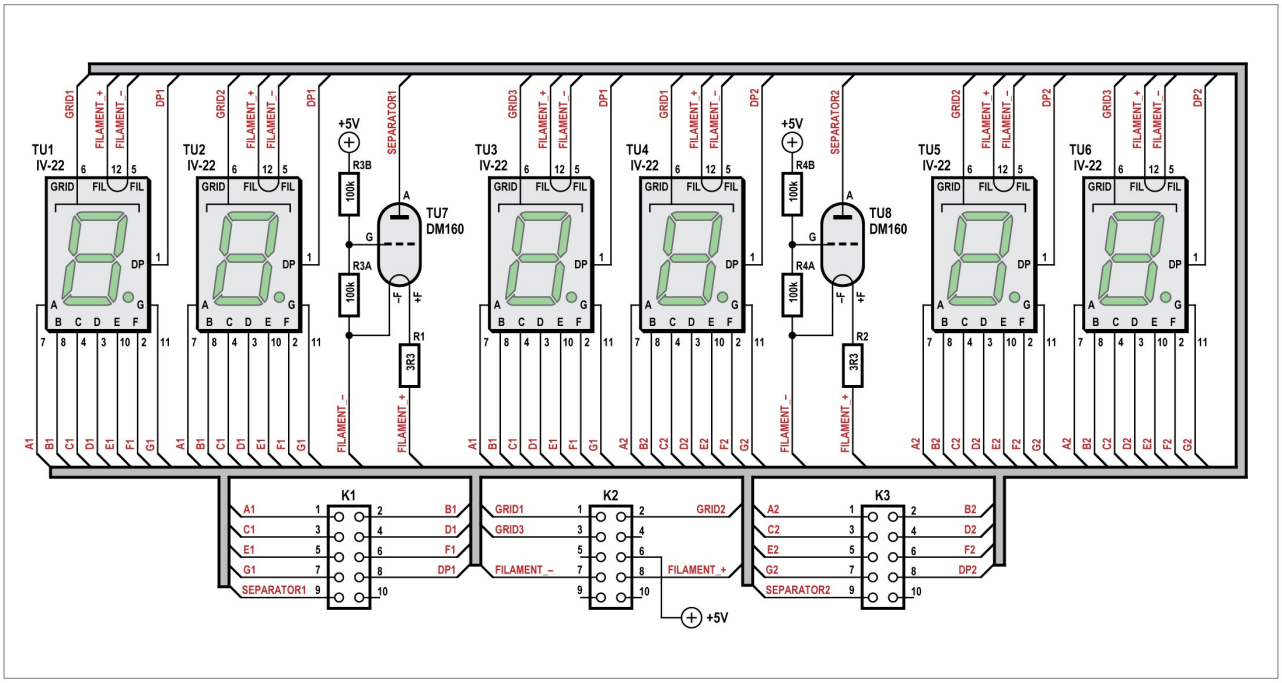
Main PCB

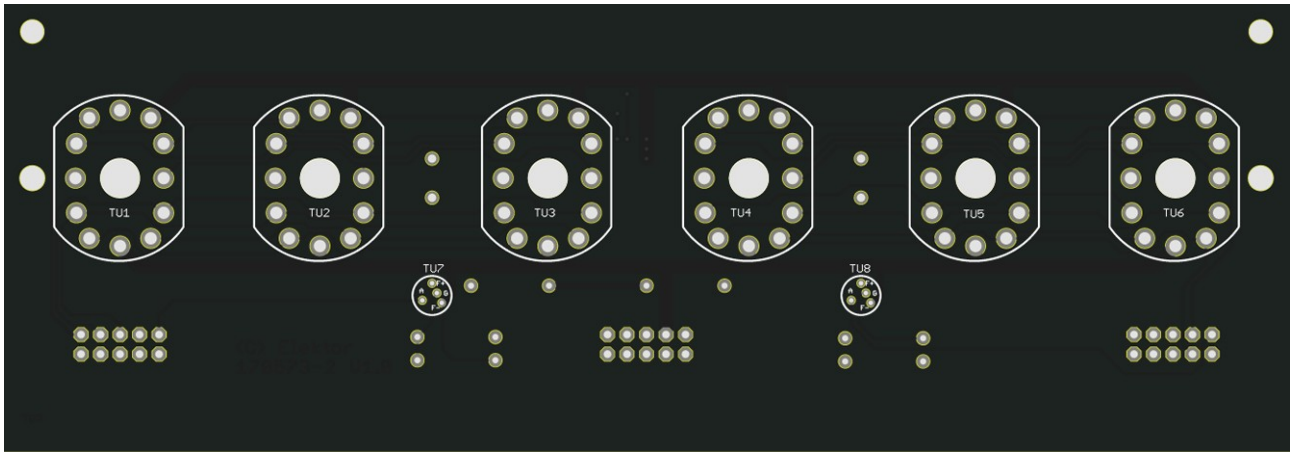


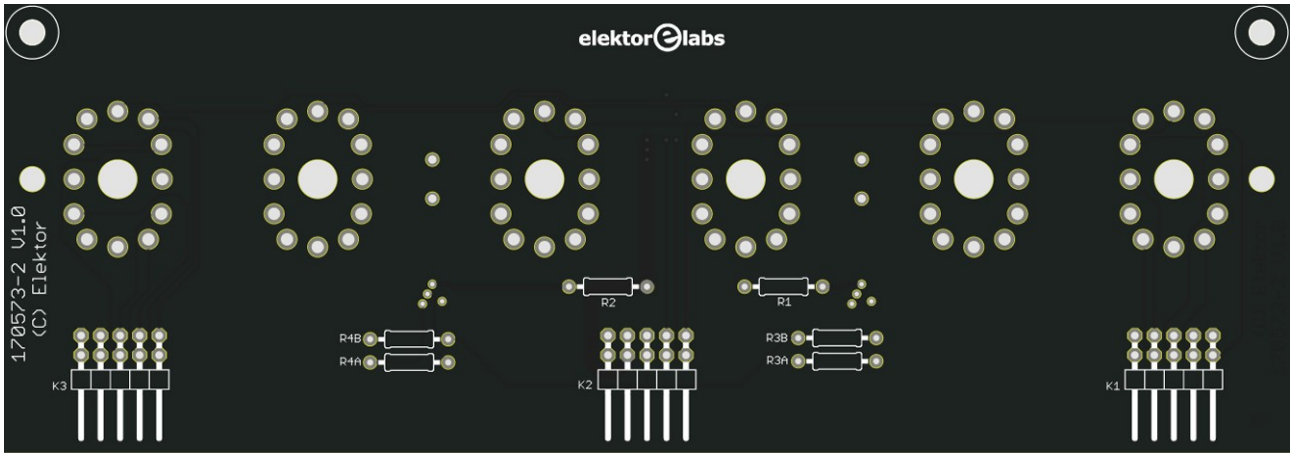

GND +9V
K4
F1
D5
C7
C8
L1
D3
C4
T2
C2
IC2
R4
R7
R19
R25
C1
R20
R6
P1
T1
IC4
GRID / ANODE VOLTAGE
WAKEUP
K5
R5
R9
T4
R8
R11
T5
R10
R13
T6
R12
elektor labs
C3
IC3
K1
K2
K3
C6
IC1
D1
D2
C5
R18
R21
T3
P2
FILAMENT VOLTAGE
CLK
SD0
SD1
IO15
IO2
IO0
IO4
IO16
IO17
IO5
IO18
IO19
GND
IO21
RXD0
TXD0
IO22
IO23
GND
K7
K6
3V3
GND
SDA
SCL
3V3
MT
GND
CMD
R15
R16
R14
IO26
R17
IO35
MOD1
ESP-32-DEVKITC
5V
SD3
SD2
IO13
GND
IO12
IO14
IO27
IO25
IO33
IO32
IO34
SVN
SVP
EN
3V3
D4
R3
R24
T9
R2
R23
T8
R1
R22
T7
K8
R
G
B
+5V
(C) Elektor
170573-1
V1.0



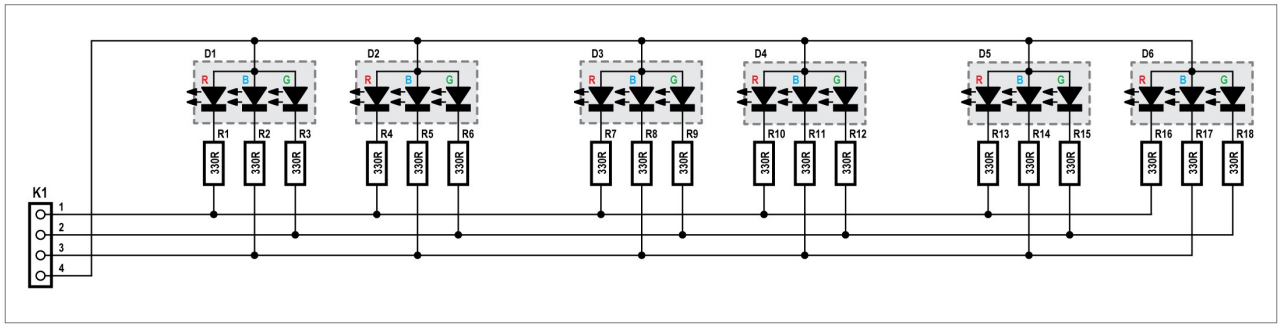
Display PCB

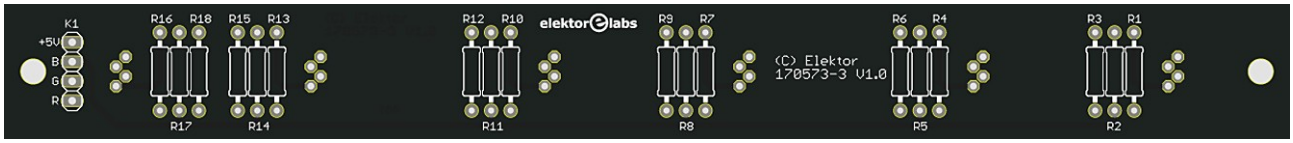

TU1 IV-22
TU2 IV-22
TU3 IV-22
TU4 IV-22
TU5 IV-22
TU6 IV-22
TU7 DM160
TU8 DM160
+5V
R3B
R3A
R4B
R4A
100k
3R3
R1
R2
SEPARATOR1
SEPARATOR2
FILAMENT +
FILAMENT –
K1
K2
K3

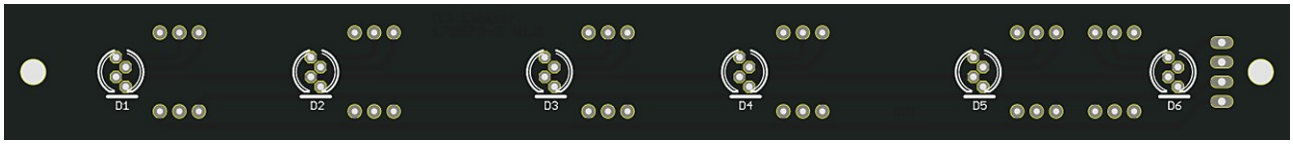

TU1
TU2
TU3
TU4
TU5
TU6
TU7
TU8


elektor labs
170573-2 V1.0
(C) Elektor
R2
R1
R4B
R4A
R3B
R3A
K3
K2
K1

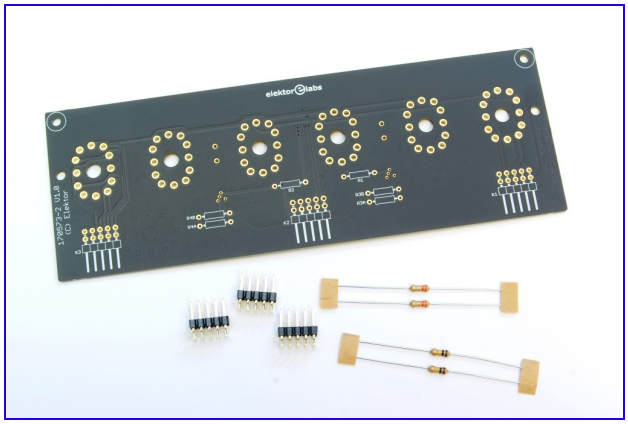
Backlight PCB

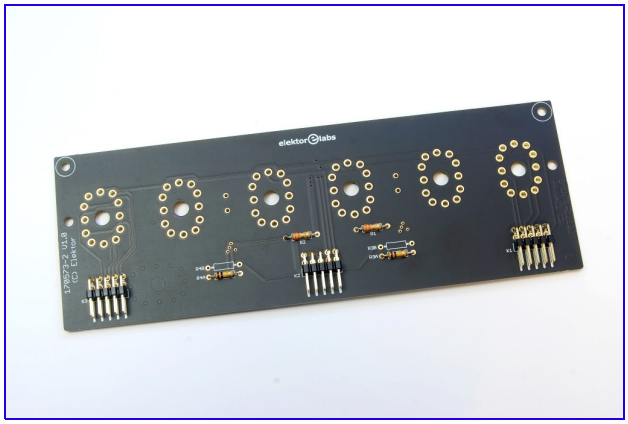






Assembling the Display PCB





Assembly instructions for DM160 tubes or equivalent (as supplied with the kit):

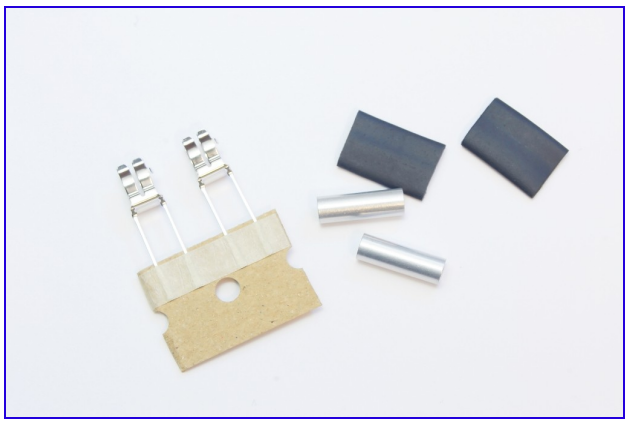
- Mount resistors R1 and R2, 3.3 Ω.
- Mount resistors R3A and R4A, 100K (leave R3B and R4B open).

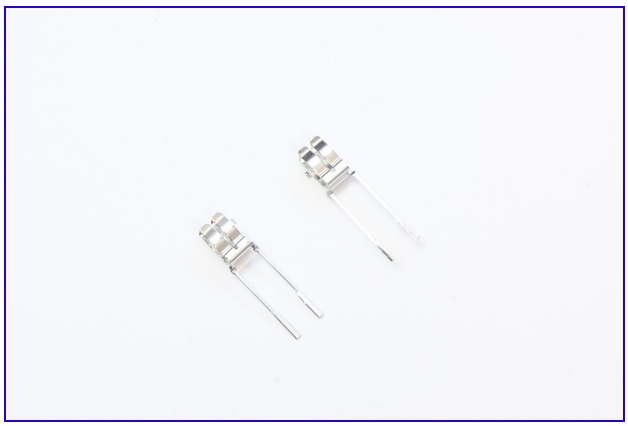
Assembly instructions for Russian IV-15 tubes (not supplied with the kit):

- Mount resistors R1 and R2, 6.8 - 10 Ω.
- Mount resistors R3B and R4B, 100K (leave R3A and R4A open). We didn't try this out in real life, some experimentation with the value of R1 and R2 may be necessary. Further in this manual we assume you use DM160 tubes. Values and results may differ somewhat when using IV-15 tubes.

When we use the term “DM160 tube”, this also refers to equivalent tubes like the CV5412, CV6094 and 6977 and possibly other compatible types.

Now mount the angled pin headers K1, K2 and K3.

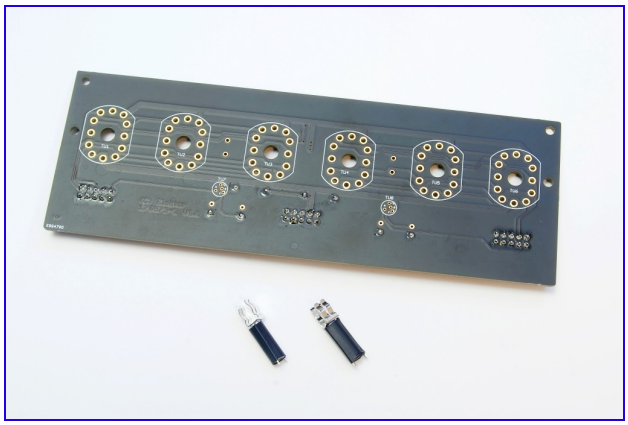


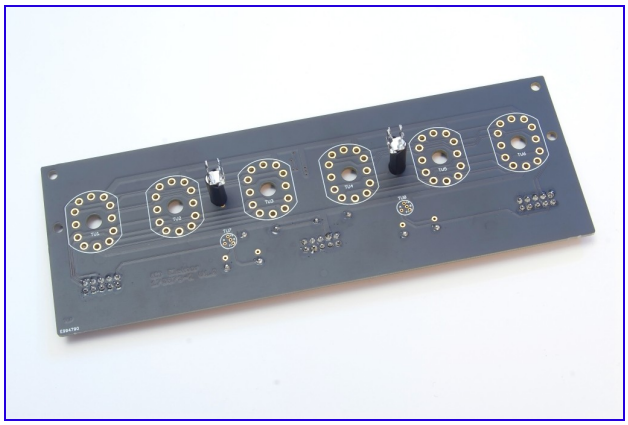


Cut two pieces of the 6.4 mm heat shrink tube with the same length as the 14 mm aluminum spacers.

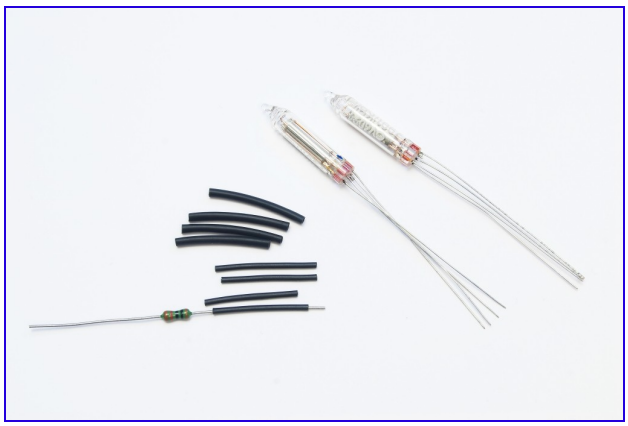
Carefully remove the fuse holders from the paper strip without cutting the leads. You will notice that the leads are somewhat wider at the ends. Trim the ends longitudinally with a sharp wire cutter so the leads have an uniform width.

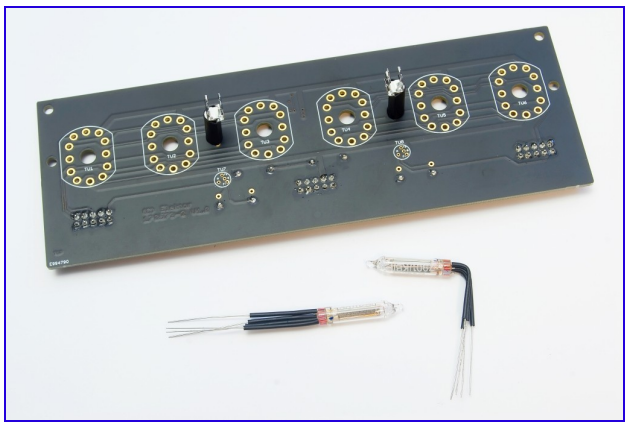
Place an aluminum spacer between the leads of the fuse holder and slide the heat shrink tube over the aluminum spacer and the leads of the fuse holder. Crimp the heatshrink tube and carefully remove the small metal tab from the fuseholder itself with a wire cutter so the DM160 tube will fit.

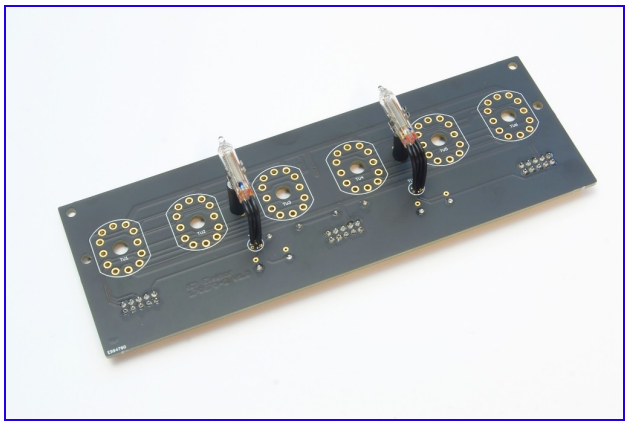


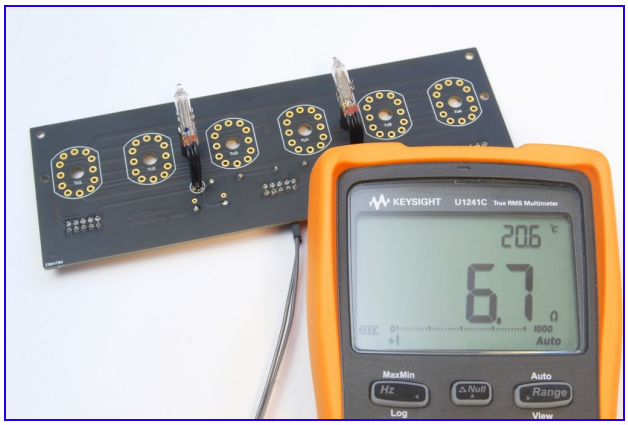


Mount the fuseholder assemblies to the front side of the display PCB.



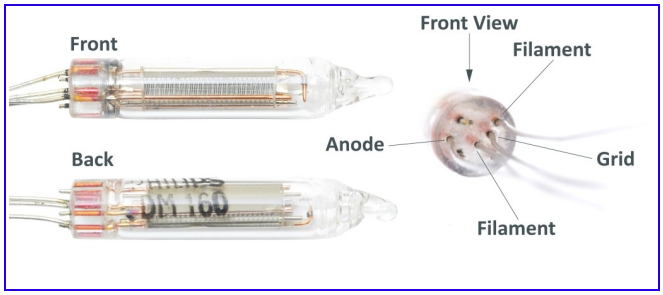






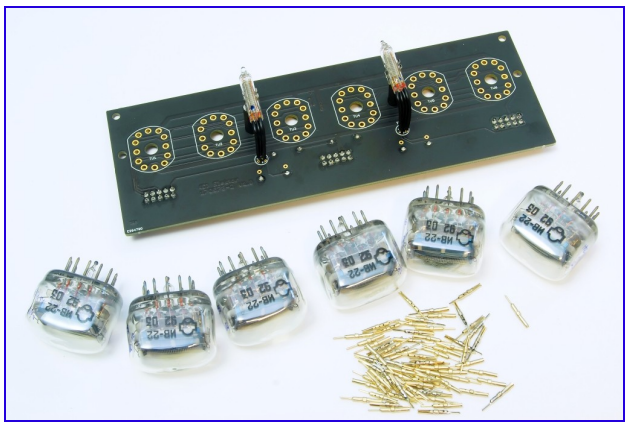
Cut eight 22 mm length pieces of the 1.6 mm heat shrink tube. Slide them over a thin piece of wire, a lead of a resistor or something similar and shrink them using a heat source.

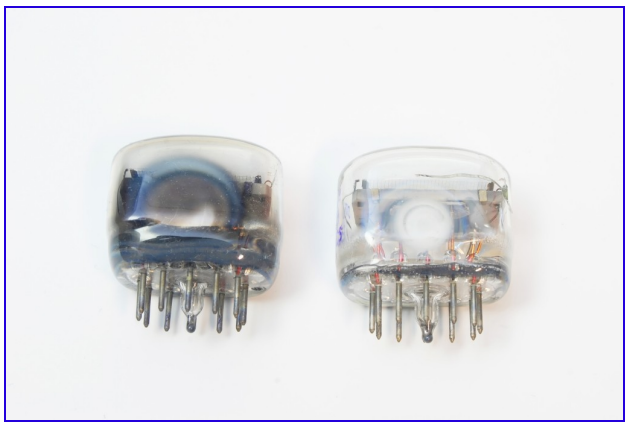
When you look at the bottom side of the DM160 tube you will see four wires. Three of them are in a single row and close to each other. The fourth wire is somewhat separate from the other three. This is also reflected on the display PCB to make mounting of the tubes easier.



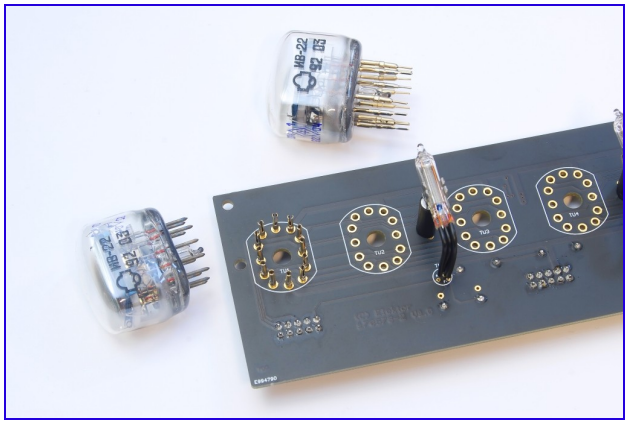
Slide the pre-shrinked heat shrink tubes over the leads of the DM160 tubes (TU7 and TU8) and bend the leads at an angle of 90 degrees (at a distance of approximately 5 mm of the tube bottom). Slide the leads through the holes of the PCB and press the tubes into the fuse holders. Make sure the front of the tubes is facing forwards and finally solder and clip the leads.

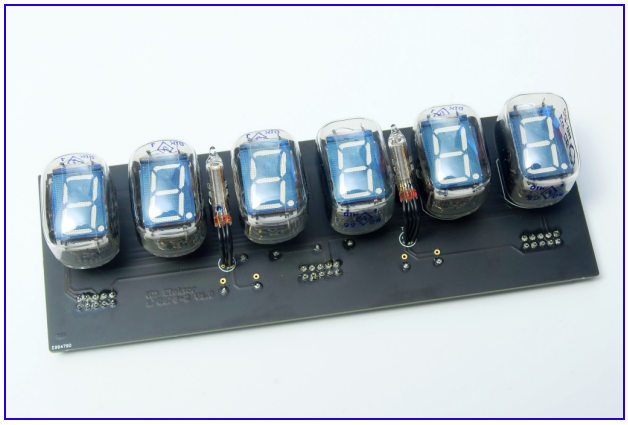
Measure the resistance between pin 7 and 8 of K2 with a multimeter. The resistance should be around 6 ... 6.5 Ω or slightly more depending on the resistance of the test leads. This is an indication that the DM160 tubes are mounted correctly.





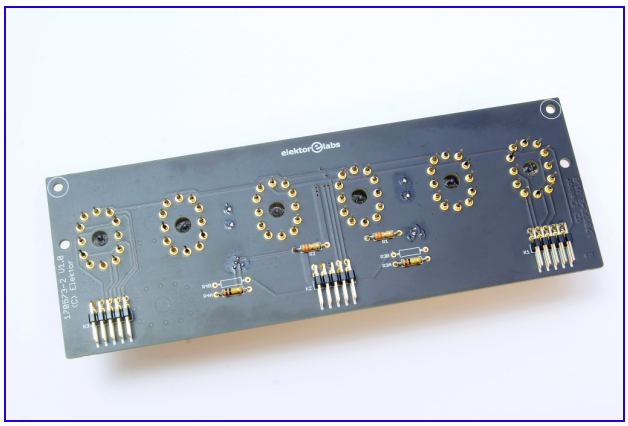
Have the IV-22 tubes and tube socket pins ready for the next step. Before starting the assembly you can put the IV-22 tubes temporarily on the PCB to see in which order they look best. IV-22 tubes have quite some tolerances, especially concerning mechanical dimensions and background color of the 7-segment digit.

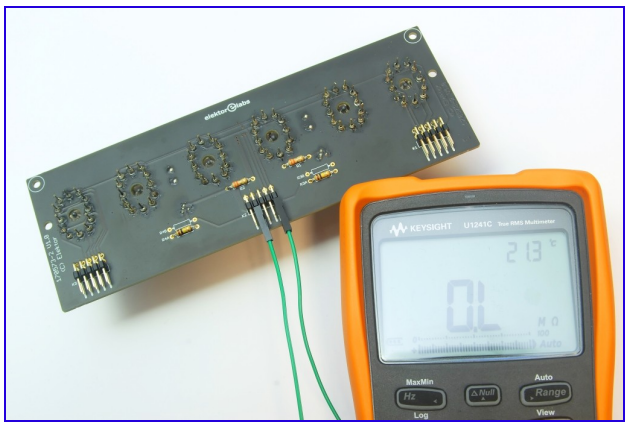




Take a look at the tubes. Normally the getter on the side of the tube should look dark with a silvery shine. If it's white, air has entered the tube and you should discard the tube as it will not work anymore.

Pinch the tube socket pins between your fingers so they will be more tight. In order to mount the tubes, you can choose between two options. You can either slide the tube socket pins over the pins of the tube and push the tube with socket pins through the holes of the PCB or fit the tube socket pins to the PCB and push the tubes in the socket pins. If you choose the latter option, make sure the pins of the tubes are correctly seated into the socket pins.





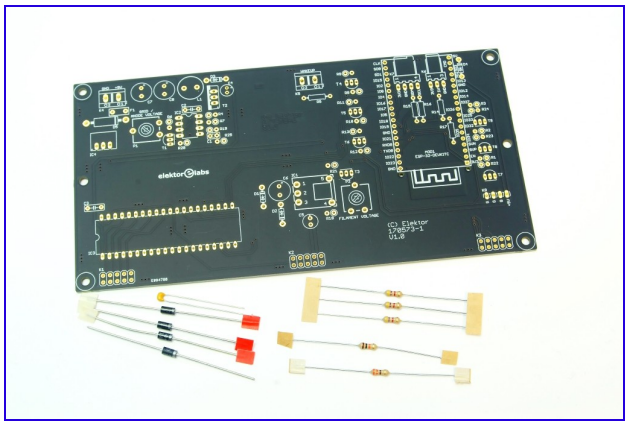
When all the tubes are in place, turn over the PCB and solder the tube socket pins from the backside. Do not use too much solder and keep soldering time short.

Finally measure the resistance between pin 7 or 8 of K2 (filament connections) and all the other pins on K1, K2 and K3. If everything is ok, you shouldn't be able to measure any resistance (open circuit) between any of the pins and the filament connections. If you measure a resistance one of the IV-22 tubes has a production fault or is mounted upside down.

The display PCB is now finished.

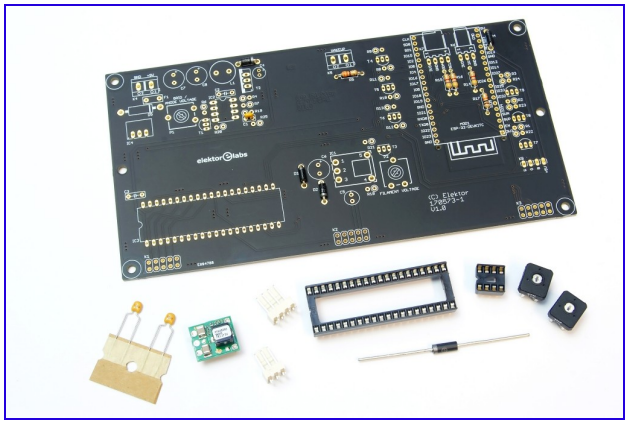
Assembling the Main PCB

Mount the components from low to high. Start with the horizontally mounted resistors R5 (330 Ω), R14 ... R16 (4K7) and R17 (10K). Then mount the diodes D1, D2 (1N4007), D3 (MUR160G) and D4 (1N5819). Finally mount C1 (330 pF).



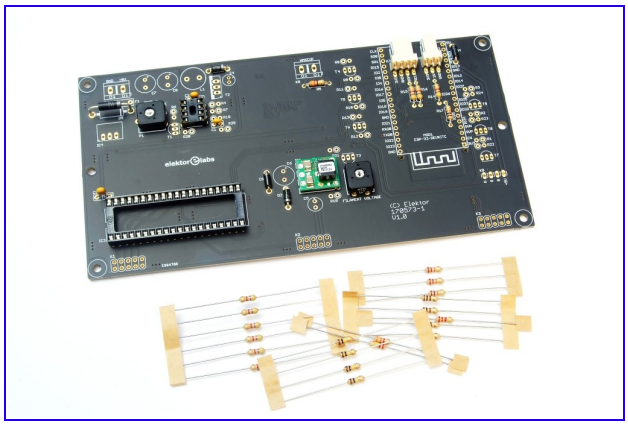
Mount the IC sockets for IC2 (8p) and IC3 (40p). Mount the DC/DC step-down converter module IC1 (PTH08080WAH). Keep the soldering time as short as possible.

Mount the trim potentiometers P1 (4K7) and P2 (47K) and capacitors C2, C3 (100 nF). The trim potentiometers should be in middle position.

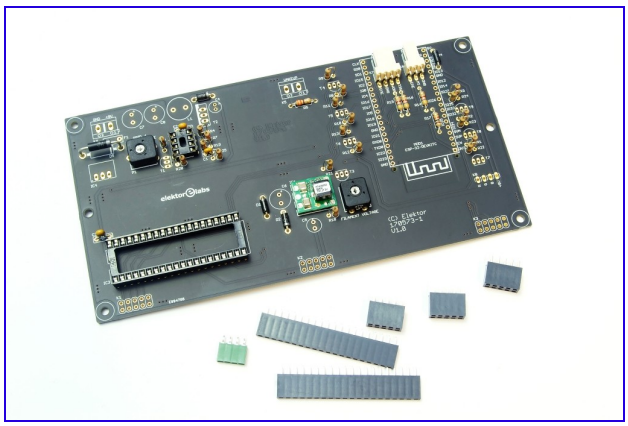


Mount the angled locking headers K6 (3p) and K7 (4p). Finally mount zener diode D5 (1N5347BG). Make sure there is a space of a few millimeters between the PCB and D5 as this component may get very hot during fault conditions (overvoltage, wrong polarity).

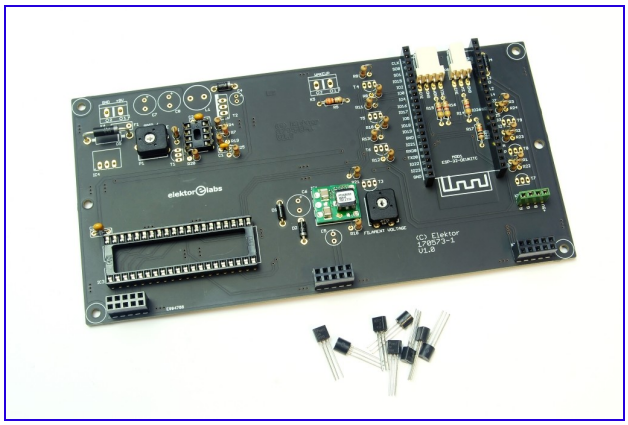
Mount the resistors R1 ... R4 (100 Ω), R6 (2K2), R7 (3K3), R8 ... R13 (4K7), R18 ... R20 (27K), R21 ... R24 (100K) and R25 (220K) in an upright position.



Mount the socket headers K1 ... K3 (2x5p), K8 (1x4p) and MOD1 (ESP32-devkitC, 2 x 1x20p).

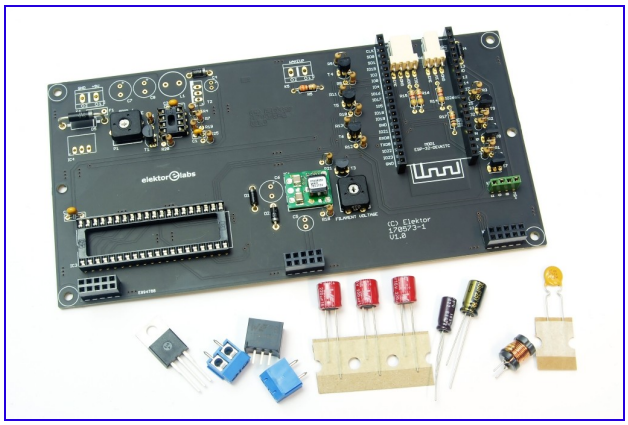


Mount the transistors with TO92 case T1 (BC574B) and T3 ... T9 (2N7000). Mount them so the top of their casings is flush with the top of the socket headers. This makes mounting easier.

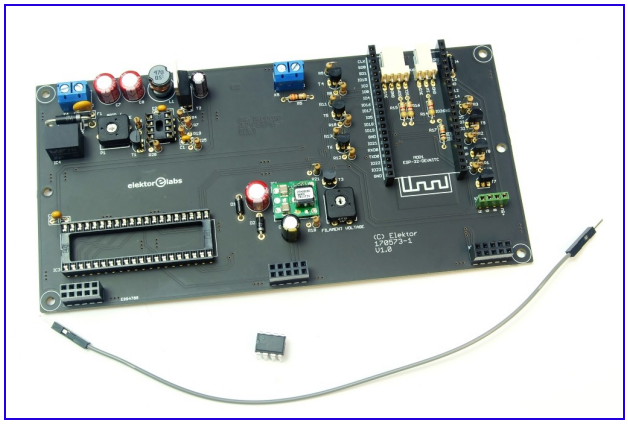


Finally mount the larger components. Start with C6 ... C8 (220 µF). Then mount the terminal blocks K4 and K5. Mount the 5V DC/DC step-down converter IC4 (Würth 173019578). Mount polyfuse F1 (500 mA), L1 (47 µH 1.2A), C4 (4.7 µF 100 V) and C6 (100 µF).

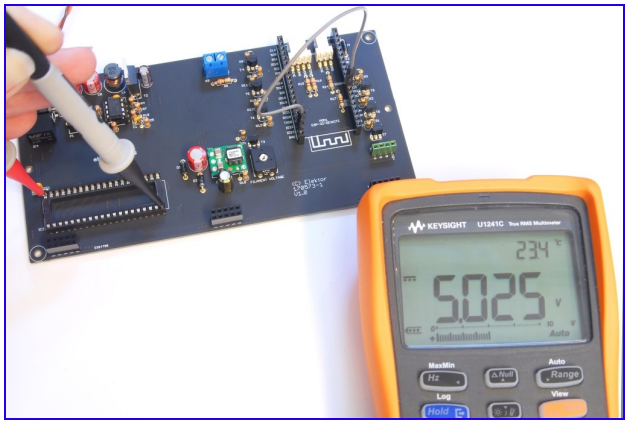
Finally mount MOSFET power transistor T2 (IPP200N15N3 G). Please note there is currently (April 2018) a shortage of these transistors. We may substitute this transistor in our kits with another type MOSFET at our discretion. This will in no way alter the functionality of the clock.



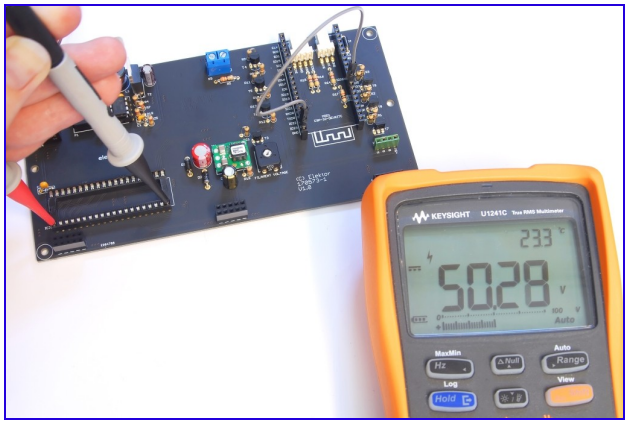
Place IC2 (ICM7555) in its socket and connect GND and pin 8 (IO33) on the ESP32-devkitC socket with a piece of jumper wire (not included with the kit).



Power up the bord using a 9 V power supply capable of delivering at least 500 mA. Measure the voltage between pin 20 (-) and pin 40(+) of the IC socket of IC3. The voltage should be approximately 5 V.

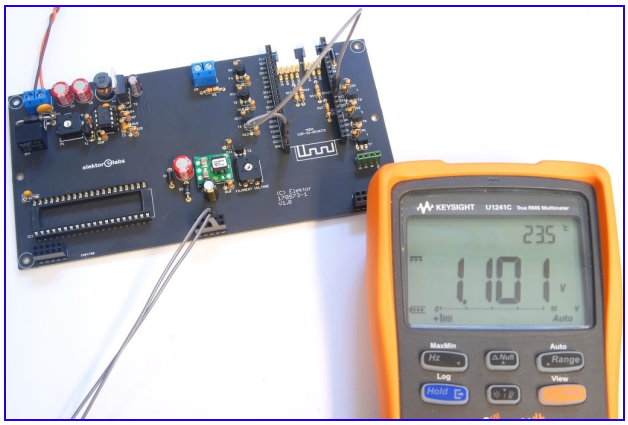


Now measure the grid/anode voltage between pin 1 (+) and pin 20 (-) of the same IC socket. Adjust this voltage to approximately 50 V using trim potentiometer P1.



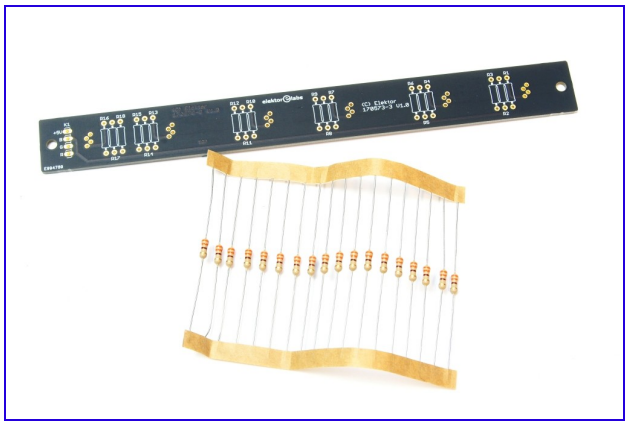
Finally measure the voltage between pin 2 (-) and pin 3 (+) of IC1 (PTH08080WAH). You can also measure this voltage on K2. Do not measure this voltage in reference to ground (GND) ! Now adjust the voltage to approximately 1.1 V using trim potentiometer P2.

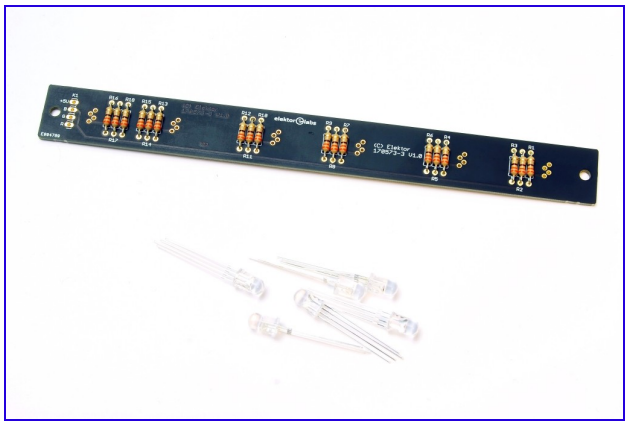
Do not continue assembling the clock if the voltages are not correct but look for assembling faults instead.



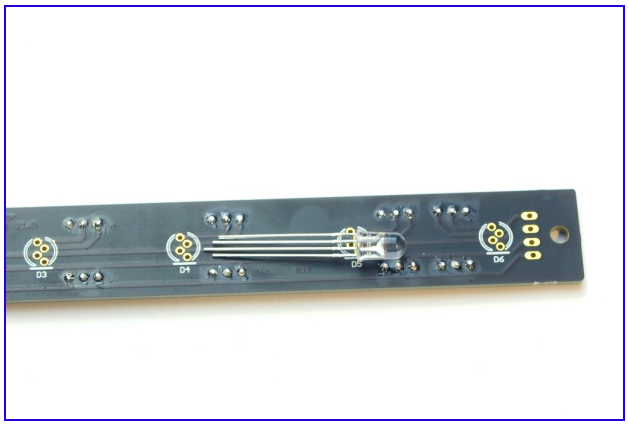
If everything is ok, disconnect the power supply.

Assembling the RGB Backlight PCB

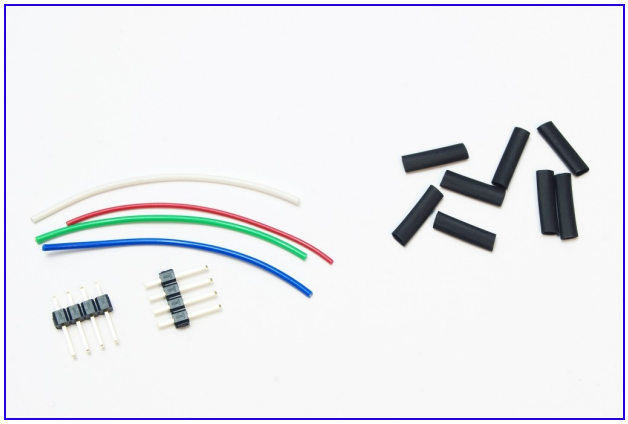


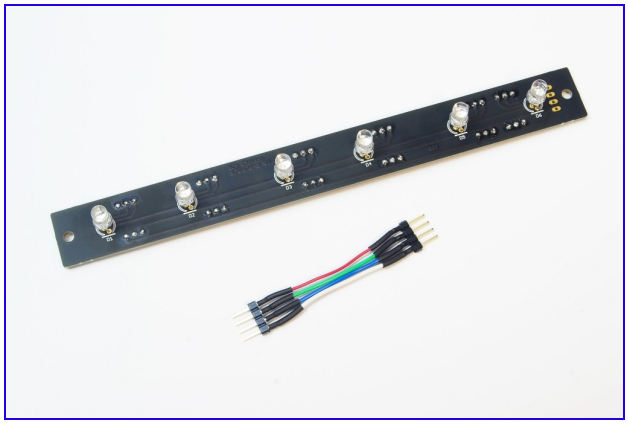


Mount the 330 Ω resistors R1 ... R18 on the backside of the PCB.



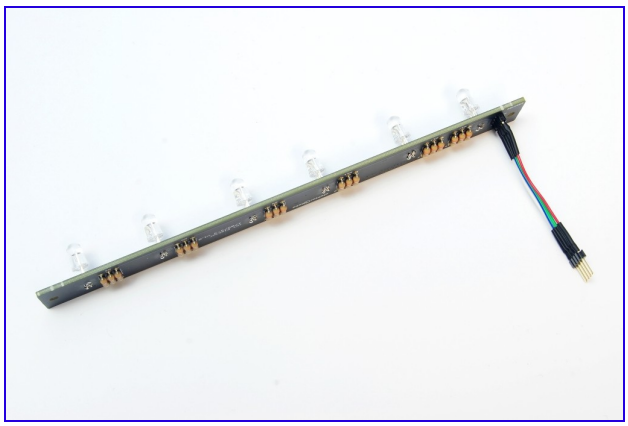
Mount the RGB LEDs on the front side of the PCB. Watch the polarity, the flat side of the LED goes where the PCB symbol is marked with a dash. Push the LEDs through the holes until they don't go any further.
Be careful not to overheat the LEDs while soldering them in place. Solder one lead of each LED first and check the alignment. Then solder the remaining leads.



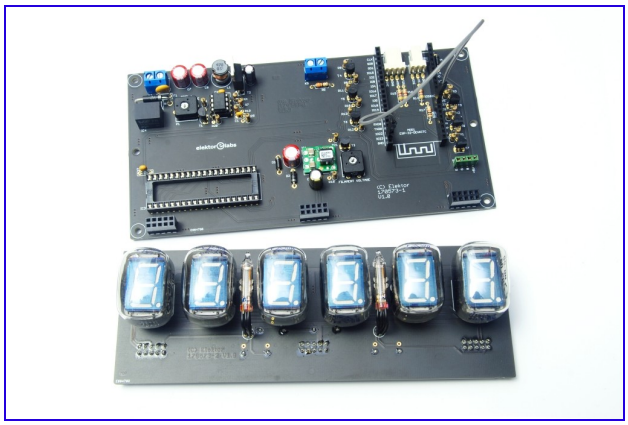


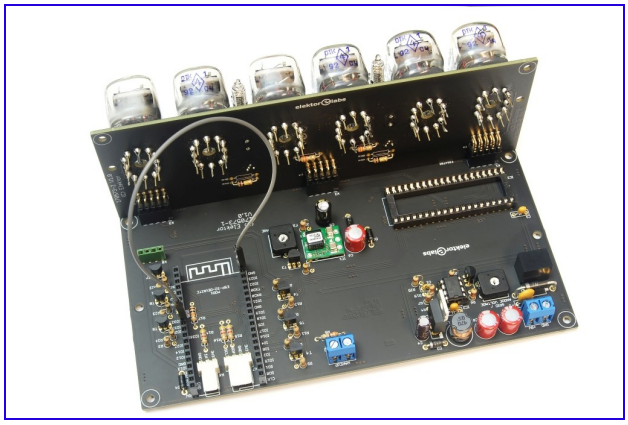
Connect two 4 pole pin headers together using 5 cm of white, red, green and blue wire. Insulate the solder joints using 1 cm 3.2 mm heat shrink tube.

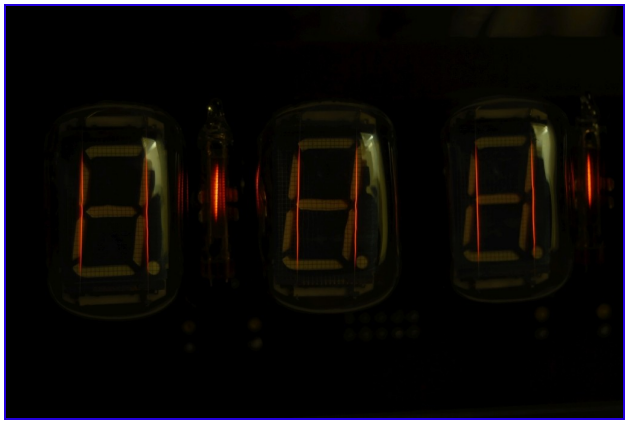
Solder 1 side to the RGB backlight PCB, so that the wires protrude from the backside. The white wire goes to the solder pad marked with +5 V. If you wish, you can test the LEDs using a 5 V (lab) power supply.



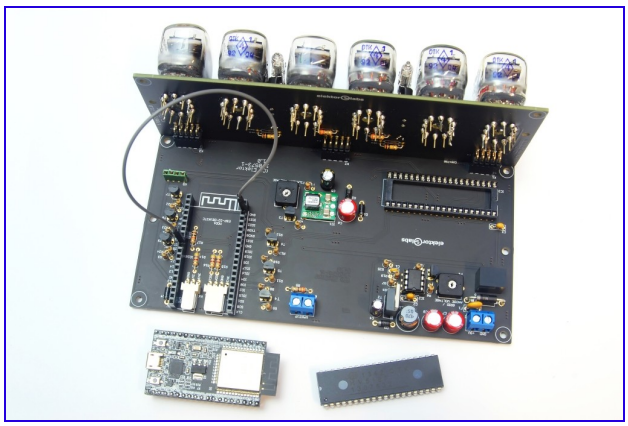
Final Assembly Steps

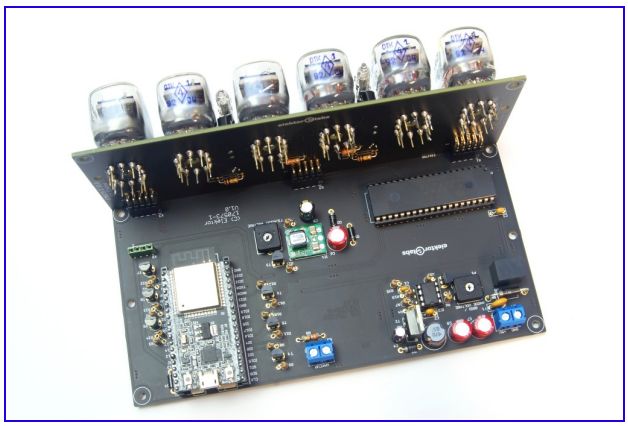




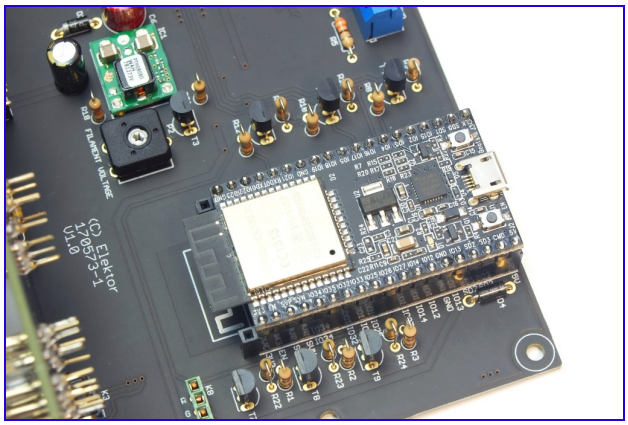


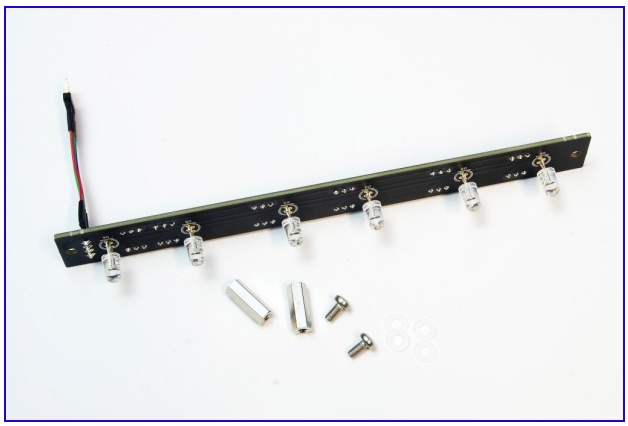
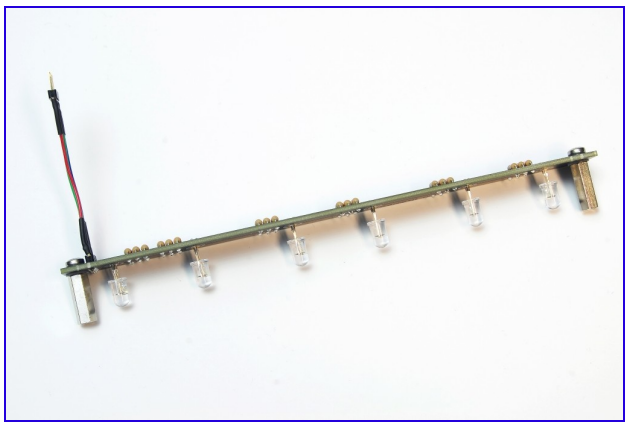
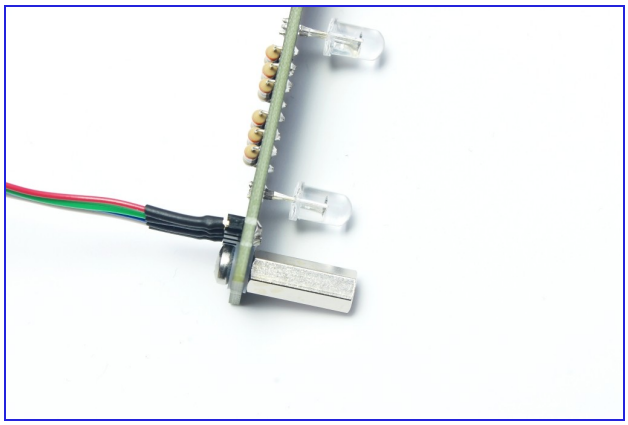
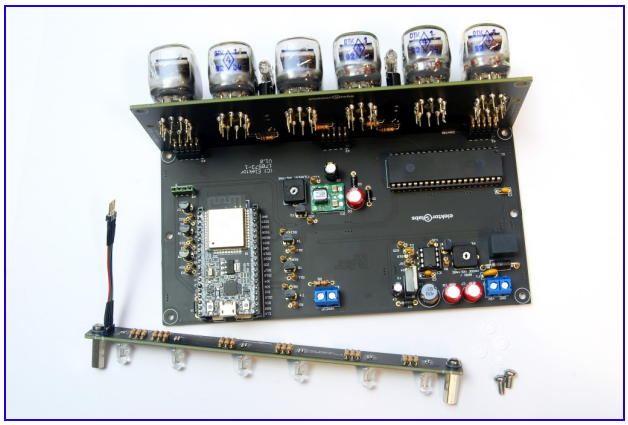
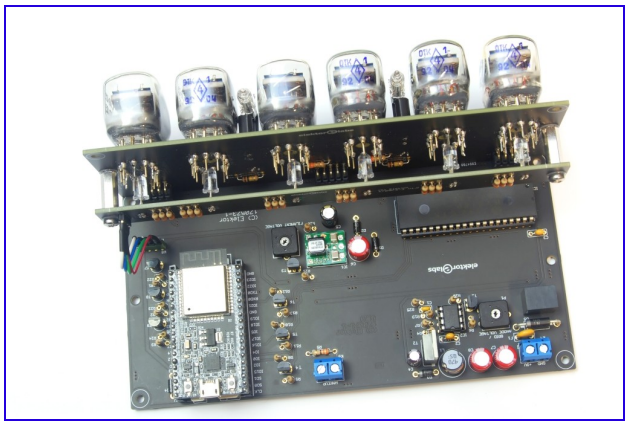
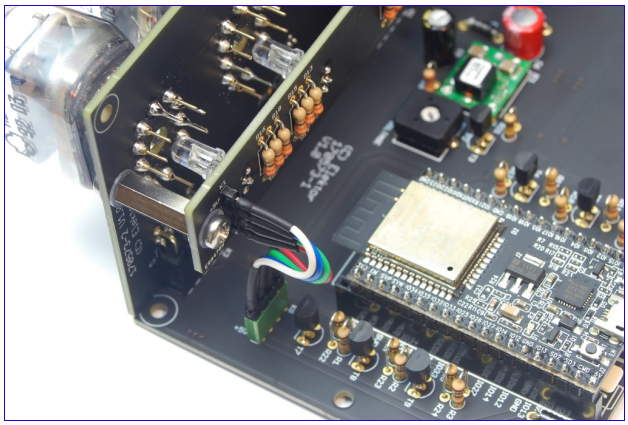
Connect the display PCB to the main PCB. Power up the main PCB and take a look at the VFD tubes in a dark room. The filaments of the tubes should glow dimly with a dark red color. If the filament of an IV-22 tube does not glow or very faint compared to the other tubes, wriggle the tube a bit back and forth in the socket pins until the filament glows properly. Sometimes there is a bad contact between the IV-22 tube pins and the socket pins on the PCB due to a thin layer of oxidation. Given the very low filament voltage of 1.1 V, this can be problematic.





Place IC3, HV518P in its socket. Remove the jumper wire between GND and pin 8 (IO33) of the ESP32-devkitC headers. Fit the ESP32-devkitC module into the socket headers. The socket headers are 20 way while the pin headers on the ESP32-devkitC have only 19 pins, so be very careful to fit the ESP32-devkitC correctly into the socket headers. We opted for 20 way socket headers as 19 way socket headers are difficult to get or even require custom manufacturing which is very costly.



Mount two 15 mm hex standoffs to the RGB backlight PCB using 2 M3 x 6 machine screws and 4 M3 nylon washers.
Attach the RGB backlight PCB to the display PCB using 2 M3 x 6 machine screws and 4 M3 nylon washers. Connect the RGB baclight PCB cable to K8 on the mainboard. Be sure to use the right orientation.

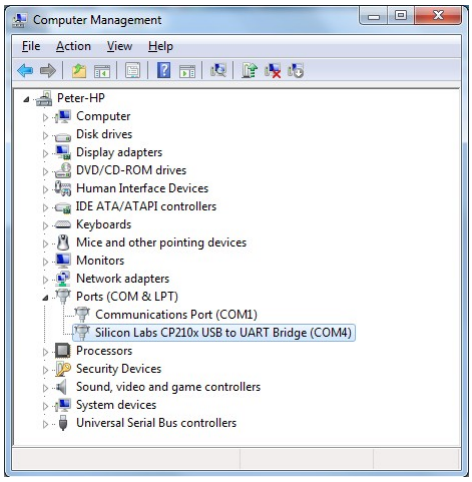
Setting up the Software

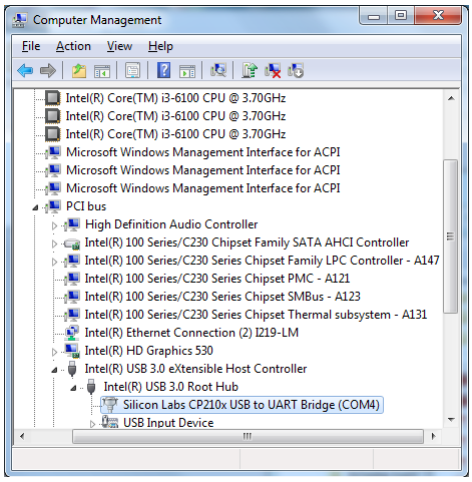
This section is for the most part aimed at using the Arduino IDE in Windows 7. You should have no problem when using another version of Windows or any other operating system that's supported by the Arduino IDE.

Serial Interface

Power up the clock and connect the ESP32-devkitC with a PC using a USB cable. The ESP32-devkitC incorporates a USB-to-serial function that enables the PC to access the clock as a serial interface.

If you're using Linux, the system will create an entry in the device directory structure e.g. **/dev/ttyUSB0**. Run command **lsusb** to obtain a list of all connected USB devices.





If you're using Windows, the operating system will assign a COM-port. A serial port is typically named **COM<x>** where **<x>** is a number between 1 and 256. You can observe the COM-port in the device manager. When the devices are displayed by type, the COM-port appears under the “Ports (COM & LPT)” branch. You can select to view devices by connection which renders a tree structure.

Clock Software

The clock software is an Arduino sketch. We used **Arduino IDE v1.8.7** for developing and testing the software. The source code is made up of .ino files. You find many useful remarks and comment blocks in these source files.

Besides the IDE you need to install the **Arduino core for the ESP32**. This package adds support for ESP32 to the Arduino IDE. Currently, this package can be obtained from GitHub:

https://github.com/espressif/arduino-esp32

This link will show you the main page of the software package. The page contains installation instructions. At the time of writing the **Arduino core for the ESP32** version 1.0.0 was marked as a stable release.

There are two ways of putting the clock software in the ESP32-devkitC:

- Use **esptool** to upload the binary files.
- Upload from within the Arduino IDE.

Either way you need to install **Arduino IDE** and the **Arduino core for the ESP32**.

To upload the binary files using **esptool**, first put all binary files in a directory, and then invoke the following command from the command prompt in that directory:

```
bin> path-to-esp32-tools\esptool.exe --chip esp32 --port COM4 --baud 921600 --before
default_reset --after hard_reset write_flash -z --flash_mode dio --flash_freq 80m
--flash_size detect 0xe000 boot_app0.bin 0x1000 bootloader_qio_80m.bin 0x10000
vfd_clock_wifi.ino.bin 0x8000 vfd_clock_wifi.ino.partitions.bin
```

Replace **COM4** with the correct serial path. Replace **bin** with the path to the directory that contains the binary files. Replace **path-to-esp32-tools** with the path to the tools directory in the **Arduino core for the ESP32**, for example:

C:\Users\Peter\AppData\Local\Arduino15\packages\esp32\tools\esptool\2.3.1\esptool.exe

The **esptool** will output information like this:

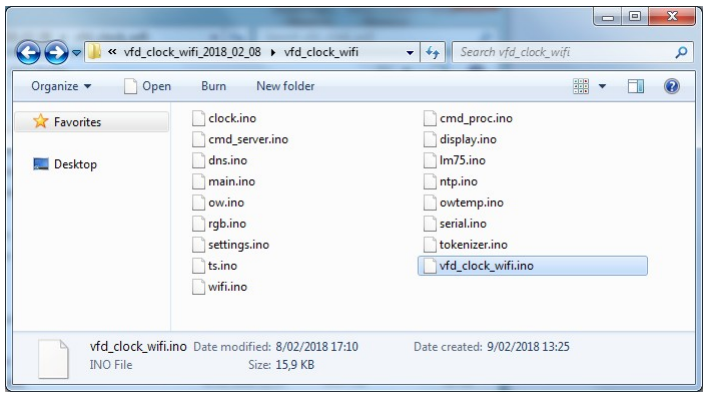
```
esptool.py v2.1
Connecting........__
Chip is ESP32D0WDQ6 (revision 0)
Uploading stub...
Running stub...
Stub running...
Changing baud rate to 921600
Changed.
Configuring flash size...
Auto-detected Flash size: 4MB
Compressed 8192 bytes to 47...
Wrote 8192 bytes (47 compressed) at 0x0000e000 in 0.0 seconds (effective 4096.0
kbit/s)...
Hash of data verified.
Flash params set to 0x022f
Compressed 12384 bytes to 8181...
Wrote 12384 bytes (8181 compressed) at 0x00001000 in 0.1 seconds (effective 792
6 kbit/s)...
Hash of data verified.
Compressed 508016 bytes to 328749...
Wrote 508016 bytes (328749 compressed) at 0x00010000 in 5.7 seconds (effective
17.7 kbit/s)...
Hash of data verified.
Compressed 3072 bytes to 122...
Wrote 3072 bytes (122 compressed) at 0x00008000 in 0.0 seconds (effective 1638.
 kbit/s)...
Hash of data verified.

Leaving...
Hard resetting...
```

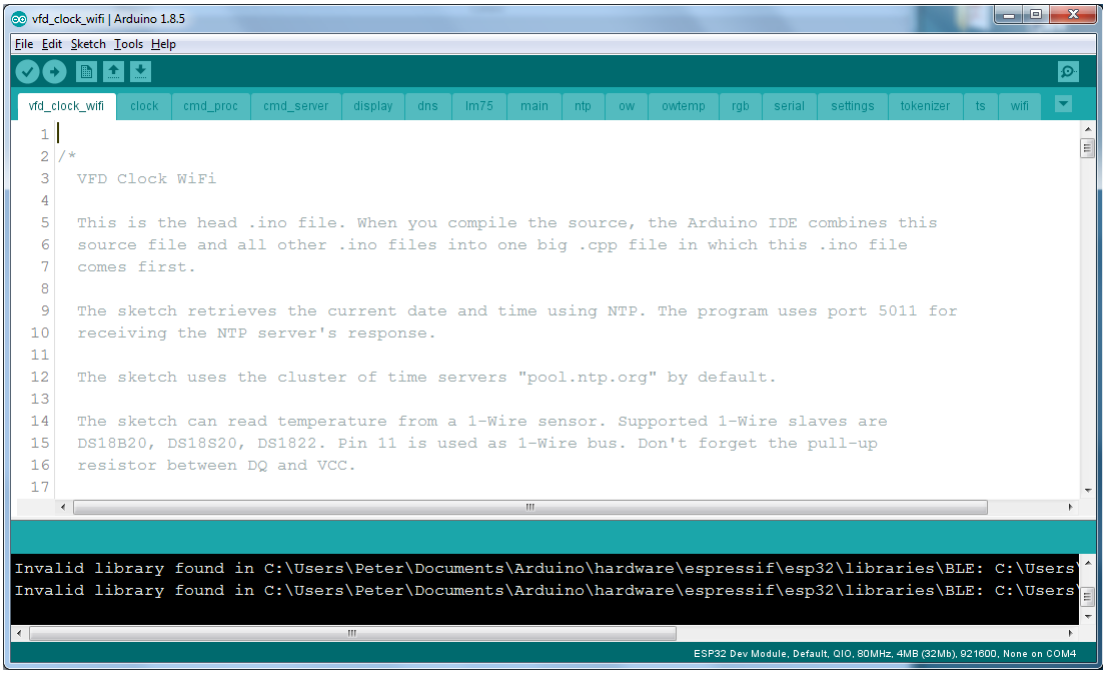
After this, the clock is ready to be set up as described further.

The other way of uploading the clock software to the ESP32-devkitC module is using the Arduino IDE.

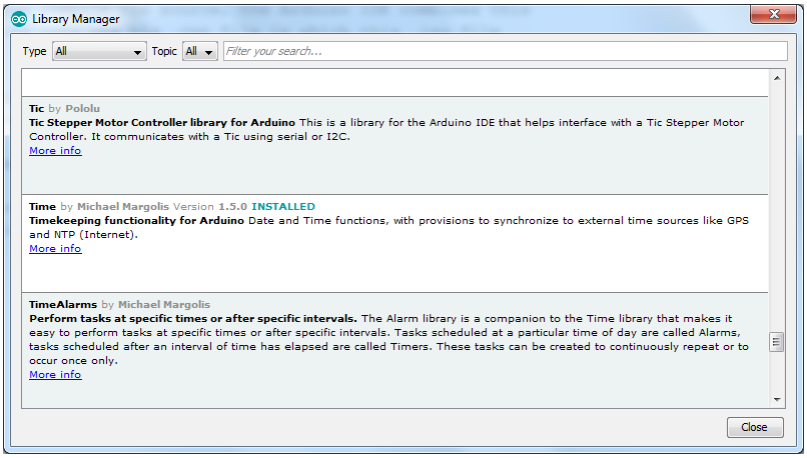
The source code consists of multiple .ino source files. The main file is called **vfd_clock_wifi.ino**, it has the same name (without .ino) as the containing folder.

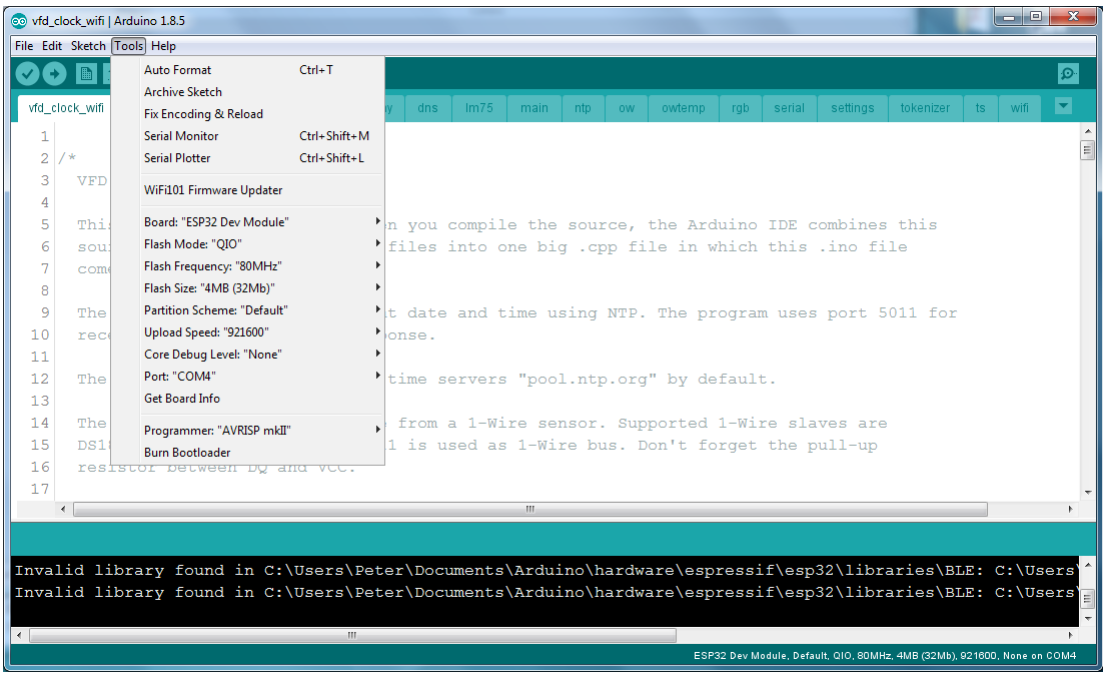


Open **vfd_clock_wifi.ino** in the Arduino IDE to open up the Sketch. The IDE shows all files in tabs, starting with the main file and followed by the other files in the folder sorted alphabetically.

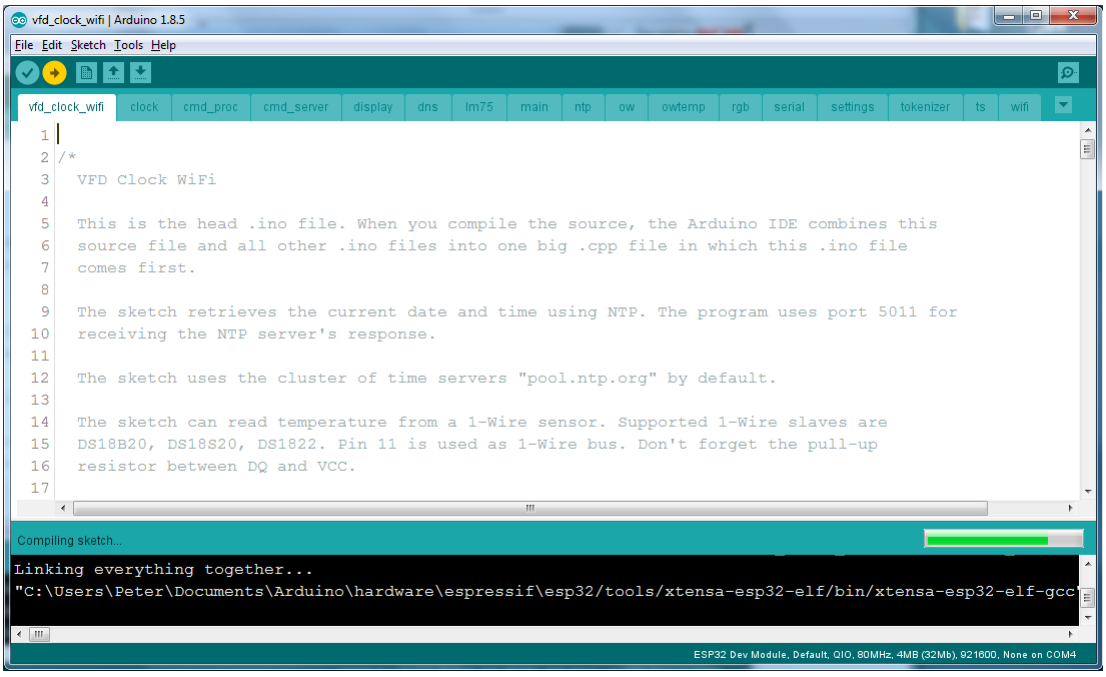


The sketch required the following libraries: **Wire** (for access to I2C), **EEPROM**, **WiFi**, and **Time**. If any of these libraries is missing, open the library manager (menu Sketch -> Include Library -> Manage Libraries...) and install the missing pieces. If multiple versions of a library are available, use the latest one. The picture to the right shows the **Time** library in the Library Manager. Version 1.5.0 of the **Time** library was installed directly from this window. Other required libraries can be found here as well.



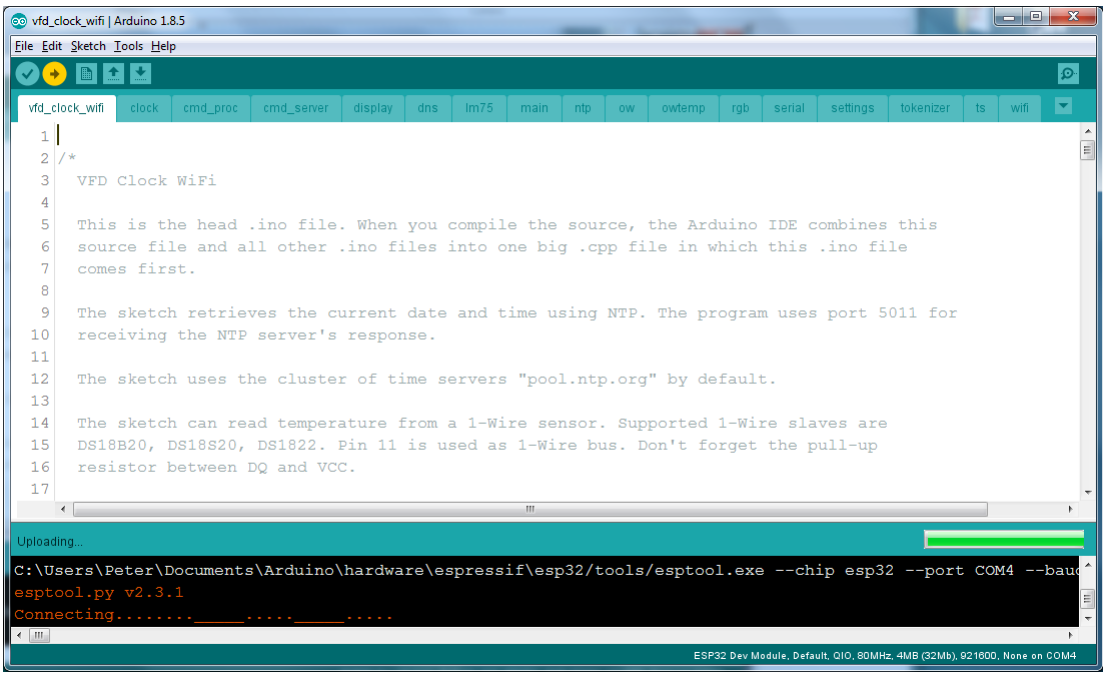


Before you start building the sources, you've to set up the IDE for use with the ESP32-devkitC module. In the Tools menu, select board type “ESP32 Dev Module” and select the COM-port assigned to your clock.



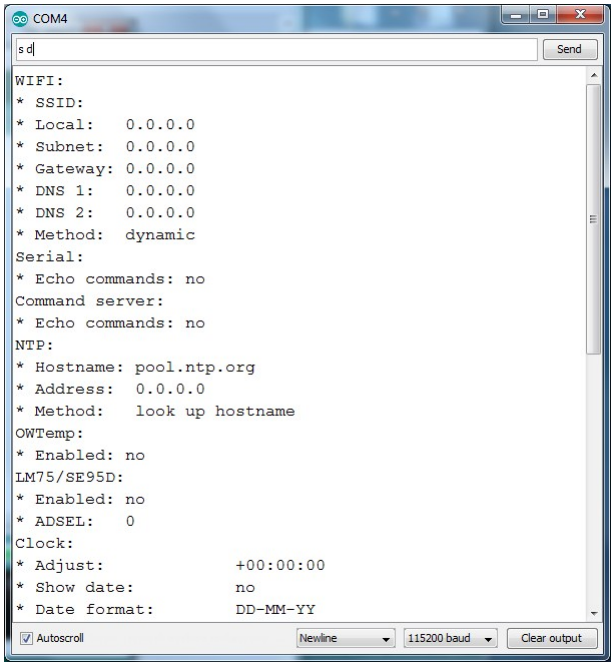
Now you can build and upload the software. In the Arduino IDE, this process is simply called “Upload”. Select menu Sketch -> Upload, or press CTRL-U to proceed.

If you get compiler warnings or the build process stops because of warnings, select menu File -> Preferences -> Settings tab and set “Compiler Warnings” to “None”.



After the IDE has successfully uploaded the binary to the ESP32-devkitC, the clock sends text to the serial interface. You can observe this information in the IDE's serial monitor. Select menu Tools -> Serial Monitor, or press CTRL-SHIFT-M to open up the serial monitor. Set the baudrate to 115200 and select something different from "no line ending".

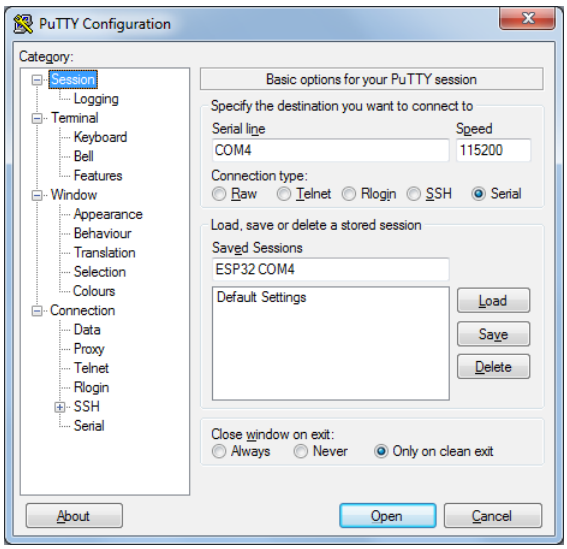
IMPORTANT! Each time you open the serial interface, the board will reset. This behavior is specified by Arduino and occurs with all Arduino-compatible boards, independent of operating system and serial monitor program (Arduino IDE's serial monitor, PuTTY, netcat, ...). So beware, when you change settings, then close and reopen the serial interface before writing the settings to non-volatile memory (a.k.a. EEPROM), the changes will be lost.

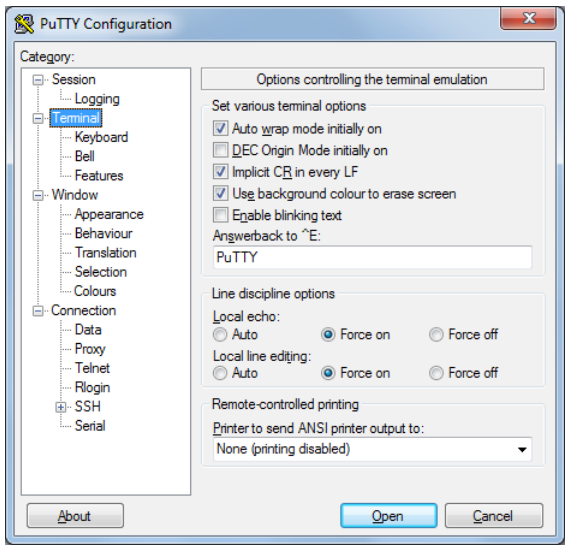


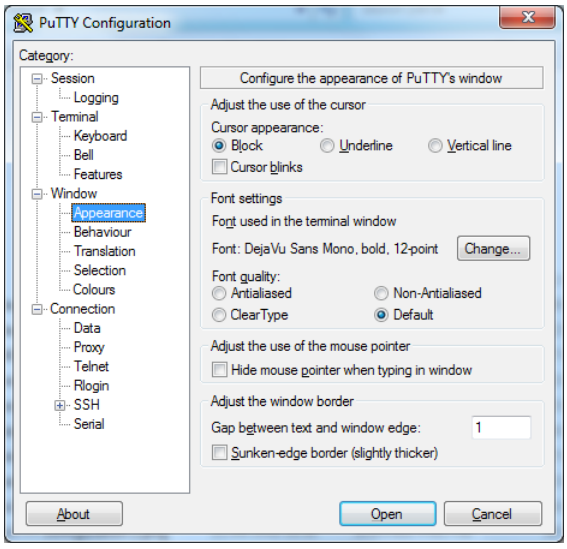
You can send commands to the clock from the serial monitor. For example, command **s d** (a short version of **settings dump**) reports a list of all current settings.

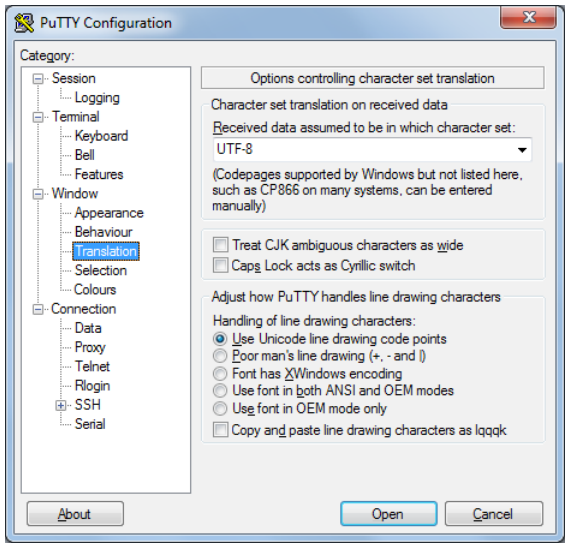
At this point, no settings are set, unless you're ESP32-devkitC was already set up for the clock. To fill in the settings, you've to send a series of commands. You can manually type each command in the serial monitor. This will take time, so let's use a better method.

You can put the commands in a text file and send its contents to the serial port. Since the serial monitor in the Arduino IDE isn't capable of sending a file or pasting multiple lines from the clipboard, we're going to use another serial monitor. A good choice is PuTTY in Windows and Linux. Another good choice is netcat in Linux.







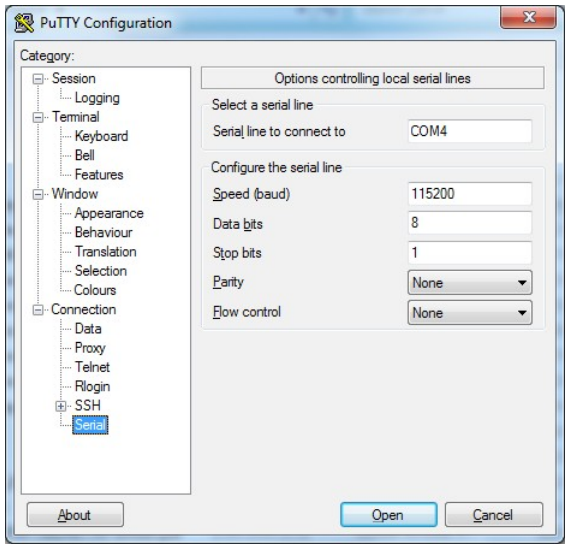


The most important PuTTY settings are:

- Select the COM-port assigned to the clock.
- Select baudrate 115200, 8 data bits, 1 stop bit, no parity, no flow control.
- Turn on implicit CR in every LF.
- Set local echo to “Force on”.
- Set local line editing to “Force on”.
- If your screen has a high resolution, you may want to select a larger font.
- Use the UTF-8 character set.

You can save these settings in a named session.

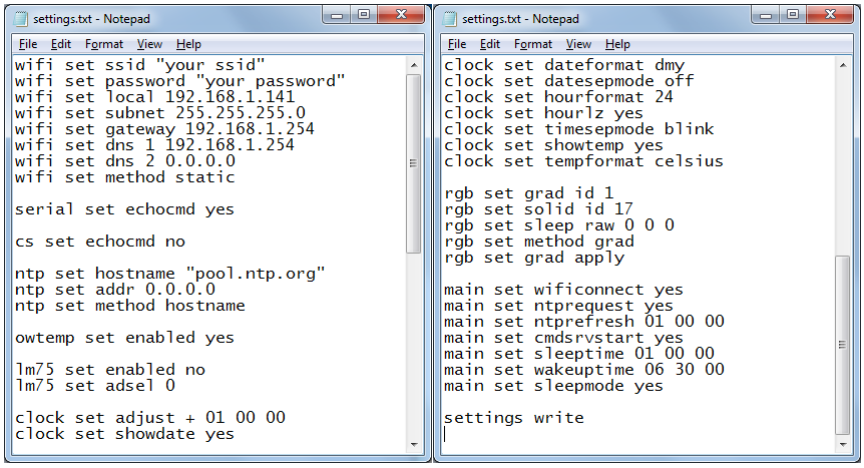
Click “Open” to make a connection with the clock.

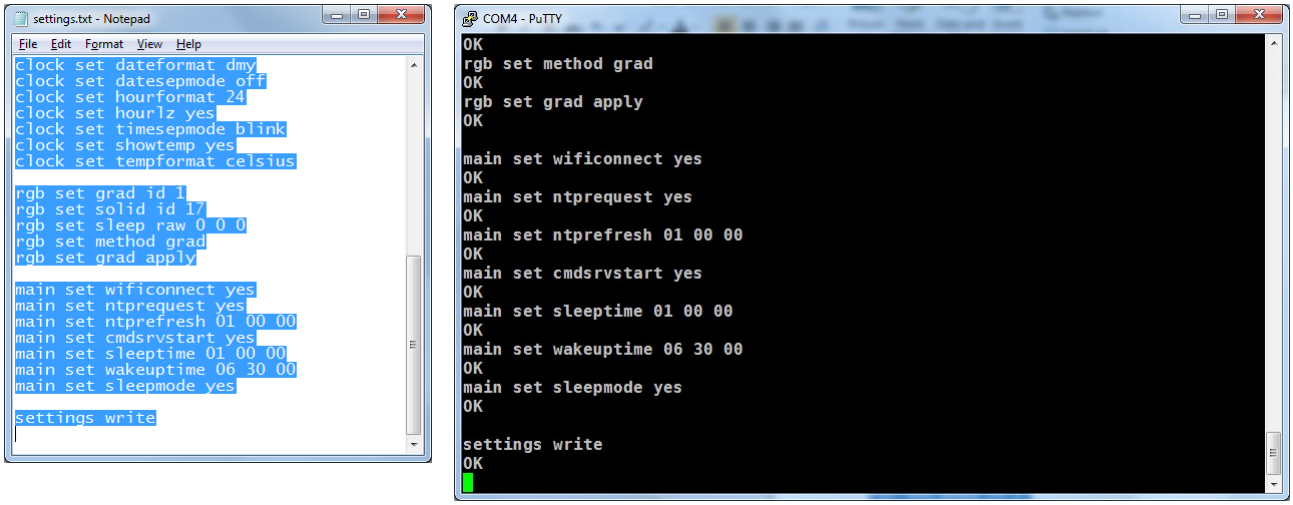


Once connected, you can send commands to the clock, like **w d** (short for **wifi dump**).

Let's create a text file that contains the necessary commands for setting up the clock. Many schemes are possible; the commands presented here create one possible setup.

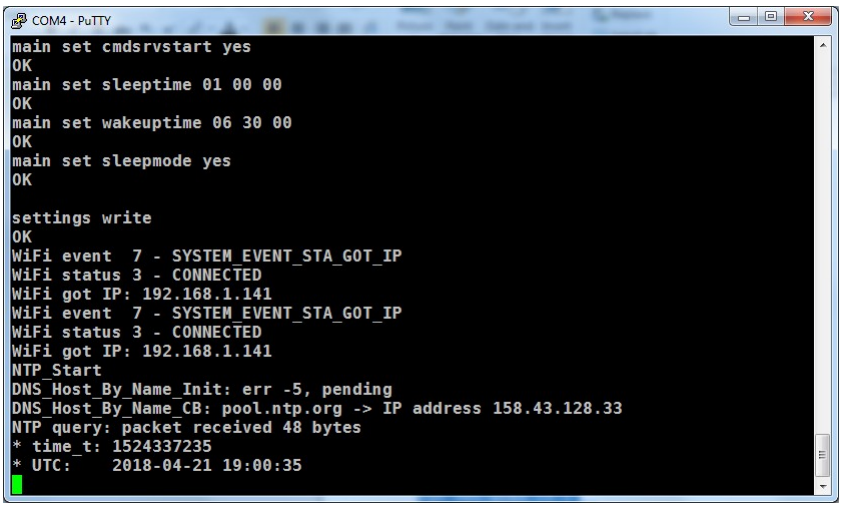
Yuo can find a list of commands in a later section.



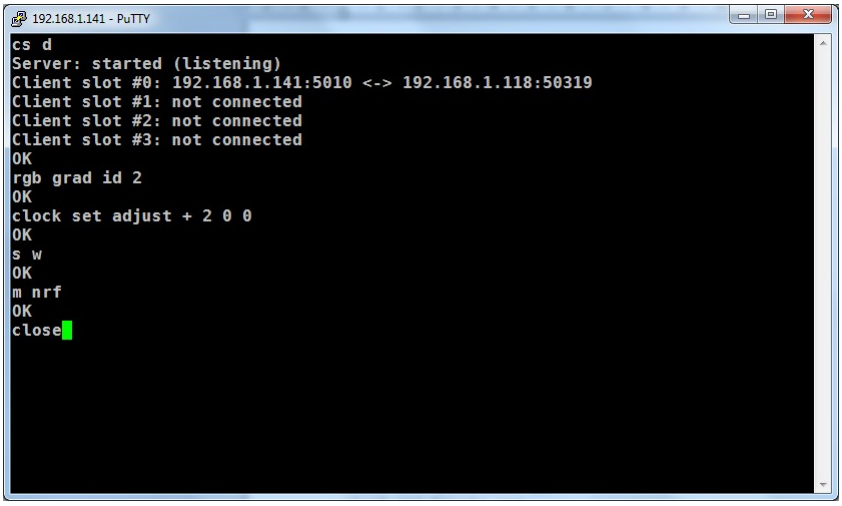


When the text file is done, you can transfer it to the serial port in the serial monitor. In the case of PuTTY, select all text in the editor and copy it to the clipboard. CTRL-C will do the trick. In PuTTY, press the right mouse button to paste the text from the clipboard.

The settings will take effect as soon as the clock receives them. If the settings are correct, the clock connects to your local wireless network, queries the date and time with the specified NTP server, and shows the time on the tubes.

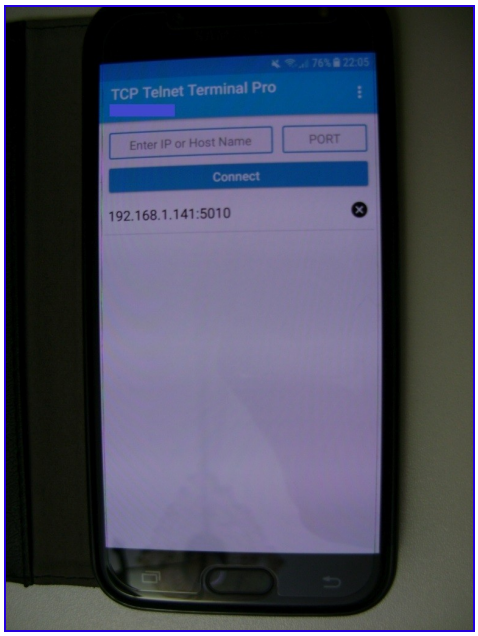


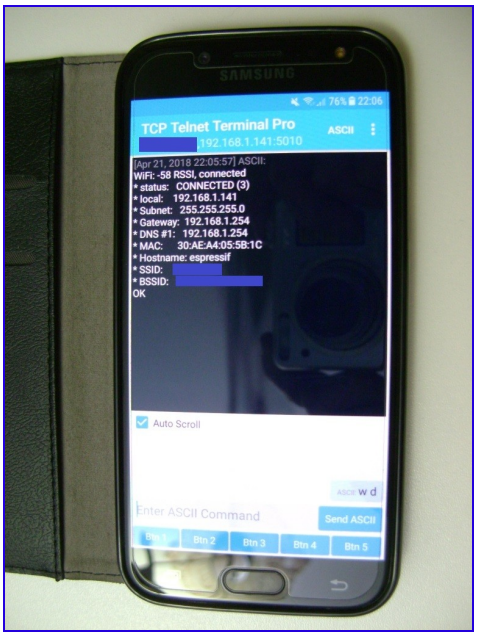
We have to store the settings in non-volatile memory to preserve them when the clock is powered down or reset. We included command **settings write** in our text file so all settings are immediately written to non-volatile storage.



The clock software allows a network client to connect using port 5010. We can use PuTTY, netcat, or similar terminal program to accomplish this. Once the terminal program has established a connection with the clock, you can send commands the same way you do with the serial monitor. Note that unlike opening the serial interface, establishing a connection over the wireless network won't reset the ESP32-devkitC module.

Besides using a PC, you can use your smartphone to send commands to the clock over the wireless network.





Here are the contents of settings.txt. You can copy the text from this document in your own editor and adjust the settings to your liking.

```
wifi set ssid "your ssid"
wifi set password "your password"
wifi set local 192.168.1.141
wifi set subnet 255.255.255.0
wifi set gateway 192.168.1.254
wifi set dns 1 192.168.1.254
wifi set dns 2 0.0.0.0
wifi set method static
wifi set hostname “your hostname”

serial set echocmd yes

cs set echocmd no

ntp set hostname "pool.ntp.org"
ntp set addr 0.0.0.0
ntp set method hostname

owtemp set enabled yes

lm75 set enabled no
lm75 set adsel 0

clock set adjust + 01 00 00
clock set showdate yes
clock set dateformat dmy
clock set datesepmode off
clock set hourformat 24
clock set hourlz yes
clock set timesepmode blink
clock set showtemp yes
clock set tempformat celsius

rgb set grad id 1
rgb set solid id 17
rgb set sleep raw 0 0 0
rgb set method grad
rgb set grad apply

main set wificonnect yes
main set ntprequest yes
main set ntprefresh 01 00 00
main set cmdsrvstart yes
main set sleeptime 01 00 00
main set wakeuptime 06 30 00
main set sleepmode yes

settings write
```

Commands

The clock software accepts an extensive list of commands. There are several groups of commands, each starting with a specific keyword e.g. **wifi**. Many commands can be abbreviated. For example, **w set m st** is short for **wifi set method static**.

Commands that change a setting have a 2nd keyword called **set** followed by the actual setting e.g. **wifi set method dynamic**. Settings are always changed in RAM. Command **s d** reports all current settings in RAM. To make the settings permanent, issue command **s w** (short for **settings write**).

Note that the **settings** command group doesn't change actual settings. These commands manage the settings as a whole.

The commands are documented and implemented in source file **cmd_proc.ino**.

Here's a list of recurring parameters. Parameters that are specific to a command are explained with the command.

```
Recurring parameters:

  IPV4AD  IPv4 address, for example: 192.168.1.1
  YEAR    1970..2225
  MONTH   1..12
  DAY     1..31
  HOUR    0..23
  MINUTE  0..59
  SECOND  0..59
  RED     0..4095
  GREEN   0..4095
  BLUE    0..4095
  YN      yes|y,no|n
```

Here's a list of all commands.

```
close                              Close the command interface (network connection only)
```

```
echocmd|ec YN                      Enable or disable echoing of commands on the command
                                     interface
```

```
sys                                System
└ reset                           System reset
```

```
wifi|w                             Wifi
└ start|s                         Start WiFi
└ stop|p                          Stop WiFi
└ dump|d                          Dump information
└ set                             Settings
  └ ssid "..."                    Specify the SSID, network name (max. 32 characters)
  └ password "..."                Specify the password (max. 63 characters)
  └ local IPV4AD                  Static IPv4 local address
  └ subnet IPV4AD                 Static IPv4 subnet mask
  └ gateway IPV4AD                Static IPv4 gateway address
  └ dns NUMBER IPV4AD             Static IPv4 DNS address (NUMBER=0..1)
  └ method|m                      Method of assigning IPv4 address
    └ dynamic|dyn                 Use DHCP
    └ static|st                   Use static address
  └ hostname "..."                Specify the hostname (max. 63 characters)
```

```
serial|ser                          Serial interface
└ set                               Settings
  └ echocmd|ec YN                   Enable or disable echoing of commands on the command
                                      interface
```

```
cmdsrv|cs                           Command server
└ start|s                           Start the command server
└ stop|p                            Stop the command server
└ dump|d                            Dump information
└ close|c
  └ all                             Close all client connections
  └ INDEX                           Close specific client connection (INDEX=0..3)
└ set                               Settings
  └ echocmd|ec YN                   Enable or disable echoing of commands on the command
                                      interface
```

```
ntp                                 NTP
└ start|s                           Start NTP request
└ set                               Settings
  └ method|m                        Method of determining IPv4 address of NTP server
    └ hostname|h                    Use hostname for looking up IPv4 address
    └ addr|a                        Use IPv4 address
  └ hostname "..."                  Hostname of NTP server
  └ addr IPV4AD                     IPv4 address of NTP server
```

```
owtemp                              1-Wire temperature sensor
└ set                               Settings
  └ enabled|ena YN                  Enable or disable temperature sensor
```

```
lm75|se95d                          I²C temperature sensor
└ set                               Settings
  └ enabled|ena YN                  Enable or disable temperature sensor
  └ adsel N                         Specify A[2..0] pin configuration of the chip (N=0..7)
```

```
clock|c                             Clock
└ write|w YEAR MONTH DAY HOUR MINUTE SECOND
                                    Write date and time
└ read|r                            Read current date and time
└ suspend                           Suspend the clock
└ resume                            Resume the clock
└ set                               Settings
  └ adjust [N] +|- HOUR MINUTE SECOND
                                    Adjustment applied on time received from NTP server
                                      (multiple adjustments, N=1..4, default is 1)
  └ selectadjust|sa N               Select adjustment (N=1..4)
  └ showdate|sd YN                  Show date y/n
  └ dateformat|df dmy|mdy|ymd       Date format:
                                      dmy=day-month-year,
                                      mdy=month-day-year,
                                      ymd=year-month-day
  └ datesepmode|dsm on|off          Mode of separator tubes when showing date:
                                      on=always on
                                      off=always off
  └ hourformat|hf 12|24             Hour format: 12=12-hour format, 24=24-hour format
  └ hourlz|hlz YN                   Show hour with leading zero y/n
  └ timesepmode|tsm blink|ampm|on|off
                                    Mode of separator tubes when showing time:
                                      blink=blink ones per second,
                                      ampm=indicate AM/PM,
                                      on=always on,
                                      off=always off
  └ showtemp|st YN                  Show temperature y/n
  └ tempformat|tf celsius|c|fahrenheit|f
                                    Temperature format
```

```
display|d                          Display driver
└ suspend                          Suspend the display driver
└ resume                           Resume the display driver
```

```
rgb                                RGB driver
└ solid|s                          Select solid RGB colors
  └ id N                           Select scheme from list (N=0..17)
  └ raw RED GREEN BLUE             Specify RGB values
└ grad|s                           Select animated gradient colors
  └ id N                           Select scheme from list (N=0..5)
└ set                              Settings
  └ method|m                       Color method
    └ solid|s                      Use solid RGB colors
    └ grad|g                       Use animated gradient colors
  └ solid|s                        Solid RGB colors
    └ id N                         Select scheme from list (N=0..17)
    └ raw RED GREEN BLUE           Specify RGB values
    └ use                          Copy active solid RGB colors to settings
    └ apply                        Apply solid RGB colors in settings as active
  └ grad|g                         Animated gradient colors
    └ id N                         Select scheme from list (N=0..5)
    └ use                          Copy active gradient colors to settings
    └ apply                        Apply gradient colors in settings as active
  └ sleep                          Solid RGB colors shown during sleep mode
    └ id N                         Select scheme from list (N=0..17)
    └ raw RED GREEN BLUE           Specify RGB values
    └ use                          Copy active solid RGB colors to settings
    └ apply                        Apply solid RGB colors in settings as active during
                                     sleep mode
```

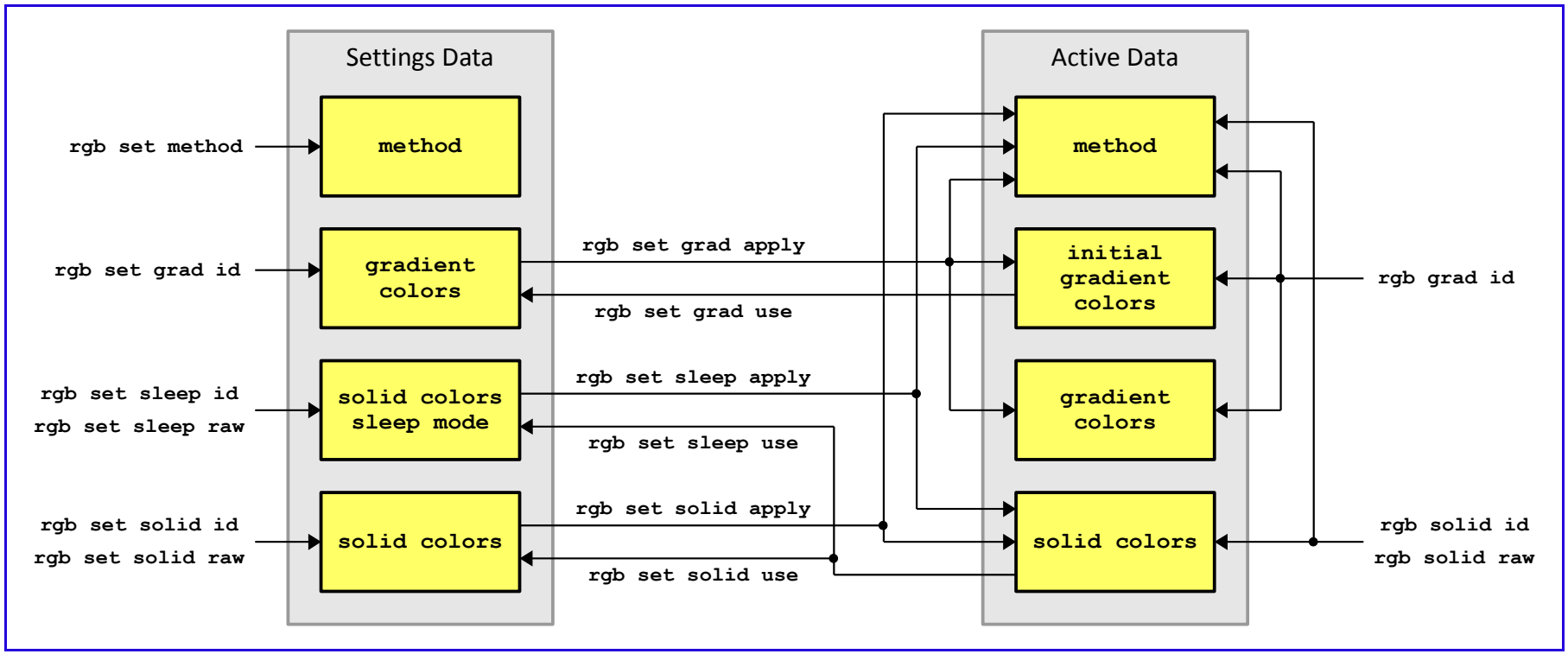
```
main|m                             Main function
└ ntprefresh|nrf                   Perform an NTP request and refresh clock date and time
└ set                              Settings
  └ wificonnect|wc YN              Automatically connect to wireless network y/n
  └ ntprequest|nrq YN              Periodically perform an NTP request y/n
  └ ntprefresh|nrf HOURS MINUTE SECOND
                                   NTP refresh period (HOURS=0..255)
  └ cmdsrvstart|css YN             Automatically start command server y/n
  └ sleeptime|st HOUR MINUTE SECOND
                                   Time to go to sleep
  └ wakeuptime|wut HOUR MINUTE SECOND
                                   Time to wake up
  └ sleepmode|sm YN                Enable or disable sleep mode
```

```
settings|s                         Settings
└ write|w                          Write settings from RAM to EEPROM
└ read|r                           Read settings from EEPROM to RAM, verify, apply
                                     default settings if invalid
└ reset                            Reset settings in RAM
└ clear                            Clear settings in EEPROM
└ dump|d                           Dump information
```

The number of **rgb** commands is extensive. This is because the software manages two sets of RGB data, one for settings and one for activity (colors actually being shown). An early version of the software had one data set, but this design led to confusion when one was updating settings while fiddling with the RGB colors. So it was decided to split up the RGB data into two data sets.

The diagram below shows how the various **rgb** commands influence the data sets. Each command induces a data flow through the associated arrow(s).

The active set stores a copy of the initial gradient colors since the colors and thus the data values are constantly changing when the animated gradient color method is active.


Settings Data
Active Data
rgb set method
method
rgb set grad id
gradient colors
rgb set sleep id
rgb set sleep raw
solid colors sleep mode
rgb set solid id
rgb set solid raw
solid colors
rgb set grad apply
rgb set grad use
rgb set sleep apply
rgb set sleep use
rgb set solid apply
rgb set solid use
method
initial gradient colors
gradient colors
solid colors
rgb grad id
rgb solid id
rgb solid raw

Time Adjustments

The clock receives date and time from an NTP server as Coordinated Universal Time (UTC). The NTP protocol supplies no information about time zones or daylight saving time (DST). To display the time correctly for your physical location, the clock software adds or subtracts a time offset to or from the displayed time and date. This is called time adjustment.

The data set for time adjustment consist of hours, minutes, seconds and a flag that indicates addition or subtraction.

The clock software maintains four time adjustment data sets. There are two commands for managing time adjustment, **clock set adjust** and **clock set selectadjust**. The former sets up a time adjustment data set, the latter select the active data set.

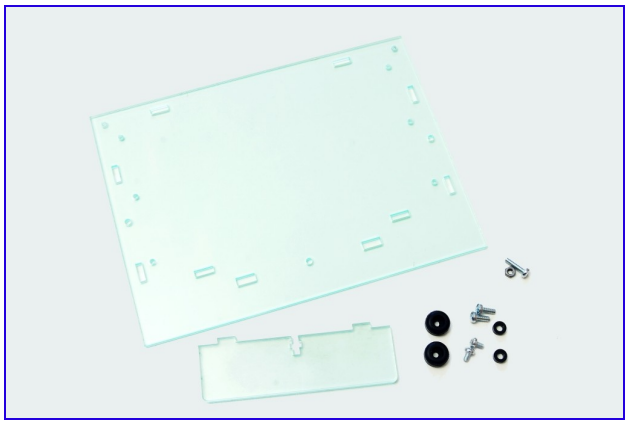
In addition, the push button on the back panel can be used for controlling the active adjustment. When you hold down the button for a couple of seconds, the tubes display the active adjustment, a value ranging from 1 to 4. By holding down the button a bit longer, the value cycles through its range until you release the button. Once the value changes, a new time adjustment comes into effect, and as soon as the button is released the clock settings are written to non-volatile memory (all settings are written, it's the same action as command **settings write**).

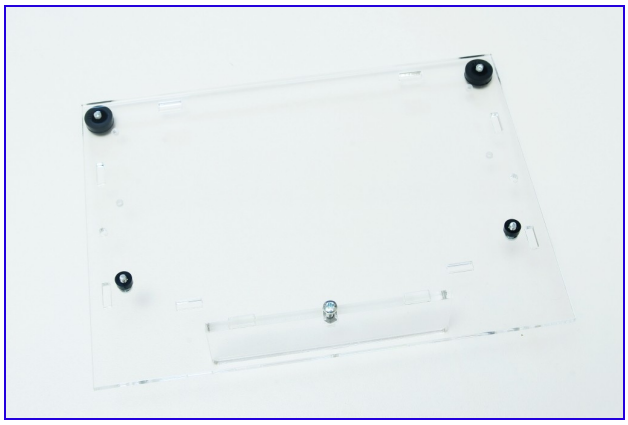
To adjust for a timezone, one data set is required. Daylight saving time requires an additional data set. For example, when your timezone is UTC+1, you can adjust the displayed time with these commands:
clock set adjust 1 + 1 0 0
clock set selectadjust 1

To support daylight saving time in this timezone, use a second data set. For example, if your location is timezone UTC+1 and it's the winter months, issues these commands:
clock set adjust 1 + 1 0 0
clock set adjust 2 + 2 0 0
clock set selectadjust 1

When daylight saving time starts, you can hold the push button to change to data set number two. When daylight saving time ends, hold the push button once again to change back to data set number one.

Assembling the Enclosure

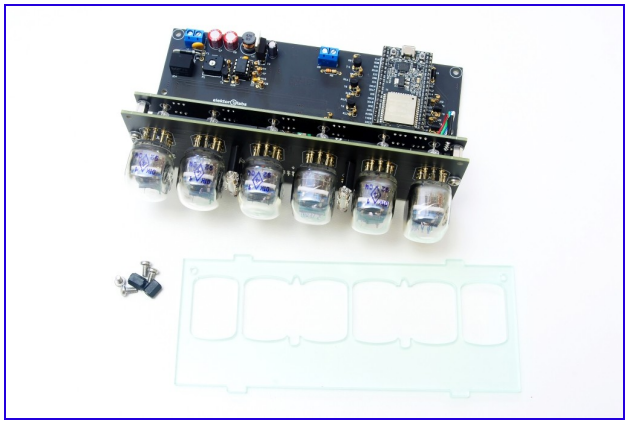




Remove the protective finish from the baseplate and the acrylic support. Mount the rubber feet on the bottom at the backside using two M3x5 machine screws. The holes are pre-threaded with an M3 thread. Do not exert too much force as the screw ends should not protrude on the other side of the base plate.

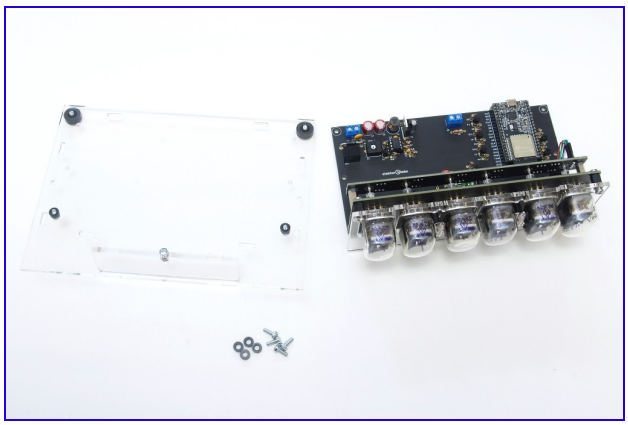
Mount the acrylic stand to the baseplate using an M3x12 machine screw and an M3 nut. Do not overtighten the screw as the acrylic may break.

Screw two M3x8 machine screws all the way from the bottom side through the baseplate and slide two 3 mm spacers over the screw ends on the top side.



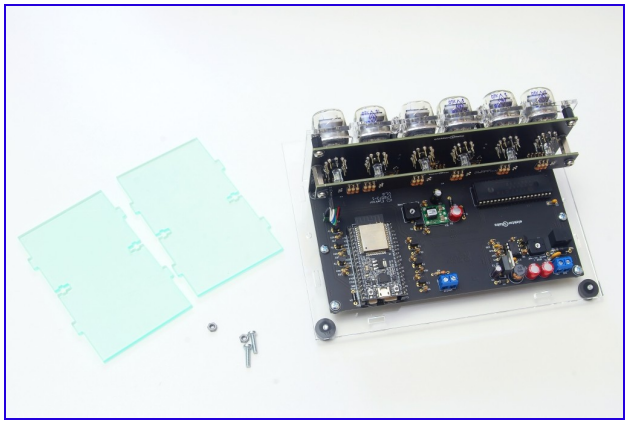
Remove the protective finish from the front panel. Attach two 8 mm M3 F/F plastic spacers to the front panel using two M3x6 machine screws.

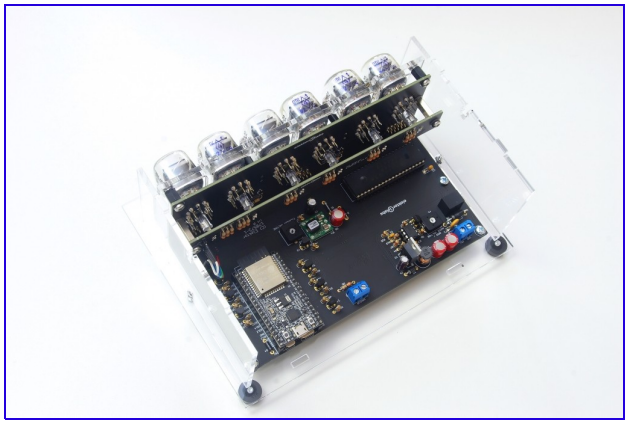
Slide the front panel over the IV-22 and DM160 tubes of the clock assembly and attach it to the display PCB using another set of two M3x6 machine screws.



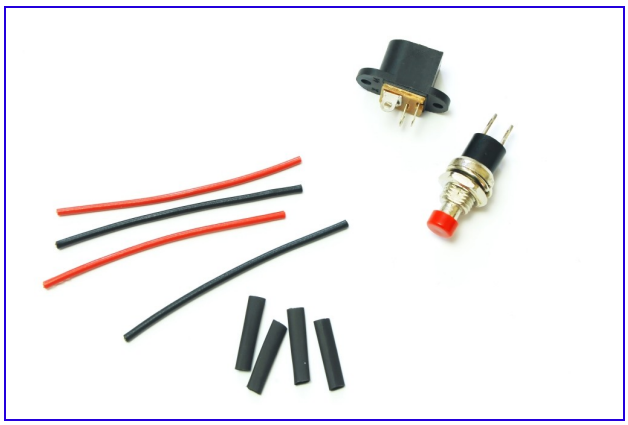
Position the main PCB on top of the baseplate so it fits over the earlier installed M3x8 screws and 3 mm spacers. Make sure the tabs on the front panel fit into the slots of the baseplate.

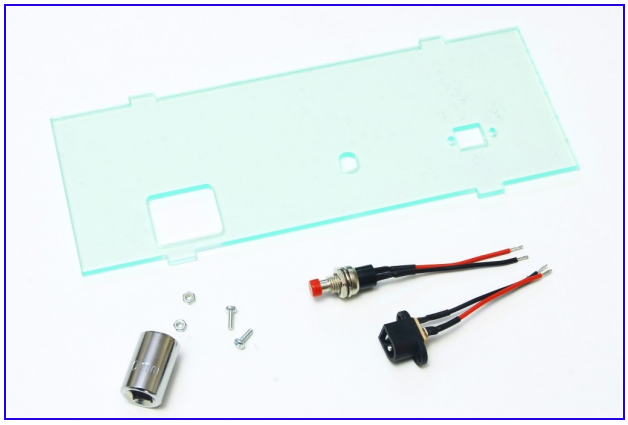
Attach the main PCB to the baseplate using four M3x8 machine screws and four 3 mm spacers.

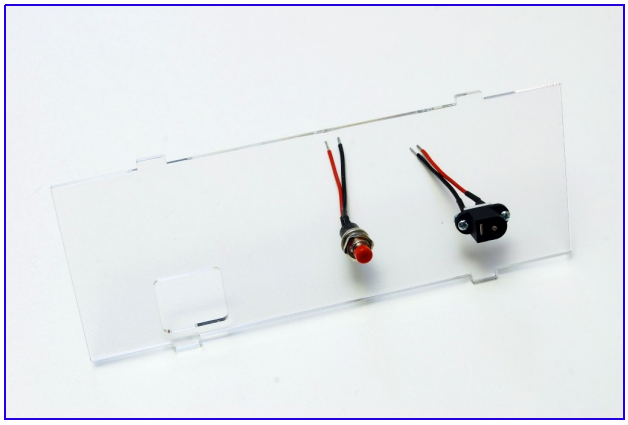




Remove the protective finish from the side panels. Look for the correct orientation and attach them to the baseplate using an M3x12 machine screw and an M3 nut. Do not overtighten the screws.



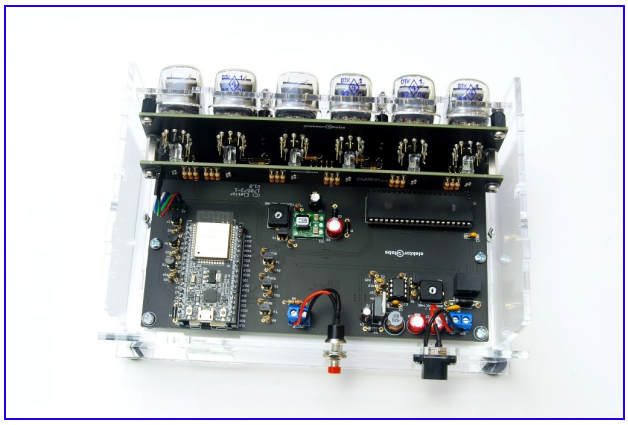


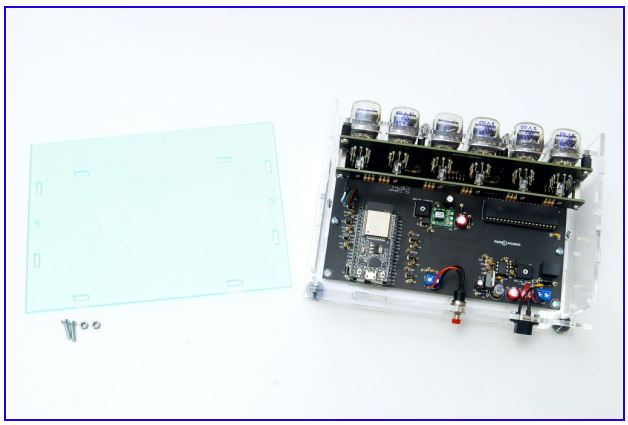


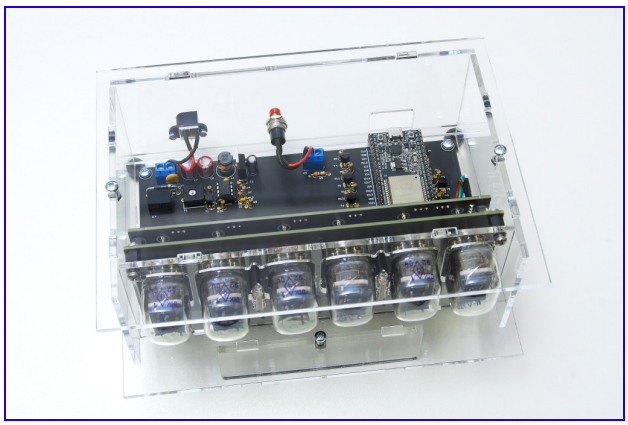
Cut two 5 cm pieces of the 0.5 mm^2 red and black wire. Strip the ends and solder the wires to the power connector and the push button. Insulate the solder joints using 1.5 cm pieces of 3.2 mm heat shrink tubing. Do not tin the other ends of the wires that will go into the terminal blocks on the main PCB.

Remove the protective finish from the back panel and attach the power connector using two M2x6 machine screws and two M2 nuts. Watch the orientation of the panel so the wires protrude at the right side. Attach the push button to the back panel. A 10mm socket will come in useful here, if not pliers will do the job. If you decide to use pliers, be careful not to scratch the acrylic.

Connect the wires to the terminal blocks on the main PCB. Watch the polarity of the power connector. Insert the tabs of the back panel into the slots of the baseplate.



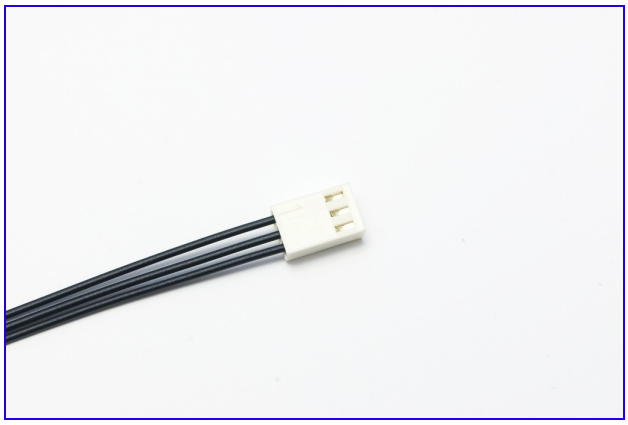




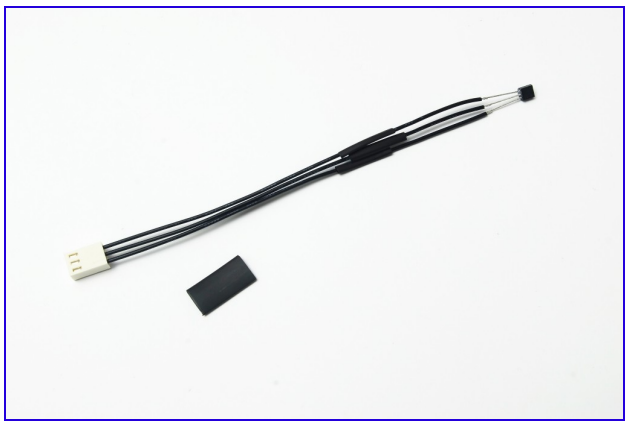
Remove the protective finish from the top panel and fit it over the front, back and side panels. Attach it to the side panels using two M3x12 machine screws and two M3 nuts. Do not overtighten the screws and be careful not to drop the M3 nuts inside the enclosure.

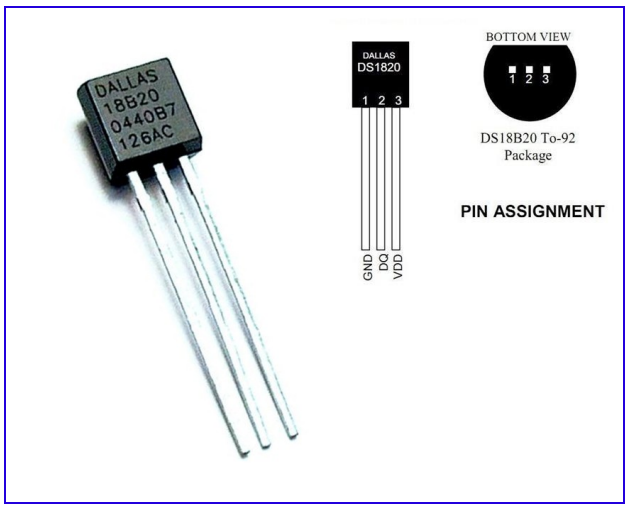
Congratulations!!! Your clock is complete now.

Assembling the Temperature Sensor



Slide the three pre-crimped wires into the 3-pole female connector from the backside until they snap into place.





Slide 2 cm pieces of 3.2 mm heat shrink tube over the wires and solder the wires to the DS18B20 sensor. The wire marked with “1” on the female connector is the +5 V power supply. The middle wire is DQ (1-Wire data). The remaining wire is ground (GND). Please take a look at the DS18B20 pinout in order to connect the wires correctly.

Crimp the heat shrink tube using a heat source, slide a 2 cm piece of 6.4 mm heat shrink tube over the sensor and shrink again. The sensor is now ready to use.

Connect the temperature sensor to K6 on the main PCB of the clock. Do not forget to enable the sensor in the software settings.