



Instructions for building and operating the FreeVario

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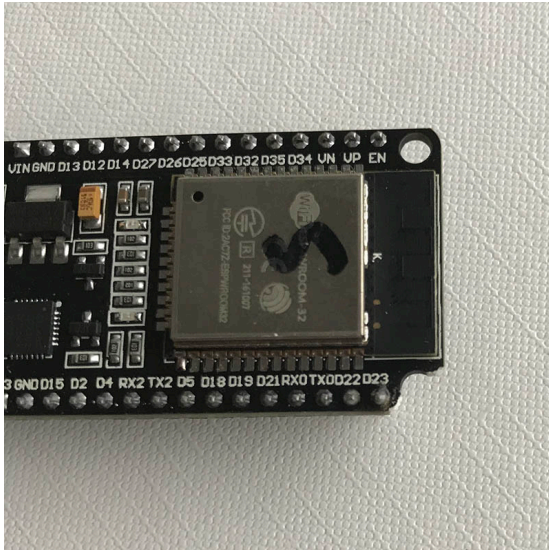
I work on a Mac or Linux system. Little things can differ on a Windows computer!

I. General

The FreeVario is operated with 12V. If e.g. the micro USB plug is only connected to 5V, it basically works, but the audio amplifier will not work properly. He will makes noises. So this is not a mistake, it is due to the wrong voltage.

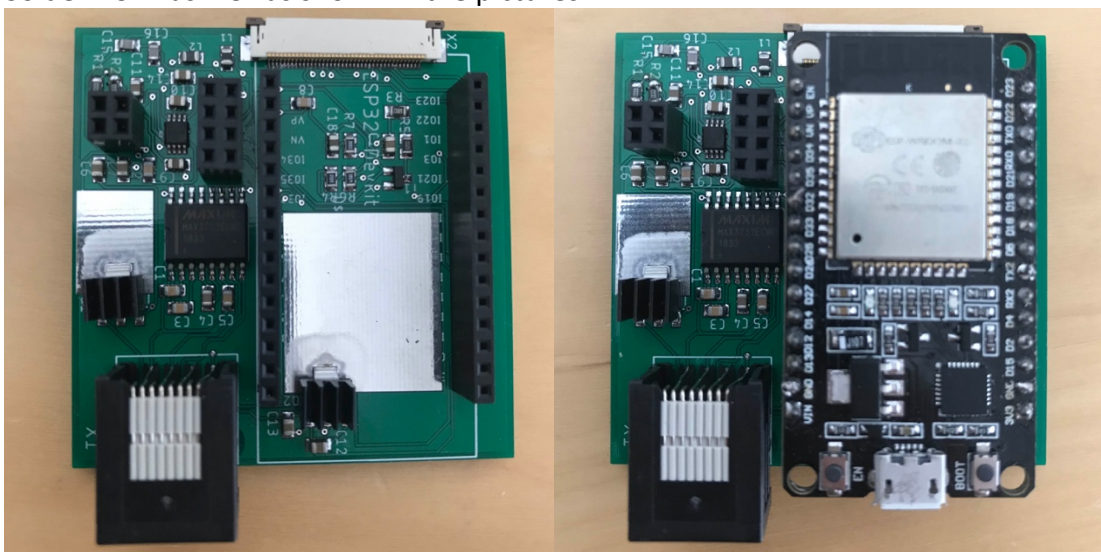
The dimensional accuracy of the 3D printed parts is extremely dependent on the settings of your printer and the material. So it can happen that the parts are too small. Then you have to print the parts a few percent larger.

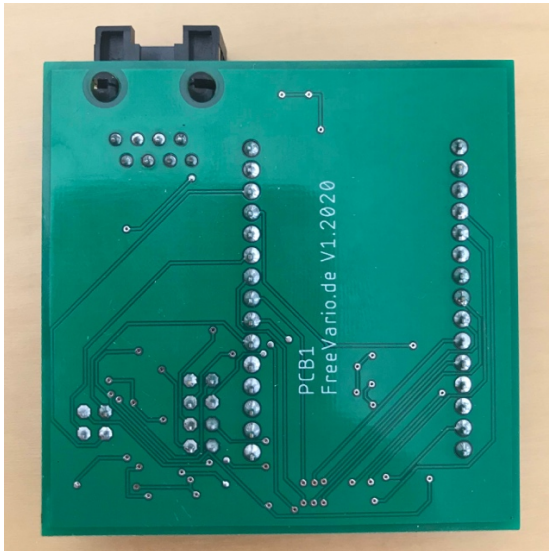
There seems to be different board sizes for the ESP32. The result is that the housing does not close properly. For this reason I always cut off one corner of the board.



II. Assembling the boards and assembling the vario gauge

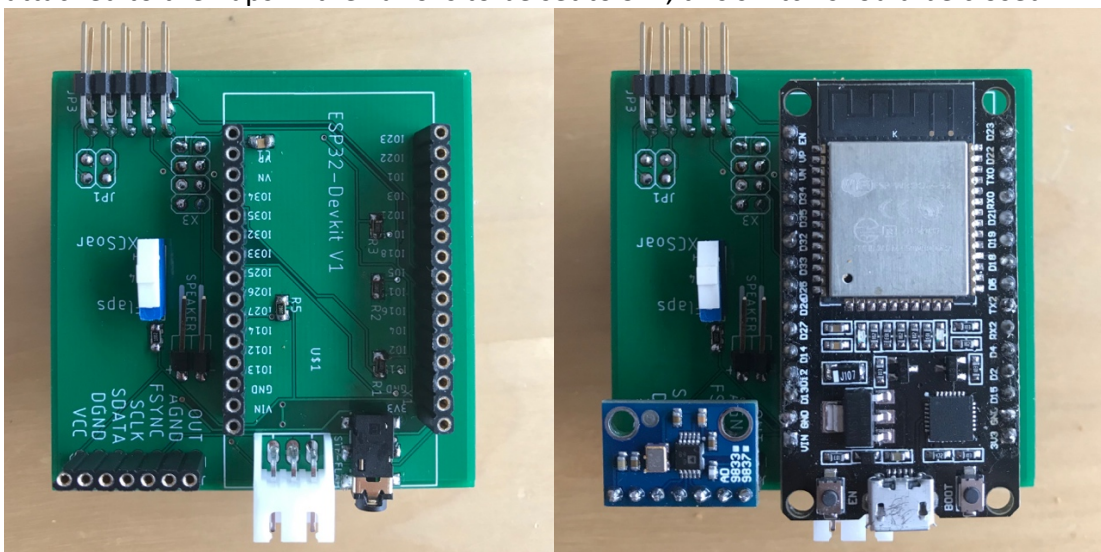
1. Solder PCB1 as well as shown in the pictures.

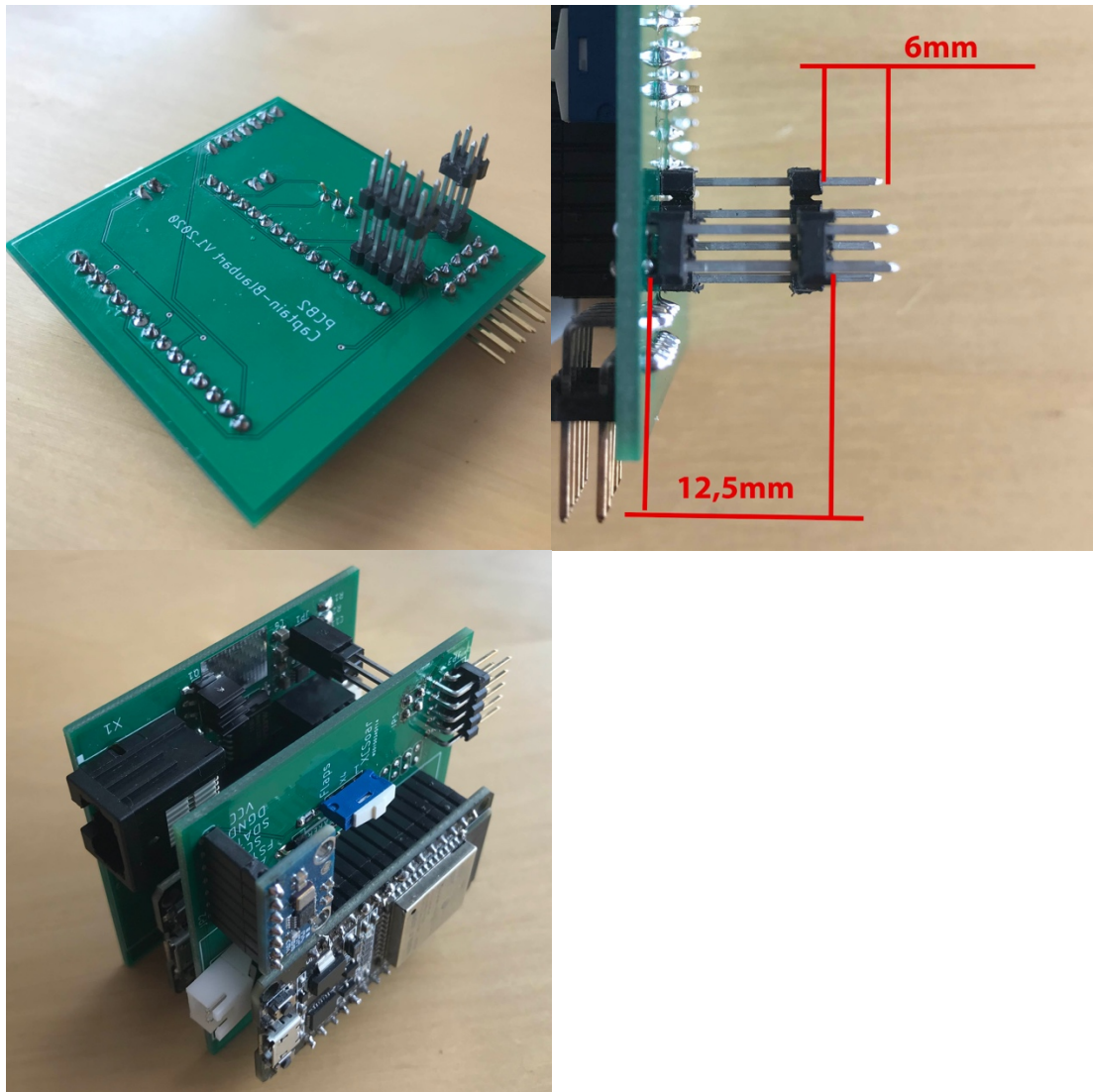




2. Solder PCB2 as well as shown in the pictures. The distance between the two plastic holders on the stacking strip must be set to 8mm. Shorten the long pins with a side cutter to 22 mm (see 3rd picture).

With the help of the slide switch you can set how the vario will later work in automatic mode. If you put it on XCSoar, XCSoar sends commands to switch between STF and vario. If you set it to flaps, the automatic mode switches between the STF and vario using a switch connected to the white, three-pin connector. This switch can e.g. be attached to the flaps. If the vario is to be set to STF, this switch should be closed.

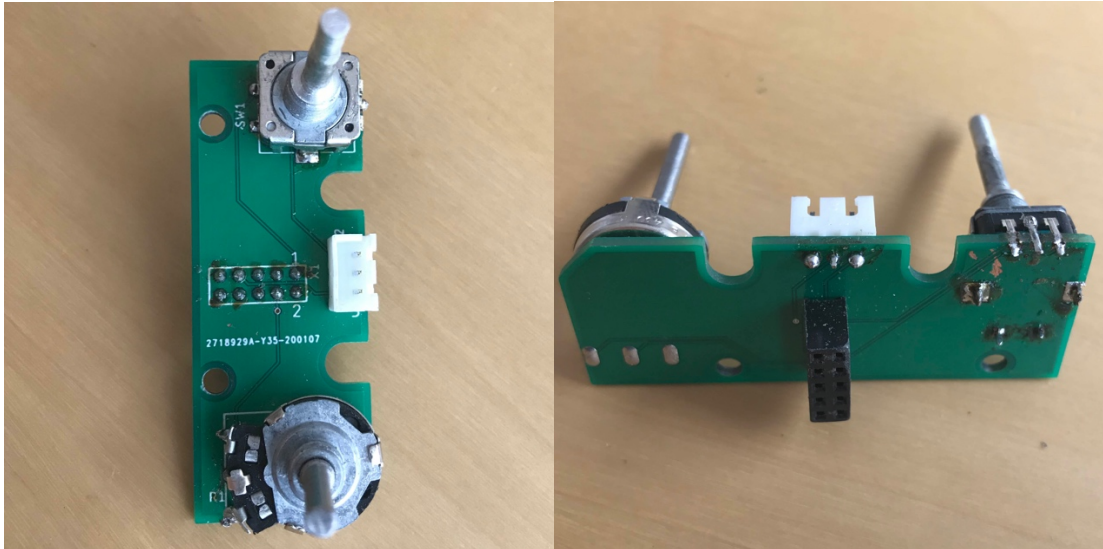




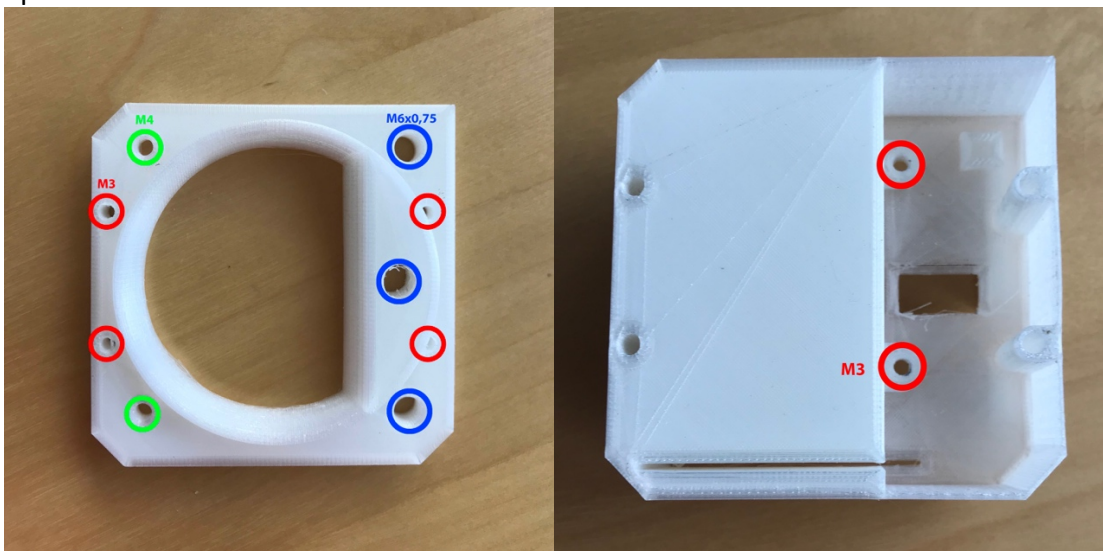
The 2.5mm jack socket is used to connect an external speaker. If the external speaker is connected, the internal one is automatically switched off. You have to be very careful when soldering the jack socket. If too much solder is used, the switch in the jack socket will not work properly because the solder penetrates and blocks. I recommend measuring the socket with and without the plug after soldering and, if necessary, unsoldering it and trying again.

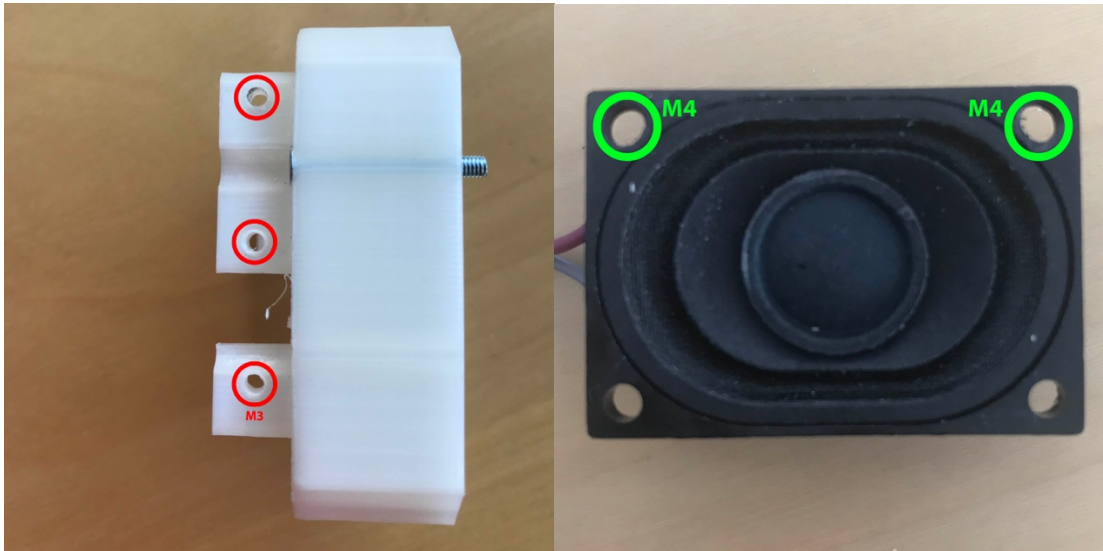
3. Carefully disassemble the rotary encoder by bending the small metal brackets. The axis of the rotary encoder is secured with a locking ring. You have to go carefully with a side cutter into the gap between the axis and the upper part of the housing and press lightly. If the axis is slightly damaged by the side cutter, file away the spot. Clamp the axes in the lathe, turn by 4mm. Then carefully reassemble the rotary encoder and bend the metal brackets back. Secure the axis of the rotary encoder again with the ring. For safety's sake, buy the encoder twice, the first time it may go wrong. Drills the banjo bolts to 4.3mm.
4. On the PCB3 at the position where the encoder is located, you have to file away the protruding part of the board on the side with the 3 PINs and above, otherwise the board will not fit into the housing without tension. It may well be that you have to file

a little more after soldering. Carefully bend the contacts of the potentiometer downwards by 90° and solder them on. Tests whether the axes of the encoder and the potentiometer fit well through the banjo bolts and are easy to operate after installing the front plate. If necessary, loosen again and move something. Solder PCB3 as well as shown in the pictures. Make sure that you solder the white connector so that the PINs are on the right side. Otherwise the board will not fit into the housing later. Shorten the axes to a length of 34mm + thickness of the instrument board, measured from the top of the board!



5. Print out the three housing parts and cut the threads into the plastic as marked in the pictures. Red = M3, green = M4, blue = M6x0.75.
I printed them out with PLA.





6. Cut two M4 threads in the speaker and fasten the speaker in the housing with 2 countersunk screws M4x8. Solder about 10cm long cables to connect the speaker beforehand. **The speaker is only required if the FreeVario is to output the vario sound. If you want to continue using the vario sound from OpenVario, you can omit the speaker.**
7. Crimp the connector to an approximately 5cm long, 3-pin cable and solder it to the toggle switch. Solder as space-saving as possible by soldering at an angle. Otherwise there will be a short circuit later between the solder joints and the contacts behind them on the PCB3. Make shrink wise the solder contacts!
The middle cable comes to the middle solder lug. Depending on how you solder the two outer cables, you will later have STF or Vario on top. If you solder the upper cable of the plug to the upper soldering tab of the toggle switch, and the lower cable of the plug to the lower soldering tab of the toggle switch, STF will be in the lower position of the toggle switch, and Vario in the upper. Automatic is in the middle.
8. Shorten the threads of the two M4 fastening screws to 3mm + instrument panel thickness. Work very precisely here, because if the screws are too long, press the display later and destroy it. It is best to screw the front panel into the cockpit on your own and check that the screws do not protrude into the area of the display.
9. Install the toggle switch and the display in the front panel.
10. Insert PCB3 in the middle part and screw tight with 2 screws M3x6. Tighten screws carefully, the threads are plastic!
11. Screw the front panel and middle section together using 4 countersunk screws M3x25. Connect the toggle switch beforehand and lead the FFC cable back through the slot. Tighten screws carefully, the threads are in plastic!
12. Now first test whether the two circuit boards can be easily pushed into the pot individually. Otherwise damage can occur later. If in doubt, rework the groove a little.

13. Carefully assemble PCB1 and PCB2, connect display, loudspeaker (do not interchange plus and minus) and connect PBC3. Close the clamping mechanism of the display cable very carefully with a small screwdriver or something similar. If you slip with your fingers or the wrong tool, it is easy for you to tear the ribbon cable.
14. The best thing to do now is to jump to the programming of the two ESP32 and then continue here.
15. Now push the housing pot carefully over the circuit boards. Make sure that the boards are in the rails and carefully guide the Western Digital socket through the rear wall.
16. Screw the housing parts together with 6 countersunk screws M3x6. Tighten screws carefully, the threads are in plastic!
17. Using the two fastening screws and the two banjo screws, install the Vario in the I-board, mount the knobs and connect the Vario. Tighten screws carefully, the threads are in plastic!
18. The connection cable has the same assignment on both sides, i.e. same color on the same PIN, like a normal LAN cable.

III. Programming the two ESP32

1. Put the Binaries folder e.g. to the desktop.
2. Open a terminal or the command prompt. There you can see if you can find the path to Binaries. For example, it is /Users/PC1/Desktop/Binaries/
3. In Arduino IDE click on Arduino -> settings.
4. Add the URL under "Additional Board Administrator URLs". If URLs have already been entered, add further URLs with commas and spaces.
https://dl.espressif.com/dl/package_esp32_index.json
5. Also click here under "Verbose output during" "Upload".
6. Click Tools -> Board -> Board Administrator and search for ESP32.
7. Select „ESP32 by Espressif Systems“ and install.
8. You may have to install the driver for the serial adapter of the ESP.
<https://www.silabs.com/products/development-tools/software/usb-to-uart-bridge-vcp-drivers>
9. Open and save a new sketch. Remember the name. To upload, set the following under Tools:

- Board: DOIT ESP32 DEVKIT V1
- Upload Speed: 115200
- Flash Frequency: 80MHz
- Core Debug Level: "none"
- Port: Check out which is added after connecting the ESP32 with the USB cable

10. Then upload the empty sketch. There is a very long command in white letters above the error message in the Arduino IDE, which is roughly as follows:

```
/Users/PC1/Documents/Arduino/hardware/espressif/esp32/tools/esptool/esptool --
chip esp32 --port /dev/cu.SLAB_USBtoUART --baud 115200 --before default_reset --
after hard_reset write_flash -z --flash_mode dio --flash_freq 80m --flash_size detect
0xe000
/Users/PC1/Documents/Arduino/hardware/espressif/esp32/tools/partitions/boot_ap
p0.bin 0x1000
/Users/PC1/Documents/Arduino/hardware/espressif/esp32/tools/sdk/bin/bootloader
_dio_80m.bin 0x10000
/var/folders/6t/qjgfw2413f7ddnjzk_08btwx0000gp/T/arduino_build_661147/sketch_
dec30d.ino.bin 0x8000
/var/folders/6t/qjgfw2413f7ddnjzk_08btwx0000gp/T/arduino_build_661147/sketch_
dec30d.ino.partitions.bin
```

11. Copy this command, you need it to load the file onto the ESP32.

12. The first part of the command shows you where Arduino IDE creates its working directory. Remember the place. In this example it would be:

```
/Users/PC1/Documents/Arduino
```

13. Change the command with your location where the Binaries folder is located. Also change the last two file names (see bold).

Display-ESP:

```
/Users/PC1/Documents/Arduino/hardware/espressif/esp32/tools/esptool/esptool --
chip esp32 --port /dev/cu.SLAB_USBtoUART --baud 115200 --before default_reset --
after hard_reset write_flash -z --flash_mode dio --flash_freq 80m --flash_size detect
0xe000 /Users/PC1/Desktop/Binaries/boot_app0.bin 0x1000
/Users/PC1/Desktop/Binaries/bootloader_dio_80m.bin 0x10000
/Users/PC1/Desktop/Binaries/FreeVarioGauge.ino.bin 0x8000
/Users/PC1/Desktop/Binaries/FreeVarioGauge.ino.partitions.bin
```

Sound-ESP:

```
/Users/PC1/Documents/Arduino/hardware/espressif/esp32/tools/esptool/esptool --
chip esp32 --port /dev/cu.SLAB_USBtoUART --baud 115200 --before default_reset --
after hard_reset write_flash -z --flash_mode dio --flash_freq 80m --flash_size detect
0xe000 /Users/PC1/Desktop/Binaries/boot_app0.bin 0x1000
/Users/PC1/Desktop/Binaries/bootloader_dio_80m.bin 0x10000
/Users/PC1/Desktop/Binaries/VarioSound.ino.bin 0x8000
/Users/PC1/Desktop/Binaries/VarioSound.ino.partitions.bin
```


14. Connect the ESP32 to the PC using the USB cable and open a terminal or the command prompt. Issue the **appropriate** command there.
15. After the upload is complete, the ESP32 restarts. The Sound-ESP32 is done. If the display is already connected, the display ESP32 ends with a black screen. Files still have to be uploaded to the memory of this ESP32.
16. Install ESP32 Sketch Data Upload. Download ESP32FS-1.0.zip from <https://github.com/me-no-dev/arduino-esp32fs-plugin/releases/>
17. On Mac, copy the extracted folder ESP32FS to /Programme/Arduino (Show package contents)/Contents/Java/tools.
18. Under Windows, copy the extracted folder ESP32FS to /Programs/Arduino/tools.
19. Unzip the data.zip file. Go to the working directory of Arduino IDE (e.g. /Users/PC1/Documents/Arduino) and there into the folder of the sketch you just created. Copy the extracted data folder here.
20. Restart the Arduino IDE and open your newly created sketch.
21. IMPORTANT!! Make sure the serial monitor is closed.
22. Click on "ESP32 Sketch Data Upload" under Tools.
23. After the upload is complete, the ESP32 restarts and, if the display is already connected, you can now see the display of the vario gauge.
24. Now go back to point 13 of the assembly part of the instructions.

IV. Install the new OV image including XCSOar with FreeVario driver

1. From the official Image 21033 of OpenVario, the FreeVario driver is integrated in the image. So you are no longer dependent on using images from FreeVario.de. If you have already installed an image higher the 21032, you can connect the FreeVario directly to your OpenVario without making any changes at the software.
2. Back up the .xcsoar folder from the old system
 - Boot OpenVario and go to the menu. Select "Exit to the shell" and confirm with Yes. Connect your USB stick to manage the OpenVario and a USB keyboard. Enter the following commands.
 - mkdir /tmp/USB
 - mount /dev/„USB-Stick“ /tmp/USB (/„USB-Stick“ usually is /dev/sda1)
 - cp -r .xcsoar /tmp/USB (takes a bit of time!)
 - cd /tmp/USB
 - mv .xcsoar xcsoar

- `rm -r openvario/upload/xcsoar`
 - `mv xcsoar openvario/upload/`
3. Save the value for calibrating the voltage display (if you have calibrated it at all, skip step otherwise):
 - Boot OpenVario and go to the menu. Select "Exit to the shell" and confirm with Yes. Connect a USB keyboard and enter the following commands.
 - `nano /opt/conf/sensord.conf`
 - write down the value for the "voltage_config" variable. For me it was „voltage_config 1592.4 4.54545“.
 - 1592.4 is the scaling factor, 4.54545 is the offset. The formula to convert the value of the AD converter into the voltage value is:
 - $U = (\text{value AD converter} / \text{scaling factor}) + \text{offset}$
 4. Save the WiFi settings:
 - Copy the folder `/var/lib/connman` to the USB stick, which is already mounted.
 - `cp -r /var/lib/connman /tmp/USB`
 5. Install the new image:

Variant 1: Use a new SD card (secure method)

- Use a Linux PC to write the new image to another SD card. So you can be sure that on the old map there is still a working system in case something goes wrong.
- unzip the image first:
- `gunzip "Path_to_Image"`
- e.g. `.: gunzip /home/USER/Schreibtisch/OpenVario-linux-openvario-image-testing-glibc-ipk-20149-openvario-7-PQ070.rootfs.img.gz`
- `dd if="Path_to_image" of=/dev/„new_SD card“`
- z.B.: `dd if=OpenVario_new.img of=/dev/sda`

Variant 2: Overwrite old SD card (insecure method)

- In the main directory of the USB stick "openvario" you put the recovery file "ov-recovery.itb", which you can download on the FTP server (<ftp://ftp.openvario.org/recovery>).
 - IMPORTANT!! If you do not want to perform a recovery, the file "ov-recovery.itb" must be renamed, e.g. in "ov-recovery.xxx".
 - Copie the image to be installed as a .gz file to the USB stick in the images subfolder
 - Insert the USB stick into the OpenVario and boot.
 - The recovery menu is shown in red. Remember that all files in OpenVario will be deleted when you restore!
 - Select "Write image to SD Card" and then "Update complete SD Card".
6. Insert the new SD card into the OpenVario and start. Then go back to the OpenVario menu.
 - Click "Copy file to and from OpenVario" -> "Upload files from USB to XCSoar". This will restore all of your settings. Wait until "done !!" is shown.
 - Then set the desired orientation of the display under "Update, Settings, ..." -> "System Settings" with "Set rotation of the display".

- If necessary, select "Calibrate Touch" under "Update, Settings,...".
 - Select "Calibrate Sensors" under "Update, Settings,...".
 - Finally, set the language under "Update, Settings, ..." -> "System Settings" -> "Set language used for XCSoar".
 - Back to the main menu with ESC and select "Restart" and confirm with Yes.
7. Restore the voltage display calibration:
 - nano /opt/conf/sensord.conf
 - „voltage_config“ reset to the noted values
 8. Restore backup of old WiFi settings:
 - Copy the connman folder saved on the USB stick back into the /var/lib directory
 - mkdir /tmp/USB
 - mount /dev/„USB-Stick“ /tmp/USB (/„USB-Stick“ usually is /dev/sda1)
 - cp -r /tmp/USB/connman /var/lib
 9. Set up WiFi again if there is no backup of the old settings:
 - Boot OpenVario and go to the menu. Select "Exit to the shell" and confirm with Yes. Connect a USB keyboard and enter the following commands.
 - connmanctl
 - enable wifi
 - scan wifi
 - services
 - agent on
 - connect wifi_...
 - Enter password

V. Install XCSoar incl. FreeVario driver without reinstalling the OV image

1. If you don't want to reinstall the complete image of OV, but only want to replace the version of XCSoar, you can do that as described below. Your settings in XCSoar remain completely intact. I would always create a backup file of the SD card beforehand. Something always can go wrong!
2. Copy the new version of the installation file from XCSoar to a USB stick, select "Exit to the shell" in the OpenVario menu. Find the path of the USB stick with fdisk -l (e.g. /dev/sda1).
3. mkdir /tmp/USB
4. mount /dev/sda1 /tmp/USB
5. cd /tmp/USB
6. opkg remove xcsoar

7. `opkg install xcsoar*.ipk`
8. Set the language in the OpenVario menu again and reboot.

VI. Switch off the vario sound from OpenVario

1. **Skip this section completely if you want to continue using the vario sound from OpenVario. If you wanted the FreeVario to make the sound, you have to work through this section.**
2. Choose "Exit to the shell" from the OpenVario menu and enter the command `"systemctl disable varied"` to switch off the vario sound from OpenVario.
3. Reboot OpenVario.
4. Changes the port of NMEA port A from 4352 to 4353.
5. If vario sound can still be heard in XCSoar, it will be generated by XCSoar.
6. At System -> Display -> Audio Vario set Audio Vario to Off. Confirm with Close.

VII. Settings for a doubleseater

1. To connect the front and rear OpenVario to each other, you have to use a crossed cable. That means you have to swap PINs 5 and 6 for RX and TX on one connector.
2. The front device is set to the RJ45 socket to be used, e.g. `ttyS3`, NMEA output is set as driver, the baud rate e.g. to 38400 (it must be the same in front and in the back!)
3. The rear device is also set to the RJ45 socket to be used, e.g. `ttyS3`, OpenVario is set as the driver, and the baud rate must be set in the same way as the front device.

VIII. Blocking the standard profile for club use

1. Go to the console in the main menu of the OpenVario, in which you select "Exit to Shell".
2. Go to the directory in which the profiles are saved with `"cd .xcsoar"`.
3. By default, the profile is called `openvario.prf`. I renamed it to `clubprofile.prf` (`mv openvario.prf clubprofile.prf`)

4. Lock the profile with the following command:
`chattr +i clubprofile.prf`
5. Unlock the profile with the following command:
`chattr -i clubprofile.prf`

IX. Settings in XCSoar

1. Click Config. -> Devices, select a free device from A, B, C or D and select Edit.
2. Select the port, where the electrical vario is connected with (e.g. ttyS1).
3. Baud rate is 115200, Driver is FreeVario, confirm with OK and Close.

X. Installation of the new OpenVario menu from Kedder

1. The OpenVario must be connected to the Internet and a keyboard must be connected.
2. Start OpenVario and go to the OV menu. Select "Exit to the shell" and confirm with Yes.
3. Enter the following commands there:
 - `echo src/gz kedder_core http://openvario.lebedev.lt/opkg/armv7vet2hf-neon/ >> /etc/opkg/customfeeds.conf`
 - `echo src/gz kedder_all http://openvario.lebedev.lt/opkg/all/ >> /etc/opkg/customfeeds.conf`
 - `opkg update`
 - `opkg install openvario-shell openvario-shell-autostart --force-removal-of-dependent-packages`
4. Use ESC to return to the main menu and select "Restart" and confirm with Yes. The new menu is now used.

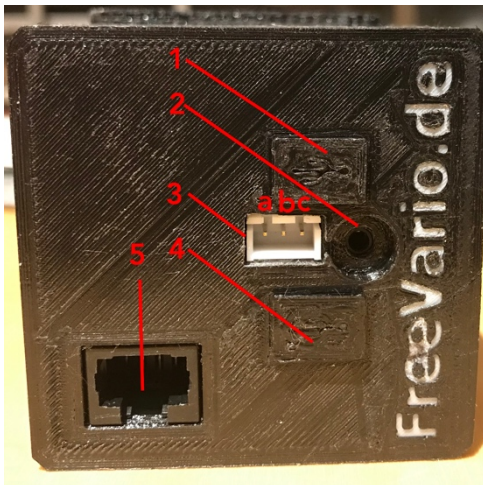
XI. Operating the FreeVario

1. Using the toggle switch, the Vario is switched to SpeedToFly (STF) or Vario mode (Vario). Automatic mode is active in the middle position. Depending on the position of the slide switch in the device on the upper board, XCSoar or an externally attached switch in automatic mode determines whether Vario or STF should be active. The external switch can, for example, be connected to the flaps, so that the Vario and STF are automatically switched depending on the flap position. If the vario is to be set to STF, this switch should be closed. Alternatively, a toggle switch on the stick could be used if the toggle switch should not be used in the FreeVario. In that case it is best not to install the toggle switch in the FreeVario.
2. If STF mode is active, the digits on the colored arc multiplied by 10 indicate the difference between true airspeed and speed to fly.

e.g. : in STF mode the colored bar is at +3. The true airspeed is 30km/h higher than speed to fly.

3. With the rotary encoder above, the McCready value is set in normal mode and sent to XCSoar.
4. If the push button of the rotary encoder is pressed for more than 0.5s, the menu is activated and the line in which the height is displayed turns red. The line with the speed display or with the McCready value can be selected by turning the encoder. The selected menu item is activated by briefly pressing the push button. In the high menu you can now choose between altitude above sea level (MSL) and altitude above ground (AGL), in the speed menu you can choose between ground speed (GS) and true air speed (TAS). Another short press on the push button selects the current setting and the desired values are shown in the display.
5. A special feature is the lower display for the McCready. Here you can choose between QNH, Bug and Mute by turning the menu. A short press on the push button activates the desired option and turning the encoder sets the value and sends it to XCSoar. Another short press on the push button closes the menu item and the McCready value is shown in the display again.
6. If the menu is not used for at least 10s, the menu is automatically exited and the setting selected at this point is adopted.
7. The 2.5mm jack socket on the back is used to connect an external speaker to get a better sound. If the external speaker is connected, the internal one is automatically deactivated.
8. If the PIN "a" of the three-pole plug is connected to the PTT switch, the Variosound is automatically muted when you are talking. **If the radio and the FreeVario are connected to different batteries, the negative pole of both batteries must be connected!** If the radio is switched off to save electricity, it is the same for the FreeVario as pressing the PTT switch. So that the FreeVario continues to output the vario tone, there is the Mute option in the bottom menu item. It can be set to ON or OFF. If you switch it OFF, the function is deactivated. It is automatically reactivated when the FreeVario is restarted.

XII. Installation



1. Micro-USB port for updating the soundboard
2. 2.5mm jack socket for external speaker
3. Plug for speed-to-fly switch/flap switch and PTT switch
 - a. PTT
 - b. STF switch
 - c. STF switch
4. Micro-USB connection for updating the display board
5. IGC plug for OpenVario

1. Slide the two hollow screws over the axis of the encoder or potentiometer and screw them to the FreeVario
2. It is essential to shorten (3mm + instrument panel thickness) the two M4 screws before assembly and check for correct length, otherwise the display will be destroyed!
3. Fasten the FreeVario with the M4 screws
4. Tighten the two rotary knobs. Make sure that the encoder button has enough space to the rear for the push button to work
5. Attach the cover caps to the rotary knobs
6. Connect FreeVario to OpenVario with an IGC-compliant cable
7. If necessary, connect the flap switch (closed, if the vario is to be set to STF) and PTT button to the three-pin plug

XIII. Disclaimer

The vario gauge is not EASA or FAA certified. Note that this is exactly the same for all the fancy commercial electronic varios and flight computers you are probably used to.

If you would like to know, if you are allowed to use it legally at your glider, ask this question to your airworthiness inspector. Can you legally install any other big brand (as well, non certified) vario gauges? If yes, you should also be able to legally install this vario gauge. If you are under EASA rules see CS-STAN, standard change CS-SC402a.

This instrument is a craft project and not an aviation-approved instrument. I explicitly point out that the use is made under exclusion of any warranty at your own risk!