MRF

Multi-format, LiDAR-powered, lens-coupled
Medium Format Rangefinder.

hello@identidem.design

Even though I loved every moment of this design, build, and putting everything together, this was a lot of work.
Buy me a beer if you want to say thank you.

Introduction

After releasing the LRF45, I was chatting to other makers about alternative position sensors. To make a very long story short, I decided I want to try and make a camera that uses LiDAR just like the large format camera, but I also wanted to be able to use multiple lenses on it. To do this, I needed to be able to electronically couple to the original rangefinder mechanism of a lens system. The obvious choice was the Mamiya Universal Press system. And I found two potential linear position sensors that would, in theory, be able to measure the position of the lens. The first iteration of the camera was based on a chopped-up version of Velvia's Open 6x12 shrunk down to shoot 6x7. That version worked well, but was awkward to use as the film is top-loaded, so you always had wires that dangled between the body and the top plate when you were changing film, and wires don't like to be flexed too much or too often.

Then I was made aware that Panomicron had [published the files for the Thulium 6x9]() - and this turned out to be the perfect foundation to build my camera on:

- I changed it from 6x9 to 6x7 to make room for a channel for the wires for the electronics and added a holder for the position sensor that couples to the lens
- Created a custom Mamiya Universal Press lens mount
- Removed the frame counting mechanism and added more teeth and tighter tolerances to the ratchet mechanism, replacing the wind-on lever with a knob, and coupling the whole thing to a rotary encoder to count frames electronically
- Made a custom top plate to house the viewfinder, optics and electronics
- Added a magnetic frame masking system to enable you to shoot multiple formats with the same camera
- Designed a custom bottom plate to house the electronics and battery
- Many other small tweaks to allow for the complexity of this camera to be realised

The end goal here was to create my ideal large format rangefinder. There was no attempt to keep things cheap, easy to source, or easy to build - so keep this in mind going in.

Some of the highlights of the final design:

- Use any of the Mamiya Universal Press lenses and calibrate them in-camera
- Shoot 35mm Panoramas, 6x4.5, 6x6 and 6x7 all in the same camera by simply selecting the relevant format from the in-camera configuration menu and installing the relevant mask
- Accurate frame counting for each format
- Upgraded "LiDAR" with higher accuracy and distance up to 12m
- In-viewfinder display with
    - Light-meter with aperture range set by selected lens
    - Lens focus distance display, and LiDAR rangefinder distance display
    - Focus accuracy indicator
    - Dynamic frame lines with size determined by lens selection, and masking determined by select format
    - Horizon level indicator
- External display with frame count, battery life, selected format, and selected lens

Bill of Materials

You will need all of the following to build your own MRF.

3D-printed parts

Main parts

- Mamiya Press Lens Cone
- Main Body
- Body door
- Top plate
- Bottom plate
- Grip (optional)
- Viewfinder
- Viewfinder cover
- Advance knob

Fine parts

- Right spool pin
- Left spool pin
- Advance post
- Advance ratchet
- Advance plate
- Pressure plate
- Power button plate
- Sensor nubbin
- Spool key (optional)

Film masks (print at least the 6x7 mask)

- 6x7
- 6x6
- 6x6 Circle
- 6x4.5
- 35mm Panoramic (use 35mm to 120 film spool adapters with this mask)

If you're printing these yourself I'd recommend printing with PETG or ASA - at least 18% Gyroid infill and 4 walls. For the fine parts use at least 0.12 layer height.

Ideally you'd print all parts except the film spool pins, advance post, advance ratchet, and sensor nubbin with MFJ Nylon 12, dyed black. What's left should ideally be printed with SLS Nylon 12.

You can download the files from Printables or Github. If you're using OrcaSlicer - you can find a file there that has recommended slicer settings, orientation, supports, etc. I've also included STEP files, so you can remix the design for use with other lenses or formats.

Electronics, optics & hardware

Optics

- 20mm Dia. x 70mm FL Plano-Convex Lens
- 25mm Dia. x -25 FL Plano-Concave Lens
- 30 x 30 x 1.2mm plate beam splitter (70R/30T is ideal, but in a pinch 50R/50T will do - message Bohr Optics directly if that link is dead)
- At least one Mamiya Press Lens - I'd recommend starting with the 65mm/f6.3 or 100mm/f3.5

Electronics

- 1 x Adafruit ESP32-S3 Feather (any variant will do)
- 1 x TFMini Plus "LiDAR" sensor
- 1 x Adafruit Monochrome 1.12" 128x128 OLED - STEMMA QT I2C at 0x3D (Product ID: 5297)
- 1 x Generic 124x32 OLED I2C display at 0x3C
- 1 x Adafruit BH1750 Light Sensor (Product ID: 4681)
- 1 x Sakae / Caldaro S8FLP-10A-10K linear position sensor
- 1 x Adafruit ADS1115 16-Bit ADC - STEMMA QT I2C (Product ID: 1085)
- 1 x Adafruit MPU-6050 6-DoF Accel and Gyro Sensor - STEMMA QT I2C (Product ID: 3886)
- 1 x Adafruit Seesaw Rotary Encoder breakout - STEMMA QT I2C (Product ID: 4991)
- 1 x PEC11-4215F-S24 Rotary Encoder (6mm D-shaft)
- 2 x Push buttons
- 1 x Power button
- 1 x 3.7v 820mAh LiPo battery - 30.5 x 44 x 6.8mm (CHECK THE POLARITY OF THE CABLE BEFORE CONNECTING TO THE FEATHER)
- 1 x Adafruit MiniBoost 5V @ 1A - TPS61023 (Product ID: 4654)
- 1 x MRF Daughterboard → **see PCB/KiCAD folder**, you'll need to order this from PCBWay, JLCPCB or another PCB manufacturer
- 1 x set of male and female JST-XH 6-pin connectors
- 1 x set of male and female JST-XH 4-pin connectors
- 1 x female JST-XH 4 pin connector
- 1 x 30cm STEMMA QT cable and 5 x 10cm STEMMA QT cables

For the JST connectors you'll probably need a crimping kit if you don't have one, or you can try to find pre-crimped connectors. You'll also need various lengths of wires if you'll be crimping your own.

Hardware

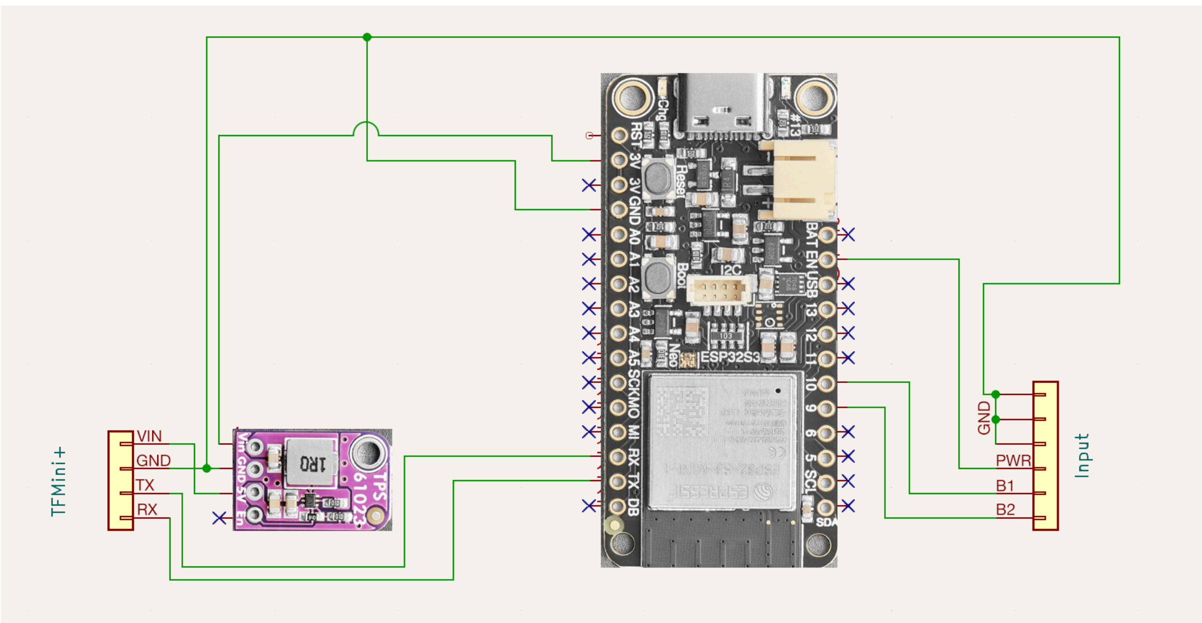
- 13 x M3x4 heat-set inserts
- 7 x M3x4 screws
- 2 x M3x6 screws
- 2 x M3x4 thumb-screw
- 15 x M2x4 heat-set inserts
- 13 x M2x6 screws
- 19 x M2x4 screws
- 2 x 20x5x2mm magnets for the body (and 2 for each film mask you print)
- 1 x 1.5mm stainless steel or brass rod, cut to ~82mm (for the film door)
- [1/4" Female to 3/8" Male Screw Adapter]
- [Cold-shoe kit]

Wiring diagram

Feather to main components

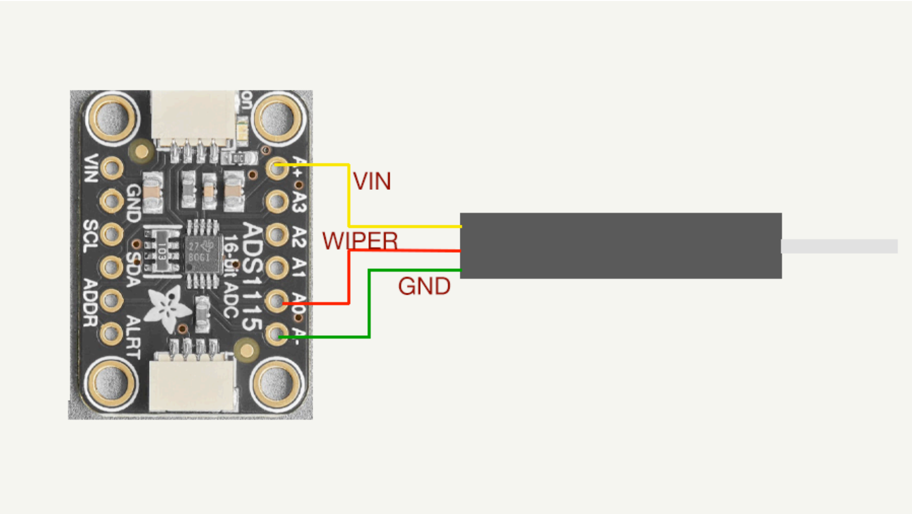
Solder the header pins to the MRF daughter-board, and then solder the Feather to those in turn. Next, solder a 4-pin header to the spot for the Miniboost, and solder the Miniboost to that in turn. Last, you'll need one 4-pin connector and one 6-pin JST-XH male connector, and solder them to the spots on the daughterboard.

If you really don't want to go to the bother of having the PCB manufactured, you can see below that it's all quite simple, and you could solder it all together without the daughterboard, but you'll need to modify the bottom plate to mount the Feather on its own, using the provided STEP files.



Position sensor to ADS1115 ADC

Solder the sensor to the ADC board **after inserting the sensor into the body** and threading the three wires out the relevant hole (see *Position Sensor* in the *Put it all together* section).



STEMMA QT Components to Feather ESP32-S3

You can chain the components in any order, but this is the one that works best for the design:

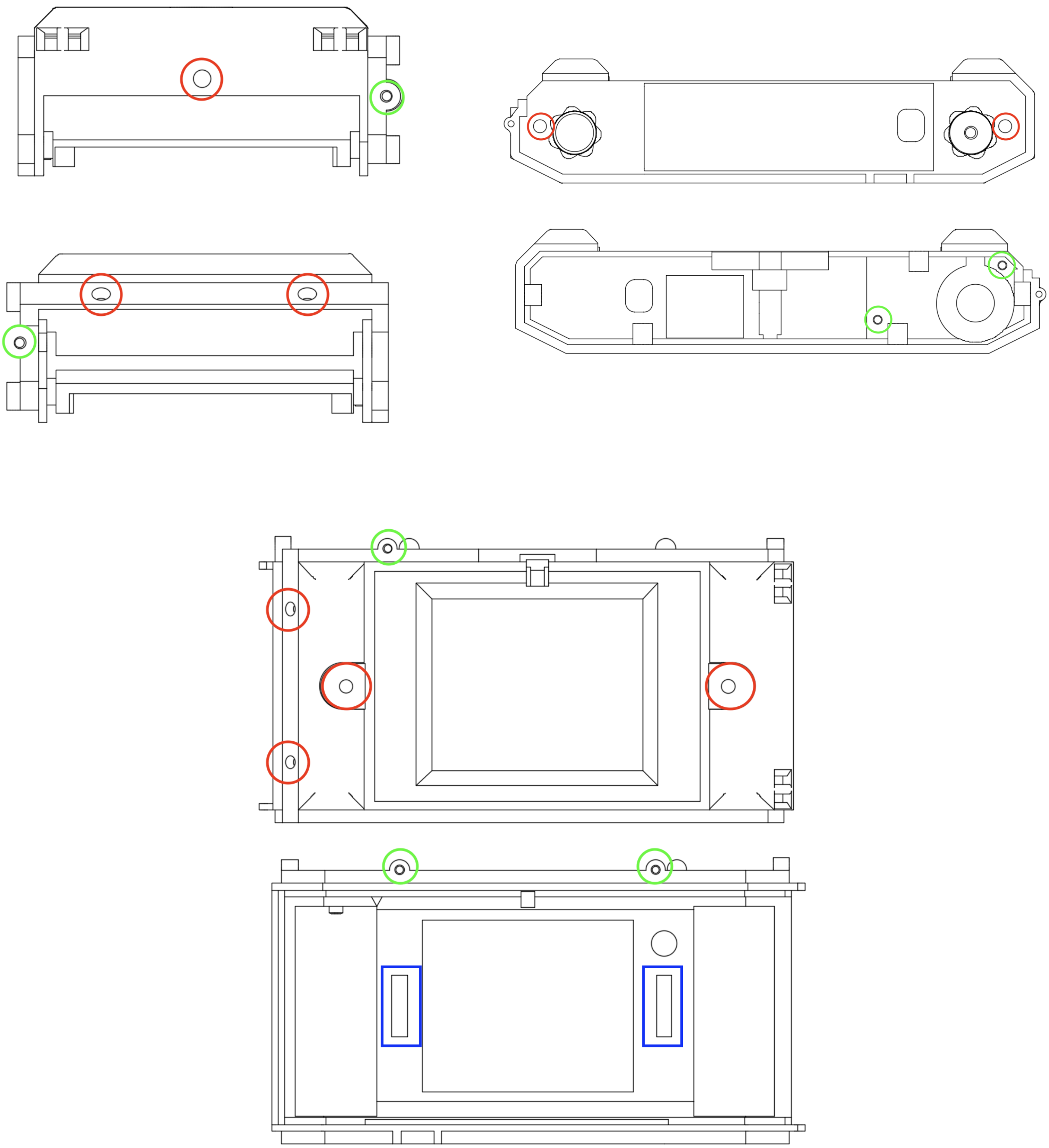
- Feather →
- BH1750 Lux Sensor →
- 128x128 OLED display →
- MPU-6050 →
- ADS1115 →
- Rotary Encoder Breakout →
- 128x32 OLED display

See the *Put it all together* section before you do this as you need to be sure that all the wires are routed correctly.

Put it all together

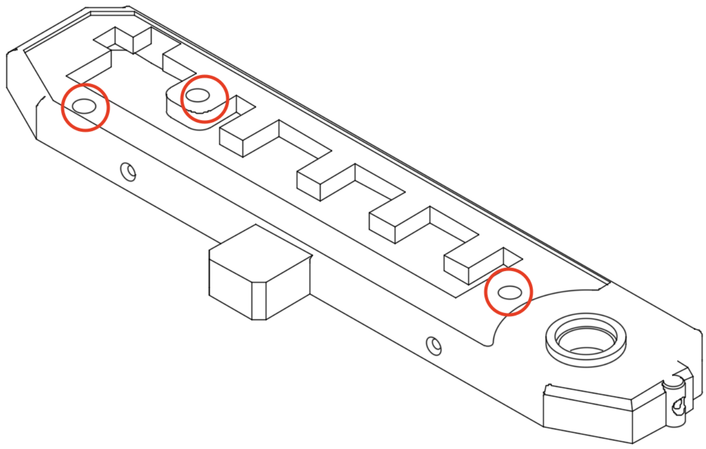
Main body heat-set inserts

The main body requires seven M3x4 and seven M2x4 heat-set inserts. This is also a good time to superglue two 20x5x2mm magnets into the recesses in the film gate, for the format masks. Make sure their polarity faces the same way.

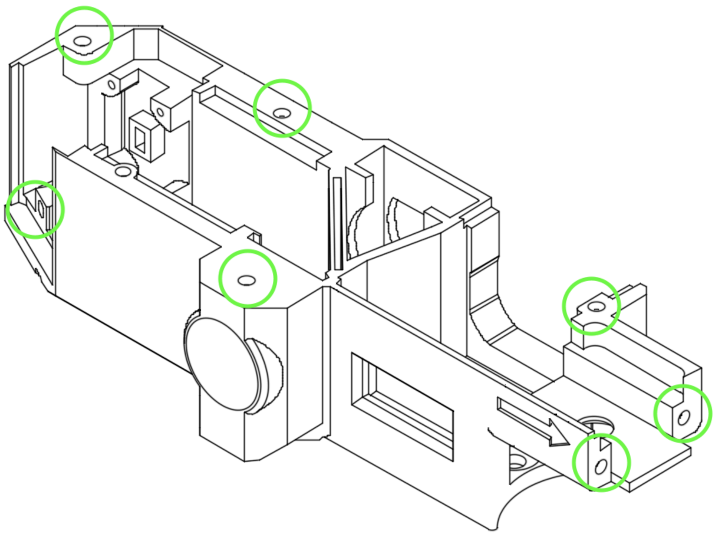


The rest of the heat-set inserts

Seat three M3x4 heat-set inserts into the **top plate**.

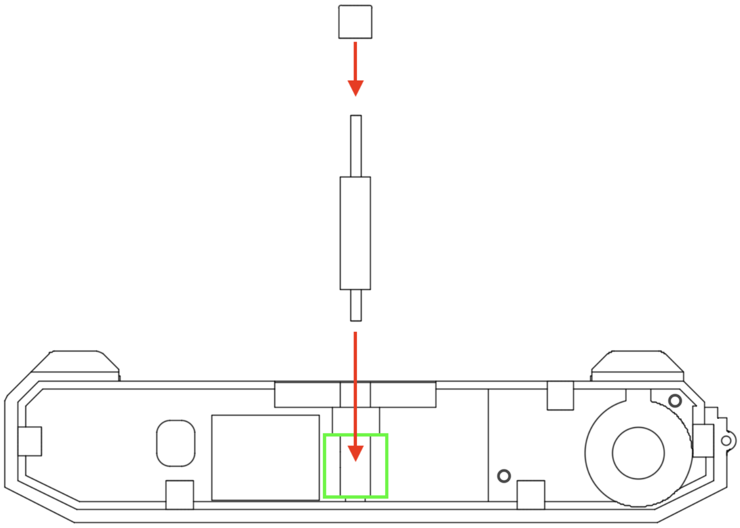


Lastly, seat seven M2x4 heat-set inserts in the viewfinder body.



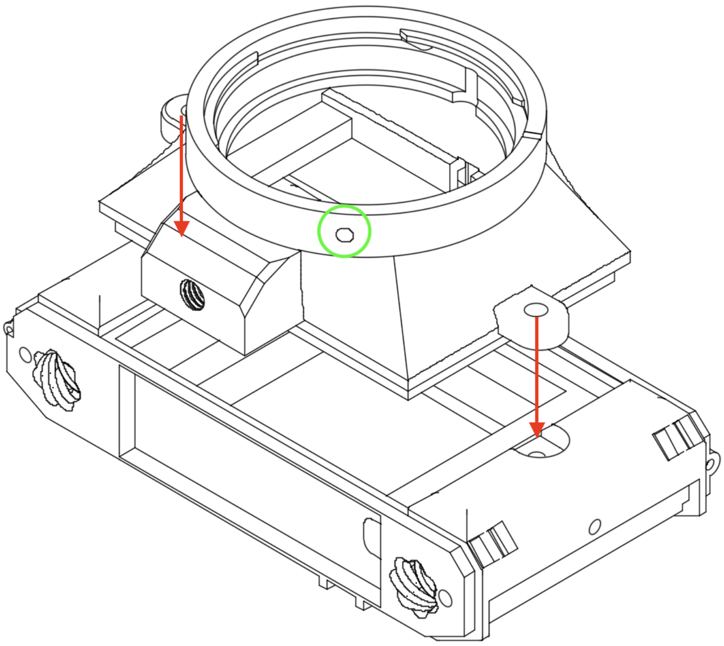
Position sensor

First, attach the **sensor nubbin** to the long end of the sensor rod. Superglue it into place if you don't have a snug fit. Then, thread all three wires of the sensor through the square sensor hole on the **front of the body**, and out through the hole in the top as you slide the sensor into place.

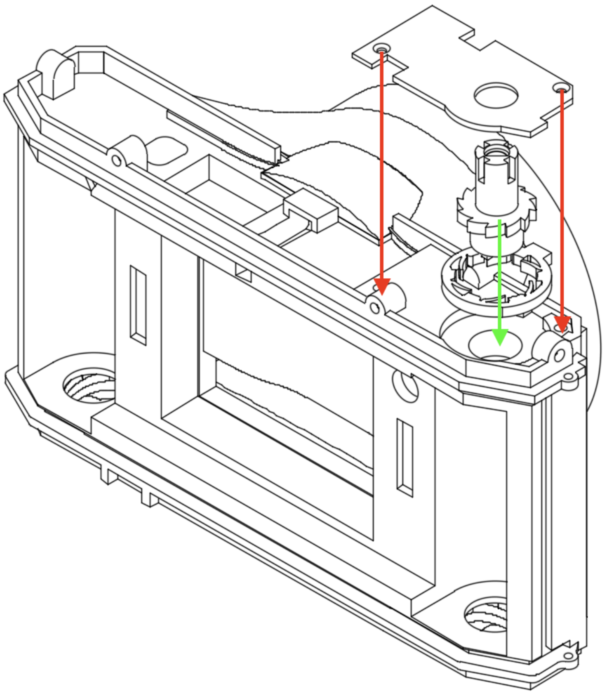


Lens cone

First place an M3x4 heat-set insert into the **lens cone**. Screw one of the M3x4 thumb screws into the heat-set insert (this will lock your lens in place). Then, place the **lens cone** on the **body** so that it sits tight, holding the position sensor in place. Fasten with two M3x4 screws.



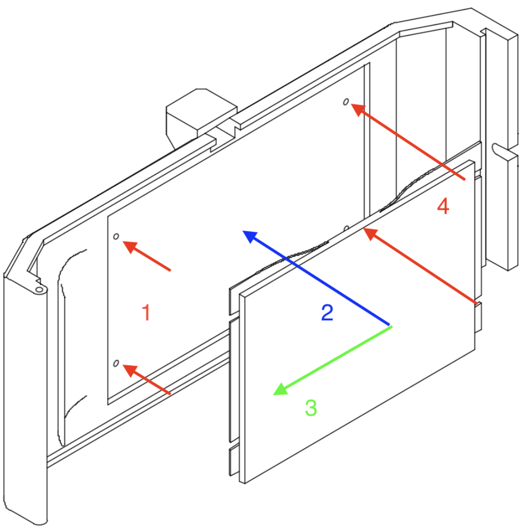
Film Advance Mechanism

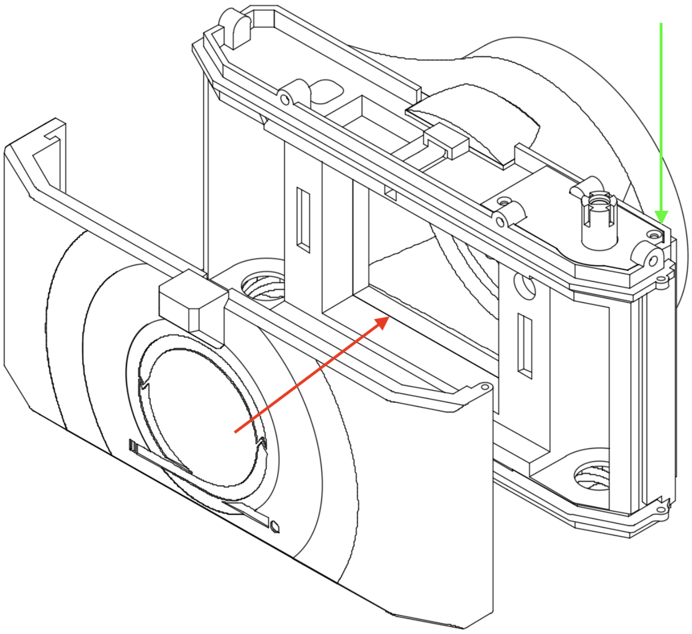


First place the **ratchet** into the **body,** paying attention to the direction. The teeth should be pointing left when viewing the camera from the back. Then insert the **advance post** / spool into the **ratchet**. Place the **plate** over both, fastening it into place with 2 x M2x4 screws.

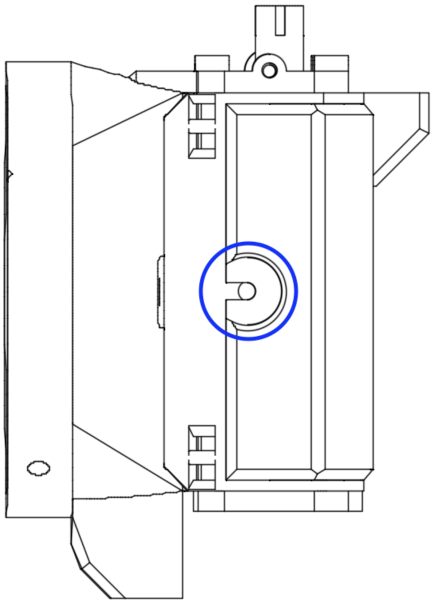
Body door

First screw two M2x4 screws right into the two little holes in the plastic until their bottoms are level with the back of the **door**. Then, place the **pressure plate** flat against the indent in the **door,** and slide it so that the two screws hold in in place. Finally, fasten the other side with two more Mx4 screws.





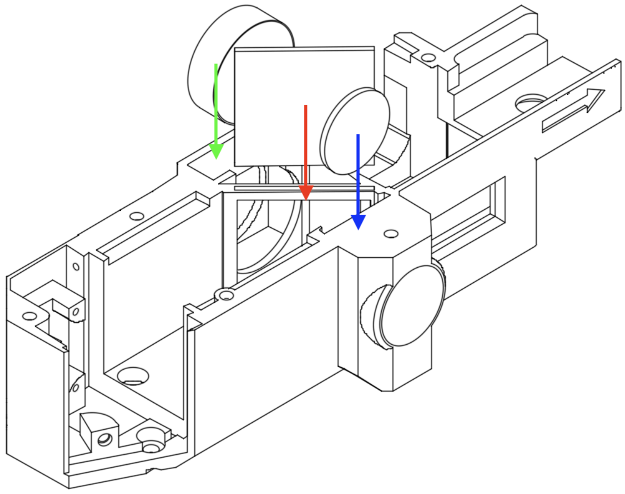
Align the door with the body and seat it in the light traps, lining up the hinge. Then cut a piece of the 1.5mm rod to length and insert it in the hinge to hold the door to the body.



Close the door and use one of the M3x4 thumb screws to hold it closed.

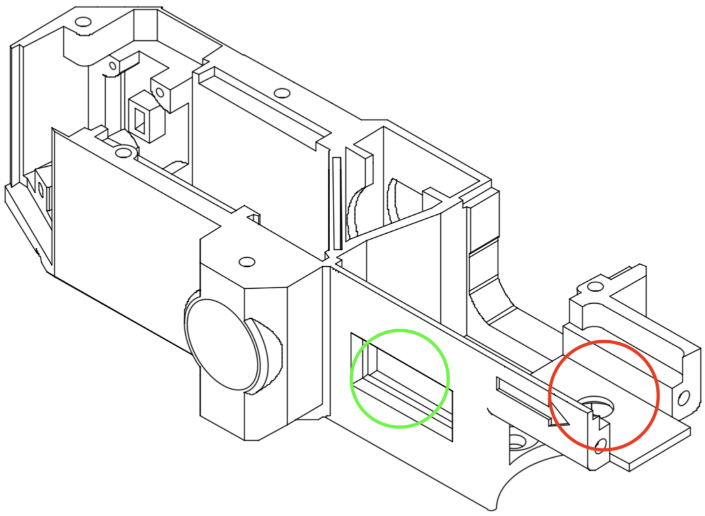
Viewfinder optics

Insert the 25mm PCV (concave surface inward), 20mm PCX (convex surface inward), and 30x30mm beam-splitter into the viewfinder body as shown.

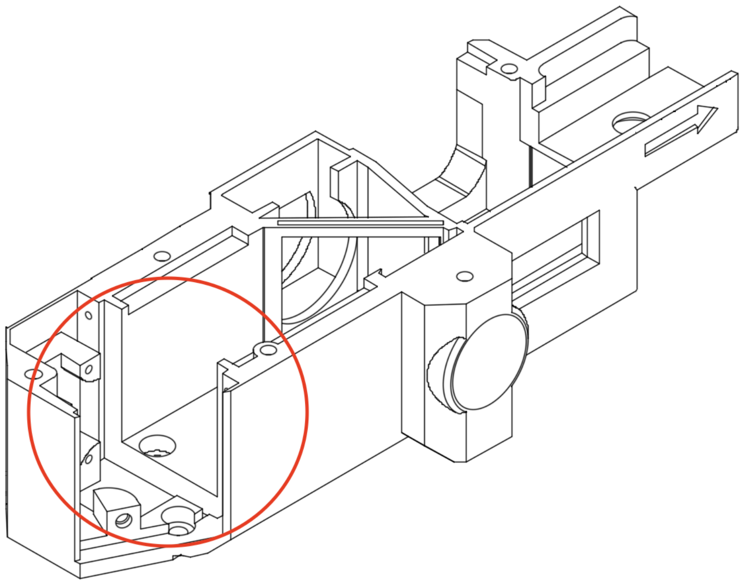


Viewfinder & top plate electronics

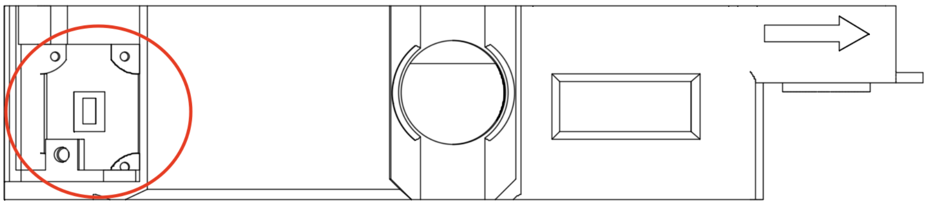
Drop the **Rotary Encoder Breakout Board** into the recess on the right (with the rotary encoder soldered in place), and secure it from the bottom with a washer and nut. Then drop the **128x32 OLED Display** into its recess.

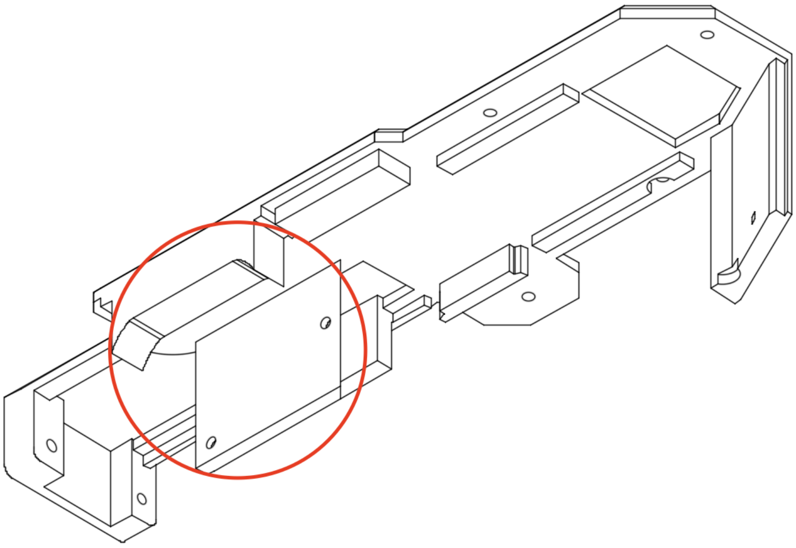


Next, seat the **128x128 OLED display** with the ribbon facing to the left and the display facing towards the optics, and screw it into place with three M2x4 screws.



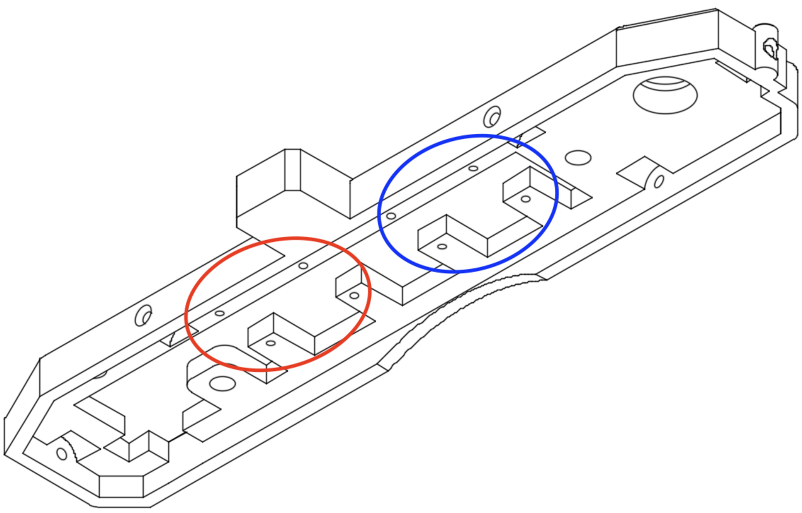
Then comes the **BH1750 Lux sensor**. Align the sensor to the holes, and screw into place with four M2x4 screws (to be honest I only use two in the most accessible holes).





Seat the **TFMini Plus LiDAR sensor** with the cable facing downwards, in the viewfinder cover and secure with two M2x4 screws.

The **ADC breakout board**, and **MPU board** are both screwed into the base of the **top plate**.

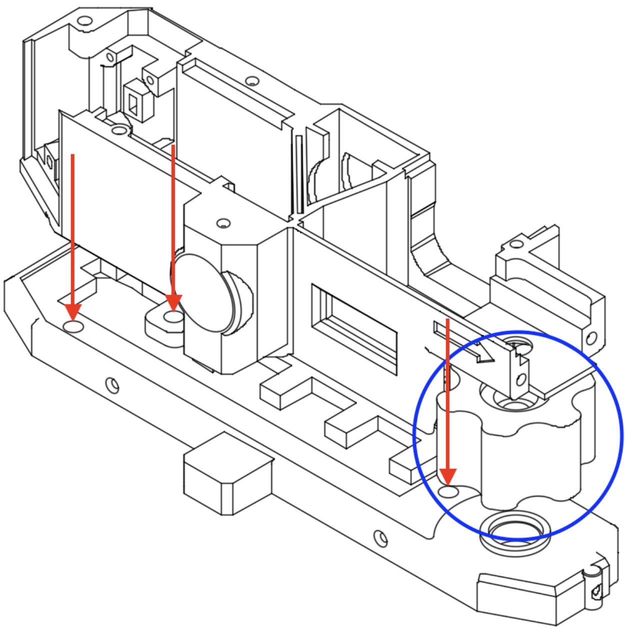


STEMMA QT cables

Connect up all the STEMMA QT cables, starting from the 128x32 OLED display (note that you will need to make a *4-pin female JST-XH to STEMMA QT cable* for this display), connecting that to the rotary encoder board. Then, the rotary encoder board connects to the MPU board, which in turn connects to the ADC breakout board. That connects to the 128x128 OLED display, which connects to the BH1750 Lux sensor. That then leads down the body as you'll see in the next section, and connects to the ESP32-S3 Feather.

Attach Top Plate to Viewfinder

Push the **advance knob** on to the rotary encoder shaft. Taking care not to pinch any of the wires, place the **viewfinder** on the **top plate** and screw into place with three M3x4 screws.

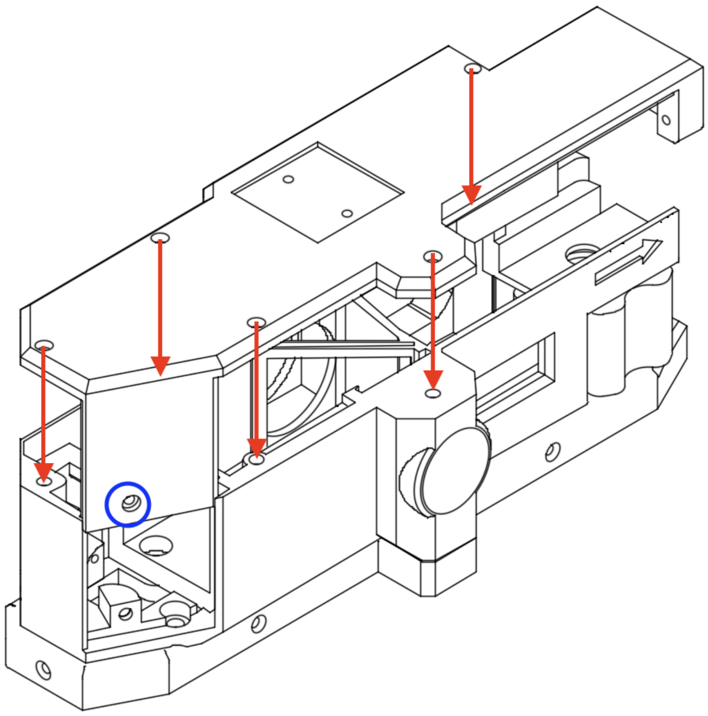


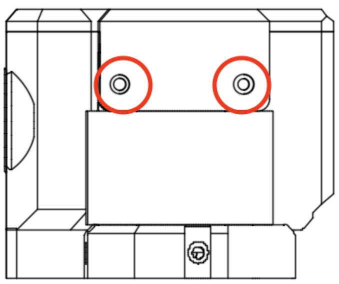
Assemble & attach viewfinder assembly to body

Position the **viewfinder cover** as shown, and slide it down into place, taking care not to pinch any of the wires.

Make sure the LiDAR sensor cable is threaded down through the hole in the base of the assembly.

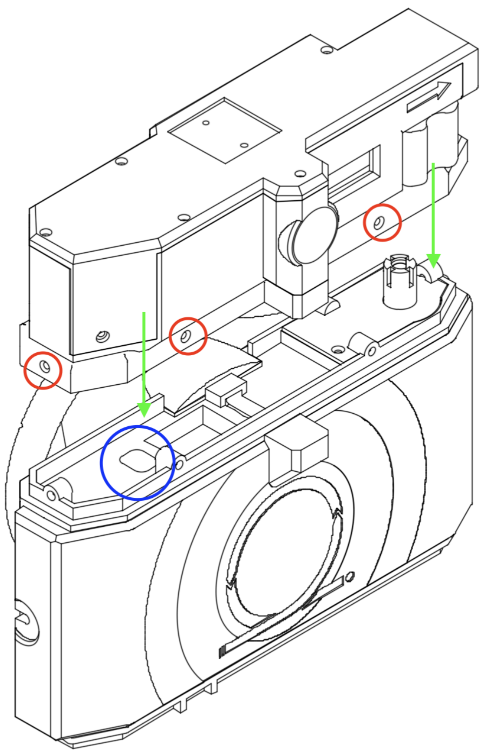
Secure with five M2x6 screws on the top and another M2x6 screw on the side.

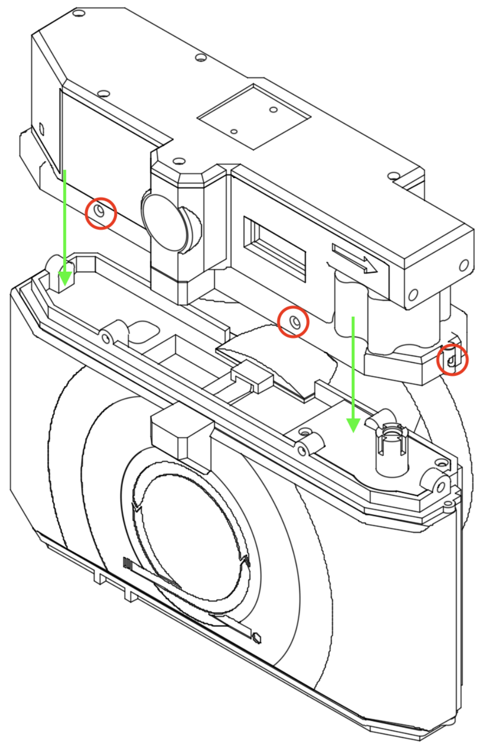


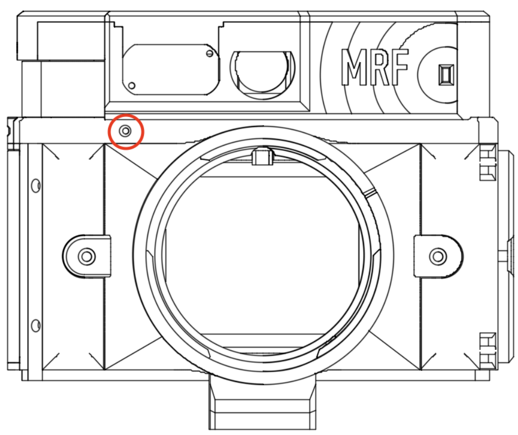


Complete the **viewfinder assembly** by screwing in two more M2x6 screws on the side.

Before placing the **viewfinder & top plate assembly** on the body, thread the STEMMA QT and LiDAR sensor cables through the body. Make sure the advance knob is oriented correctly to match the **take-up spool post**. Taking care not to pinch any wires, place the viewfinder assembly on the camera body, make sure the **advance knob** rotates to the right without issue, and then fasten with five M2x6 screws.



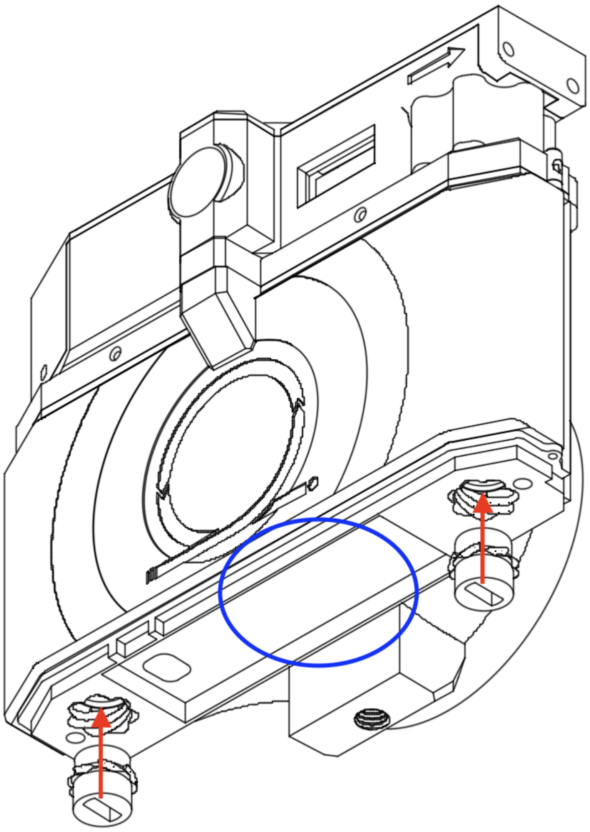




Position and insert spool pins

Position the **two spool pins** to their holes in the base of the **camera body**, and then rotate them into place using either the optional printed spool pin key, or a flat point screwdriver.

Note that there is a recess in the base of the body. This is where you'll attach the LiPO battery with double-sided tape right before you attach the bottom plate.



Bottom plate electronics

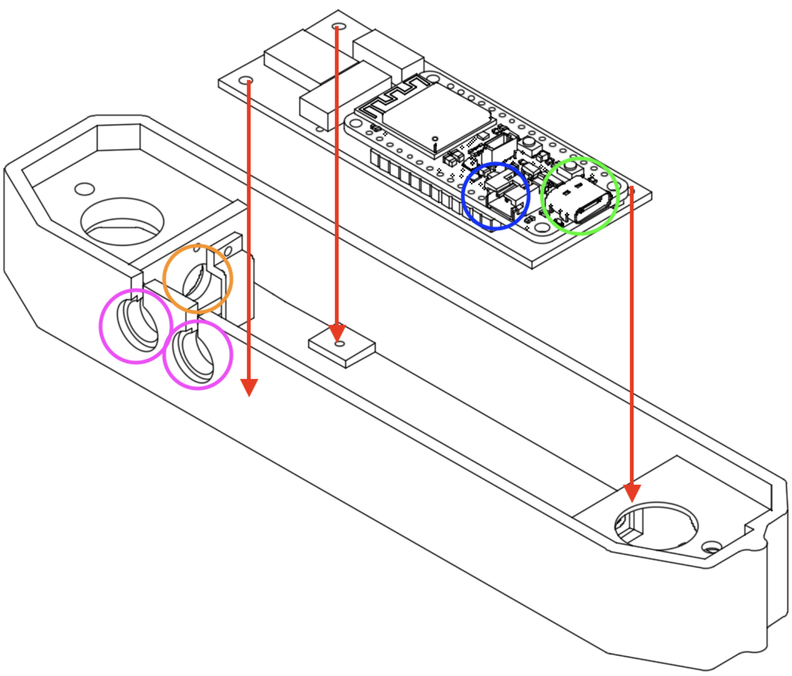
You will need to solder wires to the power button and push buttons, and then connect those to a 6-pin JST male plug as shown in the schematics, with pins:

- 1 → Button one
- 2 → Button two
- 3 → Power button
- 4 to 6 → Ground

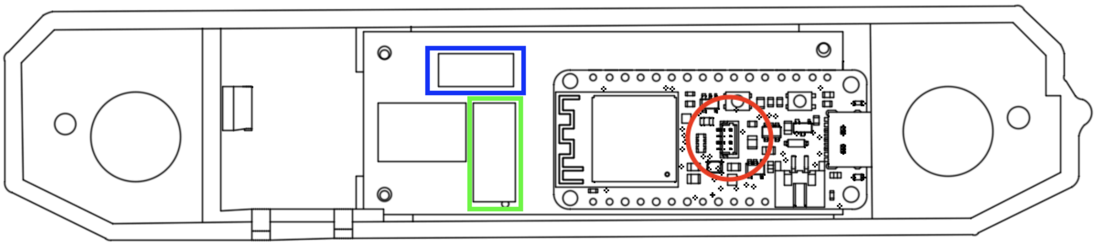
You will also need to fashion a LiDAR plug to JST plug extension with the little cable that came with the LiDAR sensor.

Place the latching push-button switch into the bottom plate and fasten into place with the button plate and one M2x4 screw. Next, insert the two 8mm push-buttons into the bottom plate and fasten in place with their nuts. Plug the LiPO battery into the Feather board.

Then, align the MRF daughter board's mounting holes to the ones in the bottom plate, and place it into the bottom plate at a slight tilt, with the USB port slightly higher than the back of the board. Once in place, take care to align the USB port with the hole in the bottom plate, and then fasten the board into place with three M2x4 screws.



Now connect the STEMMA QT cable, LiDAR sensor cable, and input cables to the JST sockets on the relevant boards.

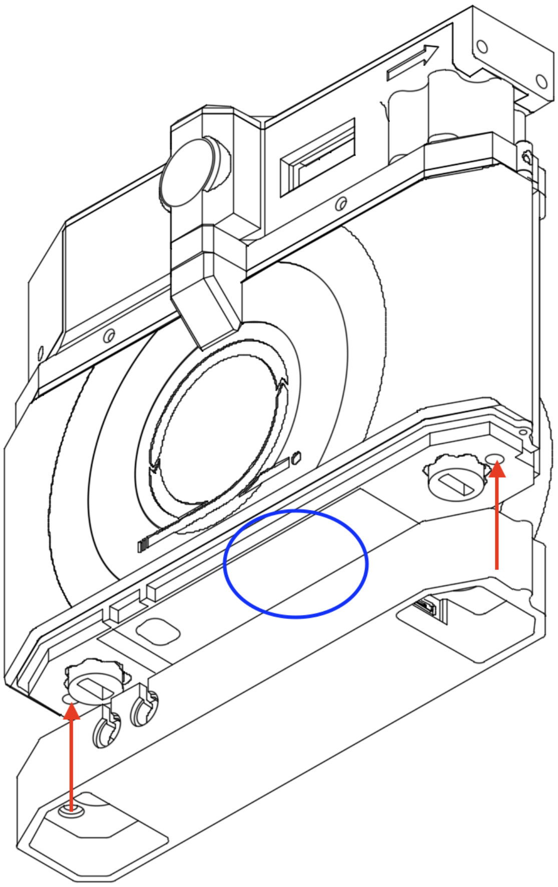


Attach bottom plate to body

As previously mentioned, affix the battery into the recess in the base of the camera body with double-sided tape.

Tuck the wires in the bottom plate, align the plate with the body, and bring the two together, once again taking care not to pinch any wires.

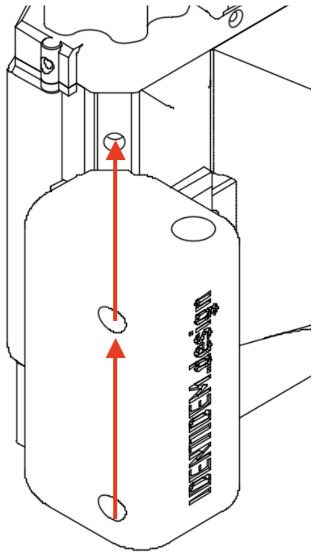
Fasten the bottom plate to the camera body with two M3x6 screws.



Camera grip

Almost there! Simply attach the grip to the camera body with two M3x4 screws.

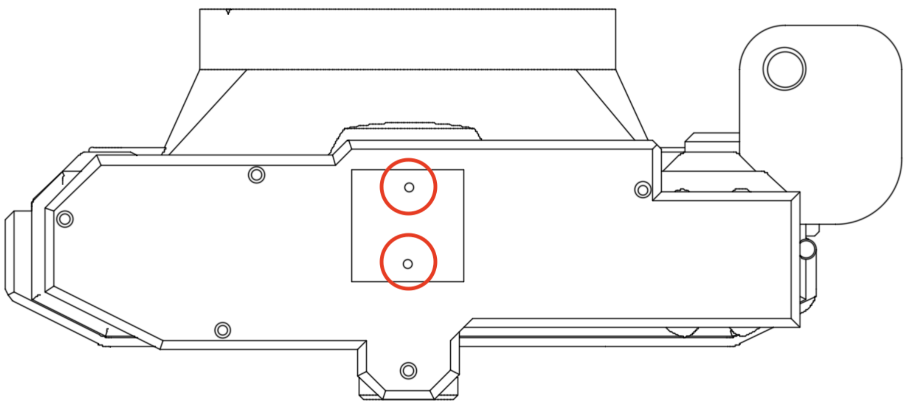
Note that you can (and should) thread a [shutter release cable](#) through the grip.



Format Masks

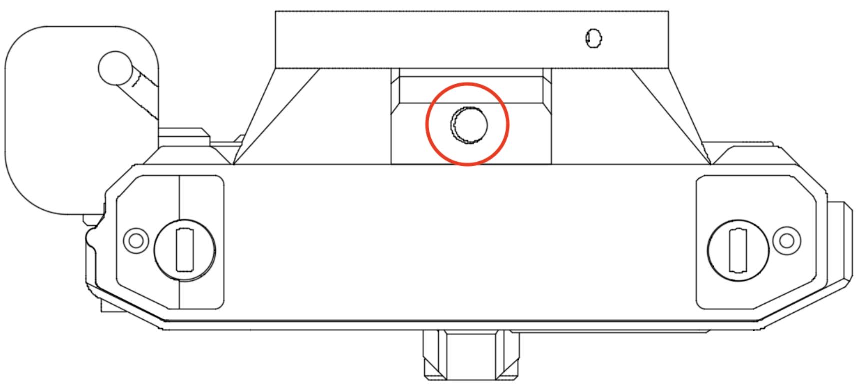
Each format mask has two recesses for 20x5x2mm magnets. Superglue them in, making sure their polarity is so that the mask is attracted to the film gate / camera body as to hold it in place.

Finishing touches



Attach the cold-shoe on the top of the camera with two M2x4 screws, screwing directly into the plastic.

Finally, use a flat-head screwdriver or 20p coin to screw in the tripod mount screw on the bottom of the camera.



Source code

The source code for the firmware the runs on the Feather ESP32-S3 can be found on Github: https://github.com/acornelissen/IDENTIDEM.design-MRF/tree/master/Firmware

It was written in Arduino C++ with PlatformIO on Visual Studio Code, and that will be the easiest way to compile and upload it to the Feather ESP32-S3.

- platformio.ini
  - PlatformIO configuration
  - Dependency list
- src/main.cpp
  - Contains all the includes, as well as the setup and loop functions
- includes/cyclefuncs.h
  - Functions to cycle through ISOs, apertures, formats, and lenses
- includes/formats.h
  - Contains the list of supported formats in a struct, and each of these contain a display name, the number of frames per roll, and the sensor values for each frame
- includes/globals.h
  - All global variables to keep track of state, etc.
- includes/hardware.h
  - All hardware instances are created in this include
- includes/helpers.h
  - Various helper functions used across the codebase
- includes/inputs.h
  - Code to handle button presses
- includes/interface.h
  - Contains code to draw all the various elements of the User Interface
- includes/lenses.h
  - Contains all supported lenses in a struct, and each of these contain the display name, sensor values for each focus distance, the focus distances for the lens, the available apertures for the lens, frame line coordinates, and whether the lens has been calibrated or not
  - You'll notice that only the 65mm f6.3 is marked as calibrated - I needed to have at least one available as a default
- includes/constants.h
  - What it says on the tin
- includes/setfuncs.h
  - Functions to update globals and saved values depending on sensor and other input

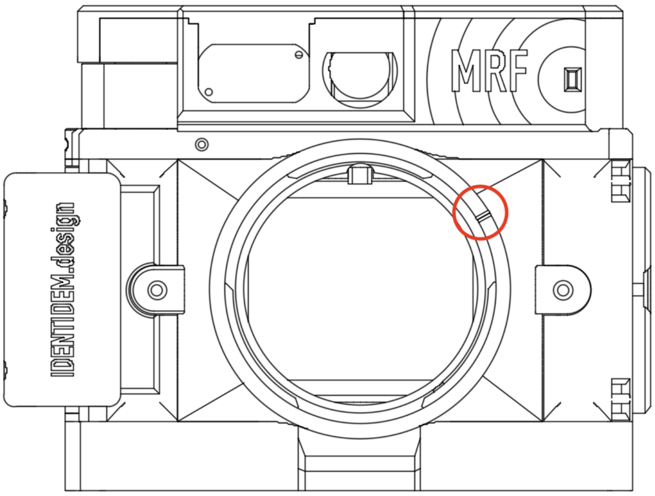
Feel free to improve the code or fix bugs, and post a pull request on Github. This is also the place to log any issues or feature requests.

Using the MRF

1. Charge the battery

The battery can be charged via the USB-C port. Because of the position of the port, I would recommend a right-angle USB-C cable. There's no charging indicator, but you can turn the camera on and it will show an updated battery percentage on the external display.

2. Attach a Lens



This is very straightforward. Loosen the thumb screw in the lens mount.

To avoid damaging the position sensor, **set your lens focus to 1m** when mounting or removing a lens. Align the red dot / arrow on the lens with the indent in the lens mount, drop the lens in, and turn it anti-clockwise until the red dot / arrow points straight up. Then tighten the thumb screw to lock the lens in place.

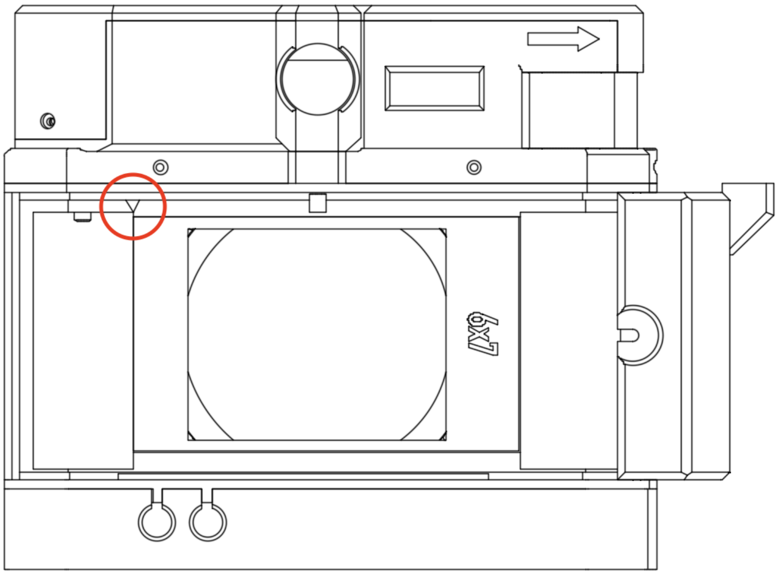
Some lenses might be tighter than others.

2. Load some film

Loosen the film door thumb screw and open up the door.

Then, use the optional printed spool pin key, flat-head screwdriver, or anything you have to hand that fits to rotate the two spool pins on the bottom of the camera body so they make space for your film spools.

Fit your chosen format frame mask on the film gate. It has an alignment pin to make sure it doesn't move as you advance the film. Place your full roll of film on the left, and take-up spool on the right, and rotate the spool pins again so they hold both spools in place.



Pull your film across to the take-up spool and insert the leader, using the advance knob to start loading your film on the take-up spool. On the top left edge of the film gate there is a downward arrow indentation. Line up the arrow on the backing paper with the arrow on the film gate.

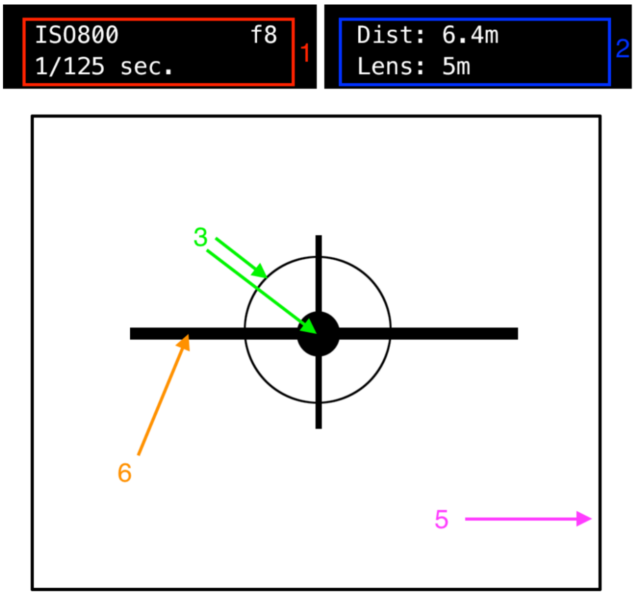
Close the film door, and lock it in place with the thumb screw.

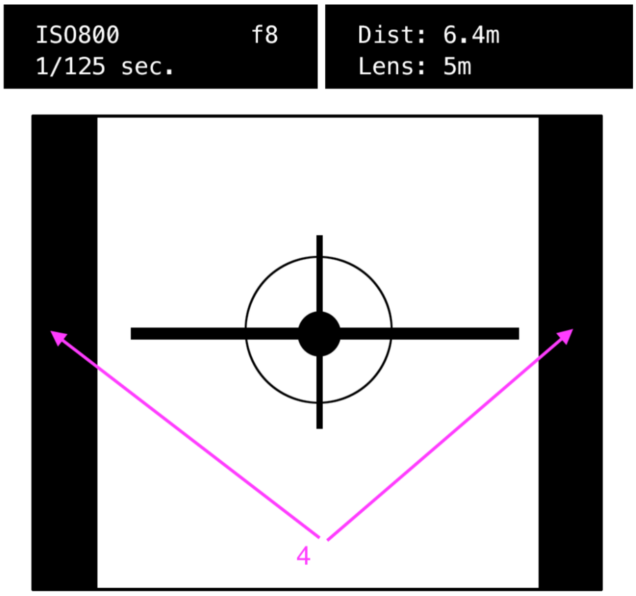
Next, turn on the camera with the power switch. Go into the Setup menu by holding the right button for 5 seconds, then releasing. Select the format for the mask you have installed, and then select **Reset Count >>** to reset the frame counter.

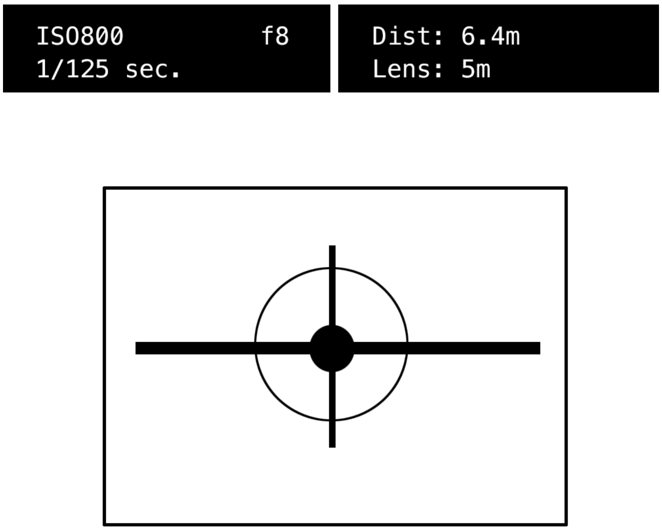
Now, look at the external display, and turn the advance knob until you reach frame 1.

You are now ready to shoot!

3. User Interface - viewfinder display

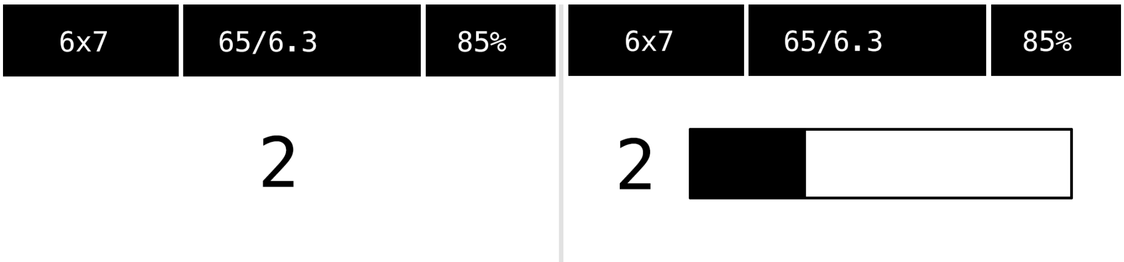






1. Lightmeter readings
2. Rangefinder distance and lens focus distance readings
3. Focus accuracy reticle (*see using the rangefinder to focus section*)
4. Focus mask - this will change depending on the Format selected in the Setup menu
5. Frame lines - this will adjust depending on the Lens selected in the setup menu
6. Horizon indicator - this will show roll and tilt as you move the camera - when it is perfectly straight and in the center of the vertical line, the camera is level to the horizon

4. User Interface - external display



The external display shows you, in turn:

- The selected Format
- The selected Lens
- Battery life percentage

It also shows you the frame you are on, and when advancing from one frame to the next, a progress bar to indicate the progress from one frame to the next as you turn the advance knob.

In addition, the Rotary Encoder breakout board has a Neopixel RGB LED on it that can be shined into an advance knob printed in clear PETG. This is violet at the start and end of the roll, blue on each frame, and then transitions from red to green as you advance to the next frame.

5. Setup menu

To enter the Setup menu, hold the Right button for 5 seconds or longer, and release. Use the Right button to cycle through the options for the currently selected menu item, or select an action, or go into a submenu. Use the Left button to cycle through menu items.

The following menu items are available:

- **ISO** select a target ISO for the lightmeter from 50 to 6400
- **Format** select the value corresponding to the currently installed format mask - PANO, 6x4.5, 6x6, or 6x7
- **Lens** select the currently mounted lens from a list of calibrated lenses
- **Lens calib. >** Takes you to the Lens Calibration submenu
- **Reset count >>** Resets film counter and takes you back to the main UI
- **Exit >>** Takes you back to the main UI

6. Lens calibration

When you mount a new lens to your camera, you will need to calibrate the camera to use it.

As the camera ages and the plastic settles and wears, it is also a good idea to re-calibrate your lenses every so often.

To do this, go into the Setup menu and select the **Lens calib. >** option.

You will be presented with a screen that has two main elements

- Lens selection
  - Left button to cycle through *all* known Mamiya Press lenses
  - Select the lens you have mounted and want to calibrate by pressing the Right button
- Focus distance to sensor reading selection
  - On the left, you will have the focus distance you need to move the lens to, starting at 1m
  - Wait until the sensor reading settles, then press the Left button to link that sensor reading for the selected lens to the relevant focus distance
  - Do this for each sensor reading up to 10m
  - You will be returned to the Setup menu when you are done, and the calibrated lens will automatically be selected
  - If you want to exit lens calibration at any time, press the Right button

Once a lens is calibrated, it is saved to the ESP32's flash memory, and can then be selected in the Setup menu.

7. Using the rangefinder to focus

This one's simple.

The focus reticle at the center of the viewfinder shows you where the LiDAR is aimed at. The outer circle is larger the further you are from being focused on the subject.

Simply turn your lens focus ring until the outer circle converges with the reticle, and you should be in focus.

I would also recommend keeping an eye on the **Distance** and **Lens** values in the top right of the viewfinder - if they're equal or very close, you should be good to take that photo.

8. The lightmeter

The lightmeter uses a lux sensor that returns a continuous reading of a weighted average of the scene you're shooting. It's mostly good enough, but use an external meter if you want more accuracy.

- Set your desired ISO in the Setup menu
- Selecting the currently mounted lens in the Setup menu will automatically adjust the available apertures to match the lens apertures
- Press the left button to cycle apertures backward
- Press the right button to cycle apertures forward

Once you've selected an ISO and aperture, point the camera in the direction you'd like to meter. The viewfinder display will show you what shutter speed you need to use for a good exposure.

9. Quirks and advice

At all times remember that this is a camera that was designed and built by one person, and that this person is a hobbyist with no formal background in anything but software development. In addition, this is a mostly 3D-printed camera. Printers differ, as does material. Plastic contracts as it cools. That means that this is not a 100% accurate machine.

With that out of the way, this has fast become my favourite camera to shoot. The Mamiya-Sekor lenses are awesome, and even with the bigger lenses this camera is nice and light. Also being able to shoot many formats with one camera is pretty awesome. It's also the most modern and as such most reliable medium format rangefinder out there at the time of writing (May 2024).

So here are **the quirks, and some advice**:

- Use a dark, matte material to print the parts that need to be light-tight - barring that, you will need to flock the inside of the camera to prevent internal reflections
- The TF Mini Plus is *not true LiDAR*
    - it's not pinpoint accurate, so be vigilant and realistic when acquiring distance to subject - you might need to move the reticle around ever so slightly to nail it
    - It can't measure past glass, so no focusing through windows
    - It really, really doesn't like super reflective surfaces, so don't expect accuracy when aiming at mirrors, shiny surfaces, or liquids
    - Maximum focus distance is 12 meters, but most Mamiya Press lenses have a hyperfocal distance at around 10 meters, so it shouldn't be a problem.
- The rotary encoder is pretty accurate, but you may still find that it clicks into place one turn *after* the external display shows the correct frame count, showing the progress bar - that's fine, you'll still get good frame spacing
- If you want to shoot 35mm panos, just like any other medium format camera, you will need 35mm to 120 spool adapters - the difference here is that this camera is *made to to shoot 35mm panos* with a specific mask and accurate frame counting - for best results use the 65mm or 50mm lenses

The future

This is my ideal camera. I've poured most of my free time in the last two or so years into getting it to this point. That being said, there's always room for improvement, and there are people out there that have the knowledge and expertise to improve on this foundation.

So that is why this project is open source, and I would love to see others remix, add to, improve, or adapt the work I've put in. If you do, please drop me an email to hello@identidem.design, showing me what you've done!

Enjoy using this camera, I've put a lot of time, effort, and myself into it! :)

- Albert