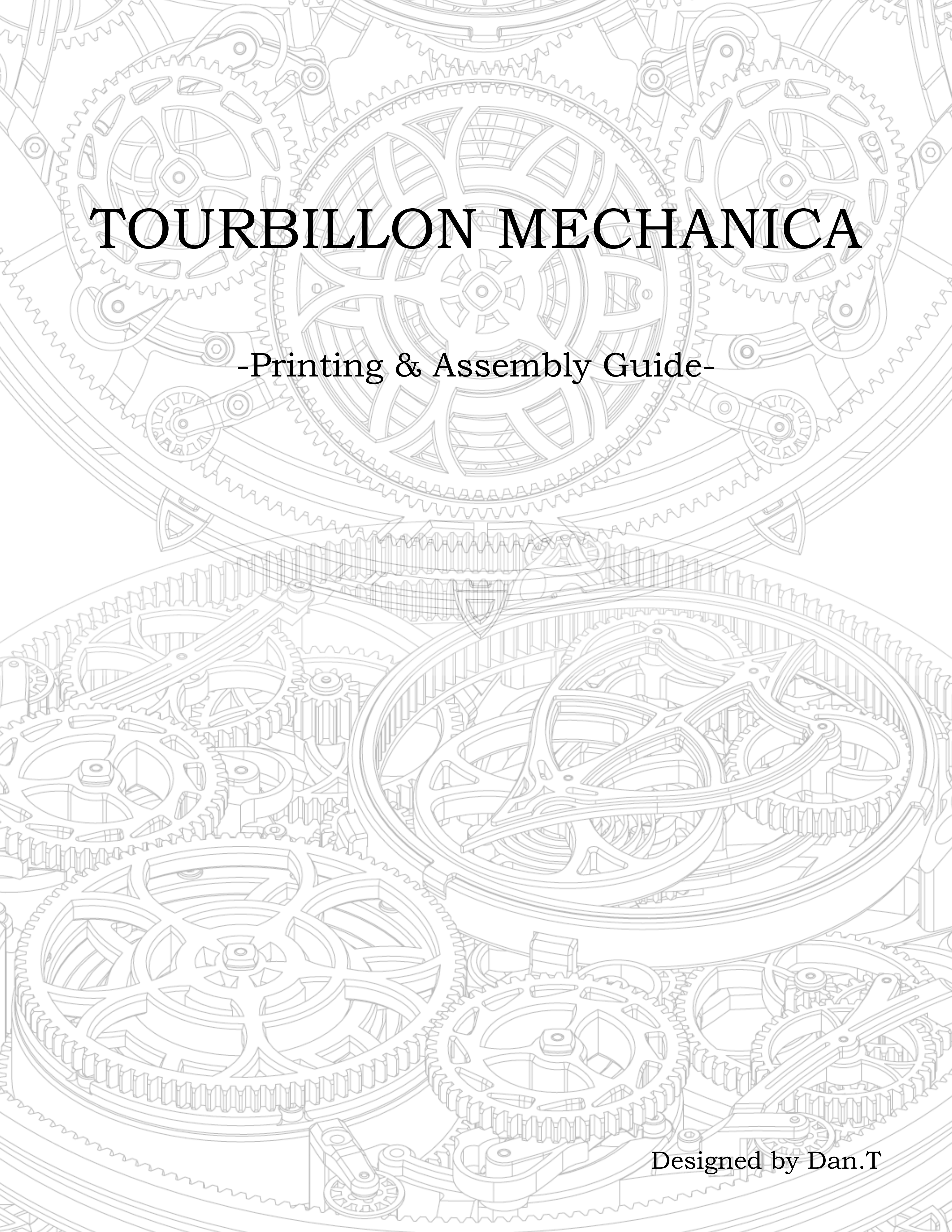


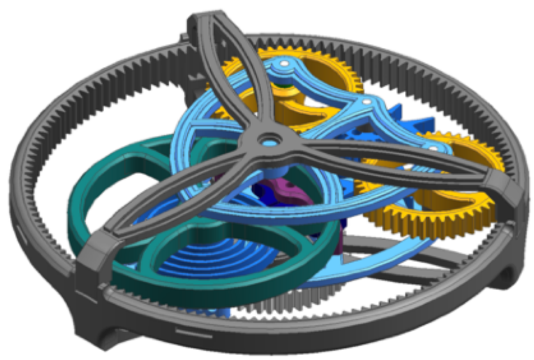
TOURBILLON MECHANICA

-Printing & Assembly Guide-

Designed by Dan.T

Background

- I am a mechanical engineer by educational background but I'm not a watch or clockmaker by any means nor do I have any related experience prior to designing the Tourbillon Mechanica. I'm always mesmerized with complex mechanical watch movements but unfortunately they usually come with an exorbitant price tag. I saw the 3D printed tourbillon clock by Christoph Lamer and Adam Wrigley and thats how the idea of designing and printing my own tourbillon sparked. I found a book that goes into details of designing the Swiss lever escapement mechanism and that is where it all started. The first successful attempt was a caged version as shown below. It is quite similar to the final version except for some gear ratio optimization and minor design tweaks.

- As someone who had absolutely no experience in designing a clock movement, striking a balance between design for form and function is very challenging. Maintaining symmetry is more challenging as it seems due to the big difference in hour and minute gear ratios yet having too many gears in the system would increase the total friction for the mainspring to overcome. Time setting mechanism is also difficult to be implemented without disturbing the design symmetry and introducing too many assembly challenges considering that this is my very first attempt. I decided to take a step back and focus on the basic mechanism that will keep the clock running while being able to tell time. Thus there are no simple ways for time setting although there are workaround solutions that will be explained at the end of the guide.

- That being said, It is important to note that this is a clock designed to illustrate the basic working principle of a mechanical clock and tourbillon escapement. It is **NOT** designed for accuracy as 3D printed parts are nowhere as accurate as a functional clock requires. The running time is also limited and it is quite loud. It is a functional mechanical sculpture for those who are interested to explore the inner workings of a mechanical watch. The assembly requires patience and some print setting tuning in order to get it right so I would not recommend this to those who are new to 3D printing. I tried my best to optimize the printing and assembly process but there will still be room for improvements. I will continue tweaking it as I receive feedbacks from fellow makers. It is also my firs time making such assembly guide so feedbacks are welcomed for me to improve on my upcoming projects.

Preparation

Tools Required

- Dremel (any model) with diamond disc cutter or any suitable tools for stainless steel pin cutting

- Drill bits (1.5mm and 2.0mm outer diameter) for pin hole enlargement 

- Hand Plier 

- Allen Wrench for M2 Screw 

- Small Hammer/Large Allen wrench for pin insertion 

- Ruler/Vernier Caliper for pin length measurement 

- Super Glue to fix broken parts (if any) 

- Hobby Pen Knife for blobs, elephant foot and uneven surface removal 

- WD-40 (Optional) For Gear Pin Lubrication 

Other Hardwares

- 1.5mm OD Pins: Link

- 2.0mm OD Pins: Link

- M2X8mm Screw: Link

- M2X5mm Screw: Link

- Sheet Spring Steel for mainspring Link (Optional as 3D printable spring can also be used)

    - Thickness: 0.2mm
    - Width: 12-13mm
    - length: 2-3m

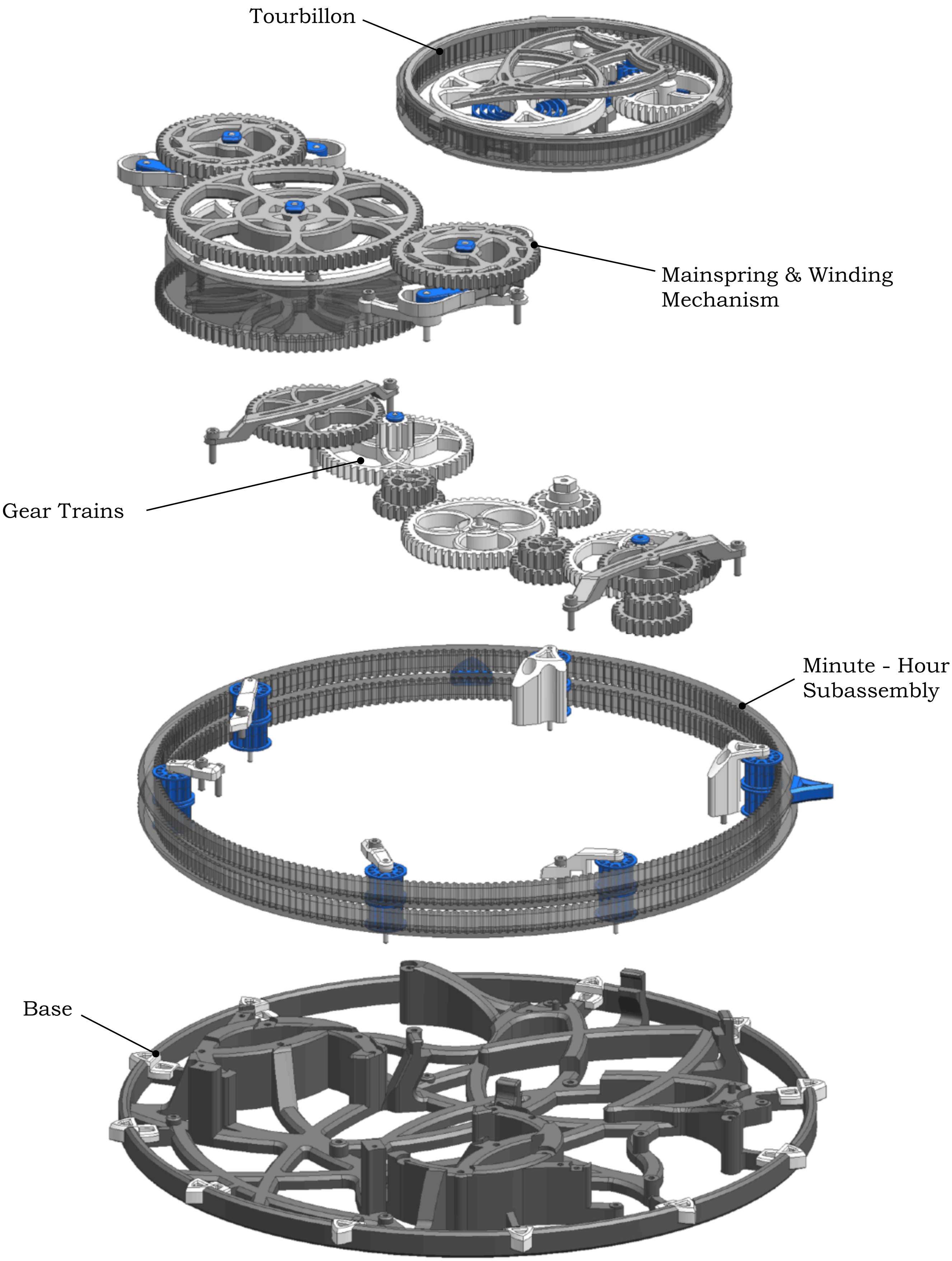
Printer

- Minimum Print Bed XY size: 220 x 220

- Nozzle Diameter: 0.3mm (must have), 0.4mm, 0.5mm

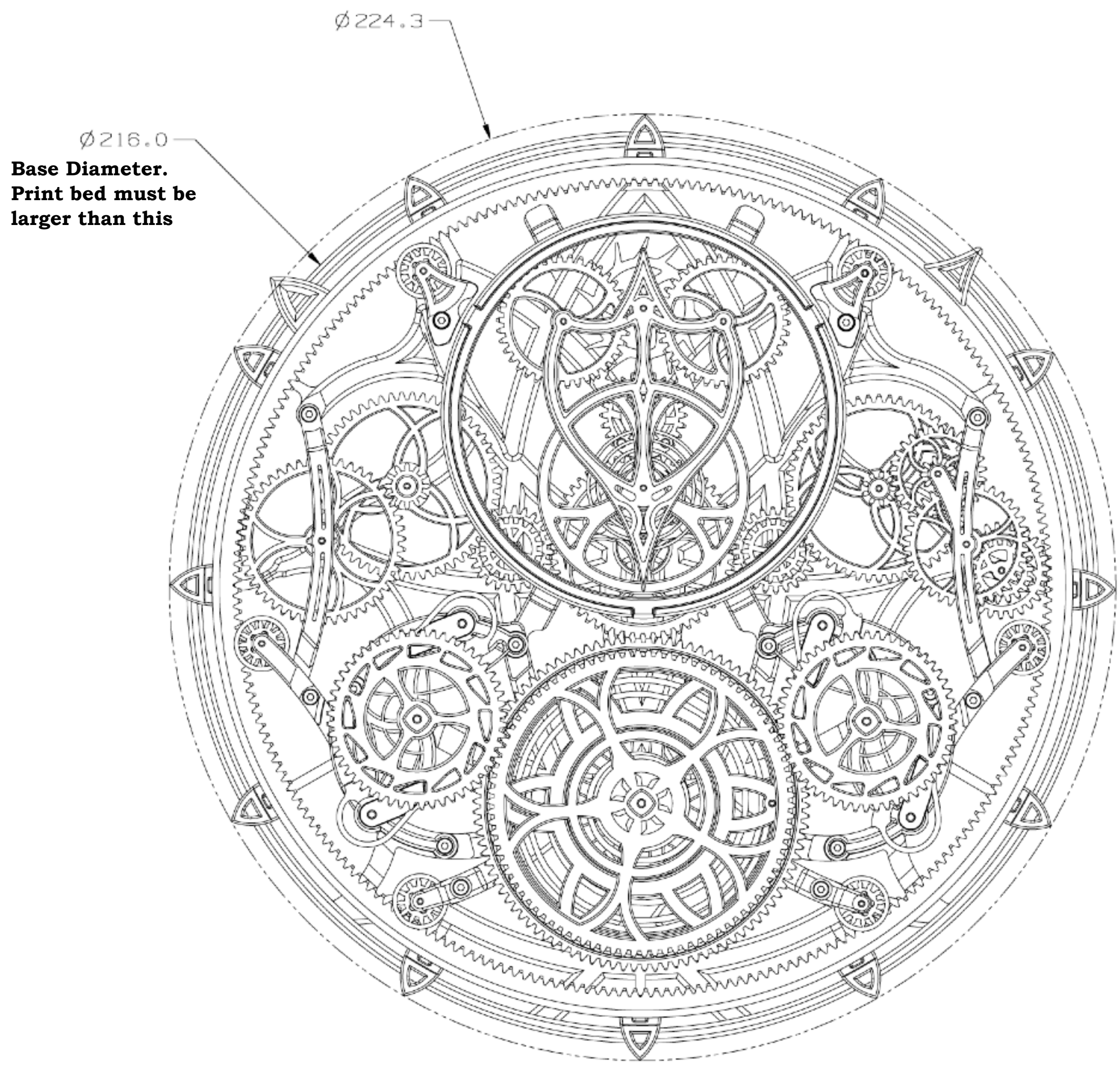
- Material: PLA and PETG

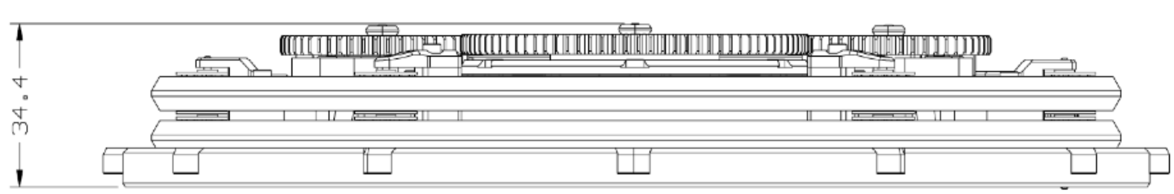
Design Overview



Dimensions and Specs

- Dimensions in mm
- Approximate running time
  - PETG Spring - 5 to 10 minutes
  - Steel Spring - 15 to 20 minutes
- Total material consumption : Approx 350g
- Total print time : Approx 110h





Complete Part List

Printed Parts		
Part Name	**Qty**	**Remarks**
01_Tourbillon_Cage_Bottom	1	
02_Escape_Wheel	1	
03_Escape_Fork	1	
04_Fork_Bridge	1	
05_Runner_Gear	2	
06_Impulse_Pin	1	
07_Hairspring	1	print with low speed
08_Balance_Wheel	1	
09_Tourbillon_Cage_Top	1	
10_Base	1	Longest print time
11_Indices	12	
12_Guide_Gear	24	
13_Ring_Gear	2	
14_Minute_Marker	1	Print with larger surface towards build plate
15_Hour_Marker	1	
16_Guide_Bracket_1	1	Print with Support
17_Guide_Bracket_2	1	
18_Guide_Bracket_3	1	
19_Guide_Bracket_4	1	
20_Guide_Bracket_5	1	
21_Guide_Bracket_6	1	
22_Core_Gear	1	
23_Tourbillon_Transmision_Gear	1	
24_Twin_Transmission	2	
25_Min_Transmission_1.prt	1	
26_Transmission_Stud.prt	2	
27_Min_Transmission_2	1	
28_Min_Transmission_2_Spacer	1	
29_Min_Transmission_Bracket	1	Print with Support
30_Hour_Transmission_1	1	
31_Hour_Transmission_2	1	
32_Hour_Transmission_2_Stud	1	
33_Hour_Transmission_3	1	
34_Hour_Transmission_4	1	
35_Hour_Transmission_Bracket	1	Print with Support
36_L_Ratchet_Base	1	Print with Support
37_R_Ratchet_Base.prt	1	Print with Support

Printed Parts		
Part Name	**Qty**	**Remarks**
38_Ratchet_Tooth	4	
39_Mainspring_Barrel	1	
40_Mainspring	1	PETG (add brim if necessary)
41_Mainspring_Cover	1	
42_Mainspring_Winder	1	
43_Ratchet_Gear	2	
44_Winding_Stud	3	
45_Tourbillon_Ring_Gear	1	
46_Tourbillon_Ring_Gear_Cover	1	
47_Washer_1.5mm	14	
48_Display_Stand_Post	1	Print with large nozzle to save time. I used 0.8mm nozzle with 0.24 layer height. No supports
49_Display_Stand_Base	1	
50_Display_Stand_Lower_Support	1	
51_Winding_Key	1	

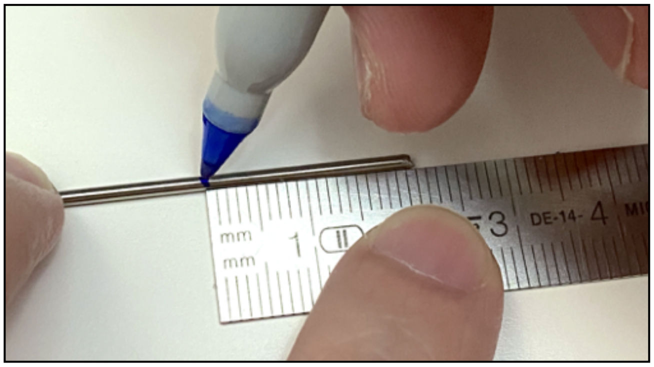
1.5mm Diameter Pins		
Pin Length (mm)	**Qty**	**Assembly Phase**
18.5	4	Part 1 (Escapement)
8.5	1	
28	6	Part 2 (Base)
15	2	
17	1	
20	1	
23	2	
10	2	Gear Train (Hour transmission bracket)
22	1	Mainspring (PETG option)

2.0mm Diameter Pins		
Pin Length	**Qty**	**Remarks**
13	1	Part 2 (Base)
15	5	Part 2 & Part 6 (Base & Winding)
20	2	Part 6 (Winding)
35	1	Part 5 Option 1 (Mainspring)

Screws		
Pin Length	**Qty**	**Remarks**
M2 X 8/10mm screw	16	
M2 X 5mm screw	6	Part 5 Mainspring barrel

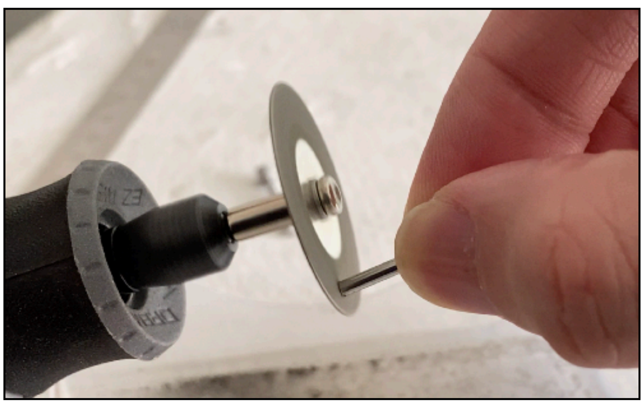
Pin Cutting

- The pin lengths are not required to be cut to high precision. +/- 0.5mm is fine. The only 4 pins that is required to be precise are the 4X 18.5mm tourbillon pins that will be used in part 1 of the assembly. These 4 pin lengths need to be as consistent as possible as they will determine the assembly height
- It is also crucial to have a chamfered feature at each ends of the pin. If u are using a Dremel, simply use a grinding tool to grind the edges of the pin at an angle while rotating the pin with your other hand to create such feature. If u do not have a Dremel, a file or sandpaper will also work although it will require more time and effort.



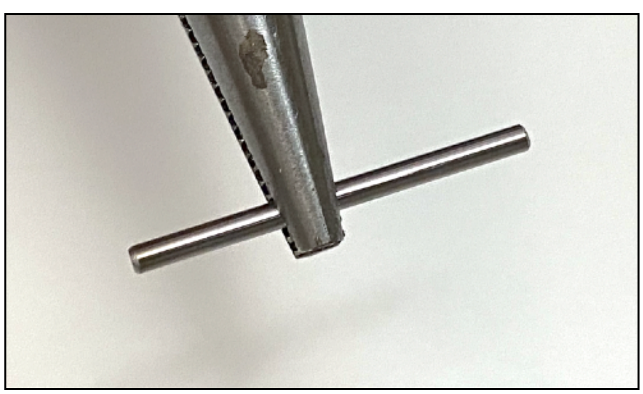
1) Measure the and mark the pins

2) Cut the pins to be slightly longer than the desired length



3) Measure the pin and grind it down to the correct length

4) remove burrs and introduce chamfer at both ends by grinding the pin at an angle while rotating it



5) The pin should look like the one in the picture above, with both ends to have some chamfer

Printing Guide

- Critical parts that require specific settings will be included in the table below. Parts that are not listed are flexible to be printed with a range of standard settings. I used **Cura** and.3mf files will be provided so that the settings can be referenced.

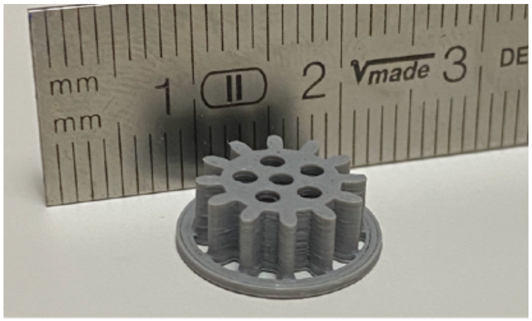
- As a general guideline, 4 outer perimeter for 0.3mm nozzle and outer wall print speed of 12-18mm/s speeds are recommended for parts with fine details such as gears and Tourbillon parts. Avoid using abrasive PLA such as the ones with particle fills as they could introduce friction to the mechanism. I personally find Hatchbox standard PLA to work well as they print fine details well and has a low friction surface finish.

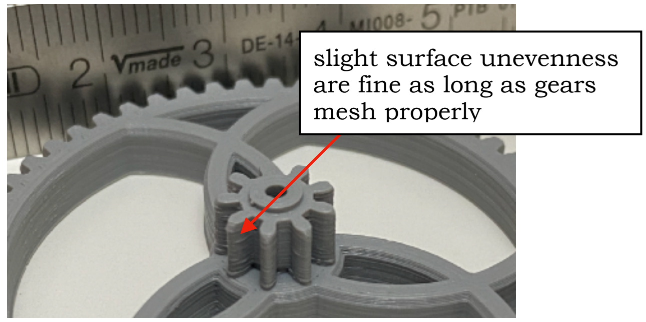
- Tip: I find it extremely helpful to slightly reduce the extruded line thickness. eg for 0.3mm nozzle, set the line width to 0.27-0.28mm. this seems to yield slightly better printed resolution.

Part Name	**Nozzle ø (mm)**	**Layer Height (mm)**	**Infill %**	**Outer Perimeter**	**Perimeter print speed (mm/s)**	**Remarks**
02_Escape_Wheel	0.3	0.1-0.15	20-30	3-4	12-17	✦ **Avoid Elephant's foot** as it will prevent parts from interacting correctly. First layer needs to be set perfectly.
03_Escape_Fork						
06_Impulse_Pin						
All Gears						
10_Base	0.5	0.2-0.25	15-30	2-3	20-30	✦ Longest Print time, approximately 13hour. ✦ Bedsize of 220mm x 220mm required.Print without a skirt or brim to save space
16_Guide_Bracket_1	0.3/0.4	0.1-0.15	20-30	3-4	20-30	✦ Print with Support. ✦ Guide Bracket 3 and 4 have a thin area that requires careful support removal to avoid breaking. In the event of part breaking, super glue fix will suffice
16_Guide_Bracket_2						
16_Guide_Bracket_3						
16_Guide_Bracket_4						
22_Core_Gear	0.3	0.1-0.15	30-40	4-5	20-30	✦ Load Bearing Gear, needs to be stronger to avoid deformation
37_L_Ratchet Base	0.3/0.4	0.1-0.15	20-30	3-4	20-30	✦ Print with Support. ✦ Careful support removal to avoid breaking of spring feature. In the event of part breaking, super glue fix will suffice
38_R_Ratchet Base						
40_Mainspring_Barrel	0.3	0.15-0.2	50-70	4-5	12-17	✦ Highest Load Bearing Part. Print with slightly higher temperature for better layer adhesion. ✦ Only gear tooth area requires slow print speed. Speed can be manually increased after gear teeth portion is completed
42_Mainspring_Winder	0.3	0.15-0.2	50-70	5-7	12-17	

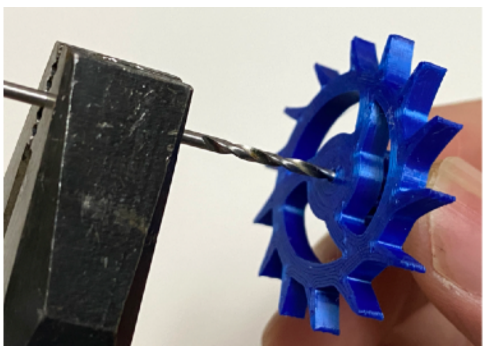
Printed Parts Finishing

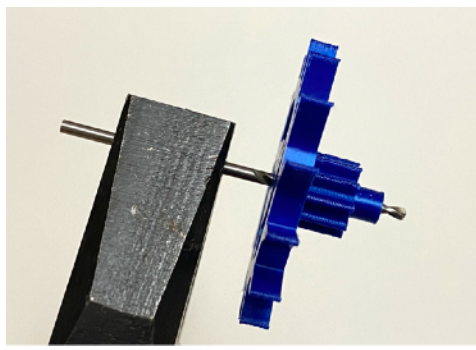
- Printed gears should be free from blobs, stringing, excessive layer shifts, and elephant’s foot. Blobs and small amount of elephants foot can be removed using a hobby pen knife. Minor layer inconsistencies are fine as long as the gear meshing is sufficiently smooth. An example of a good gear tooth is is shown below:



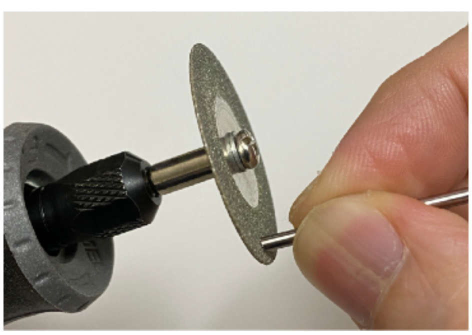


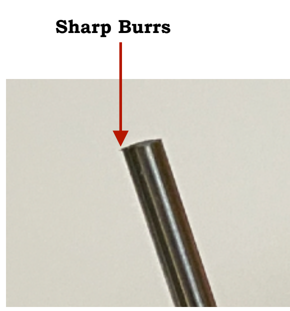
- Most gears will require pin hole finishing to achieve the best pin fitting and smooth rotation with minimal friction. Due to the combination of nozzle diameter variation, printer setup and materials, It is impossible to have one diameter that will yield a smooth transition fit with the pins right off the print bed. A loose pin to gear fitting will introduce significant backlash in the system. Hence Pin hole preparation is required in the following steps:

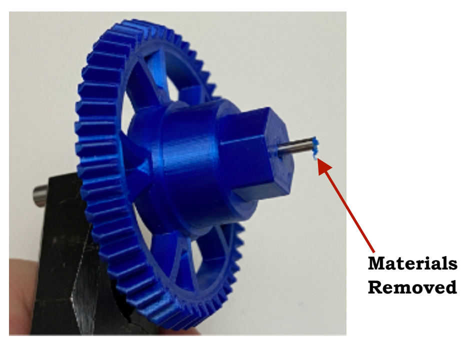




Step 1: Grab a 1.5 or 2.0 mm drill bit (wherever applicable) with a hand plier. Hold the 3D printed gear with another hand and gently rotate the gear towards towards the drill bit. Be careful to not allow the drill bit to tilt too much along the way. Continue on till the drill bit exits from the other side of pin hole. You could also use a hand drill but there is a higher risk of having the drill bit tilting as it is driven through the gear.







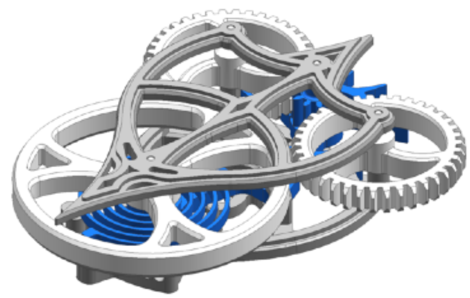
Step 2: Grab a pin and intentionally introduce some burrs at the edge either by using a Dremel or sandpaper as shown. Repeat Step 1 but replace the drill bit with the burred pin. You should notice some plastic material being removed with every pass. Try rotating the gears every time it is fully inserted to the pin. At one point, it will rotate smoothly without jamming. This indicates that the pin hole is sufficiently enlarged.

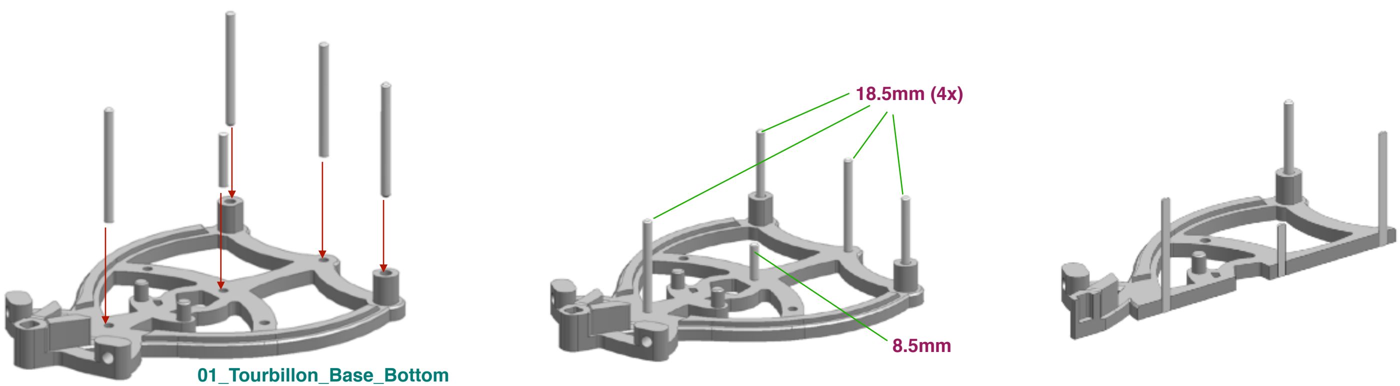
Assembly

- I highly recommend watching my detailed video assembly guide before following this guide as I will be illustrating some of the critical checks and assembly procedures that is difficult to illustrate here.
- Video Link: https://www.youtube.com/watch?v=E9prY3ky6Bo

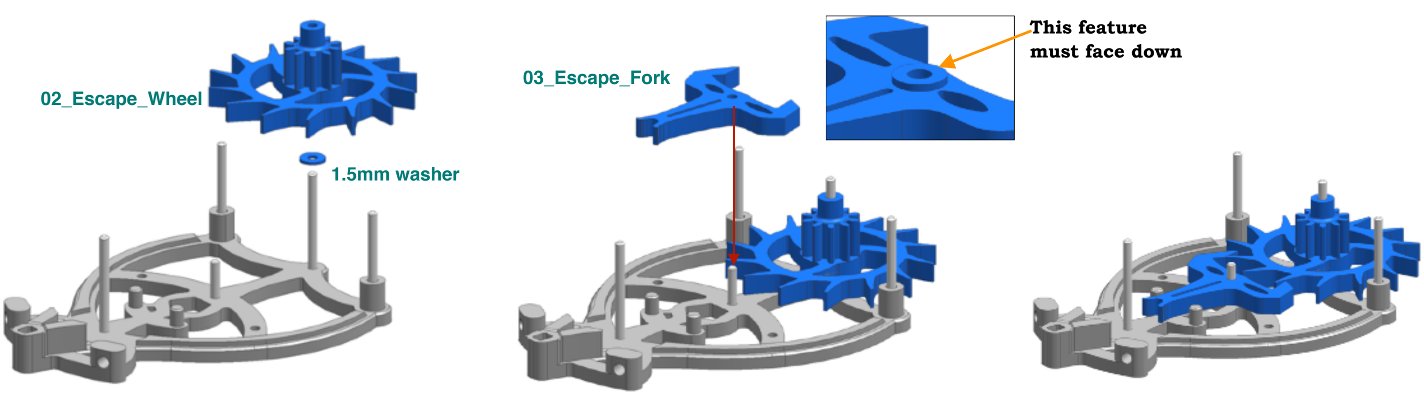
Part 1: Escapement Mechanism

- This is the most critical part of the entire assembly. **I've published the files as a free download and I highly recommend to try that out first before purchasing the full design**. If you are able successfully print and assemble a working escapement mechanism, you should be able to build the entire clock with the same print settings, materials, and assembly process.





1) Prepare 5x 1.5mm with lengths specified above. Place the bottom base on a flat surface and carefully knock the pins all the way through to the flat surface. Ensure that the pins are not tilted

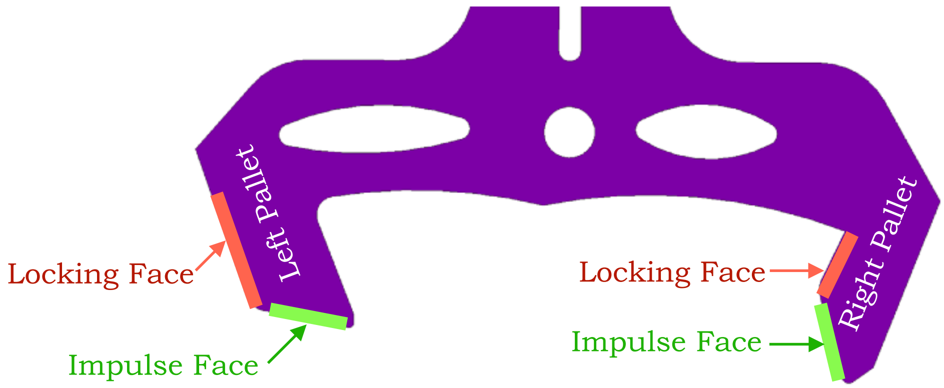


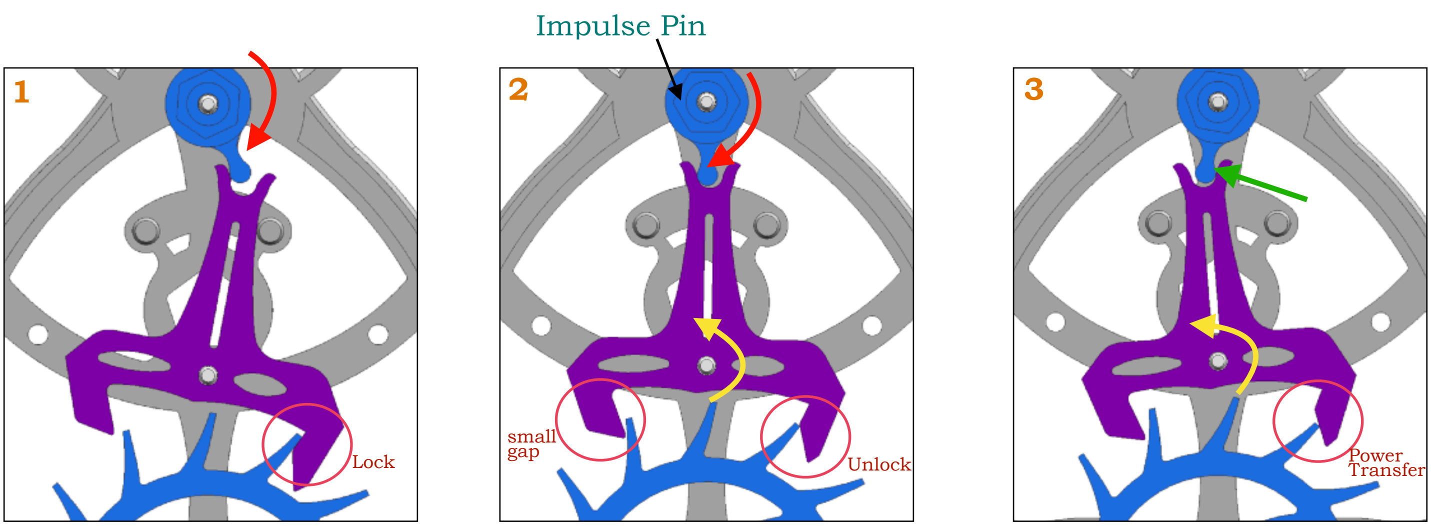
2) Insert a 3D printed washer to the escape wheel pin followed by the escape wheel. Insert the escape fork thereafter. The escape fork has a protruding side and that has to face towards the base

Part 1.1: Understanding the Escapement Mechanism

- There are 3 escapement fork designs. I highly recommend trying all three to see which one is best suited for your print setting and printer setup. I'll first explain the escapement mechanism followed by the differences between the designs to help understand how the differences affect the efficiency of the mechanism. I also highly recommend watching this video https://www.youtube.com/watch?v=Wmk2mA6dg3o of the Swiss Lever escapement in action.

Some Terminologies

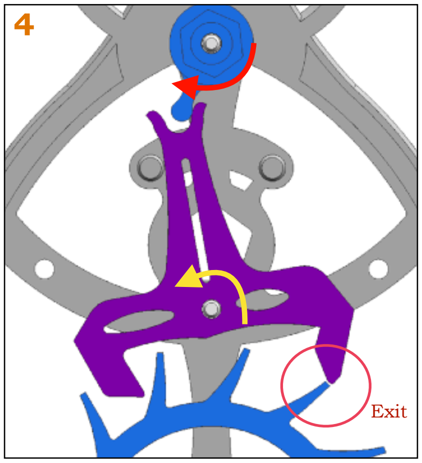




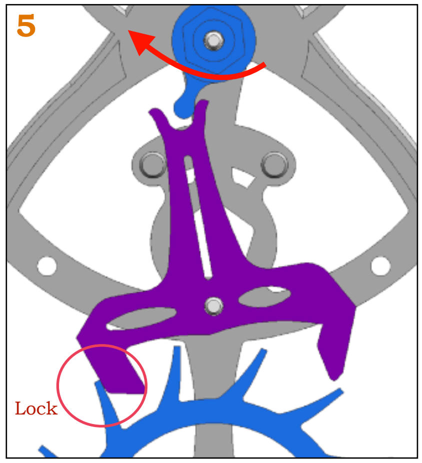
We will start from the right pallet locking face engagement. Escape wheel always tries to rotate clockwise and is in locking contact with the fork as shown above.

The balance wheel + impulse pin swings back in the counterclockwise motion and nudges the fork to rotate counter clockwise, causing the escape wheel finger to be released from the locked position. Notice the small gap between the left pallet with the escape wheel finger. It is critical to ensure there are sufficient gap there

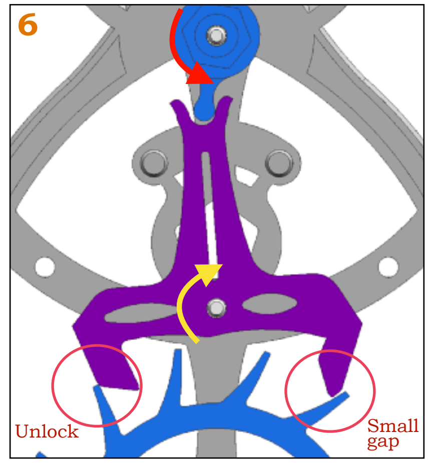
The escape wheel finger now slides along the impulse face of the right pallet. the energy from the mainspring that is transferred all the way to the escape wheel is now partly being transferred to the fork and finally to the impulse pin + balance wheel



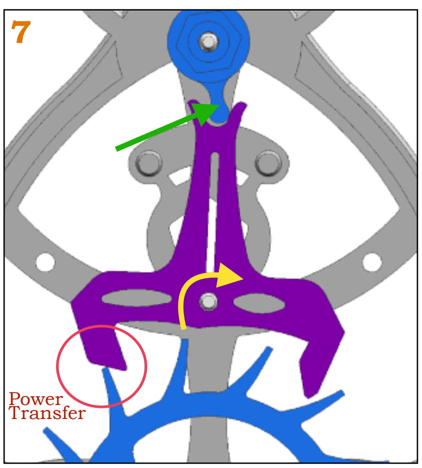
The escape wheel finger eventually exits the right pallet when the fork fully swings to the left.



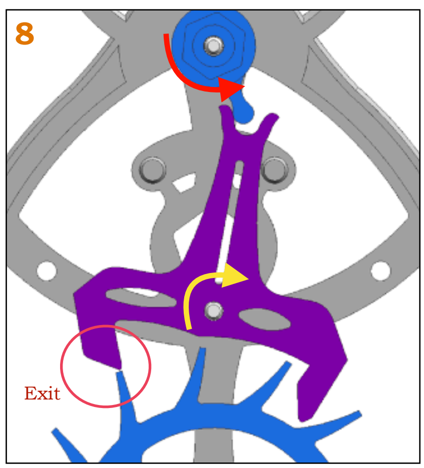
The escape wheel finger now engages with the left pallet locking face and will remain in this position till the balance wheel makes another full swing, coming back counter clockwise



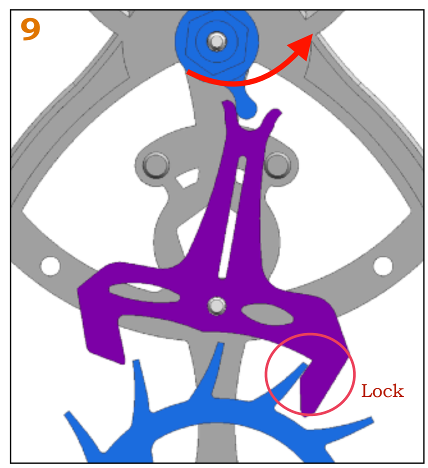
The identical cycle as the right pallet now repeats for the left pallet when the impulse pin nudges the fork again. escape wheel + fork will unlocked. At this position, the right pallet will have the smallest gap vs the wheel finger



Escape wheel finger slides along impulse face of the fork, Providing energy once again to rotate the fork clockwise. to the impulse pin and hence balance wheel.



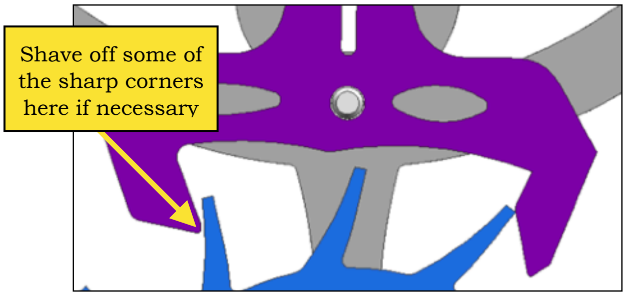
The wheel finger now exits the left pallet as the fork is fully swing to the right.

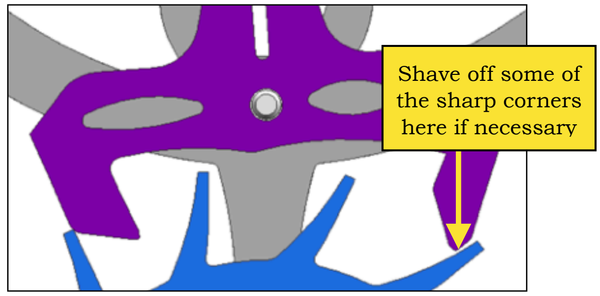


The wheel eventually locks with the fork again on the right pallet and the mechanism completes a full cycle that repeats itself.

The 3 Escape Fork Design Variants

03_Escape_Fork_Reference

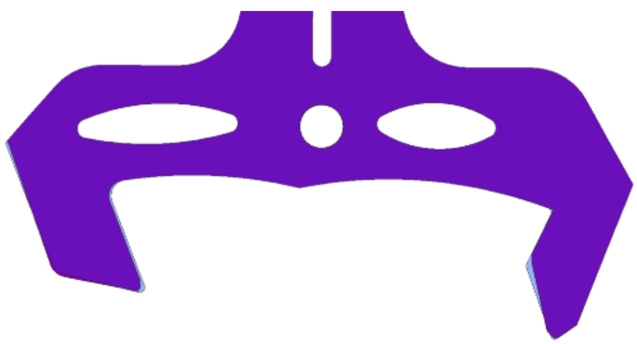




The **reference** design is the one that is shown in the cycle illustration above. It is designed to maximize the efficiency of power transfer to the wheel by having a close to 45 deg impulse faces relative to the wheel finger contact and also having minimal locking face to minimize energy loss. However, it is very sensitive to assembly variations and thus some might experience locking face slipping (especially on the right pallet due to the larger travel between the exit to lock steps) where the escape wheel finger is unable to properly engage the locking face and slips, causing the mechanism to be jammed.

The gaps at the unlocking steps are also very small and some might find the assembly to be jammed at those positions. I would recommend to take a pen knife to slowly trim off the sharp corners of the pallet to fix the issue.

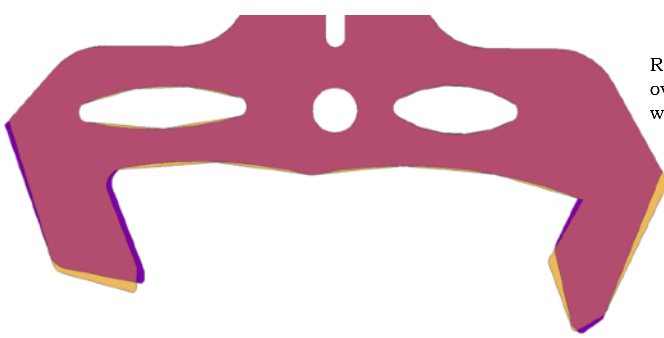
03_Escape_Fork_Extended



Extended (blue colour) overlapping comparison with reference design

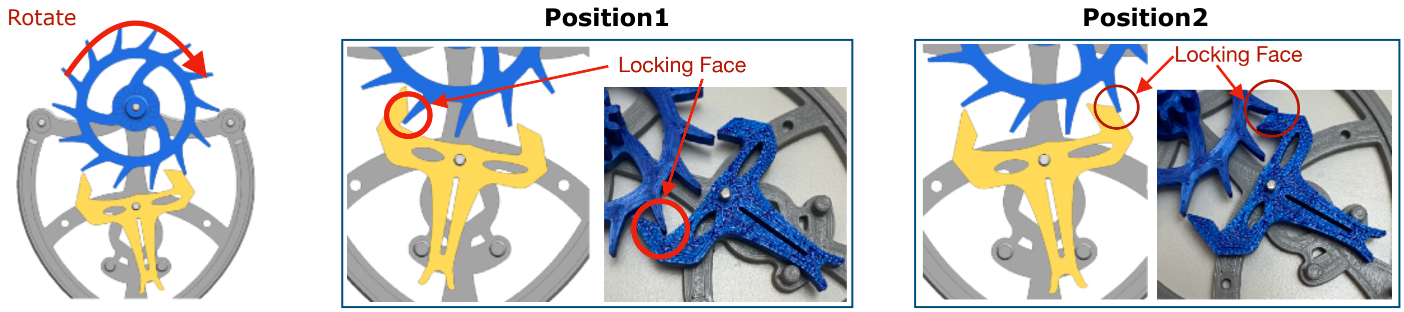
The **extended** variant tries to address the right pallet slipping without compromising too much on efficiency by extending the right pallet locking face. with some expense of right pallet impulse angle (that slightly reduces the power transfer efficiency.

03_Escape_Fork_Reduced



Reduced (orange colour) overlapping comparison with reference design

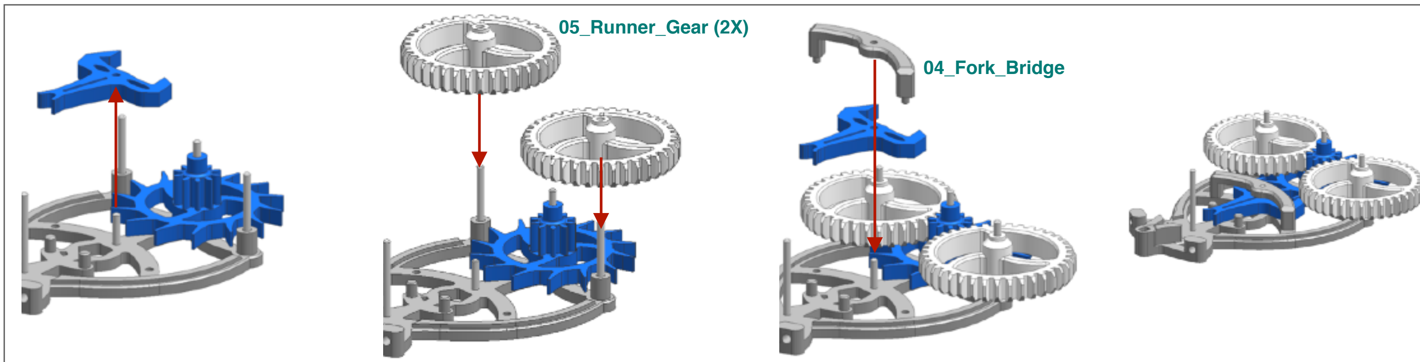
The **reduced** variant should be the safest design where locking faces and clearances are maximized. Negative locking face angle is also introduced to further reduce risk of slipping. All those of course comes with the expense of efficiency reduction but it will be able to comply to a greater degree of printing and assembly inconsistencies.



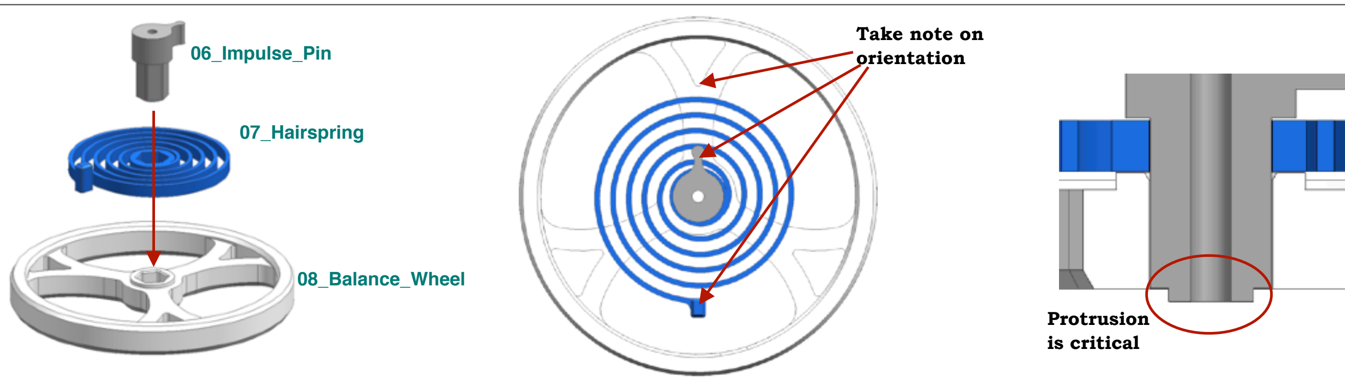
3) Inspect the escape wheel - fork engagement. while constantly applying a light force to rotate the escape wheel in a clockwise direction as shown above, Swing the fork to either of the position and check the escape wheel contact. This is called the locking contact. There should be sufficient visual contact between the wheel and teeth. the escape wheel should not be able to rotate when the fork is either of the positions shown above. Simulate all 9 positions of the fork + wheel as explained in section 1.1 above and inspect the gaps.

Common issues and recommended solutions:

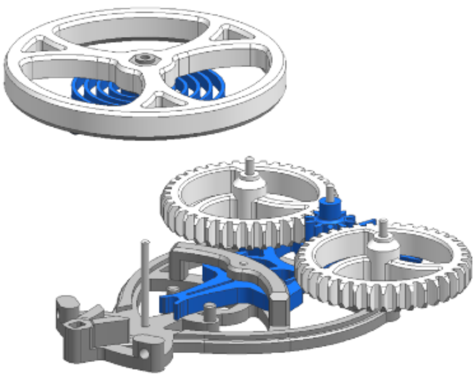
- **Insufficient locking contact** indicates that the printed parts are on the small side or the features are not sufficiently well defined. Try increasing extrusion multiplier to compensate for the smaller dimensions, Print slower or use a smaller nozzle diameter.
- **Escape fork and wheel jamming** indicates that the printed parts are on the large side. it is usually caused by elephant's foot or blobs and stringing. try to identify the areas where jamming occurs and slightly trim the escape fork or wheel. Reducing the extrusion multiplier and printing temperature could also help

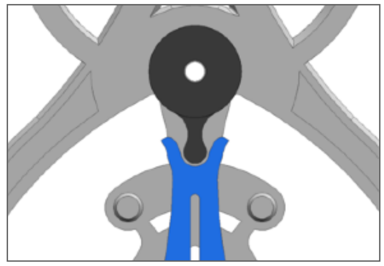


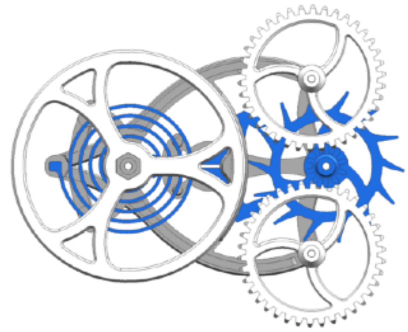
4) Remove the fork and insert the 2X runner gears. Give the gears a spin to ensure that all gears are meshing smoothly. They should rotate freely for awhile after given a spin. Insert the fork followed by fork bridge.



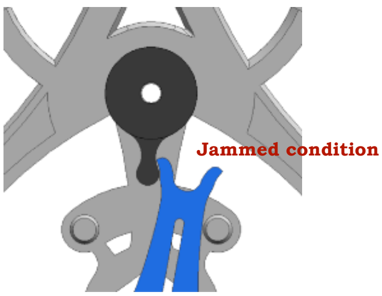
5) Insert impulse pin through the hairspring and balance wheel. Some force will be needed to assemble these parts as they are meant to be tightly fitted with no clearance. Take special note on the relative orientation of the 3 parts. The hairspring should be fully wedged between the balance wheel and impulse pin. The pin should slightly protrude from the balance wheel

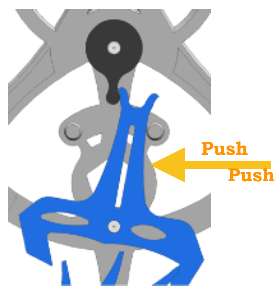


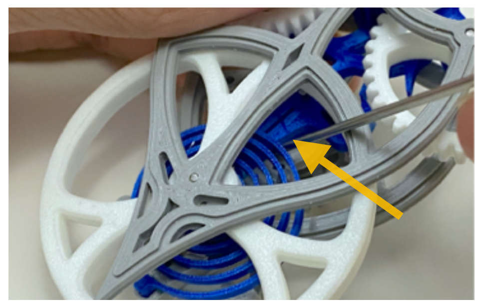




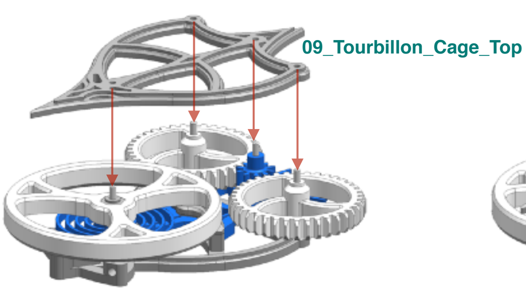
6) Insert the assembly from step 5 onto the base. Make sure the impulse pin is seated inside the fork opening as shown in the second illustration above. Try rotating the runner gears counter clockwise with minimal force as viewed from the top. If everything is right, the escapement mechanism will start ticking.

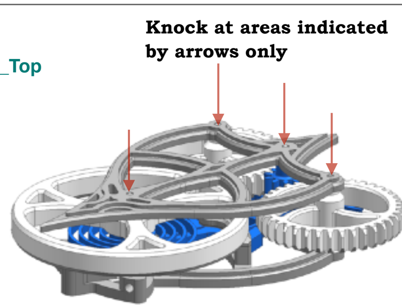


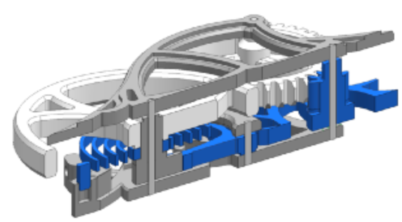




7) Manual interaction with the escapement mechanism will occasionally cause the fork to be jammed relative to the impulse pin. This happens when the impulse pin rests outside the fork as shown above. the simple fix for this would be to take a long 1.5mm pin and give the fork a nudge in the direction shown (or vice versa) all the way to the other side. This will relocate the impulse pin back into the fork.

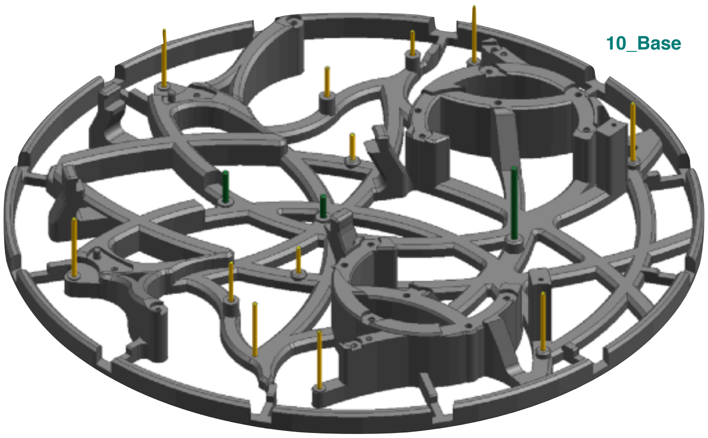


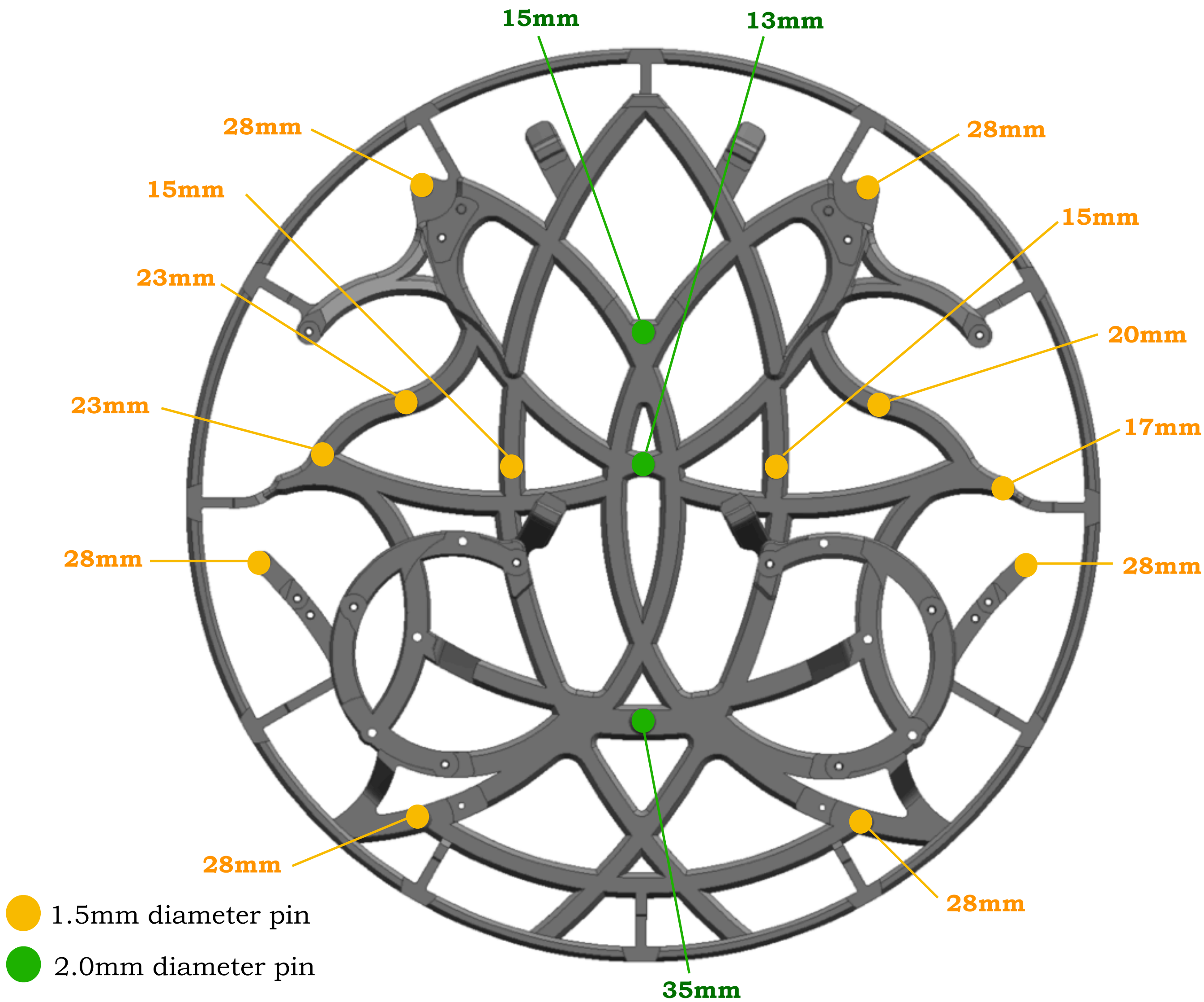




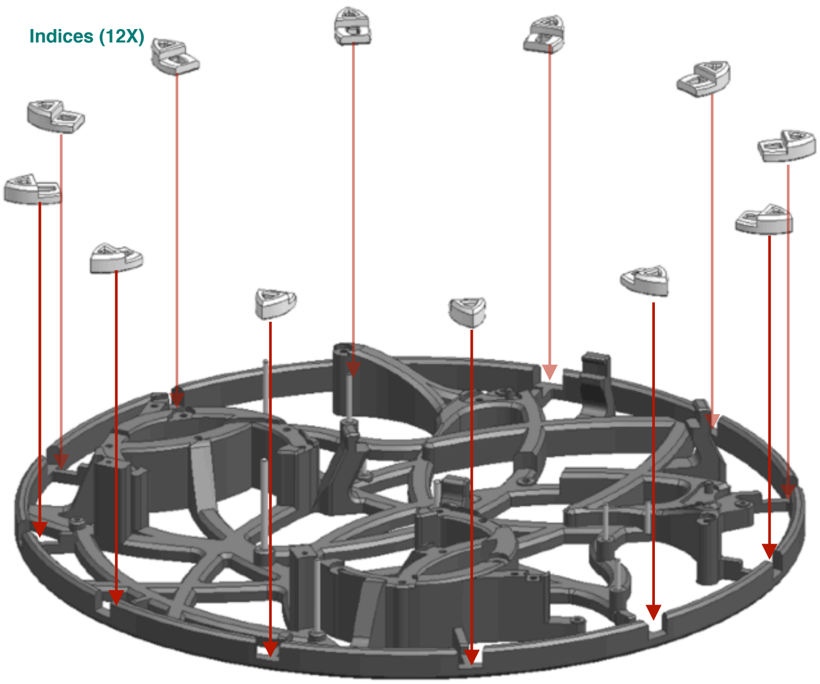
8) Place the base assembly on a flat rigid surface and align the Tourbillon top cage holes to the pins as illustrated above. use a small hammer or allen wrench to gently knock on top cage directly above the pin holes till the top cage fully sits flushed with the pins. There must be a small gap between the top cage and all other components beneath the top cage. Try rotating the runner gears CCW again, if the mechanism runs smoothly, The assembly is complete.

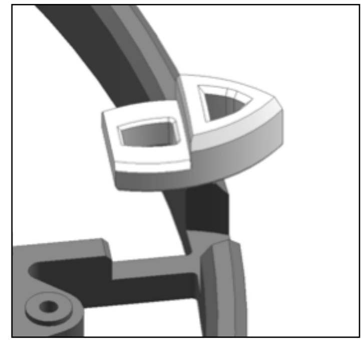
Part 2: Base

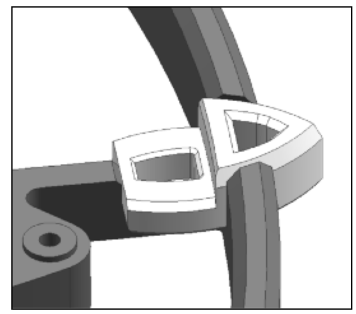




1) knock all the pins as specified above into the base. Note that the pin should be inserted all the way till the bottom side of the base. Ensure that all pins are straight and not tilted.

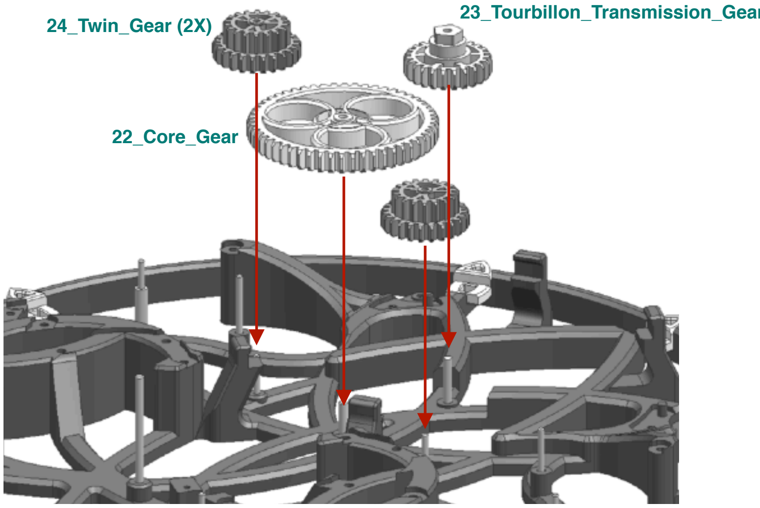


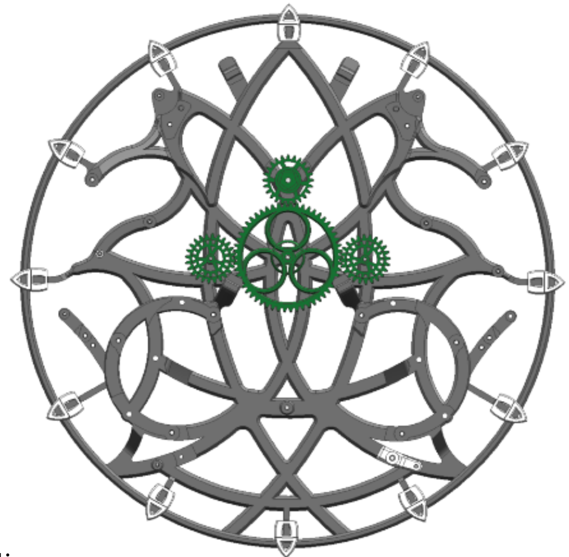




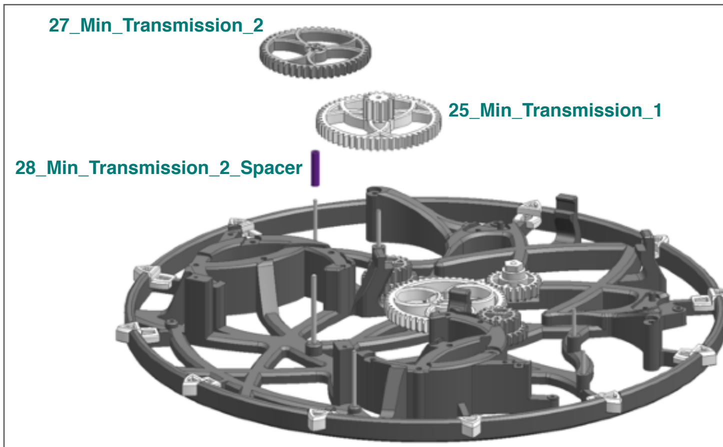
2) insert 12X indices to the designated slots on the base. They should click into place with some force. if some of the parts are loose, apply some super glue to fix it in place.

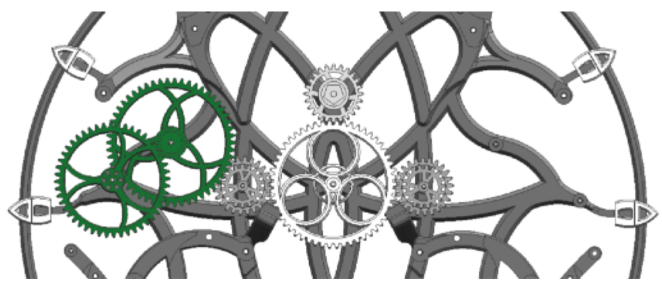
Part 3: Gear Train





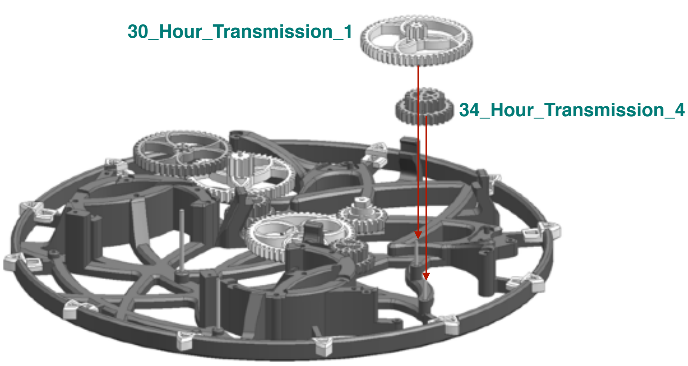
1) Insert the following gears to the designated pins as illustrated above in any desired order. The twin gear may require some fiddling to be inserted. Check that all gears mesh smoothly

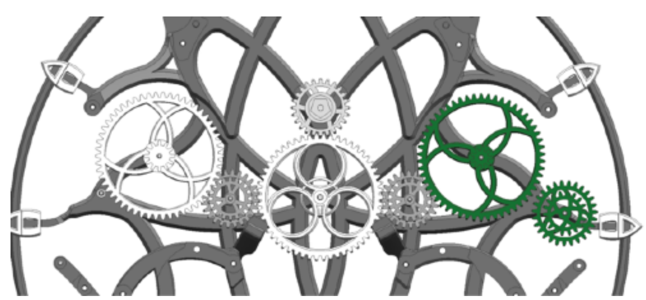




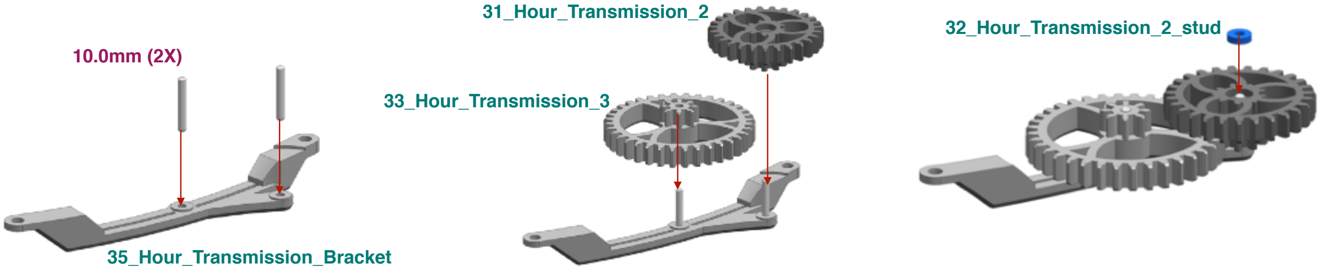
2) Assemble the listed parts above in the following order:

- 25_Min_Transmission_1
- 28_Min_Transmission_2_Spacer
- 27_Min_Transmission_2

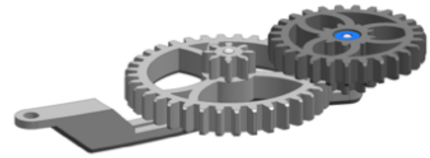


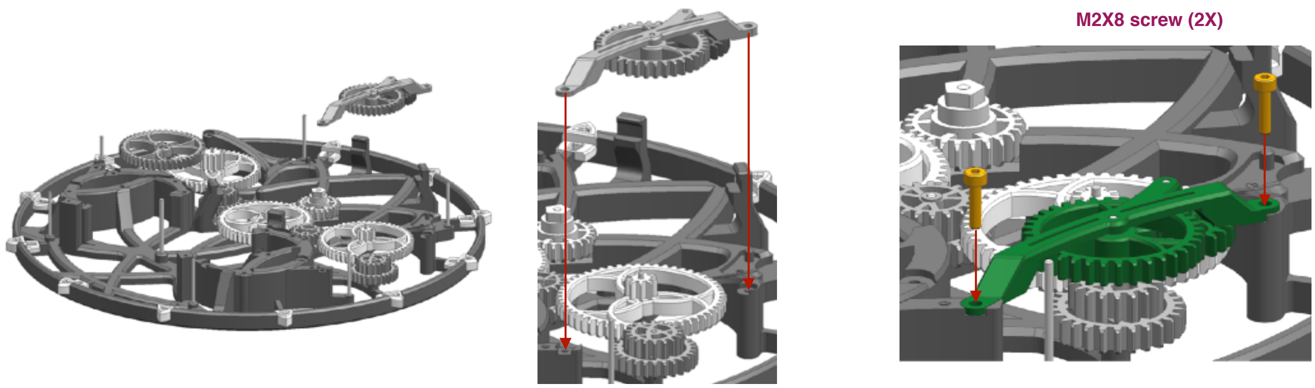


3) Assemble the hour gear trains

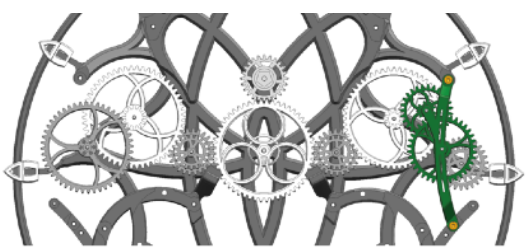


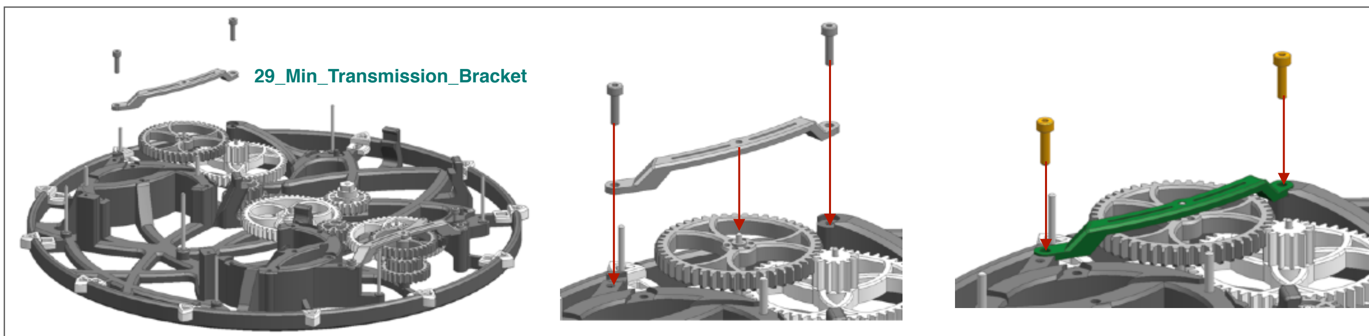
4) Insert the 1.5mm diameter pins into the Hour Transmission Bracket. Insert the gears followed by a stud for Hour Transmission 2 gear. If the stud is loosely fitted to the pin, apply some glue to secure it, ensuring that both gears can still rotate freely



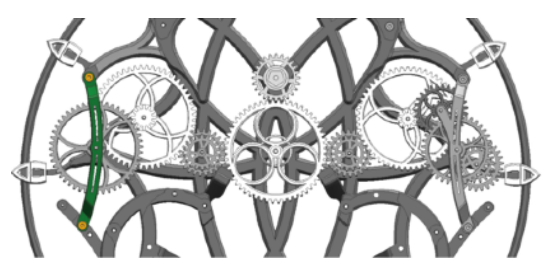


5) Assemble the parts in step 4 onto the base. The hour transmission bracket should sit into the matching feature on the base. Secure the Bracket with 2 M2X8 screw. All threads are printed into the model. Apply some force while driving the screw into the base. Do not over-tighten the screws as it will wear off the printed threads. This applies for all other screws.

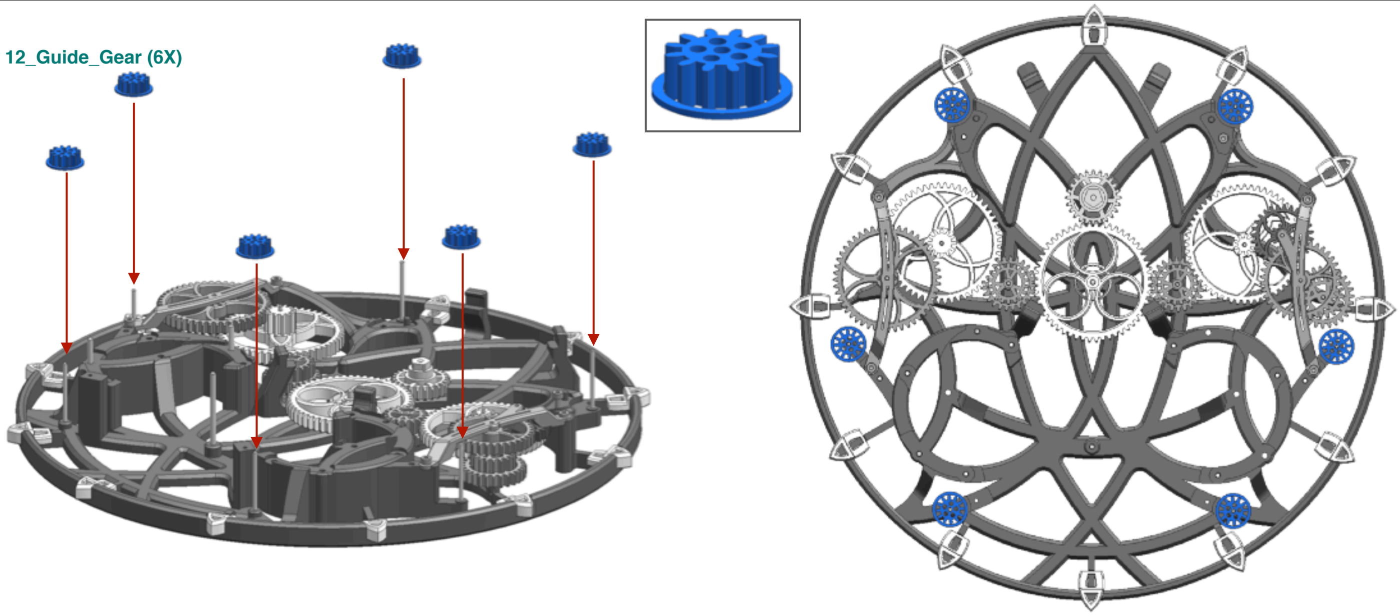




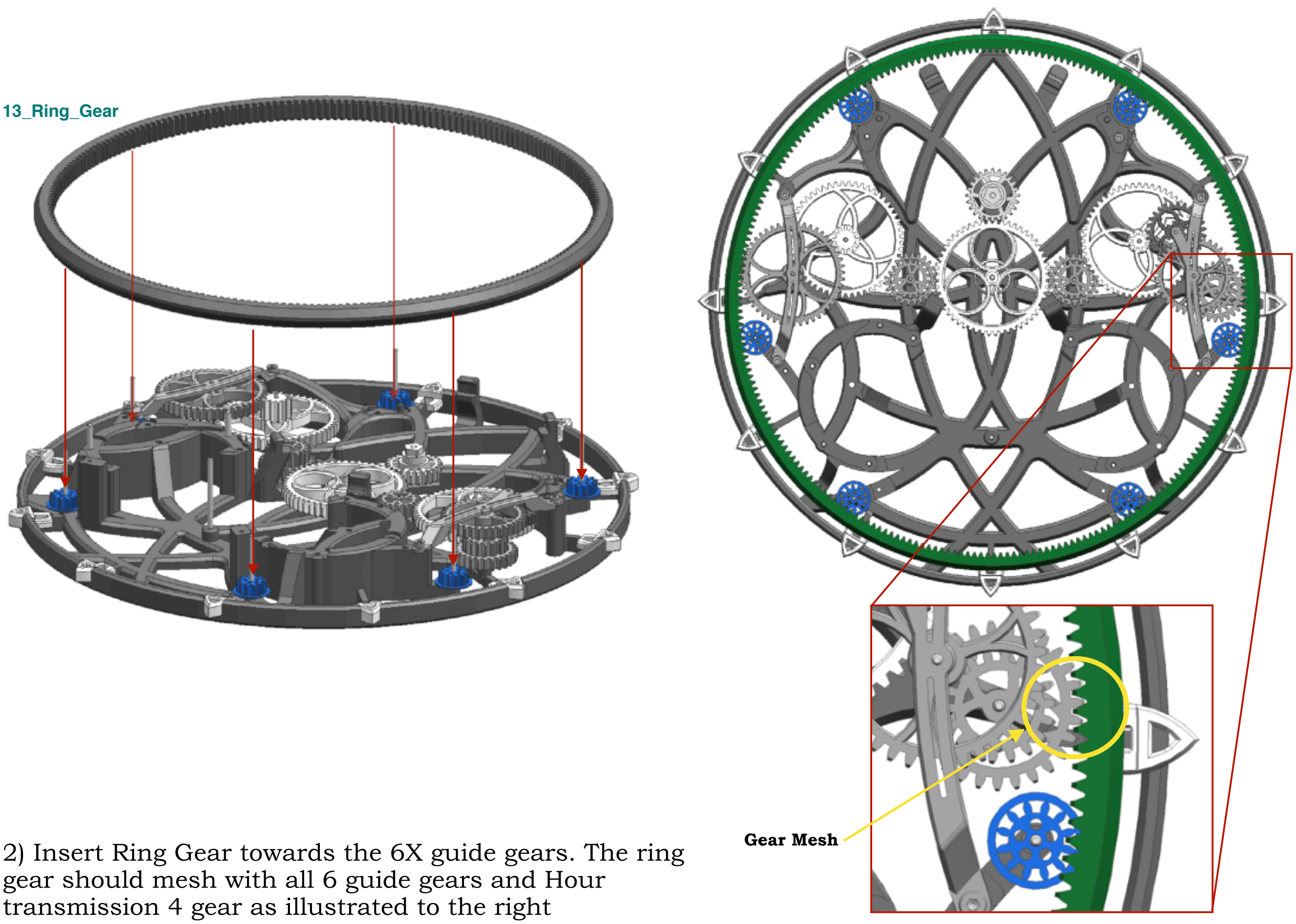
6) Assemble the minute transmission bracket and secure it with M2X8 screws. Perform a final check to ensure that the gear trains can mesh and rotate smoothly.



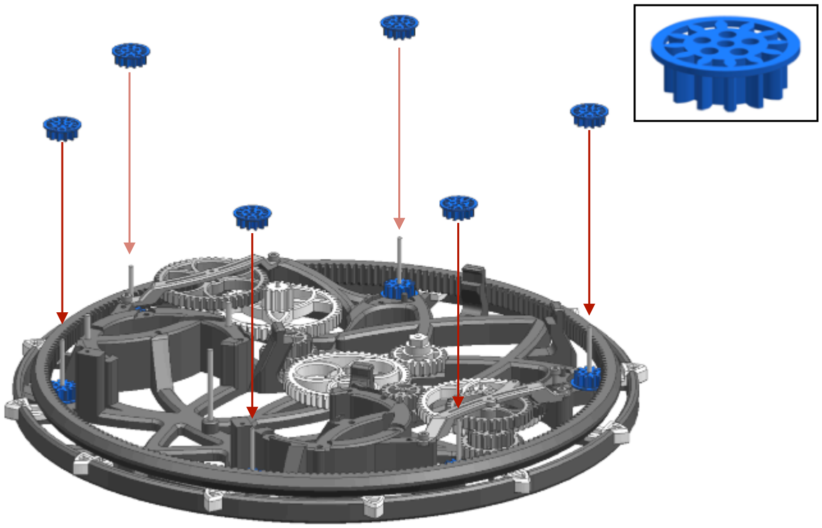
Part 4: Minute and Hour Ring

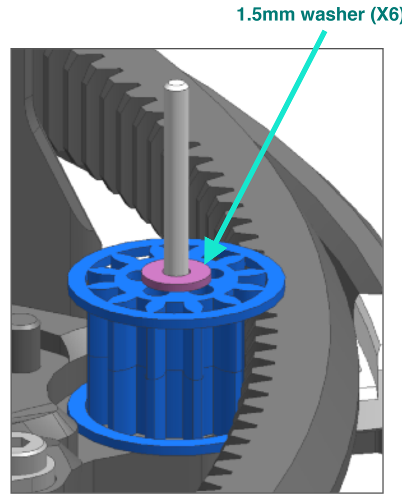


1) Insert 6X guide gear into the pins as indicated above. Take note on the orientation of the guide gears

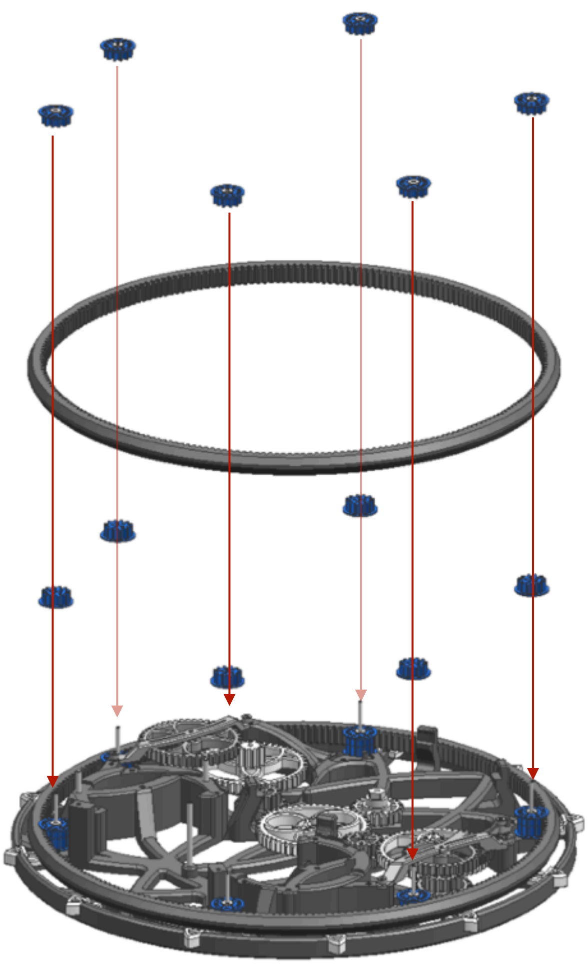


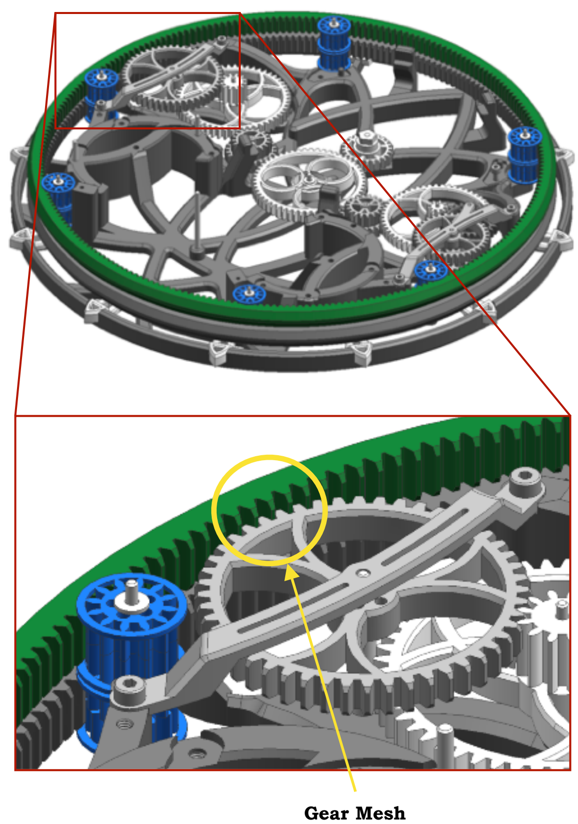
2) Insert Ring Gear towards the 6X guide gears. The ring gear should mesh with all 6 guide gears and Hour transmission 4 gear as illustrated to the right



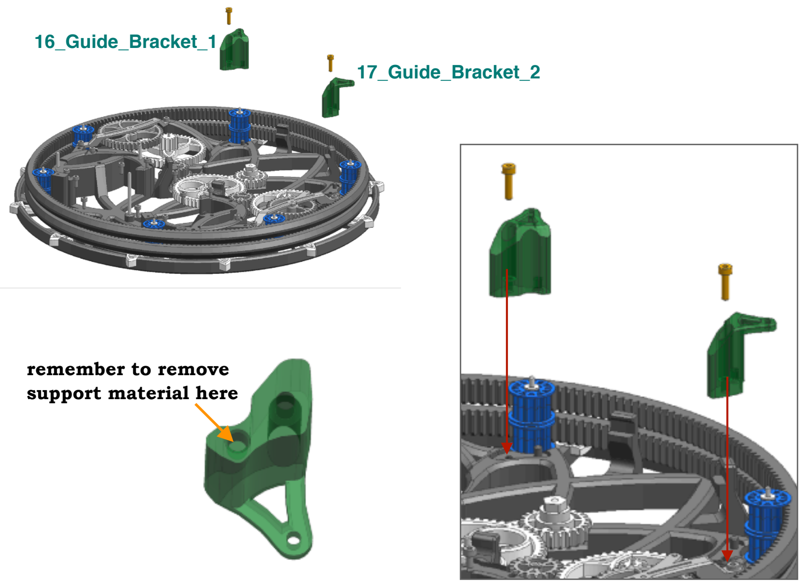


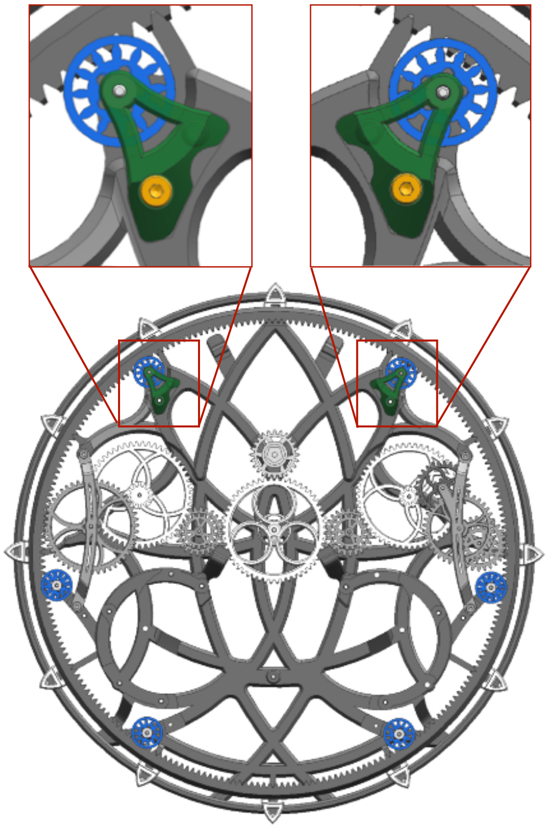
3) Insert 6X more guide gears with opposite orientation followed by 6 1.5mm washers



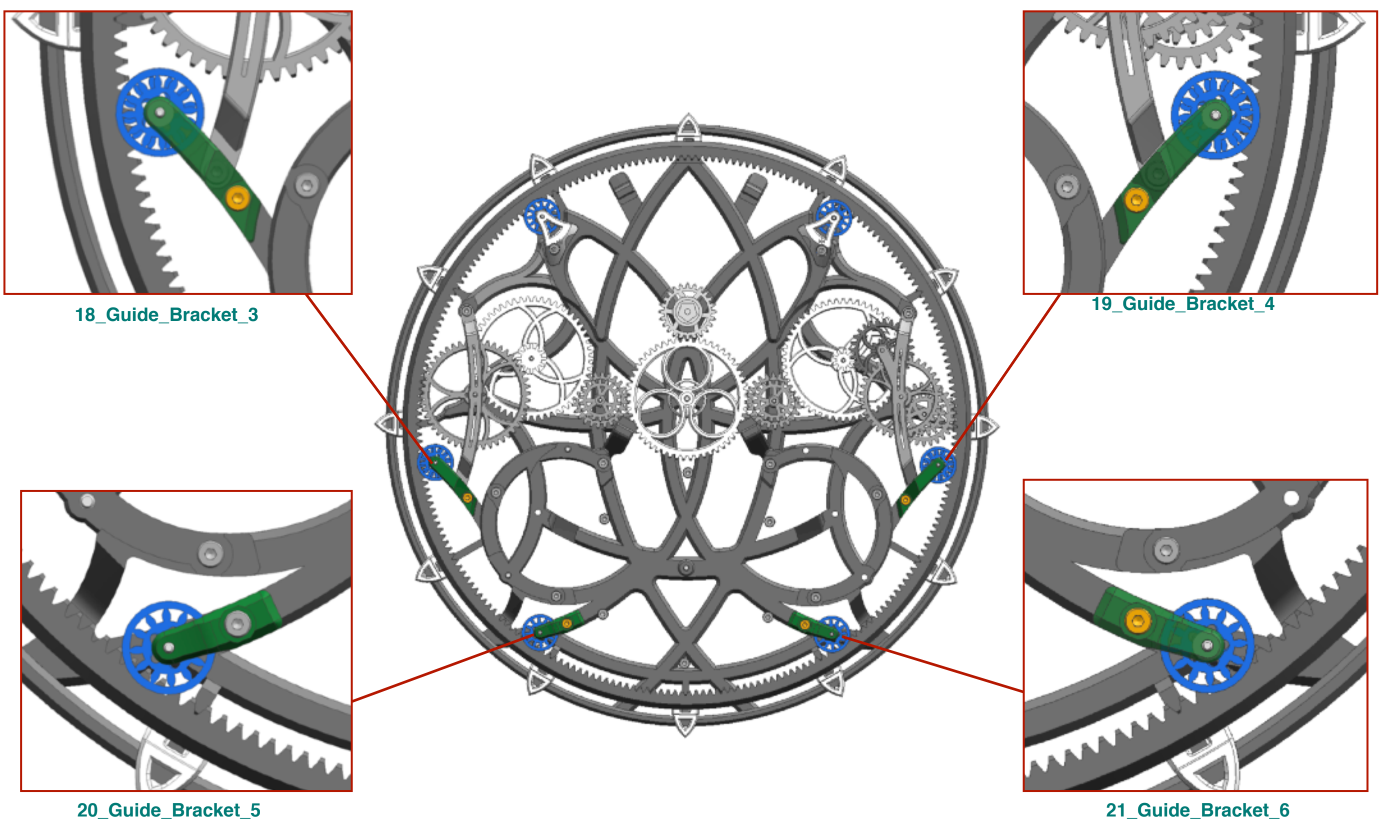


4) Repeat steps 1-3 for the second ring gear. This time, the upper ring gear will mesh with the minute transmission 2 gear



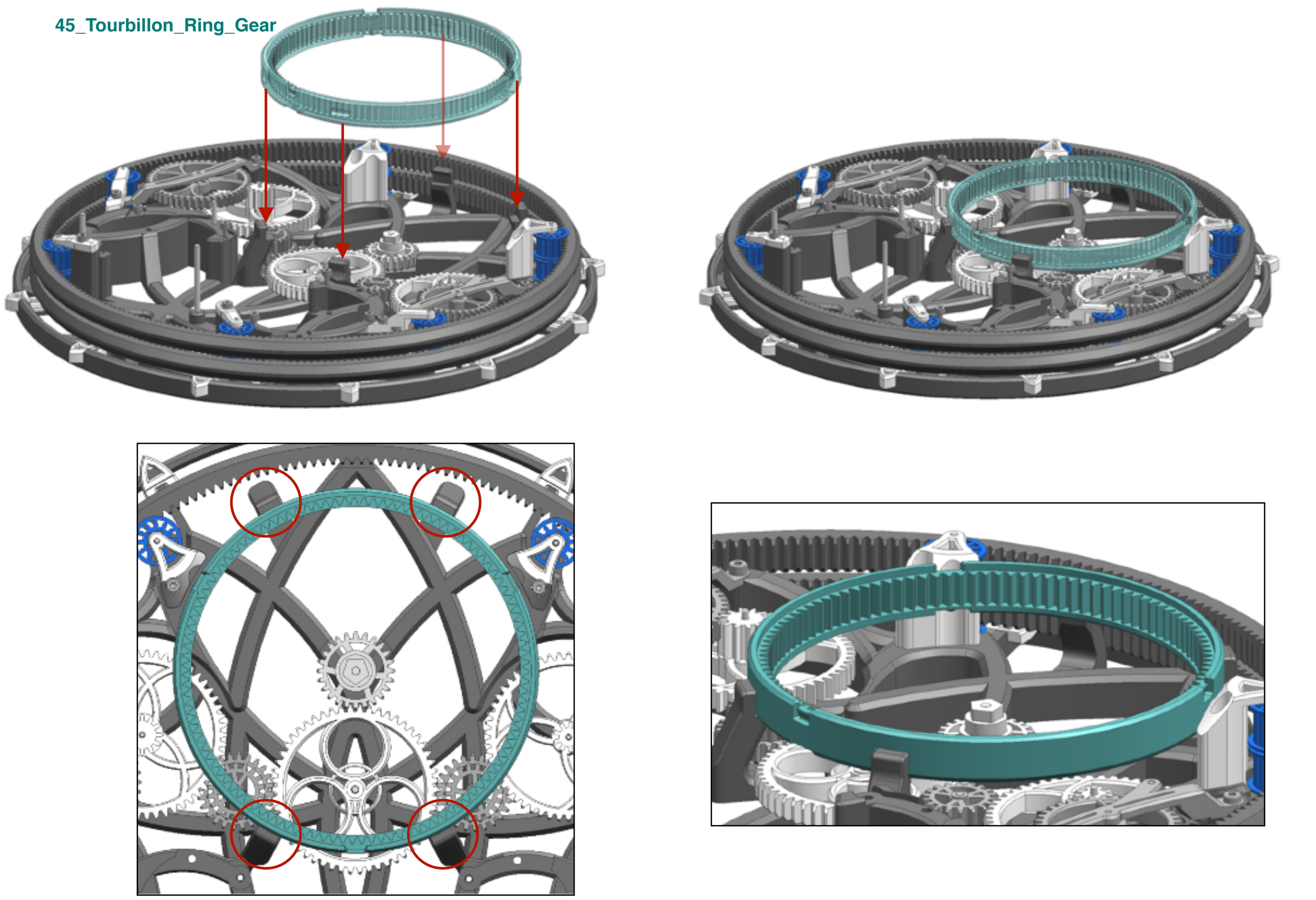


5) Assemble the top two guide gear brackets and secure them via M2X8 screws as illustrated. Take note of the orientations and there is a locating hole below the brackets. Ensure that support material is removed from the hole.

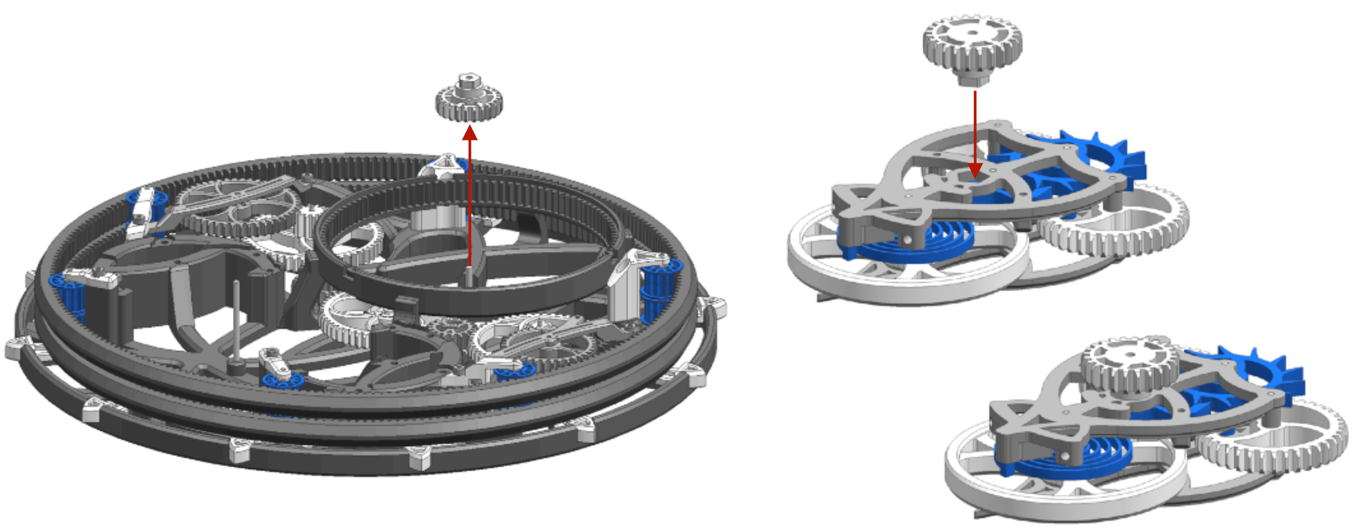


5) Assemble the remaining guide gear brackets followed by M2 screws in a similar fashion as step 5. Ensure that all guide gears are not being clamped and can freely rotate.

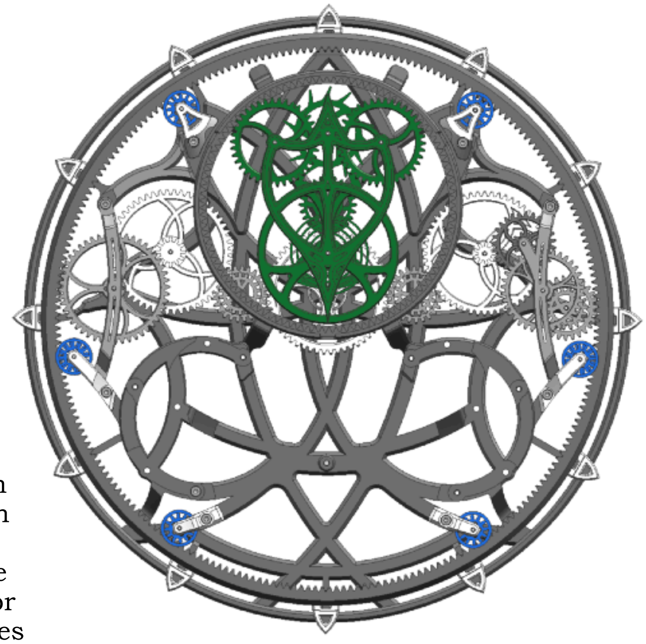
Part 5: Tourbillon Assembly



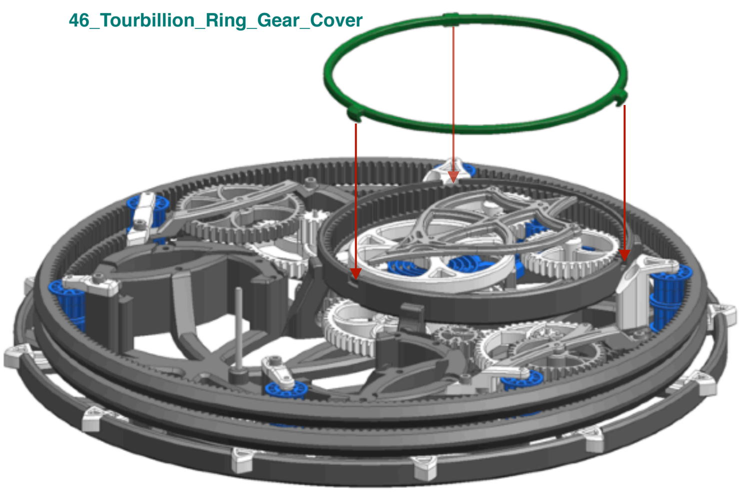
1) Insert the Tourbillon Ring Gear onto the base. The exposed gear teeth side of the cage must be facing upwards. Gently snap the ring gear into the clamping features

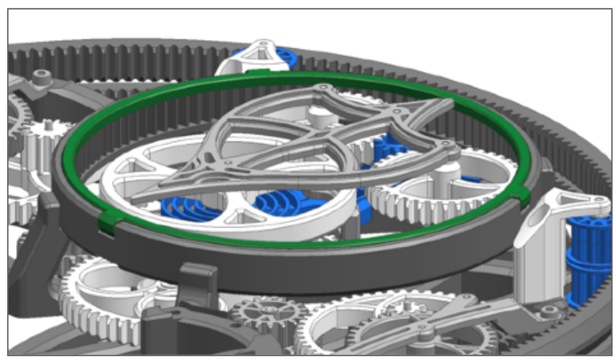


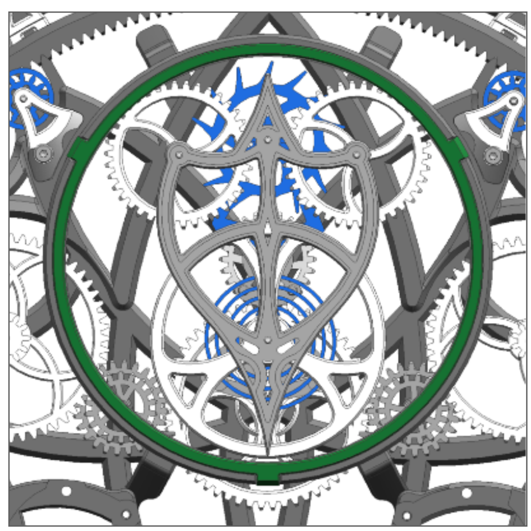
2) Remove the tourbillon transmission gear and insert it into the escapement assembly bottom base from part 1. This gear needs to have a tight fit towards the tourbillon bottom base. Apply some glue if the fitting is loose



3) Insert the escapement mechanism back into the tourbillon transmission gear pin. The 2 runner gears on the escapement mechanism should mesh smoothly with the tourbillon ring gear. Try rotating the escapement mechanism clockwise and you should be able to see the tourbillon mechanism in motion. Remember to check for escape fork jamming (Part 1 step 7) if the movement does not initiate.



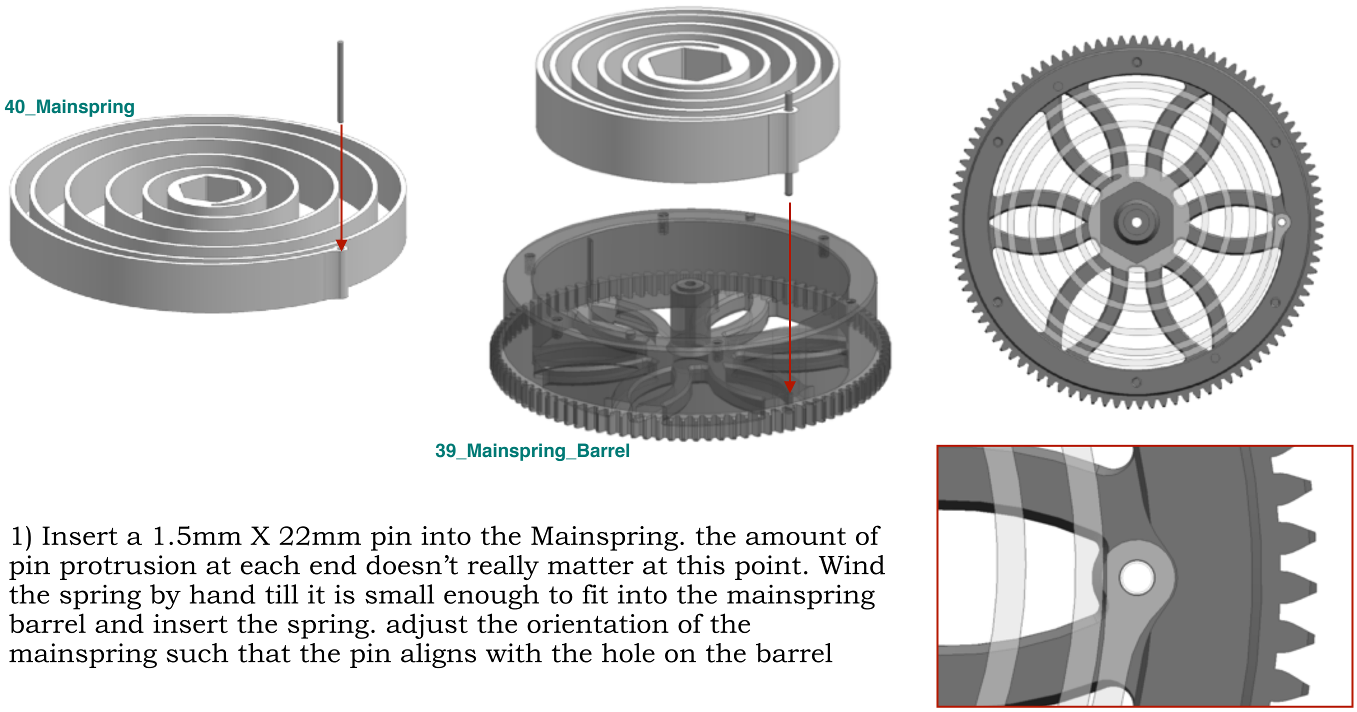




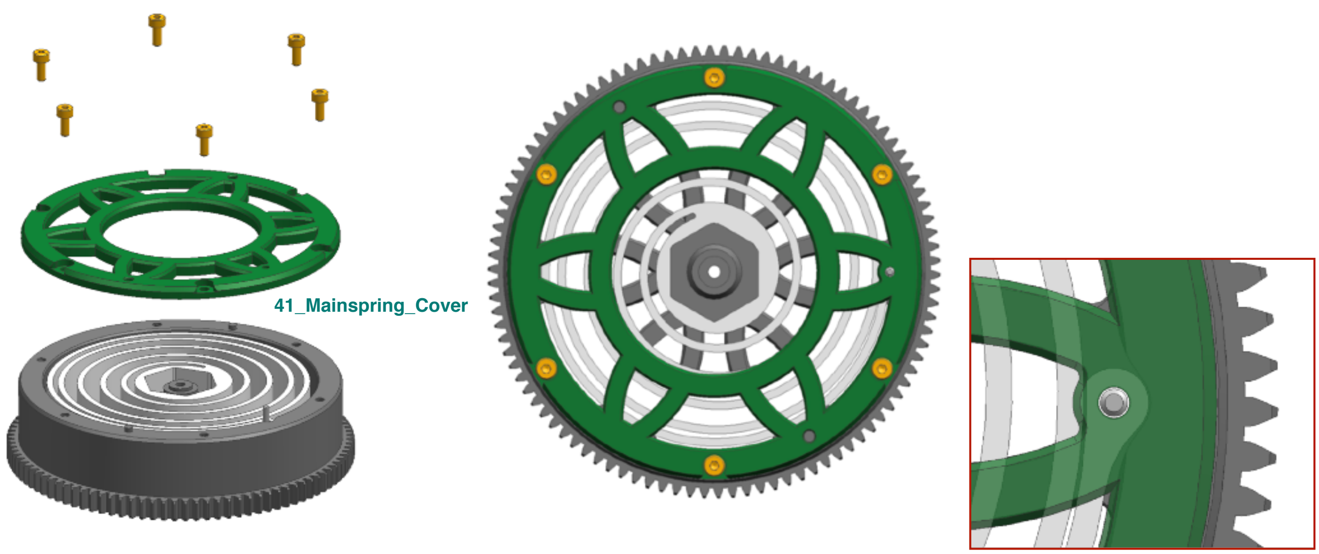
4) Insert the Tourbillon ring cover. It should snap into the 3 slots on the tourbillon ring gear. Be gentle on the assembly as the ring cover is a delicate part. The snapping features breaks easily and if that happens, just apply some super glue to hold the parts in place.

Part 6: Mainspring Barrel

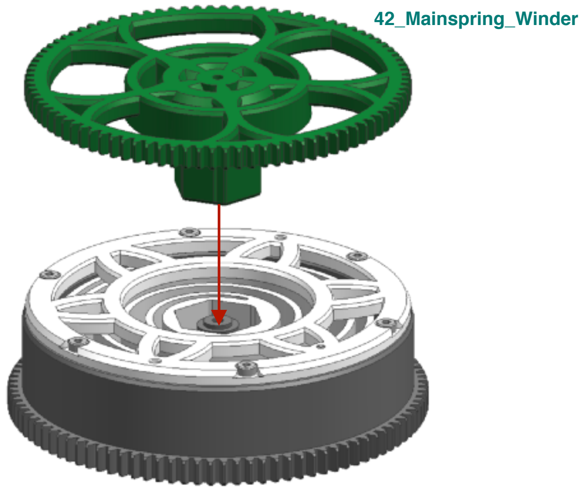
Option 1 - 3D Printed PETG Spring

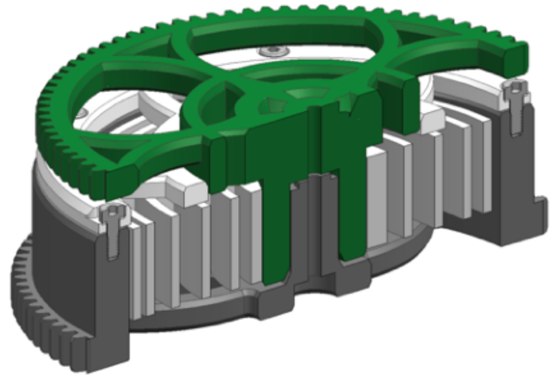


1) Insert a 1.5mm X 22mm pin into the Mainspring. the amount of pin protrusion at each end doesn't really matter at this point. Wind the spring by hand till it is small enough to fit into the mainspring barrel and insert the spring. adjust the orientation of the mainspring such that the pin aligns with the hole on the barrel

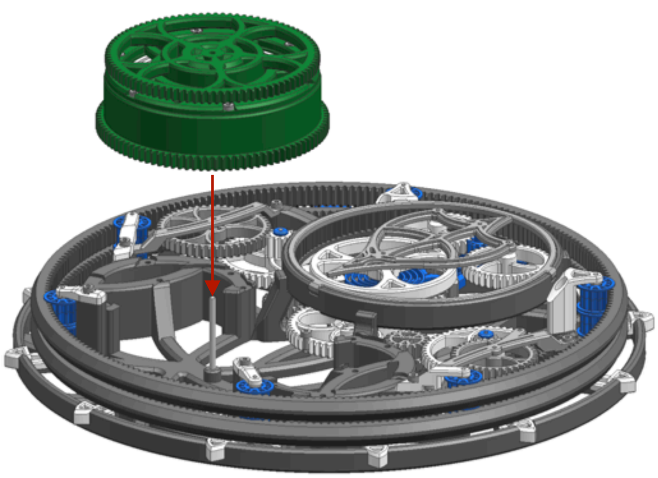


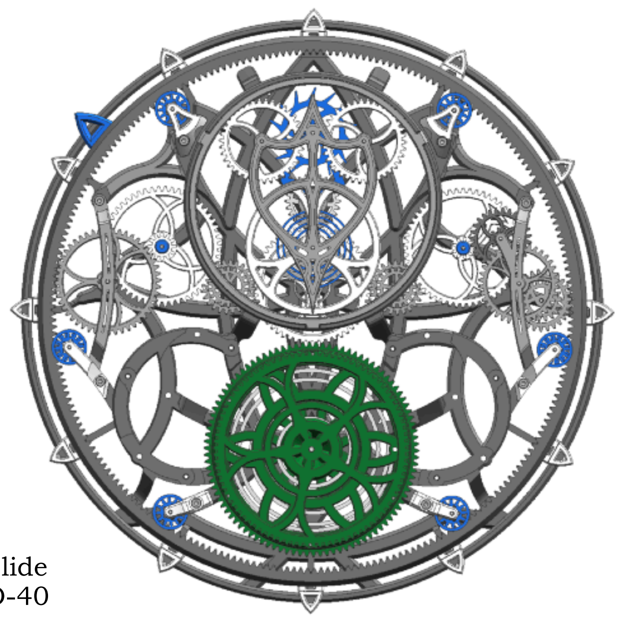
2) Assemble the Mainspring Cover with 6 M2X5 screws there is a pin hole on the cover that needs to be aligned to the mainspring pin.





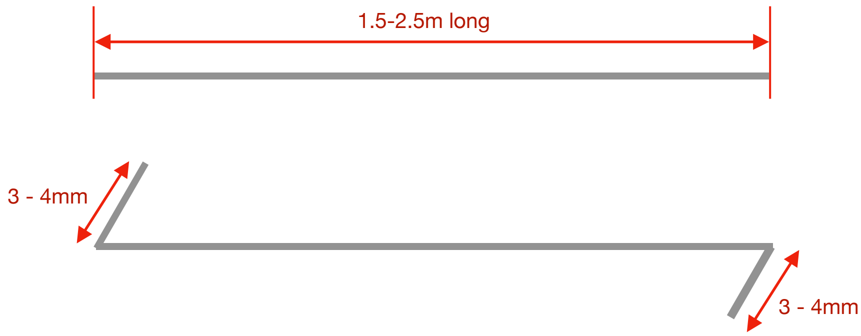
3) Insert the mainspring winder into the hexagonal opening of the mainspring. The fitting could be slightly loose and its fine that way

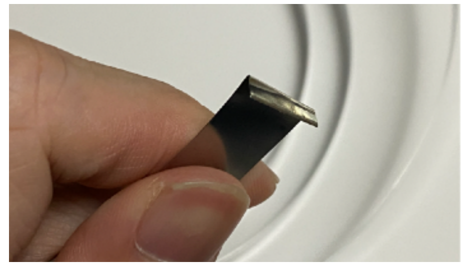




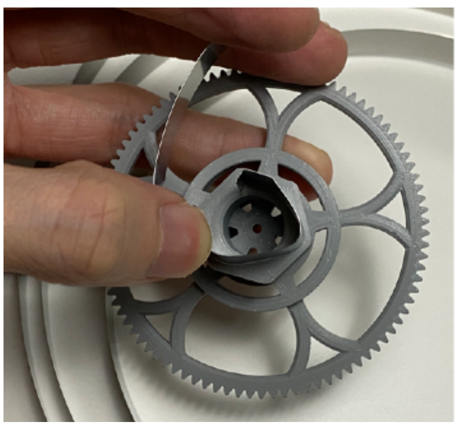
4) Insert the mainspring assembly to the base. it should slide into the mainspring pin smoothly. Apply some grease/WD-40 on the pin for lubrication if needed.

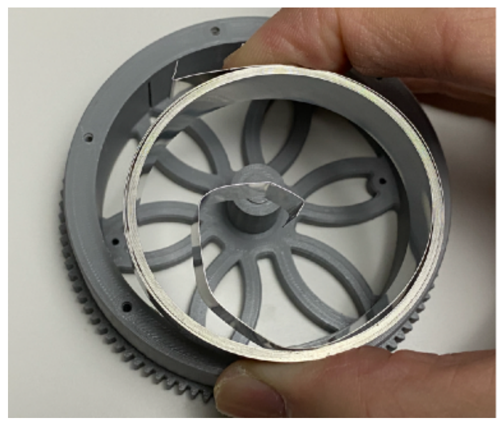
Option 2 - Steel Spring



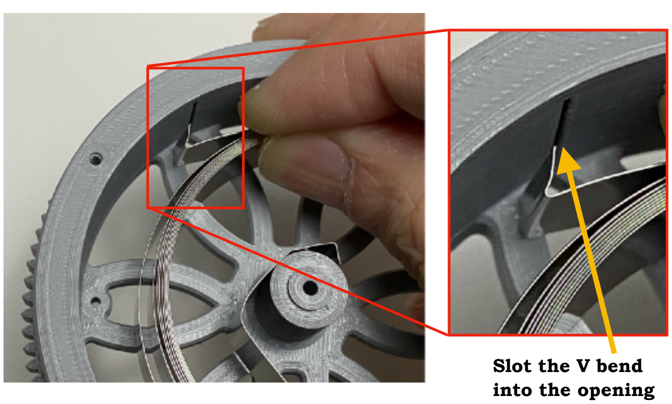


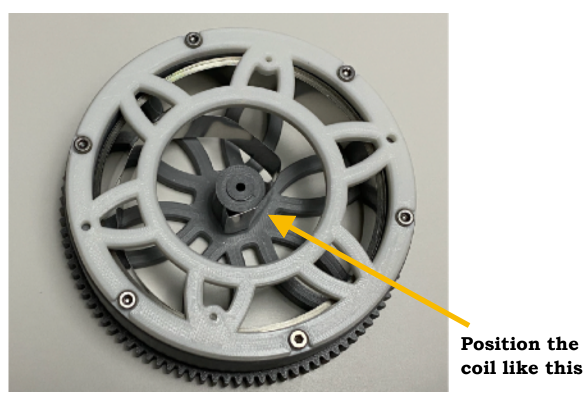
1) Use approximately 2-3m of the 0.2mm thickness coil spring and make 2 V bends on each end using hand pliers or any other suitable tools as illustrated above



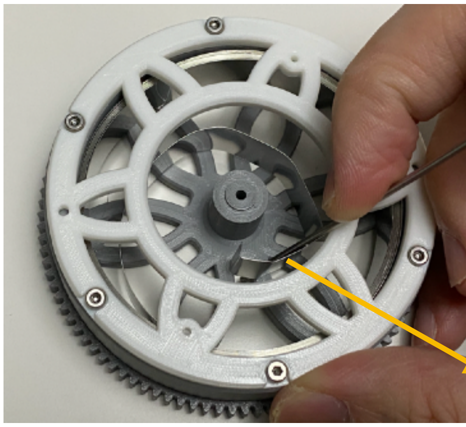


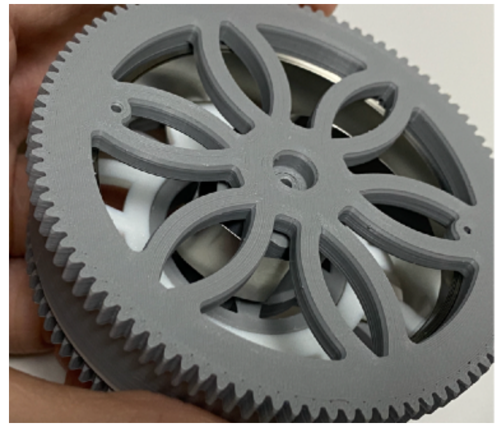
2) Make another loop on either end of the coil. This loop does not need to be a perfect circle as long as it is smaller than the hexagonal feature on the winding gear as shown above. Coil the springs into a small circle till the entire coil is smaller than the mainspring barrel. Take note of the direction of the coil as illustrated.





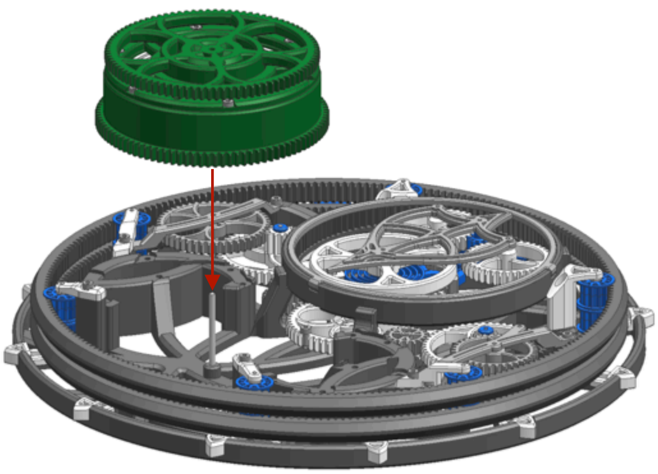
3) Insert the mainspring into the barrel and tuck the V bend on the outer side into the slot on the barrel. Assemble the mainspring cover by referring to option 1 step 2. The other end of the coil should be positioned in the middle of the barrel as shown above.

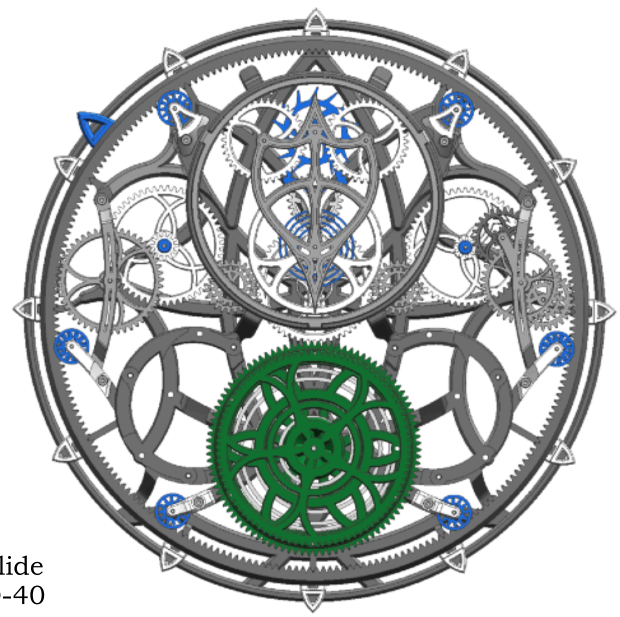




Open up the coil to make room for mainspring winder insertion

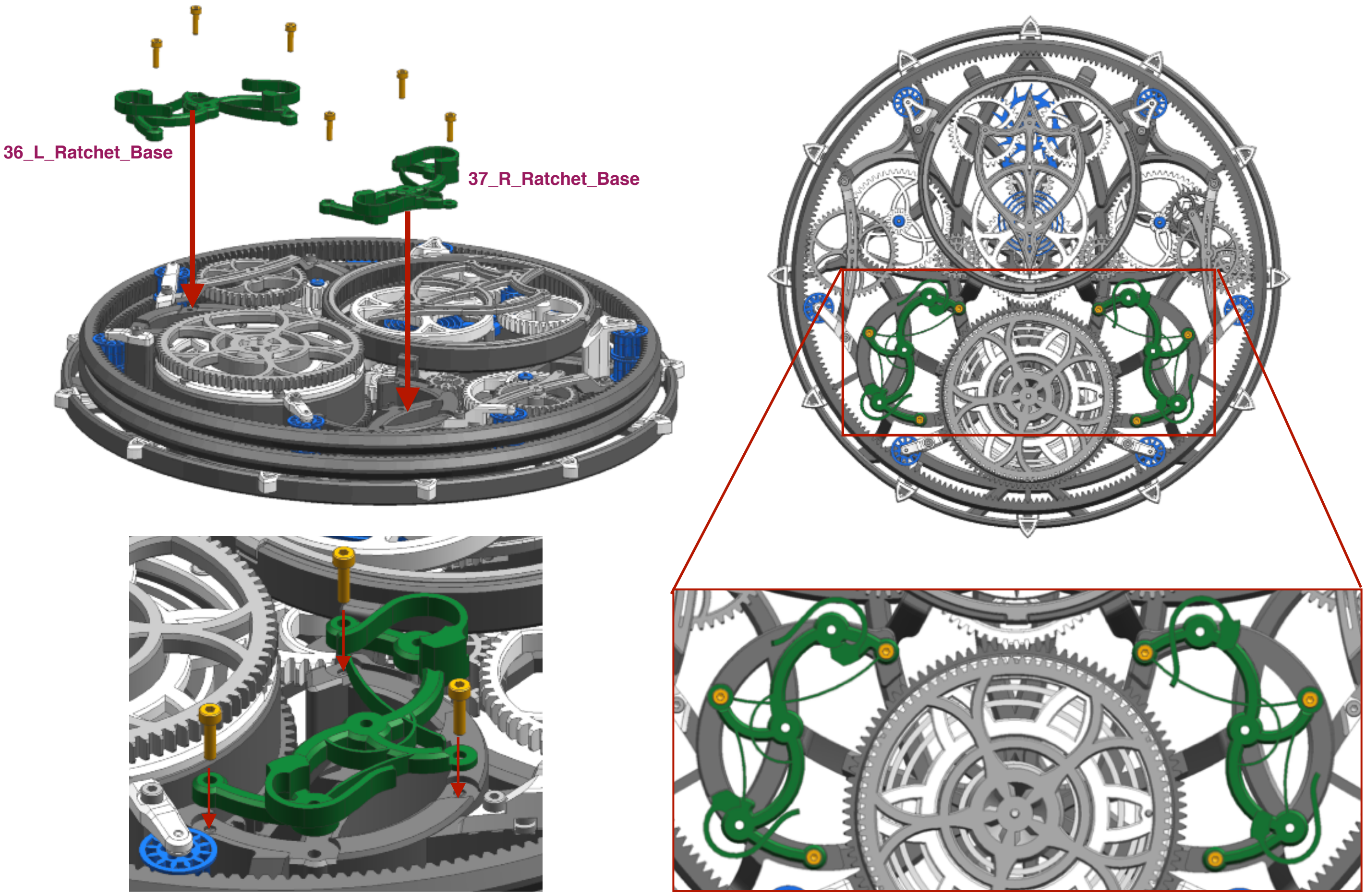
4) Use a long tool to open up the inner coil and carefully insert the mainspring winder (refer to step 3 for option 1). The coil should wrap around the mainspring winder hexagonal core. You can inspect and adjust the coil from the bottom side of the mainspring. The V slot does not need to be inserted into the slot on the mainspring winder. The tightening action of the coil will eventually guide the V bend to the slot as you wind up the spring.



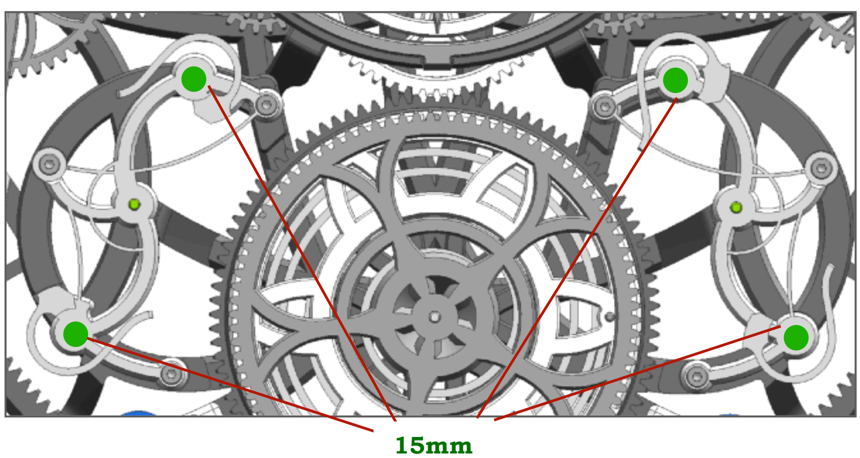


5) Insert the mainspring assembly to the base. it should slide into the mainspring pin smoothly. Apply some grease/WD-40 on the pin for lubrication if needed.

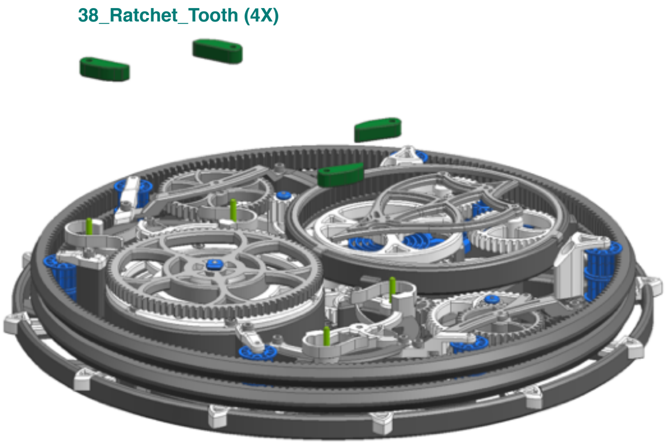
Part 7: Winding Mechanism

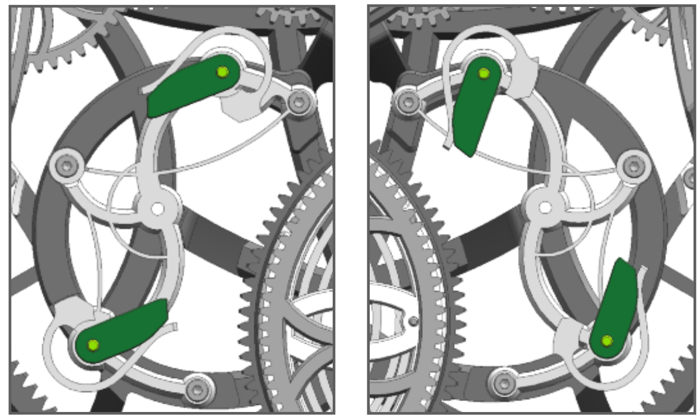


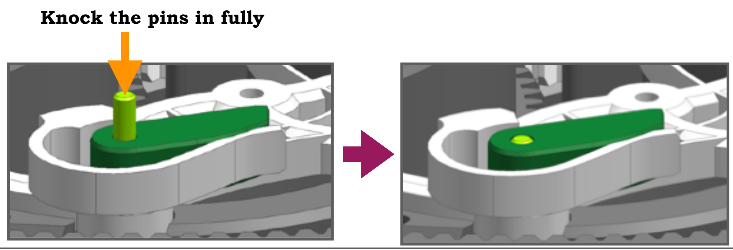
1) Assemble the Left and Right Ratchet Base with 3X M2X8 screws respectively. If the base does not sit too well into the features on the Base, use a small tool to knock the parts till it sits flat on the base.



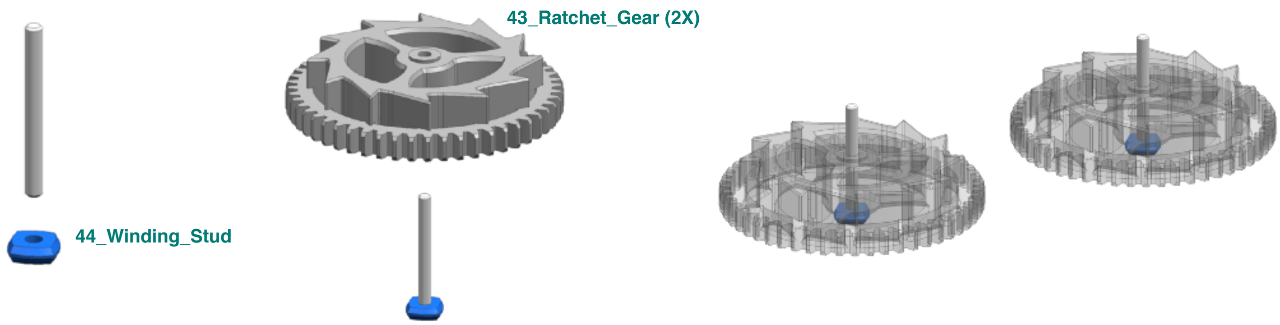
2) Knock in the 2mm diameter pins with specified lengths to the locations as illustrated above. Just insert the pins sufficiently for them to stay in place for now. We will fully insert these pins once the ratchet components are assembled



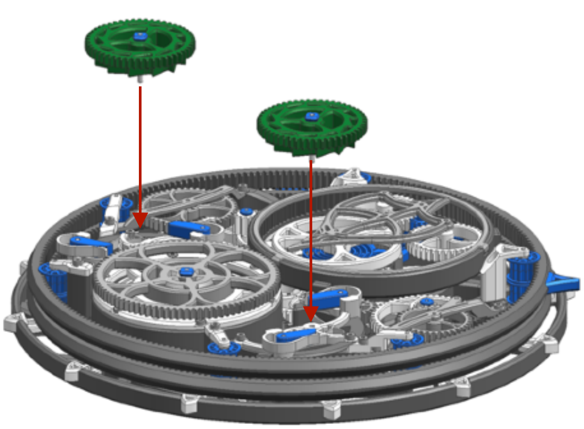


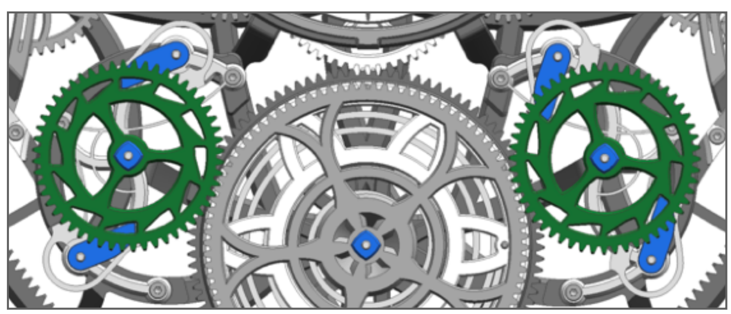


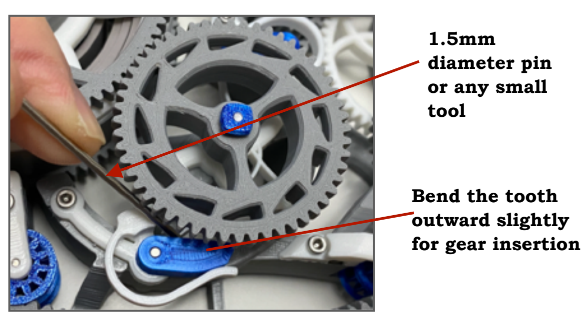
3) Insert the 4X ratchet tooth and knock the 4 pins till they are flushed with the tooth surface.



3) Insert studs onto two 20mm 2mm diameter pins. It should fit in tightly. Apply glue if they are loose. Slide the 2x ratchet gear into the pins and then insert the entire assembly into the ratchet base

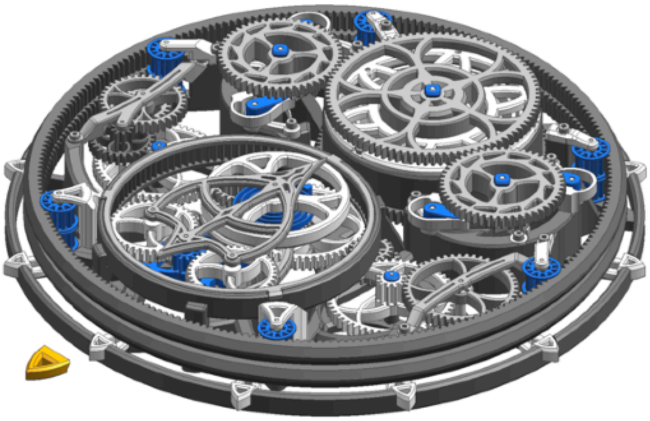


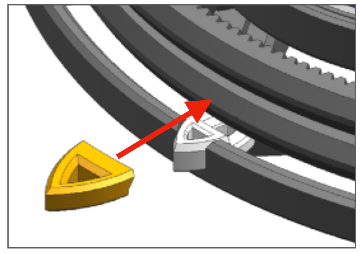


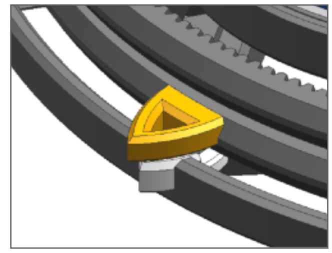


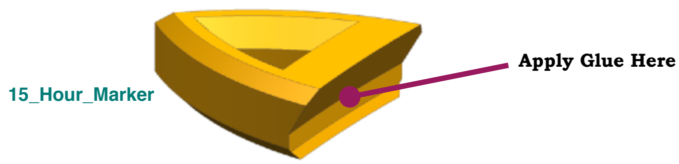
4) Assemble the ratchet gears into the base. Knock the pins into the base but make sure to leave some gap between the stud and ratchet gear to ensure that it is not clamped. U will need to use a long 1.5mm diameter pin to bend the tooth outwards to make space for the ratchet gear to be inserted

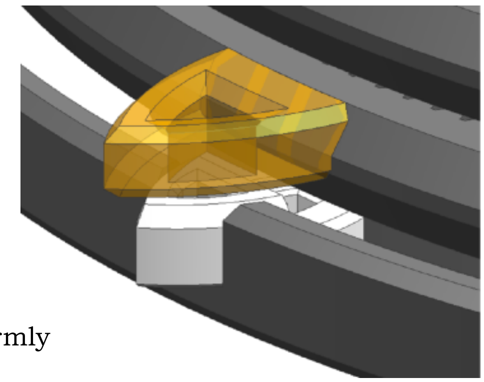
Part 7: Hour and Minute Marker



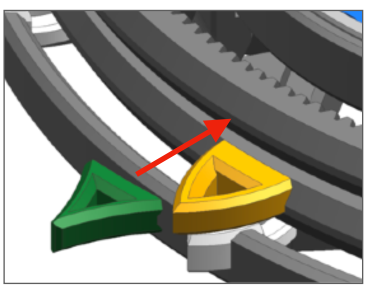


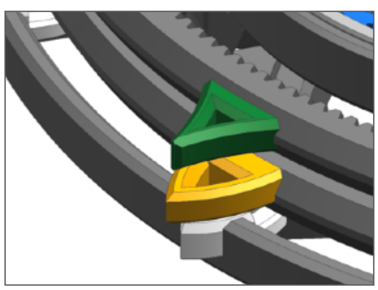


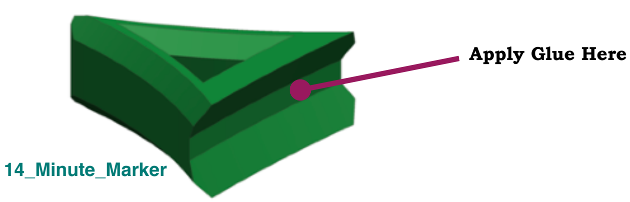


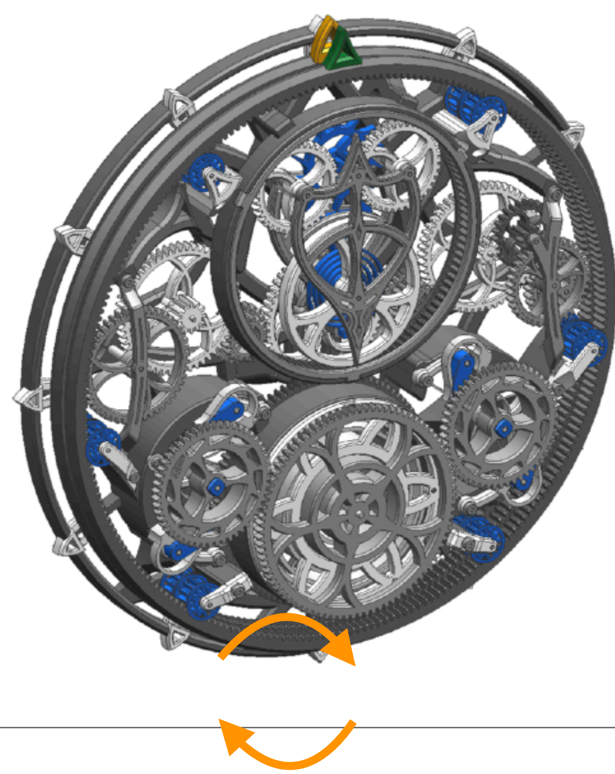


1) Apply some super glue to the hour Marker as illustrated and firmly attach the hour indicator to the bottom side ring gear at the 12 o'clock position. Take note of the orientation as it is not symmetrical.

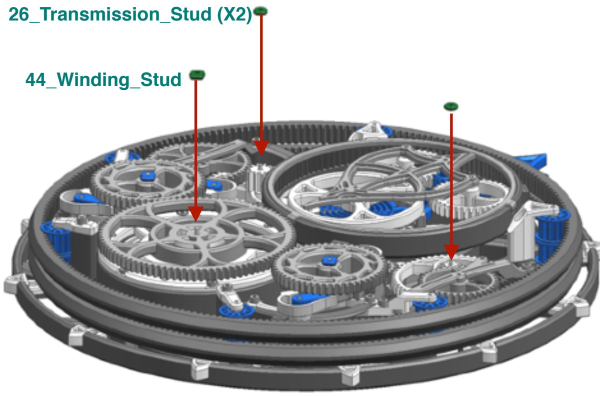


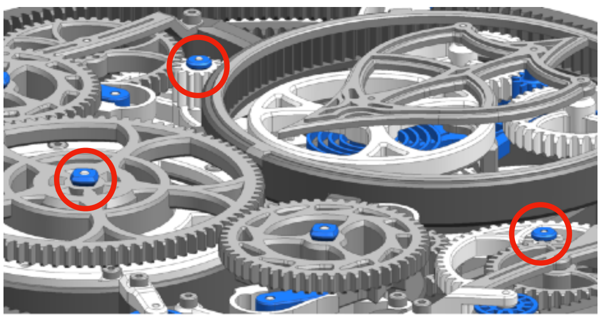


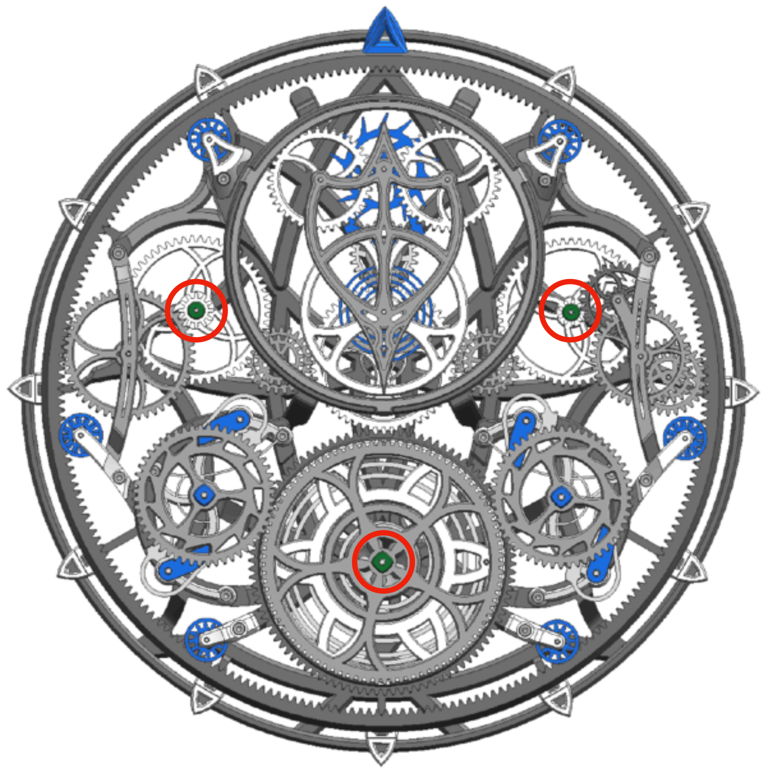




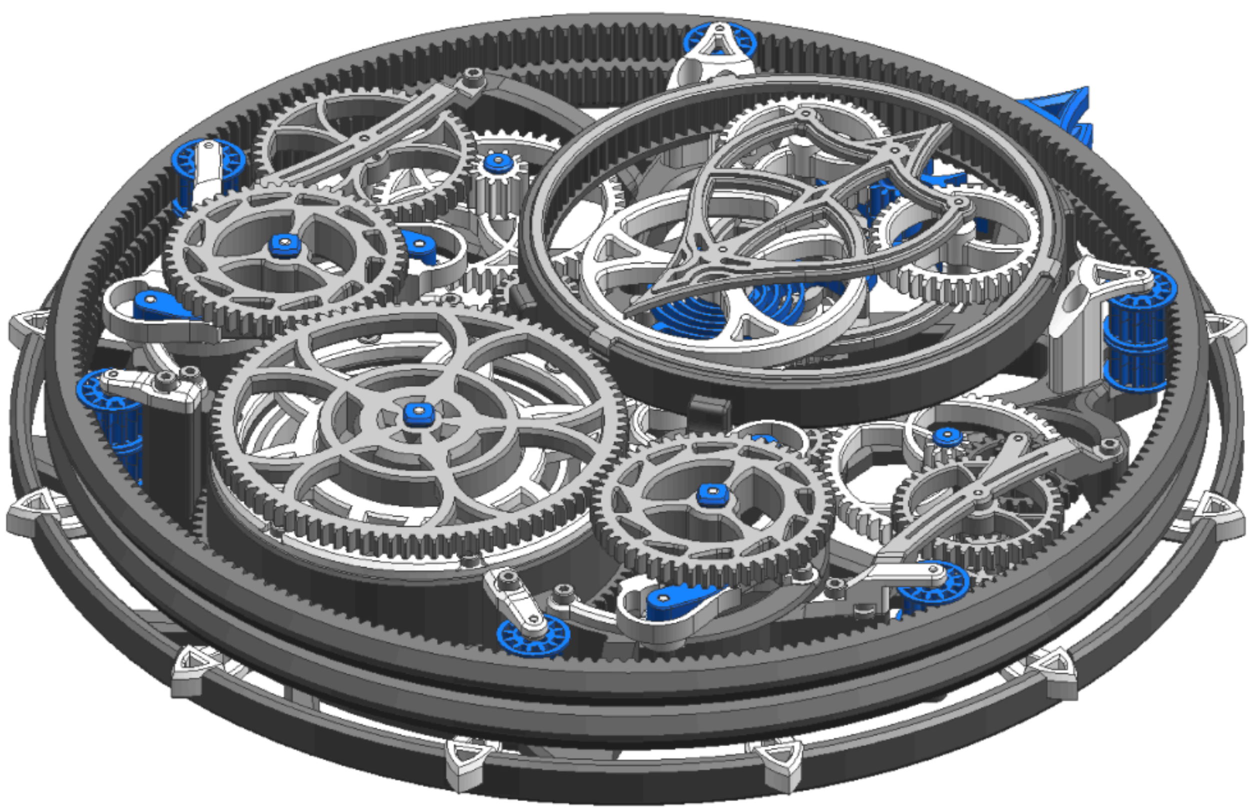
2) Repeat step 1 for the minute indicator. Attach it to the upper ring gear as illustrated. Be sure to attach it at the 12 o'clock position as well.



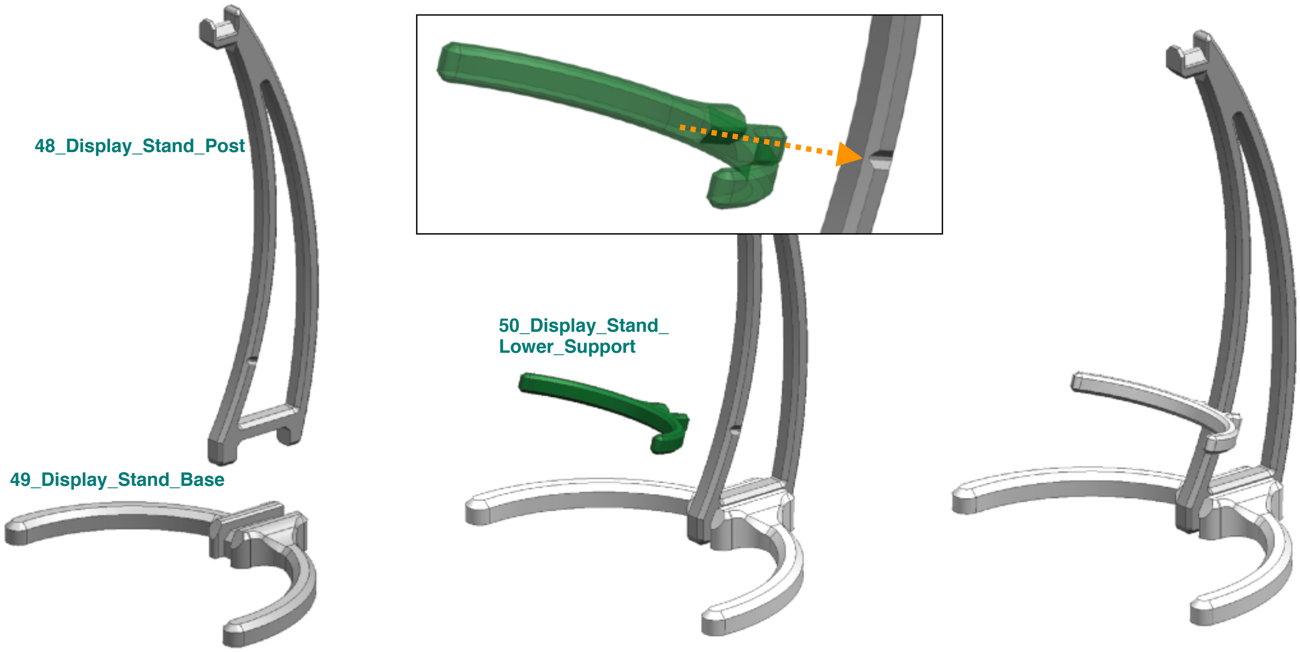




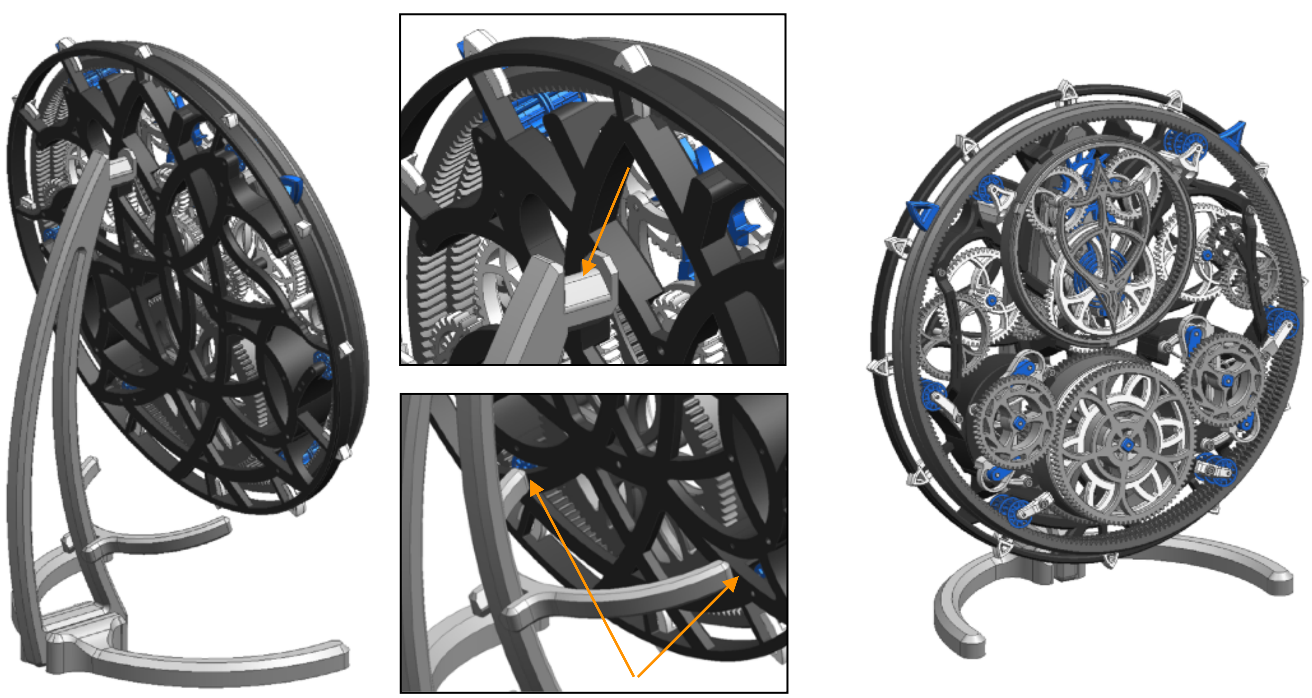
3) Attach the remaining studs for the minute transmission, hour transmission, and mainspring barrel as illustrated above. Be sure to maintain some gap between the stud and gear. The assembly is now complete! Give the winding gear several clockwise turns and the clock should start ticking.



Part 8: Display Stand (Optional)



1) Attach the stand post to the base. You might require to use some force to assemble them together, In the event that the assembly is loose, apply some super glue.
2) Assemble the display stand lower support to the post. There is a v groove feature on the lower support that matches the post. Slide the lower support with some force and apply some glue if necessary.



1) hang the clock assembly onto the upper hook and rest the bottom side of the base as illustrated

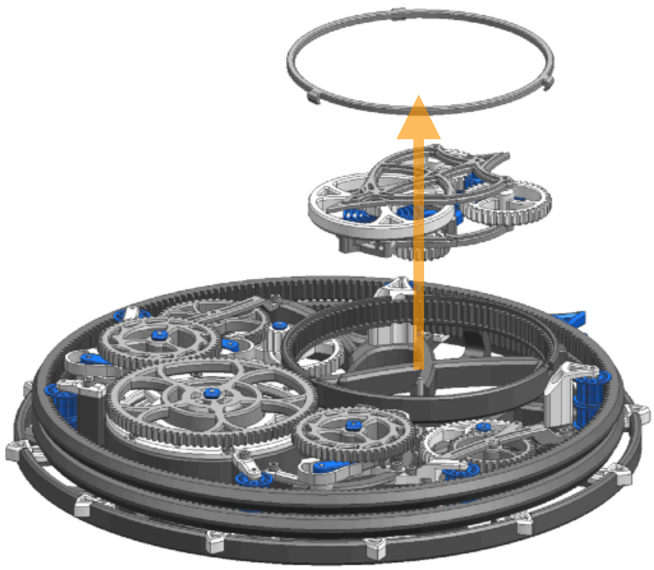
Tuning the escapement

- The movement is designed to run based on the rate of tourbillon rotating one fill round in one minute (the tourbillon is also the second hand). If you are interested to get it to tick at the right rate, I will be publishing the hairspring design (the spring effect differs quite significantly with different PLA) and you can adjust the thickness of the hairspring to try to get the right escapement rate. I

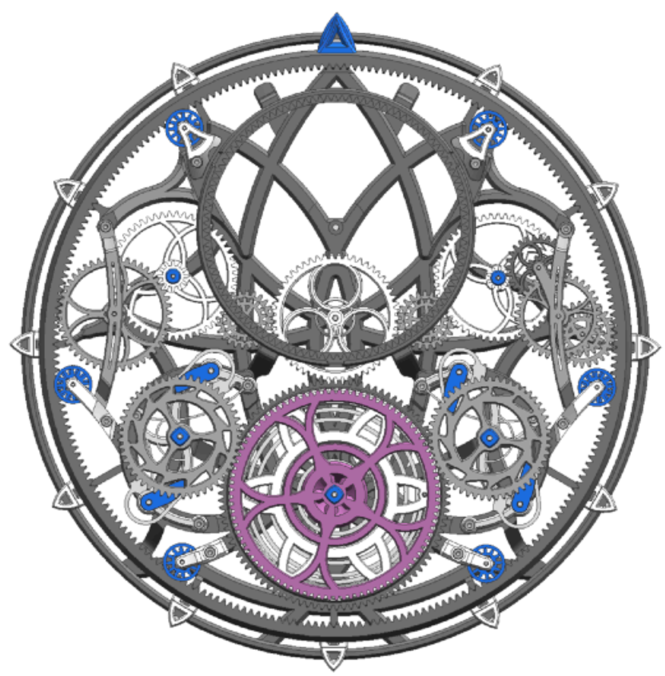
Setting the time

- As mentioned earlier, I was unable to incorporate a proper time setting mechanism because it will greatly disturb the symmetry of the design as well as introduce assembly complications. However it is still possible to set the time with the following method:

1) Carefully remove the tourbillon ring cover followed by the escapement mechanism and set them aside.

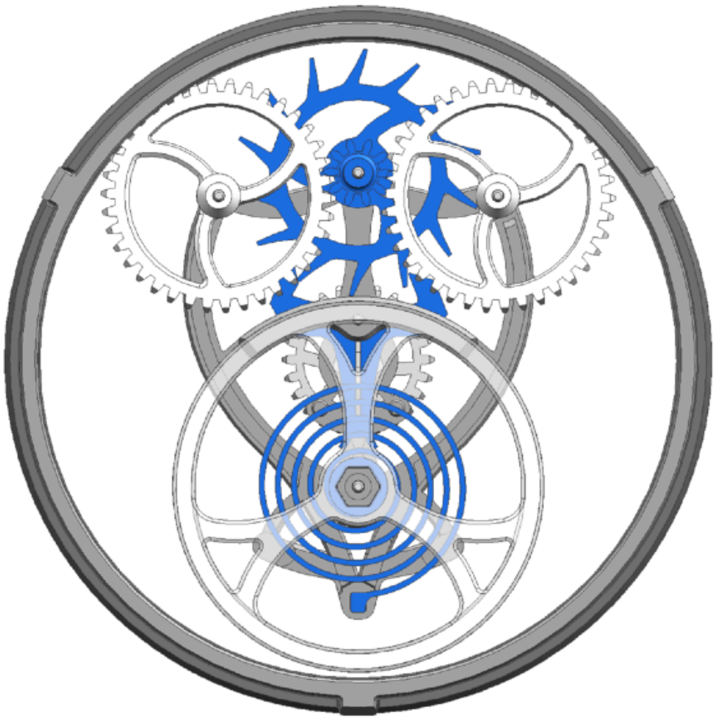


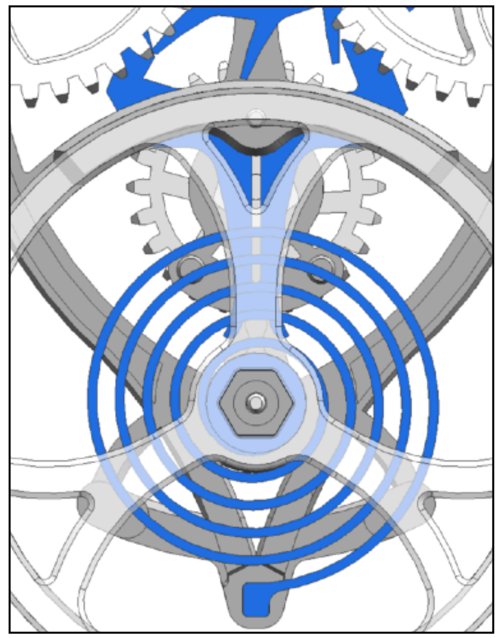
2) turn the Mainspring winder clockwise to set the time.



Final Notes

- PLA will deform over time if there is a constant load acting on them. If you are planning to store the clock aside for a long time, ensure that the mainspring barrel is completely unwind and that the balance wheel + hairspring is left at the relaxed state. To ensure the mainspring is completely unwinded, simply repeat step 1 of the time setting method. Once the escapement mechanism is removed, the mainspring will fully unwind. You can then reassemble the parts prior to storing.





Appendix