3D PRINTED PENDULUM CLOCK DEBUG

Debug notes for 3D printed pendulum clocks

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15-Mar-2024 Original version

Overview

I design 3D printed clocks with the intention of making them easy for others to build. I also hope that each clock becomes a useful timekeeper. This implies that they have long runtimes so winding is not a burden. Reducing friction and keeping tight tolerances are important steps in building a clock with a long runtime. Fine tuning a few parts is expected.

One issue with tolerances is that your printer is different than mine, and your filament is different than mine. Even a part I print today may be slightly different than the one I printed yesterday. The easiest solution is to design parts with loose tolerances where possible and make minor adjustments after printing so all parts function as designed. This document describes the process of pre-assembly adjustments and debug steps after assembly to get your clock running as quickly as possible.

The diagrams used were taken from my newest clock, the Large Moon Phase Clock. This clock shares many features with my other wall mounted weight driven pendulum clocks. It adds a moon phase dial, but all other features are similar. The gear naming conventions are relatively consistent so you should be able to follow along for any other clock design. One clock may have a gear3_36_8 and another clock has gear3_54_12. Both are in the gear3 position and only the number of teeth are different.

Details

All my clock are designed to be easy to print and assemble. The manual will walk you through the process. Here is a summary of the most important steps.

1) Order the non-printed components and follow the cut list in the manual.
2) Print the frame components using 0.2mm layer height and 4 perimeters.
3) Print the gears using 0.15mm layer heights and 5 perimeters.
4) Refer to the gear and spacer cross reference charts.
5) Follow the pre-assembly cleanup steps.
6) Pre-assemble a few gears as described in the manual.
7) Add the gears from the bottom layer to the top according to the instructions.
8) Adjust the clock so it hangs properly on the wall.
9) Determine how much weight your clock needs and print a weight shell.
10) Follow additional debug steps as needed.
11) Calibrate the clock by adjusting the pendulum length.

Printing the Parts

Most of my clocks utilize gear tooth profiles that are an extension of the “fancy gear” profile first described on a web site called “Gary’s Wooden Clocks”. Only one side of each gear tooth in a clock is actually used because clock gears only rotate clockwise. The gear teeth in my clocks have been optimized to take advantage of this.

My oldest clocks were designed before the Arachne slicing algorithm was commonly available. They print best using the classic slicer if you have that option. The newer clocks have updated tooth profiles that adjust for the Arachne slicing algorithm and print best using it. The key point is to look at the slicer output for each layer to determine what prints best.

Strive for an image in the slicer like the one shown below. Notice the continuous filament paths.

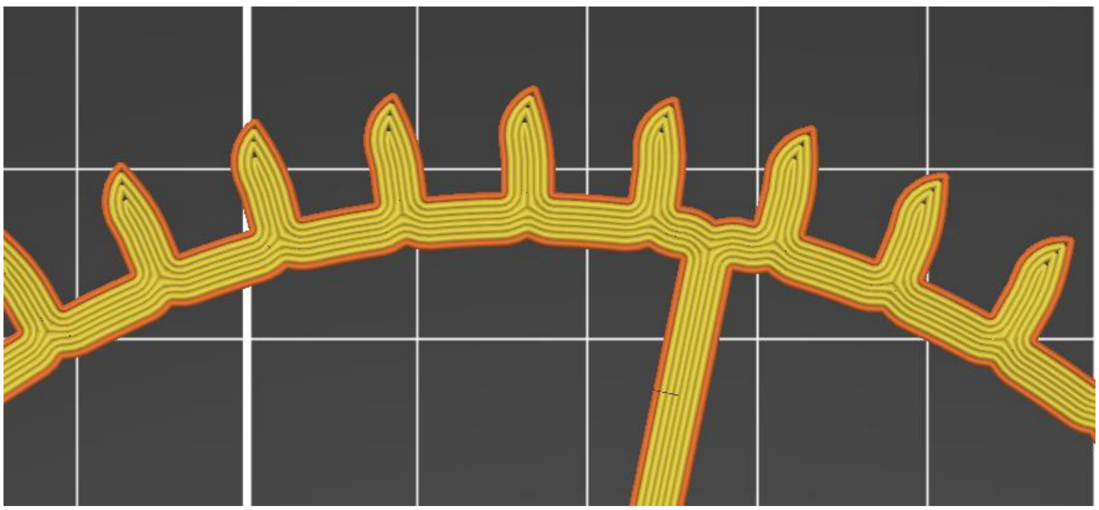

Figure 1: Fancy gear slicer details when optimized for Arachne

This is a gear from one of my older clocks optimized for the classic slicing algorithm, but sliced using Arachne. The root of every gear tooth has a small infill dot requiring a retraction step and an increased likelihood of stringing. This gear should be sliced using the classic slicing engine if possible.

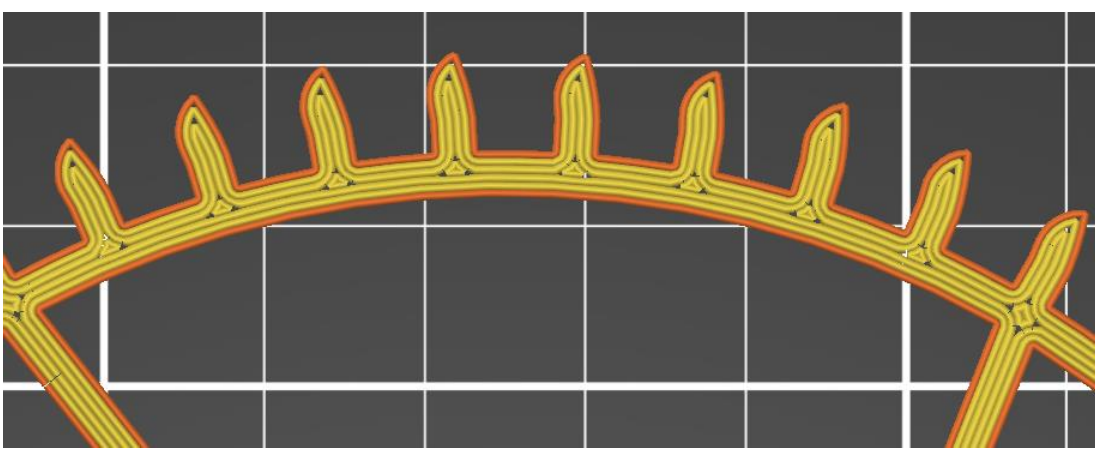

Figure 2: Classic style gear sliced with Arachne

The other possibility is a gear optimized for Arachne should only be sliced with Arachne. The image below occurs when an Arachne gear is sliced using the classic slicer. Notice the inner lines are completely broken. The key message here is to look at the slicer layers and change parameters to get optimal results.

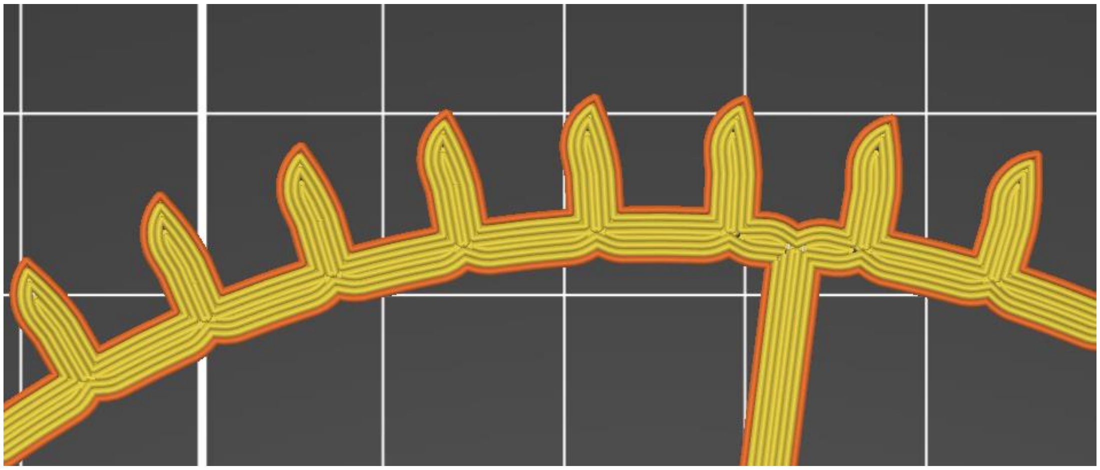

Figure 3: Classic slicer output when Arachne is preferred

Component Pre-Assembly

IMPORTANT: This section will guide you through the process of getting the components ready to build the clock. You may be eager to rush in and start putting the clock together, but more effort spent in this section of the assembly process will reduce debug time later.

You will need:

- 3D printed frame parts
- 3D printed gears
- 3D printed pendulum arm and bob
- Pennies or small weights for the pendulum bob
- Screws and bearings from the “additional components” list
- Phillips head screwdriver and hex key to match M3x8mm screws
- Cut metal arbors with the ends de-burred
- 1.6mm (1/16”) drill bit
- 3.2mm (1/8”) drill bit
- Pin vise or slow speed hand drill
- 90+% alcohol or mineral spirits for cleaning bearings

Optional tools and supplies:

- Sandpaper or small hand files
- Lithium grease for ratchet and sometimes for the pinions
- Teflon dry lube for bearings

Component Pre-fit

The most important step in reducing friction is to dry-fit the components and make adjustments as needed. The first step is to drill the arbor holes to the proper sizes. 3D printers often make holes smaller than expected. The easiest solution is to drill them to the proper size. I use small pin vises to manually drill through the center of each gear. A power drill will also work, but go slowly to avoid melting the part.

Figure 4: Pin vise

Drill the ends of every gear to the proper size. Most of my clocks use 1.5mm or 1/16" arbors for the lightly loaded gears and 3mm arbors for the heavily loaded gears. The gears are designed so only a short portion from each end needs to be drilled out. The middle portion opens up to provide extra clearance around the arbor. Use a 1/16" or 1.6mm drill bit for the 1.5mm arbors and a 1/8" or 3.2mm drill bit for the 3mm arbors. This provides the proper amount of clearance without being too loose.

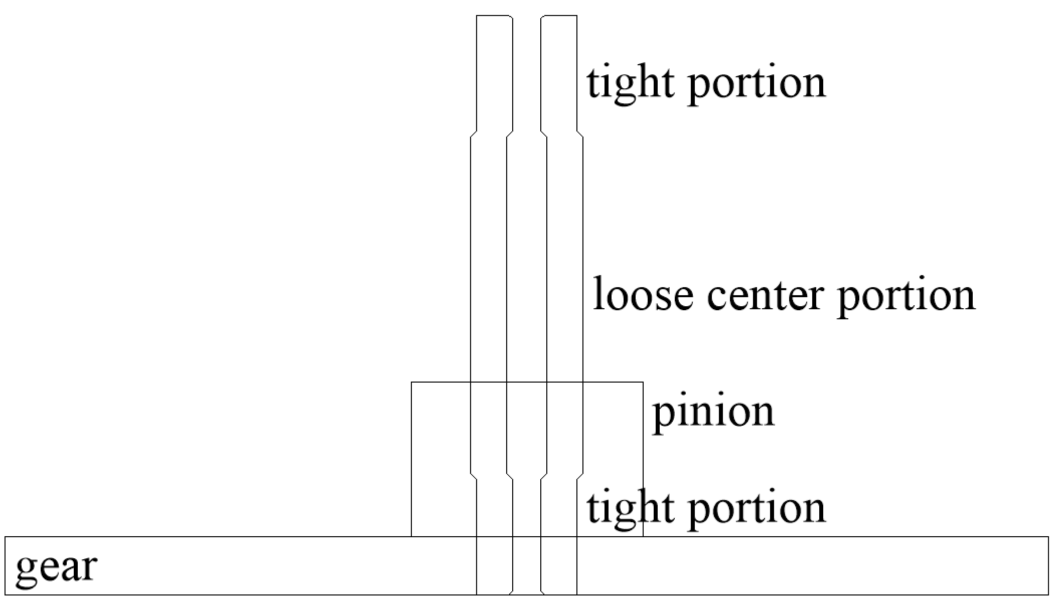

Figure 5: Gear side profile

Drill both ends of every gear and blow through the hole to clean out the swarf. Test each gear by spinning it on an arbor. Gears with properly sized holes should spin for 10-20 seconds. If it slows quickly, then drill it again. It will be obvious when the hole has enough clearance.

Also, drill the frame arbor holes so the arbors easily spin in the frame. This provides two degrees of freedom for the gears to rotate with minimal friction. The arbors spin in the frame and the gears spin around the arbors.

There are a few 3D printed parts that need to move inside other printed parts when the clock is running. They need to be checked for the proper fit and adjusted if needed. Use hand files or sandpaper to adjust the sizes of either component until the parts rotate smoothly. These parts involve PLA rubbing against PLA. Feel free to add a light coat of lithium grease to the sliding parts.

One common concern from builders is a clock that appears to function, but the hands do not move. The builder may first blame the friction clutch when the real cause is gear 6 binding in the frame. Check for friction where gear 6 (hour hand gear) passes through the dial. Gear 6 is highlighted below in red. It rotates slowly, but excess friction here may allow the pendulum to swing without allowing the hands to move.

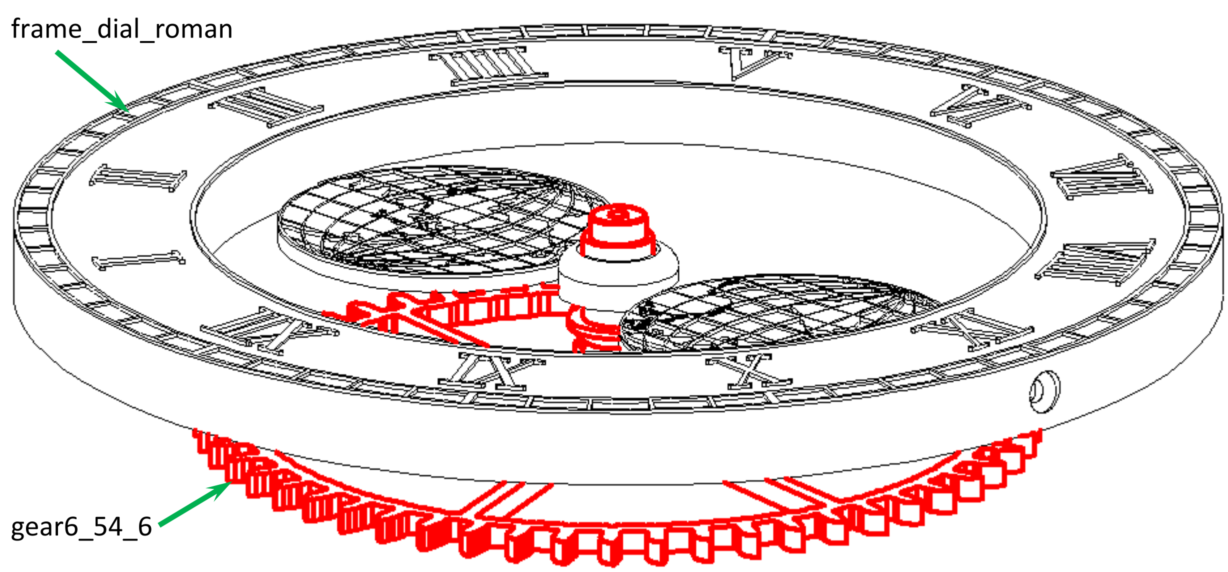

Figure 6: Gear 6 fit into main dial

Another potential cause for the lack of hand movement no end shake on the central arbor. This will be covered later.

Some clocks have a center post on gear 7a (highlighted red) that needs to fit into gear 7b. It must be able to rotate freely. Sand the post if needed. A touch of grease to the post can be added.

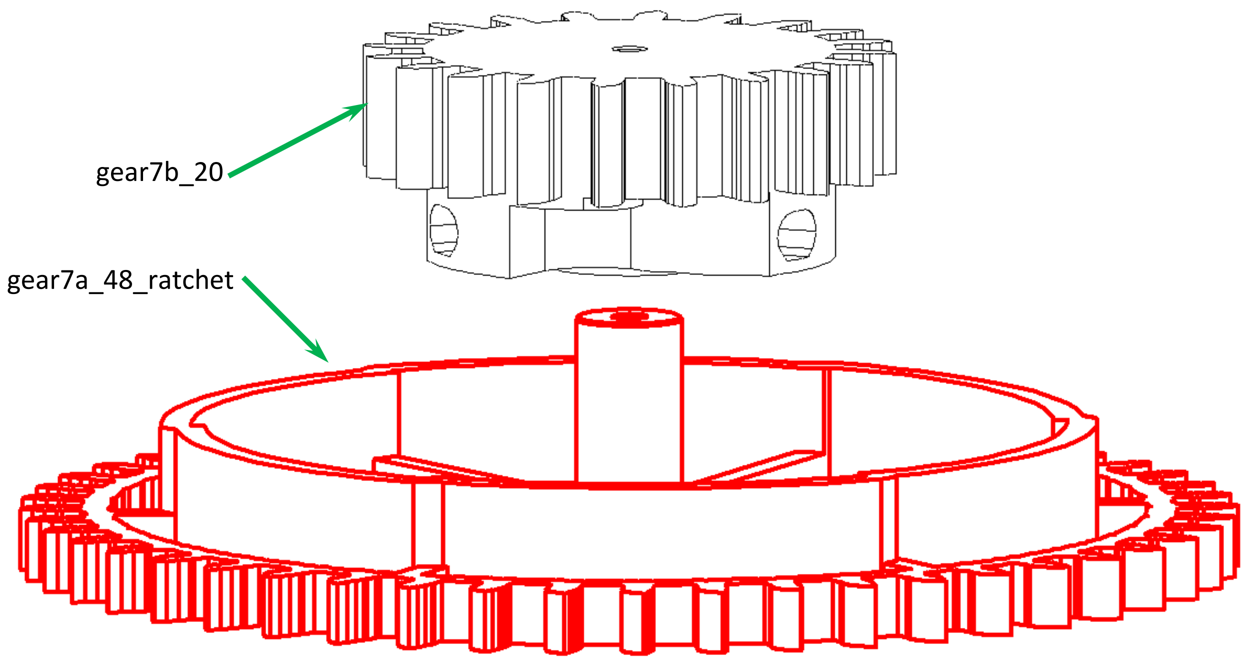

Figure 7: Gear 7b fit onto gear 7a

The ratchet clicks need to be able to swing freely when added to gear 7b. Add the three screws and test that the clicks move easily. Enlarge the holes in the clicks using a 9/64" or 3.6mm drill bit if needed.

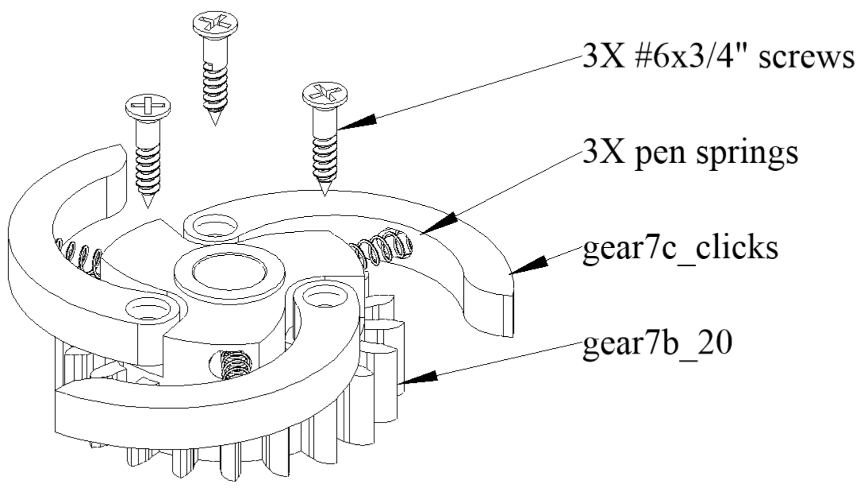

Figure 8: Clicks added into gear 7b

Notes on Friction

It is worth stating how important it is to reduce friction in a mechanical clock. The moon phase clock uses 7.5 pounds of weight falling 46” every 7.8 days. The pendulum will tick 852,930times in 7.8 days, so the energy of the weight shell dropping one inch (2.54cm) needs to provide enough energy to keep the pendulum swinging for more than four hours. This gives us an idea about how little energy is available to keep the clock ticking. There is not much room for wasted friction.

Make sure to complete the component pre-checks to minimize friction before moving on to building the clock. Another equally important test on the pendulum support bearings will be done later.

My clock has been running great using around 7.5lbs of drive weight. Your clock may require slightly more or less weight depending on overall friction in your clock. Hold off on printing the weight shell until you clock is closer to completion.

I sometimes add dry Teflon lubrication to all of the moving parts of the clock, but the clock also seems to run just fine without any lubrication. I have also used lithium grease on the pinions and pallet arms on some of my clocks. Just a tiny bit is needed. Apply it with a toothpick and wipe away most of it. It is generally considered a bad idea to oil or grease clock gears because oil holds dust that can scrape the surfaces. I have not noticed any bad effects from greasing PLA clock gears, even after running for several years. PLA even seems to be safe with the solvent in dry Teflon lubrication, but try a small component before adding lubricants to the entire clock.

The small 623 bearings used to support the pendulum work best with the thick factory grease removed to minimize friction. Remove the rubber seals using a needle and wash the grease using solvent (paint thinner, mineral spirits, acetone, 90%+ alcohol, etc.). 91% isopropyl alcohol used for cleaning the print bed works great for removing the factory grease from the bearings. Let them soak overnight and brush out the grease or use a blast of compressed air, then let them soak again in fresh alcohol. Add a drop of dry Teflon lubrication or lightweight oil to minimize rust if desired.

Frame Assembly

Each clock will have a different frame design. Follow the assembly instructions in the manual for your clock. You should dry fit the parts and file or sand pieces for a proper fit. The parts should fit together easily, especially the newer designs with tapered pegs to align various parts.

One thing to keep in mind is that the alignment pins or pegs do most of the work in positioning the frame components. The screws should not be used to pull the parts together, but rather to hold the parts in position. There is no need to over-tighten the screws. You may need to take the front frame off several times during debug and you do not want to strip the screw holes.

Gear Pre-Assembly

A few gears should be assembled into larger modules before adding them into the clock. Refer to the manual for your clock for specific details. A few common issues will be highlighted here.

One question that gets asked frequently is “My clock seems to be running, but the hands are not moving. What is wrong?”. The most likely cause if the friction clutch is not strong enough to overcome binding in the hour hand gears. The gears should have very low friction and even a weak friction clutch should be strong enough to turn the hands.

The friction clutch uses a spring to apply pressure against a gear to allow it to rotate when the clock is running, but also allow it to slip when setting the time. Most clocks have a gear 4a (sometimes labeled simply as gear 4) that is allowed to spin freely around the minute hand arbor. Gear 4b and a spacer below gear 4a are both firmly attached to the minute hand arbor. A spring pushes gear 4a into the spacer. The spring holds everything so they rotate together during normal operation, but a small amount of pressure on the minute hand allows the arbor to slip.

Here is the assembly instruction for the moon clock friction clutch:

The gear 4 assembly includes the friction clutch used to change the time while the clock is running. Insert the components in the order shown and secure the positions using two M3x8mm set screws. The arbor should extend through the bottom by about 0.25” (6mm). Spacer4b should completely interlock with the notch in gear4a_54_18. You should be able to hold gear4b_18 and rotate gear4a_54_18 with a small amount of resistance. You can stretch the spring if needed to apply additional pressure.

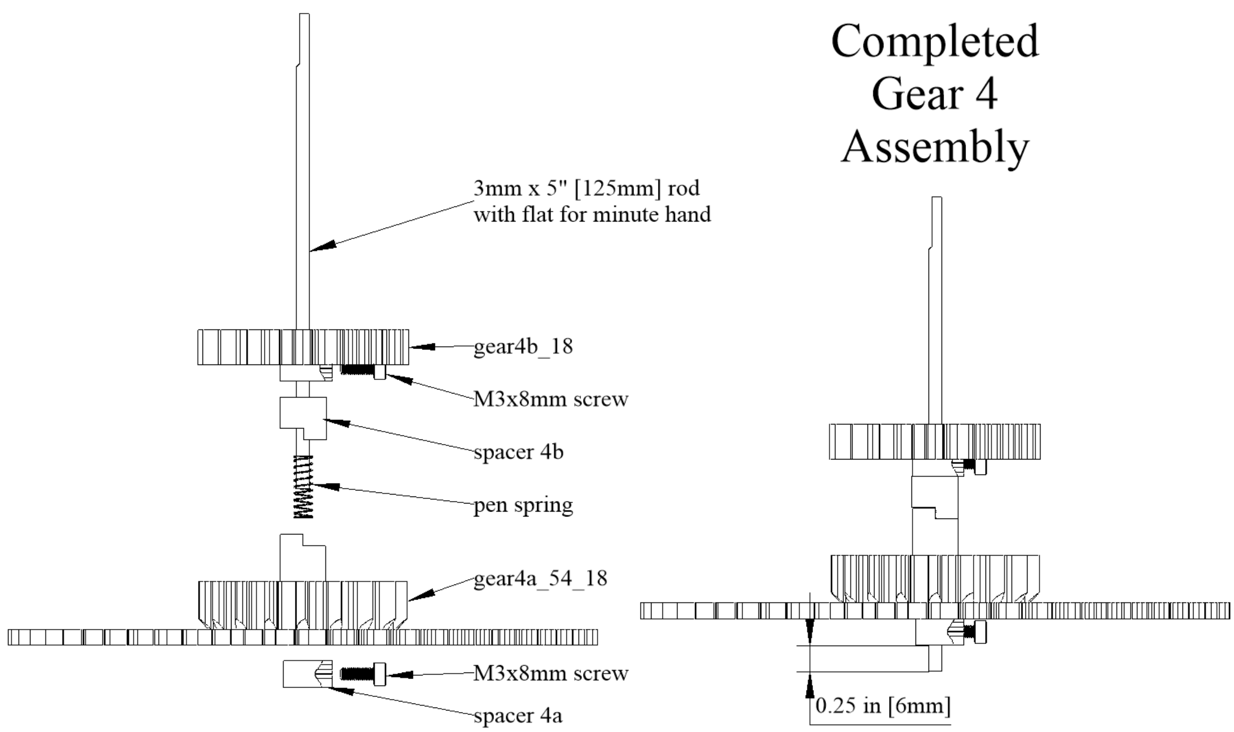

Figure 9: Gear 4 pre-assembly

Pre-Assembly Checks

It is a good idea to test a few things before assembling the entire clock. We will be testing the pendulum free swing time and checking for proper clearances in the gear stacks with the most components. If these tests pass, then there is a greater chance of having a functional clock. Any adjustments that need to be made are easier to do before the entire clock is assembled.

The pendulum support bearings are an important feature in all of my clocks. I believe that if small ball bearings with modern quality were available 500 years ago, we would see a lot of them supporting pendulums. They are extremely durable when operating well below their maximum load capacity. My oldest clock is nearly 5 years old using a ball bearing pendulum support with no signs of wear. The pendulum amplitude is still as strong as it was 5 years ago.

The first step is to remove the thick factory grease to minimize friction. Use a pin to remove the rubber seal from the 623RS bearings and soak them in alcohol or mineral spirits to remove the grease. A coat of Teflon dry lube or very light weight oil can be added to minimize rust.

Add a 623 bearing into the back frame and insert the previously assembled pallet module. Add spacer_0 and another 623 bearing. Add the front frame and secure it with the upper screw. The other frame screws are not important at this point.

Here is the pallet assembly detail for the moon phase clock:

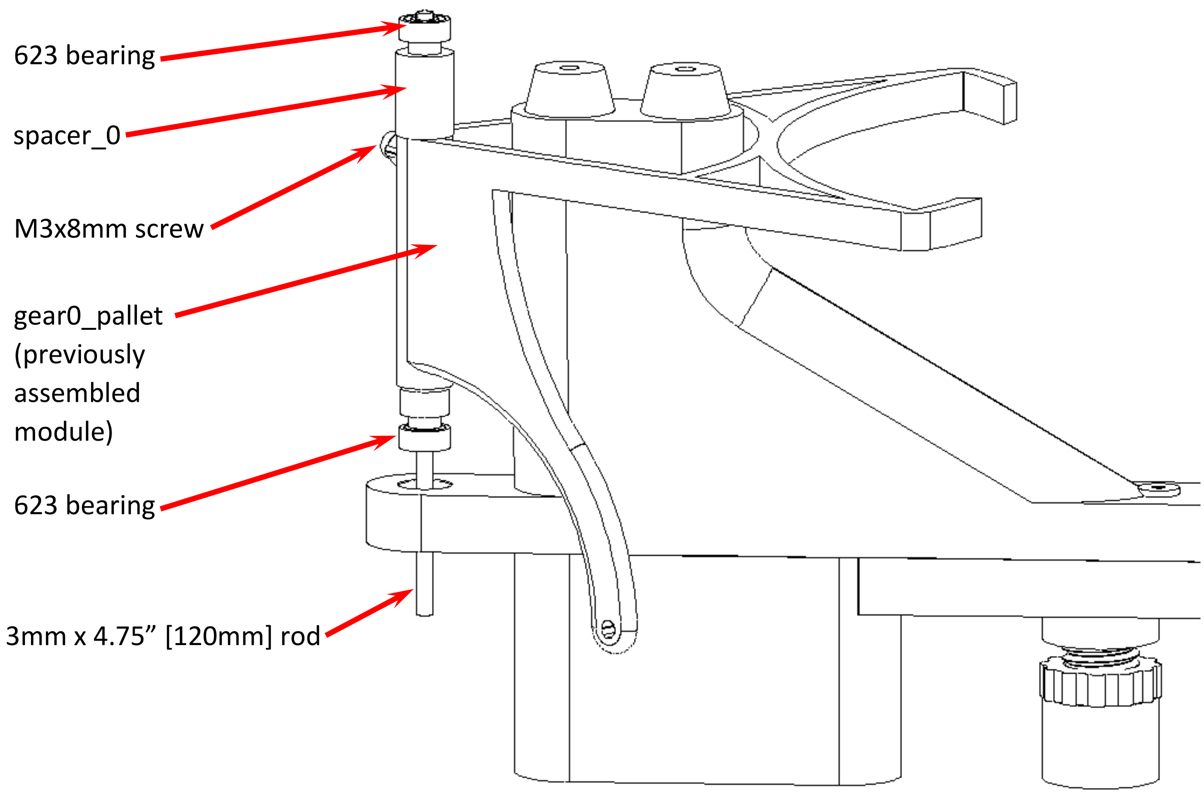

Figure 10: Pallet assembly for bearing free swing test

The pendulum arm usually consists of three or four segments depending on the clock model. Some of the older designs have a one piece pendulum arm. Follow the assembly instructions in the manual.

The moon phase clock pendulum arm construction is shown below. Hang the clock on the wall using a #8x1-1/2" or M4.2x38mm pan head wood screw. Other screw sizes will work as long as they fit into the upper standoff and are long enough to go into a wall stud. This test only needs to support a lightly loaded frame and pendulum arm. Eventually, the one screw will need to support 8-10lb (4-5kg) without pulling away from the wall. It will need to be fairly strong. Follow the guidelines further ahead about hanging the clock.

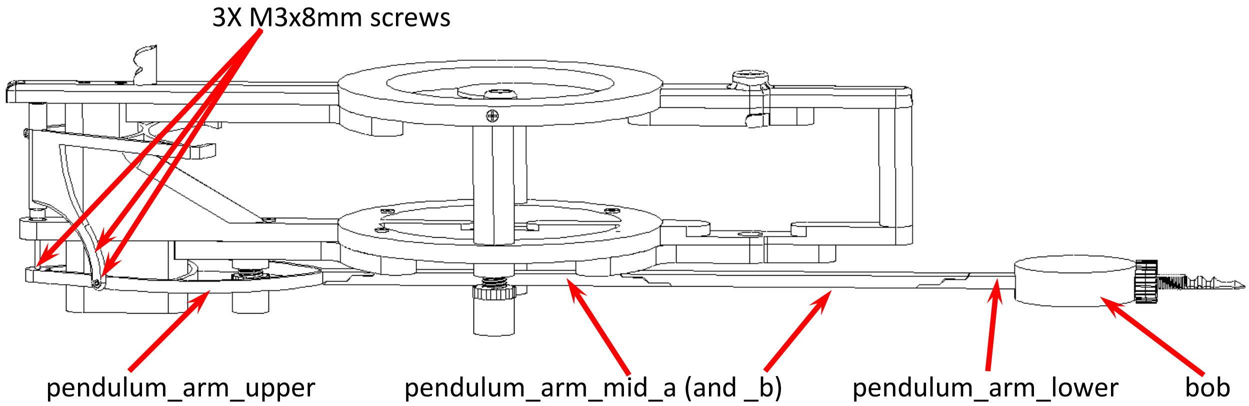

Figure 11: Pendulum assembly

Hang the clock frame on the wall and add the pendulum arm and pendulum bob. Each pendulum arm segment hangs on the segment above it. This makes it easy to remove the pendulum when moving the clock. Swing the pendulum to one side and measure how long it takes for the amplitude to degrade to a negligible amplitude. It should swing for at least 5 minutes, preferably 10 or up to 20 minutes. Bearings that degrade in amplitude in less than 5 minutes will not make a reliable clock without an extremely large drive weight. Swap the bearings or clean them again before proceeding.

I have purchased 323 bearings from multiple vendors and have never seen a batch of 10 bearings without at least 9 perfect bearings that swing for over 10 minutes. Most swing for around 18-20 minutes. This assumes that the rubber seals have been removed and the thick factory grease has been removed. The free swing test does require a properly weighted pendulum bob and bearings that fit loosely in the frame so the rod is not binding.

I usually purchase the cheapest bearings from Amazon, eBay, and AliExpress. Nearly every single one is good enough to work as a pendulum support bearing. The few rare bad bearings will feel gritty, as if they were dropped in sand. I suspect that even they would start to work if they were cleaned again, but bearings are cheap enough that I throw them out and use the remaining good ones.

The minute hand arbor has the most components stacked in one place. If each component prints slightly taller than expected, the stack can be pinched when the front frame is attached. Add the gears shown in the picture below, starting with the previously constructed gear 4 assembly, spacer_6, gear6_54_6, and gear10_60_moon_3d (or _flat). Don't forget about spacer_6 between gear4b_18 and gear6_54_6. Place the front frame on top and make sure it is fully seated. Check that there is clearance between gear10_60_moon and the front frame. This is called end shake. The target is more than 0, but less than 1mm of end shake. If the frame pinches the gears, trim a tiny bit from the tips of gear4a_54_18 and spacer_4b, or make spacer_6 thinner. Test that the top two gears spin freely and independently from the gear 4 assembly.

Note that this image is for the moon phase clock with a gear 10 at the top. All other clocks are similar except they do not have a gear 10. There is still a concern of components getting pinched by the frame, so the central arbor gear stack in every clock should be checked for end shake.

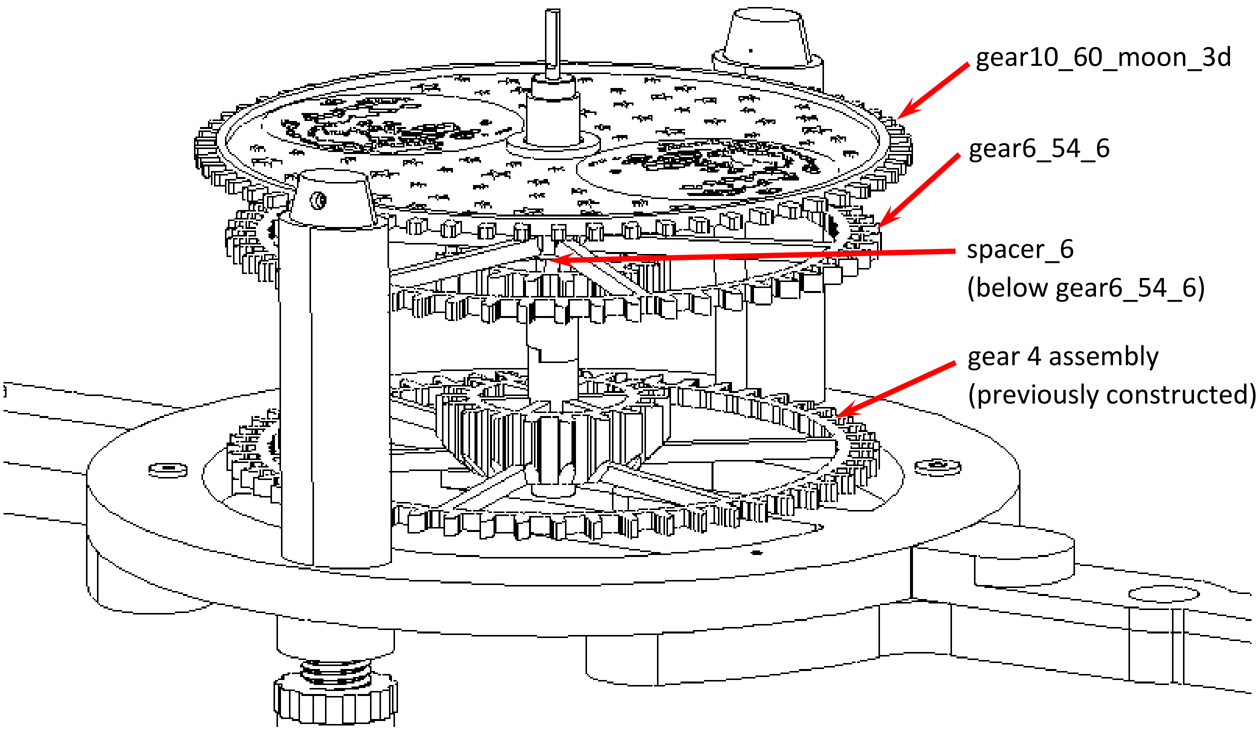

Figure 12: Central arbor end shake test

Hanging the Clock

IMPORTANT: The clock frame is designed to support a heavy weight shell without sagging. The weight distribution has about 40% of the weight hanging on the back frame and 60% hanging on the front frame. There is a strong horizontal support beam holding up the front of the clock and it is critical to set it up properly so the beam can function as intended.

The steps to hang the clock are:

1) The most important step is to adjust the mounting screw depth so the upper standoff is held tight against the wall. This will allow the support beam to stay horizontal as it is intended. The screw should go into a wall stud so the screw does not pull away from the wall.
2) Move the adjustable lower standoffs to their shortest position close to the back frame.
3) Hang the clock on the mounting screw.
4) Adjust the mounting screw depth until the upper standoff is tight against the wall. You should be able to gently pull down on the front frame without creating a gap between the upper standoff and the wall.
5) Adjust the lower standoffs so they touch the wall. They should not push the frame away from the wall.
6) Pull down the front frame to make sure there is minimal frame sag.

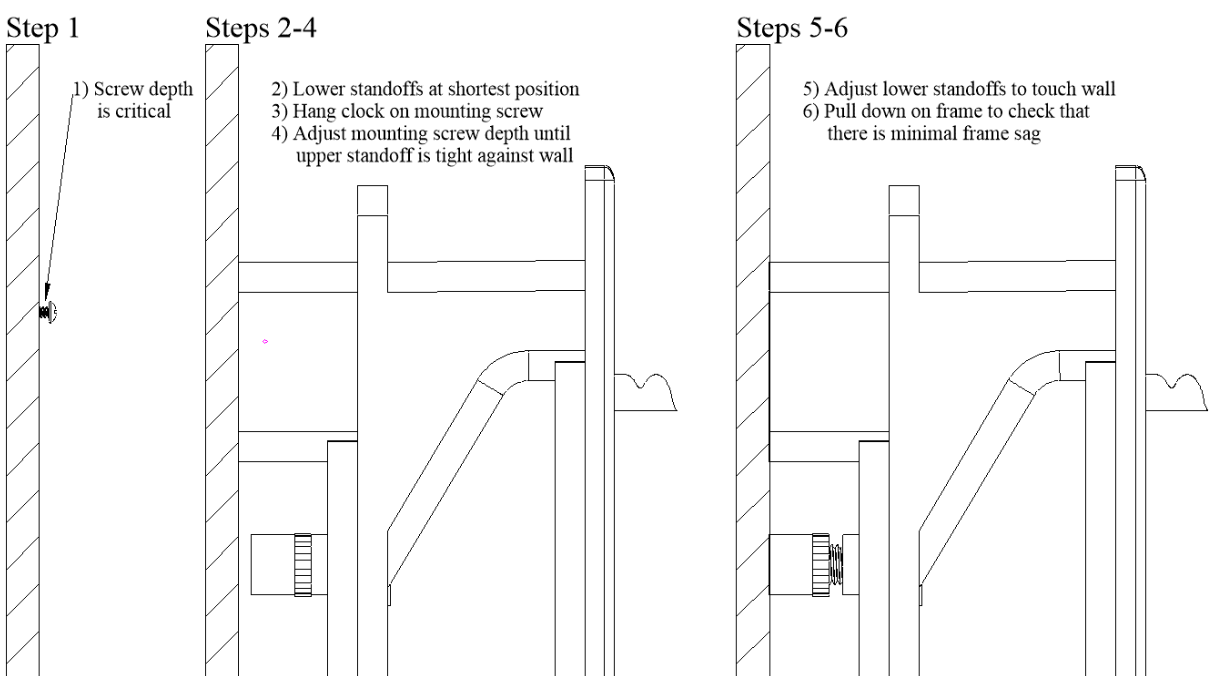

Figure 13: Hanging the clock

Pre-check Summary

Don't start assembling the clock until all of the previously listed pre-checks have been completed.

1) Visually inspect the gears for defects like elephant foot or excess stringing
2) All gears spin on their arbors
3) All arbors spin in the frame arbor holes
4) Gear 6 fits through the front dial and spins easily
5) Gear 7b spins on gear 7a and the ratchet is working
6) Pendulum bearing free swing test runs for at least 5 minutes, preferably 10-20 minutes
7) The gear 4 assembly, spacer_6, and gear 6 have some end shake inside the frame
8) The moon phase clock adds checks for gear 9 and gear 10 end shake

If all of these pre-checks are good, then it should be OK to start the final clock assembly. The most common issues that might cause the clock to be non-functional are the bearing free-swing test, excess friction on arbors, or lack of end shake.

Testing the Clock

The clock mounts on the wall using a single screw driven into a wall stud. I use an #8x1-1/2" or #8x1-1/4 pan head wood screw, but anything that fits securely in the keyhole hanger should work. Placing the screw 74" (1.88m) from the floor will give around 46" (1.17m) of drop for the weights to fall during 7.8 days of run time.

It is very important for the hanging screw depth to be set properly for the clock frame to be supported without sagging. Follow the procedure on the previous page. The horizontal support beam at the top of the clock frame is very robust, but needs the upper standoff to be tight against the wall for it to work properly. Start with the adjustable standoffs adjusted to a short position so they are not touching the wall. Hang the clock on the mounting screw and keep adjusting the screw depth until the upper standoff is tight against the wall. Then adjust the lower standoffs so they are flush against the wall. You should be able to pull down on the front of the clock without seeing any sagging. If there is any sag, the clock hanging screw depth probably needs to be tightened further.

The pendulum on this clock uses simple drop-in components. Hang the pendulum on the clock according to a previous diagram. The pendulum_arm_mid_a and pendulum_arm_mid_b segments have different lengths that can be changed if needed for further range of adjusting the time. Two copies of mid_a creates a longer pendulum to slow the clock down. Two copies of mid_b can be used to speed up the clock. The two pendulum_nuts should start just below the center of the threaded portion on pendulum_arm_lower.

Hanging the Weight

Printing the weight shell should be delayed until the end so you can determine the exact size needed for your clock to operate properly. My moon phase clock will run with a very shallow pendulum amplitude using a 5lb (2.3kg) weight. It is very robust using a 7.5lb (3.4kg) weight. Your clock may need more or less depending on the overall gear train friction.

Tie a loop at the end of the line for the weight. It needs to be able to slip over the small hook on the side of the clock. It is easier to thread the line through the weight shell pulley if the loop is a few inches long. Using a pulley on the weight shell keeps the weight balanced near the center of the clock.

Hang various size weights on the line to see how much your clock needs to stay running. An easy method is to use a water jug where you can easily add or take away weight while testing. Start with around 3lb (1.4kg) directly on the line. This amount will later be doubled when the pulley is used. Make sure the frame stays vertical during this test so the clock stays in beat.

Move the pendulum to the side and release it. The escapement should turn one tick with each beat of the pendulum. Watch how the escapement moves. It should start to rotate as soon as the pallet tips move past the escapement teeth.

If the escapement is sluggish, it will not add any energy into the pendulum and the clock will quickly stop. Try adding more weight or reduce friction in the gear train until the escapement responds quickly with each tick.

Once everything is working reliably, start reducing the weight to see the minimum amount needed to keep the clock running. We can use this value to determine what size weight shell to print. Take the minimum working amount and double this value to account for the pulley, then add a 50% safety margin, for a total increase of 3X. My clock will run for hours with 2.5lb (1.1kg) directly on the line. Tripling this to 7.5lb (3.4kg) makes the clock extremely reliable.

Weight Shell

The weight shell assembly has been moved towards the end of the manual to let you test your specific clock to determine how much weight it needs. Many of the clocks use a similar weight shell design with slight differences in the pulleys. The following table can help determine what size weight shell to start with. An extension can always be added if needed to provide extra drive weight. You can add multiple extensions if needed.

Weight Shell Diameter	Lead Shot Normal Height	Lead Shot with One Extension	Normal Height Filled with BBs	One Extension Filled with BBs
2.4”	5.3lb (2.4kg)	6.4lb (2.9kg)	4.3lb (2.0kg)	5.2lb (2.4kg)
2.6”	6.5lb (3.0kg)	8.0lb (3.6kg)	5.3lb (2.4kg)	6.4lb (2.9kg)
2.8”	7.9lb (3.6kg)	9.7lb (4.4kg)	6.3lb (2.9kg)	7.8lb (3.6kg)
3.0”	9.4lb (4.3kg)	11.7lb (5.3kg)	7.6lb (3.5kg)	9.4lb (4.3kg)
3.2”	10.9lb (5.0kg)	13.5lb (6.1kg)	8.8lb (4.0kg)	10.9lb (5.0kg)

Table 1: Approximate weight shell capacities

Adjusting the Rate

The clock should be reasonably accurate with the pendulum nuts near the middle of the adjustment range. Lowering the pendulum bob will make the clock run slower and raising it will make the clock run faster. Every 0.035" in change in pendulum length should change the rate of the moon phase clock by about a minute per day. Clocks with different pendulum lengths will have different rates of adjustment. Refer to the manual for each specific clock.

The threads below the bob have around 12.3 threads per inch. One full rotation changes the length by 0.081". This would change the time by about 2.3 minutes per day. It is relatively easy to make small adjustments to get the time accurate to a minute or two per week.

The clock may change its rate during the first week or two as the components settle in to position and everything stabilizes to a consistent rate. Get past this break-in period before attempting the final timing adjustment. My clock is accurate to about a minute per week. I consider this to be pretty amazing.

Winding

Wind the clock by placing the key in the winding hole and rotate counter-clockwise. The ratchet should click as the cord is wound. Watch the cord to keep it spread across the winding drum instead of piling up in one spot. Sometimes, I guide the line while winding to help distribute the cord evenly.

The clock mounts to the wall on a single screw, so the clock may shift when winding and change the beat. I usually hold the frame steady with one hand while winding to keep it from tilting. You may need to reset the beat after winding if the position shifted.

Debugging

This clock was designed with the intention of being easy to assemble. Parts are designed to simply fit together and the clock will start working. However, there are hundreds of different printer designs with different tolerances that make each part slightly different. Some adjustment to get the parts to fit properly is expected.

This section of the manual will help guide you through some additional debug steps if your clock does not start working right away.

The pre-check summary is repeated to emphasize the importance of these steps. They are all related to reducing friction. Going through this list again will give your clock a good head start.

1) Visually inspect the gears for defects like elephant foot or excess stringing
2) All gears spin on their arbors
3) All arbors spin in the frame arbor holes
4) Gear 6 fits through the front dial and spins easily
5) Gear 7b spins on gear 7a and the ratchet is working
6) Pendulum bearing free swing test runs for at least 5 minutes, preferably 10-20 minutes
7) The gear 4 assembly, spacer_6, and gear 6 have some end shake inside the frame

A few additional checks can be added after the clock is assembled. It is important to notice how the clock is stopping to decide where to focus your debug efforts.

8) Is the clock hanging properly to minimize frame sag?
   The first thing to check is if the clock is hanging properly. If the clock is simply hung on a nail, the main support beam will tilt downwards from the weight on the front of the clock. This will cause the thin sections of the frame to bend so the entire frame becomes a parallelogram and the gears can go out of alignment. They could become pinched by the frame. Or the gears could tilt so the sidewalls interfere. The hanging screw depth needs to be properly adjusted and it needs to be strong enough so it will not pull away from the wall.

9) Is the clock in beat? Move the pendulum slowly from side to side to observe.
   A clock that is in beat will have a balanced tick tock sound as the pendulum moves back and forth. This clock should be close to being in beat with the frame vertical. The only adjustment is to tilt the frame left or right. Only a small amount of adjustment should be necessary. It is a good idea to check the beat after each winding since the frame might have shifted. A clock that was previously working great but stops running within 30 minutes of winding is often an indication that the beat was changed while winding.

10) Does the escapement rotate quickly when the pallet arms clear the escapement teeth?
    This clock has a Graham deadbeat escapement that allows the pendulum to swing freely to its natural amplitude without pushing the escapement backwards. The escapement needs to rotate quickly when it changes from the "dead" portion to the active portion where the angled teeth engage and the escapement pushes on the pendulum. If the escapement is really sluggish, it will not impart any energy into the pendulum and the clock will quickly stop.
    If the escapement starts spinning slowly, it might barely touch the pallet arms before the pallet moves past. Some energy is transferred, but not the full amount. The clock may run, but the pendulum amplitude will be weak. The problem could be friction in the gear train or not enough drive weight. The friction pre-checks may help. You could also try a small bit of grease on the pinion teeth. PLA seems perfectly tolerant of most lubricants. Adding extra drive weight may also help.

11) Does the pendulum slowly loose amplitude and eventually stop?
    This could either be too much pendulum support bearing friction or not enough drive weight. Some builders mention that they get less than a minute on the pendulum free-swing test. I have not found a 623 bearing that runs for less than 5 minutes unless the bearing felt like it was dropped in sand. I have ordered hundreds of bearings and never see more than 1-2% that are bad. And I buy the cheapest bearings I can find. The bearings usually come in sets of 5 or 10. Try different bearings.
    Another thing to check is if the bearings are really tight in the frame, they might be skewed and adding a side load which will cause extra friction. Enlarge the hole slightly so the bearings are loose but not sloppy in the frame.
    If all the pre-check friction tests are working, then try adding a weight shell extension.

12) Does the clock stop in less than a minute?
    If the pendulum free-swing test runs for 10 minutes, then the clock should run for several minutes unless the escapement is getting in the way of the pallet. You may see the escapement jump from the pallet arms hitting it. This may be caused by friction in the gear train not allowing the escapement to rotate quickly. Repeat the pre-check tests looking for where the excess friction is coming from.

13) What is the pendulum amplitude?
    The minimum pendulum amplitude for the clock to run is one degree in each direction, however a clock with only one degree of swing will stop from the slightest disturbance. Two degrees in each direction will be much more stable. Try reducing friction or adding more weight to get closer to the two degree target.

14) Does the clock appear to run, but the time does not change?
    This is usually a simple fix to reduce friction in the hour hand gears or increase pressure on the friction clutch spring. If gear 6 is binding where it passes through the frame, then the friction clutch will slip and the time will not change. Sand the gear 6 shaft or the frame opening where gear 6 passes through. Or it could be caused by a lack of end shake on the central arbor. Reduce the height of one of the gears in the stack or the spacers making up the friction clutch. Another option is to stretch the spring so it applies more pressure. The good news is that the primary gear train is working so the clock is almost completely functional.

15) Look at the clock from the side. Are any gear side walls touching?
    The clock is designed with a reasonable amount of clearance between gears that are not supposed to touch. It is a balance between just enough clearance to make a compact clock or a lot of clearance making a really large clock. Possible causes include frame sag, warped gears, or too much end shake allowing extra sideways movement. Frame sag is usually fixed by following the clock hanging procedure. Warped gears may need to be re-printed. Excess end shake can be solved by adding spacers to limit the sideways movement.

16) If all else fails, test gear pairs looking for excess friction.
    Most of the pre-check tests focus on individual components or small modules. Sometimes, the extra friction occurs when gears don't mesh properly. Try testing gear pairs and spin them by hand. For example, put just gears 3 and 4 into the clock. Do they spin easily? You may need the spacers or other gears above gears 3 and 4 so you can add the front frame to hold the arbors straight. Try again with gears 2 and 3. Keep going through the gear train testing pairs.

17) Test the entire gear train without the pallet.
    After testing all the gear pairs, try the entire set of gears without the pallet. Hang the clock on the wall. Add the weight shell. All the gears and the escapement should spin. It may take an hour for the weight to reach the floor. This is also a great way to break in the clock.
    It the gears stop, look for friction where they stop. Touch each gear. If it starts spinning, see if you can find anything near that gear causing friction. Start and stop the escapement. It should start spinning quickly each time.

These are the most common reasons why your clock might not be working right away. A mechanical clock is a complex piece of engineering, so there may be other reasons. There are a lot of moving parts. I try to design using loose tolerances, but there can still be things that need adjustment for your clock to function properly.

Once the clock is working properly, it should continue to work for many years. I have been running mine for a few months so far and it has been working flawlessly. My other clocks with similar construction techniques have been running for years.

I am available to answer questions and help you complete the last few debug steps to get your clock working. You can ask questions on YouTube, MyMiniFactory, Printables, or the forum on web site at https://www.stevesclocks.com/forum Try to provide as much information as possible. Mention which clock you are building. If there are runtime options, mention which option you are using and how much weight you are using. The pendulum free-swing time for your clock may also be useful information.

You can post pictures of your clock on any of the web sites. The forum allows any type of clock related questions and comments, even related to clock designs from other designers.

Final Comments

I strive to make my clocks as easy to build as possible while still turning them into useful timepieces. There are a lot of complex moving parts that all need to operate as designed for the clock to be functional. Some fine tuning and debug is expected.

This debug guide is an attempt to answer some of the hundreds of questions I have received over the past 5 years. The questions that get asked most often are included here. Some of the details are specific to my latest moon phase clock, but there are enough similarities for this guide to be useful for all of my pendulum clocks.

Each clock I design has improvements over the previous designs. Hopefully, the manuals are also getting easier to follow. I try to improve and clarify the sections where I get the most questions. If something is not clear, send me a message and the manual may get an update. Minor updates often get posted to my website at https://www.stevesclocks.com under each specific clock. Major updates to the manual will sometimes get posted to MyMiniFactory. The best place to find the latest manual is on my website.

Good luck with your clock build.

Steve