Introduction to the Lego Astronomical Clock by John Stouffer

For the past several years, I have been designing and building a mechanical Astronomical Clock made out of Lego parts. In 2014 it won the People's Choice Award at the NAWCC National Convention craft competition in Milwaukee, Wisconsin. This article describes the Lego clock features and design principles for a wider audience. Future articles will describe specialized mechanisms in greater detail.

In 2014 the Lego clock (JS2) was accurate to 1 minute per day, had concentric minute and hour hands, a seconds pendulum, and displays for mean day, day of week, lunar phase, earth orbit, and tropical month. Since then it has been rebuilt and today JS3 is also an Equation Clock with more astronomical complications: simple tide clock (lunar day), tropical day, equation of time (EoT), and indicators for solstice, equinox, perihelion, and aphelion. It is still completely mechanical using no electricity or motors.

What sets this Lego clock apart in the NAWCC craft competition is that all the other clocks are one-of-a-kind masterpieces. The Lego clock is intentionally NOT one-of-a-kind. It was specifically designed using Lego parts as a medium to be affordable, easily copied, and improved. It can be used as a hands-on project to teach and inspire the next generation of horologists and makers and to teach STEAM topics (STEM Science, Technology, Engineering, Math + Arts/Humanities).

This article is a brief introduction to the project goals and the design choices. More details are available on BuildSTEAM.com including videos, pictures, posts, spreadsheets, and building hints.

Design of an accurate mechanical clock just using Lego parts presents many engineering challenges, which was part of the fun of this project. Staying true to Lego, the builder is not allowed to create new parts or modify Lego parts. What You Get Is What Lego Sells (WYGIWLS - pronounced Wiggles). There are no specially shaped escapement gears or pallets. Axle (arbor) spacing is based on standard Lego brick distances.

So the craftsmanship and innovation in this clock is all about using extremely limited resources in completely new ways and inventing different solutions. For example, consider that the only available gears have teeth counts in multiples of 4 (8, 12, 16, 20, 24, 36, 40), a 28 tooth differential frame gear and a 14 tooth bevel gear. There are no historical astronomical clock gear trains to copy just using these gears. While Lego parts are manufactured with tight tolerances, they are bendable plastic so friction is another big challenge. All the wider gears (12, 20, 36 tooth) must be moved away from brick walls to prevent rubbing contact during rotation. The plastic base plate also deforms under the weight of the pendulum and the power weight. Plastic axles bend under stress causing pinching. Of course there are no jewels or lubrication to reduce the considerable axle rotation friction. Adding more weight to overcome friction is simply not an option; it has to be found and reduced. While friction is the enemy, it is also what holds Lego bricks together. Without any glue or screws to hold things fast, the clock design must account for forces that would separate bricks.

The only Lego gears available, all multiples of 4 teeth except the 14 tooth bevel (gray, lower right)

The clock design evolved as each mechanism proved what was possible using only Lego parts. Most of the astronomical complications were not even considered until a reliable escapement was completed and the clock was an accurate and robust timekeeper. As each larger time event mechanism was completed, the next larger duration was considered. Earth orbit in 365.25 days was not designed until after the indicators for 7 day week and lunar month of 29.53 days were working. In a way, building this Lego clock was my personal journey through the way historical invention usually happens; new leaps depend on the previous achievements paving the way and showing what is possible. Frequently the clock was put aside with no viable solution only to be obvious after a few weeks of researching historical clocks or working on other Lego machines.

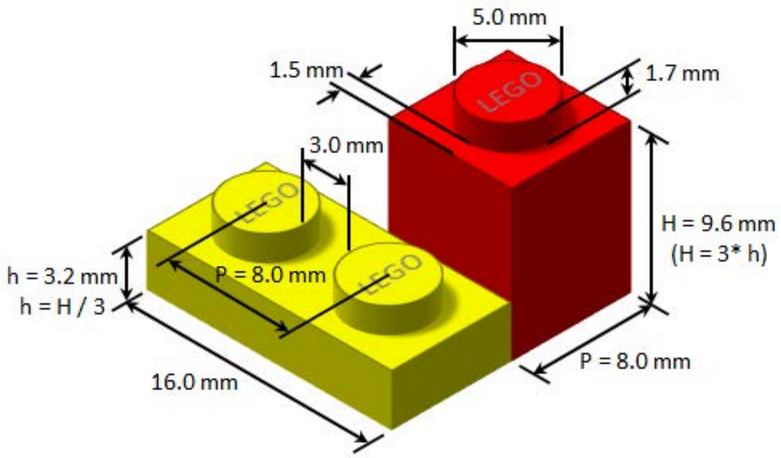
Several historical and modern clocks were inspiring and quite useful in the creation of this Lego clock. Harrison's longitude and tower clocks provided the Grasshopper escapement and roller bearings, and the inspiration to keep trying. Harrison's wooden clock that has run for 300 years without any lubrication proved useful to my design. Danny Hillis' Clock of the Long Now guided me to have a higher purpose for the clock activity (teaching STEAM subjects) and shares the goal of getting people to think long term. The Henry Ford Museum in Dearborn Michigan uses a saying "Past Forward" that fits perfectly. In my case, with the "Clock of the LEGO Now", I want students and mentors to think long term both backward into the history of invention and forward preparing the next generations of makers. Tower clocks with remontoire were an area of research that helped my clock design, especially the videos from Mark Frank. I gained understanding of the historical solutions to astronomical gearing from articles by Graham White and others. Finally, encouragement from my Dearborn NAWCC chapter got me to the convention craft competition and Bob Holmstrom's interest kept me continuously trying to document and improve the clock.

Since this clock is meant to be copied and improved, my basic design goals were for it to be Accurate, Reproducible, Transparent, Educational, and Fun. The clock and my other Lego machines are designed to be small and affordable, transparent and modifiable, and significant in the instruction of math, science, history, and innovation. Most of all they are fun to build and watch as they move in mesmerizing ways.

Accurate - First, I had to define "accurate" since this is after all a clock made out of plastic parts. The accuracy target was set to be within plus/minus 1 minute per day. Without any way (yet) to compensate for temperature and air humidity/density, that seemed like a good stretch goal. It also had to last 24 hours on one winding. The clock had to run without adjustment for months at a time which it now can easily do unless the house cat stops the pendulum. The target for the earth orbit year was set to 365.25 days since it matched the civil leap year convention and simplified the design. The accuracy target for the astronomical complication rotations (irrational numbers) was to be within one hour over several years. Any greater accuracy would be too difficult to read on the Lego clock since the displays and hands are not fine enough to discern small changes.

Reproducible - Like Eli Terry's clock parts, every Lego part is interchangeable, and Lego parts snap together in consistent ways. For the entire Lego clock to be reproducible its performance would have to be built on solid bracing, standard hole distances, and stability. Variable distance spacing using axles and bushings is possible and occasionally necessary (e.g. for the escapement) but overuse of variable spacing would make the clock's performance hard to reproduce. The design philosophy was to first make it work then make it better, cheaper, stronger and reproducible. With those goals in mind, the clock has been completely revamped since the 2014 NAWCC convention. Since I can't seem to work on any part of it without getting improvement ideas for other parts, the clock has frequently been torn apart in the last 2 years. Even when updating the gear diagram for this article, I removed three gears near the remontoire that are still in the photographs. Finally, since Lego's are expensive, the ongoing improvement process included replacing expensive parts (like Lego chain and weights) with more common and affordable solutions.

Gear train spacing is based on brick axle (arbor) holes defined by standard Lego brick dimensions.



Transparent – The clock is built in a skeleton style to show most of the inner workings. It is purposely made in contrasting colors so photographs and videos show individual bricks well. Making the machines beautiful (other than the beautiful mechanisms) is left to the builder who recreates these models. The operation of the clock needs to be understandable, adjustable, and modular. The clock was built in modules that can be removed, improved, and easily updated. As much as possible, every gear is exposed so the clock can be understood. The web page BuildSTEAM.com also helps with transparency by providing photos, videos, and explanations.

Educational – This is a teaching clock. Besides being a great hobby for me, it was created to teach lessons in horology, innovation, science, math, engineering, and history. It can foster curiosity, persistence, and ingenuity. At the NAWCC meetings and national convention I noticed there were almost no young people and very few under 50. In an era of digital clocks on our phones, this Lego clock can help explain mechanical clocks and the rich history of the cultural impact of clocks. The clock could help prepare a new generation to participate in our hobby and become stewards of these timepieces. Today, there aren't any fewer mechanical things out there; they are just smaller, hidden, and disposable and still need to be understood. Most of all, this clock is just one of many Industrial Revolution working machines that can be built with Lego to inspire young innovators.

Fun – The Lego clock was designed to be fun to build and fun to watch. Rather than keep most of the gears in a single plane, this clock has gears in three planes and extremely dense gear trains with pieces barely clearing plates and other gears. The clock comes alive when the fan fly rotates every 40 seconds. In demonstration mode, the moon and earth move quickly in their orbits and phases. The clock will amaze kids and adults and get them asking questions about how it works and what goes in to making a clock. A lot of learning can take place when children are having fun. This clock and my other machines make up a new category for Lego: historical machines that actually perform the mechanical task rather than a model that simply resembles the real thing. It complements the Lego education goals by providing hands-on mechanical challenges without the programming or robotics.

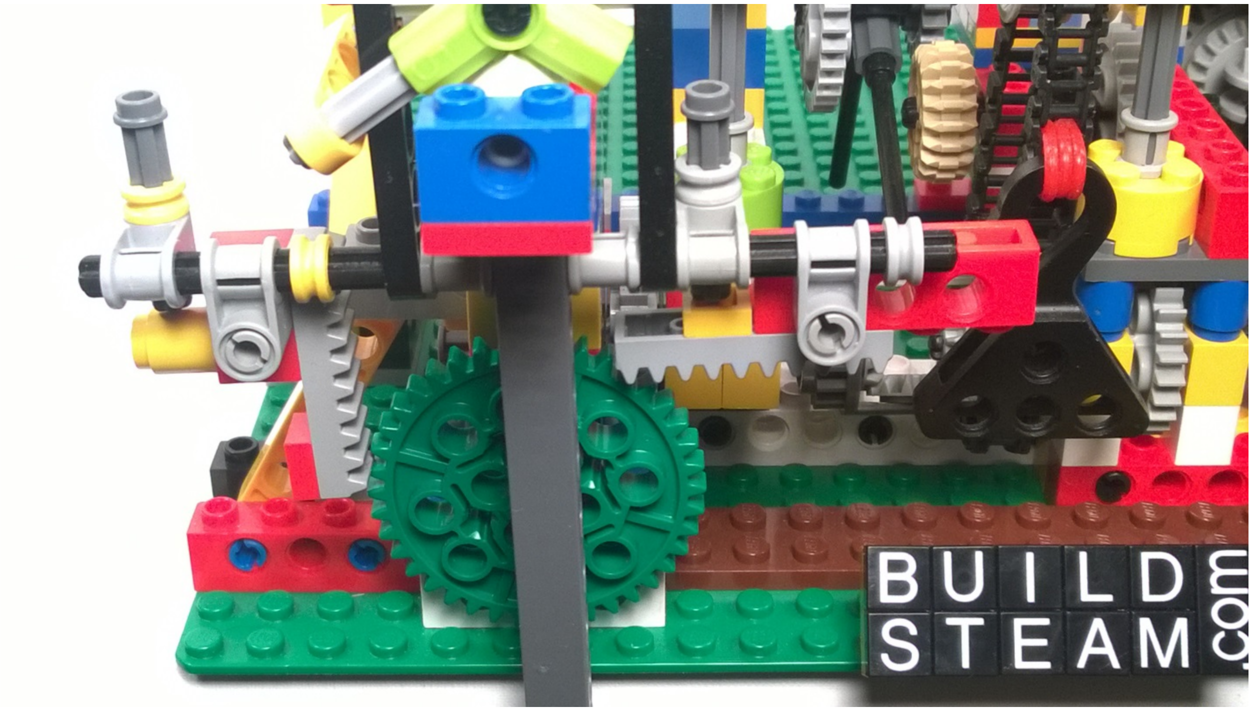
View from behind showing differentials for summing rotations for the astronomical complications.

This Lego clock has the usual five mechanical components: escapement, oscillator, power source, display, and gear train. A less common sixth component, a remontoire, was added in order to isolate the escapement from variations in the power source as is done in some tower and precision clocks. In tower clocks, this resolved the problem of ice and snow on the clock hands robbing energy that should go to the pendulum. In the Lego clock, this allowed the main weight to be increased to provide more power to new astronomical complications without altering the basic clock pendulum timing.

Escapement - Without an accurate and reliable escapement, there would be no Lego clock. Lego doesn't have any specialized clock parts with the convenient gear tooth shapes and pallet angles. All the Lego gears have standard involute shaped teeth which tend to make pallets slip off the teeth under pressure. The space between the gear teeth is quite small and Lego parts don't have fine tips with just the right angles which makes building an efficient escapement a real challenge.

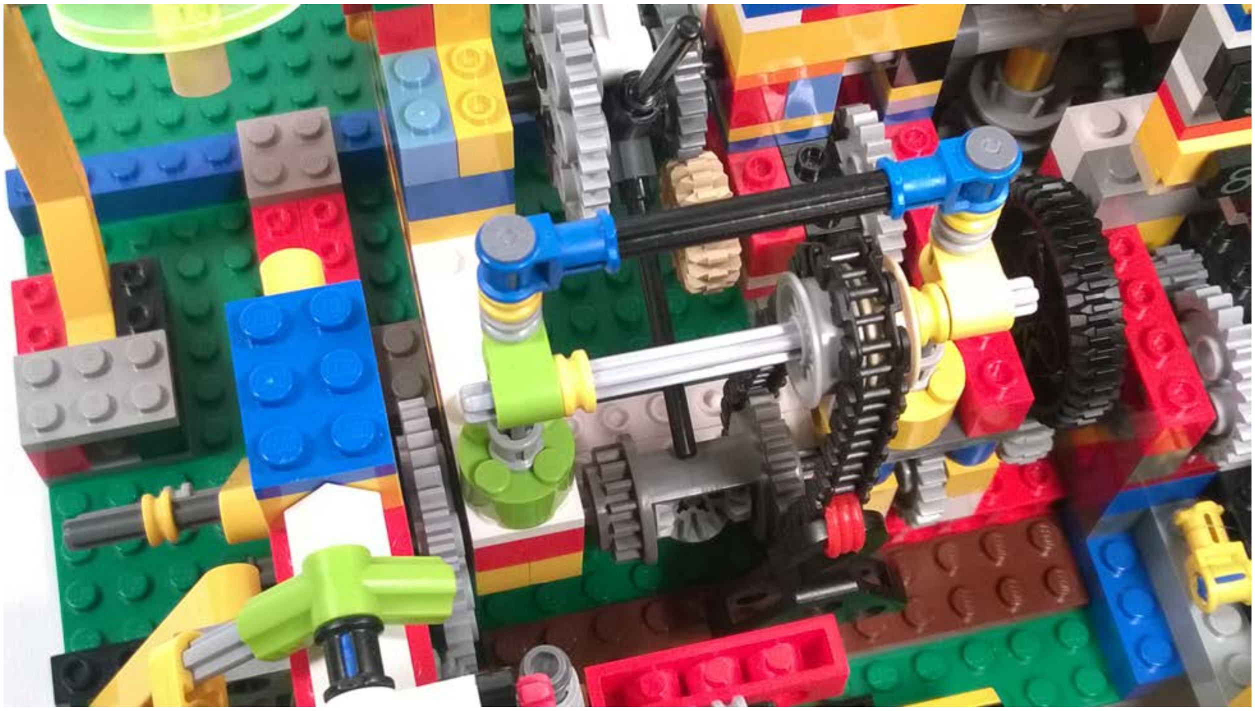
There are many YouTube videos of Lego escapements, but it is safe to say that few of them could ever be turned into an accurate long running clock. They appear to have too much friction, wasted motion, noise (energy), and vibration. I got new ideas and learned what to avoid from watching those videos. After many different escapement attempts, the turning point was reading William Andrewes' The Quest for Longitude about John Harrison's lifelong pursuit. Not only was Harrison's story of perseverance very inspiring, but his inventions were critical to a successful Lego clock. My variation of his grasshopper escapement proved to have the lowest friction of all my attempts and was also the most forgiving. Even misaligned it just kept going. The pallet supports are directly attached to the pendulum rod. They can be finely adjusted in two dimensions and have gravity "springs" to absorb the contact and return the energy. The spacing is 12 ½ teeth between pallets (on a 40 tooth gear). Pallets are prevented from slipping off the gear tooth by positioning the pallet rotation center such that any slipping would force the pallet radius to go through the tooth tip. It was fitting that a grasshopper escapement clock won the NAWCC People's Choice award on the 300th anniversary of the enactment of the Longitude Prize.

Lego Clock grasshopper escapement with gravity "springs", variable spacing pallets, and remontoire weight and chain. Pallets can be positioned left/right along shaft and up/down using gravity springs.



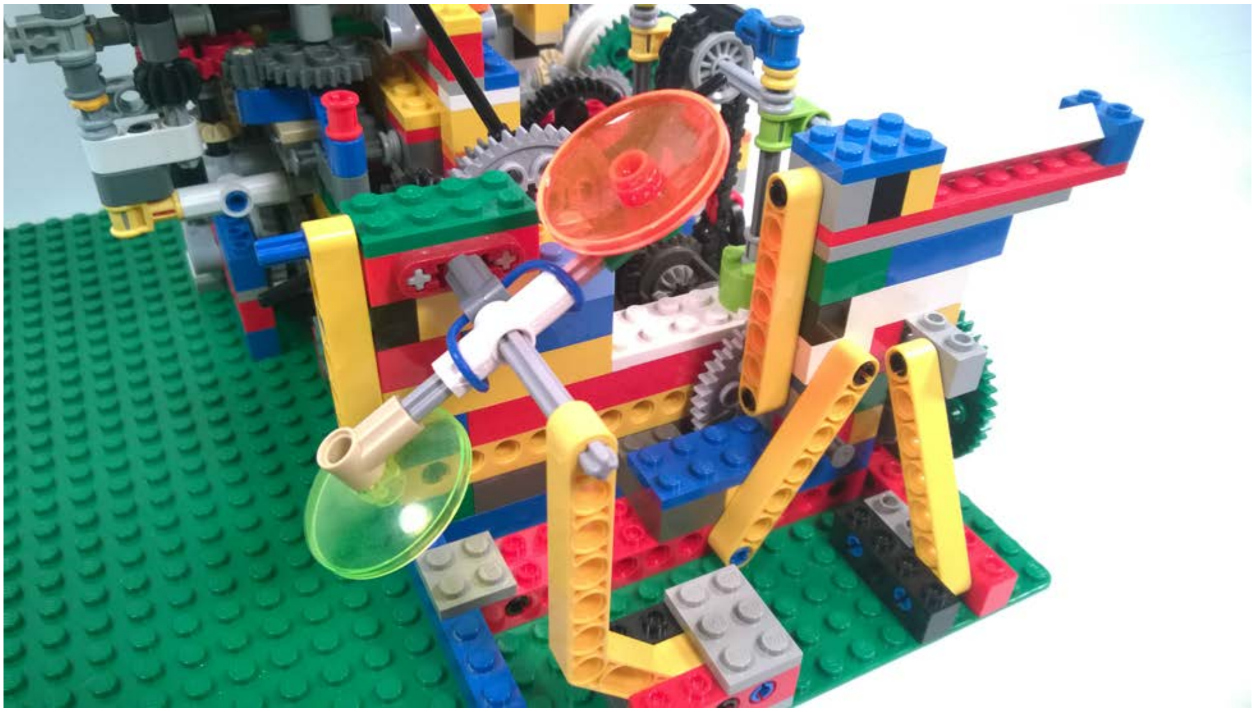
The new grasshopper escapement required so little energy compared to rejected escapement options (without lubrication) that I was not able to give it a consistently light force. Consequently the clock timing kept changing as I added complications to the clock. Historical solutions to create accurate low maintenance tower clocks led me to create a differential remontoire using a 10.7 gram weight made out of a Lego hook, one of the few metal parts. The remontoire weight is attached to a balanced chain loop which is rewound by the main weight every 40 seconds and slowed by a fan fly. With the remontoire, the main weight can be increased without affecting the clock timing and is only limited by the additional remontoire arm friction on the differential gear frame. It also prevents the escapement backlash from reaching the gears under tension from the main weight. The four ¼ turn remontoire arms are also as long as practical in order to reduce their friction on the differential frame.

1 of 4 remontoire arms resting on differential (gray) with chain loop supporting small metal weight. Falling weight rotates the differential for 40 seconds allowing the arm to clear the differential frame.



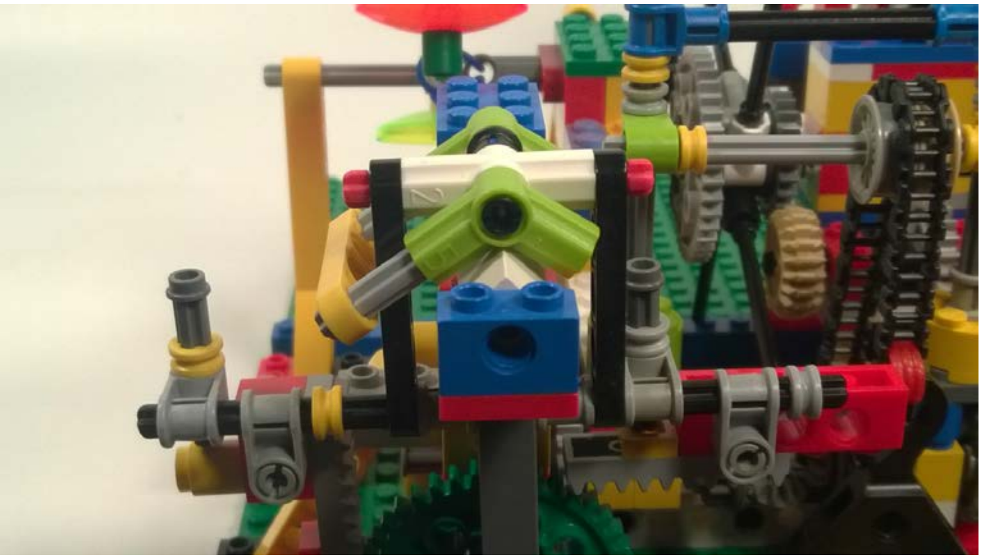
The weight of the pendulum and the main weight deformed the plastic base plate and created friction on the fan fly axle. Since the fan fly is the fastest moving part of the clock and farthest gearing from the power source, the effect of any friction is magnified. Attempts to brace the two fan fly supports failed to keep them aligned with low friction. The solution was to support the fly axle only from one side and power it from the other side eliminating the need for perfect support alignment. Together, the escapement, remontoire, and fan fly accomplished the +/- 1 minute accuracy per day.

Fan Fly with single support, rubber band drive, and pendulum pivot cantilever supports.



Oscillator – With no good clock springs available for an oscillator, I used a meter pendulum on a knife-edge pivot. Lego also doesn't really have a knife-edge but if you've ever stepped on a Lego, you know the 90 degree edges and corners are quite sharp. All I needed was a pivot that was at least 90 degrees plus the maximum swing angles. Making the pendulum pivot out of a 112.5 degree angle connector (Lego #5) and balancing it on a 90 degree brick edge did the trick.

Knife-Edge pivot (light green) and 2 adjustable gravity "springs" controlling pallet resting position.

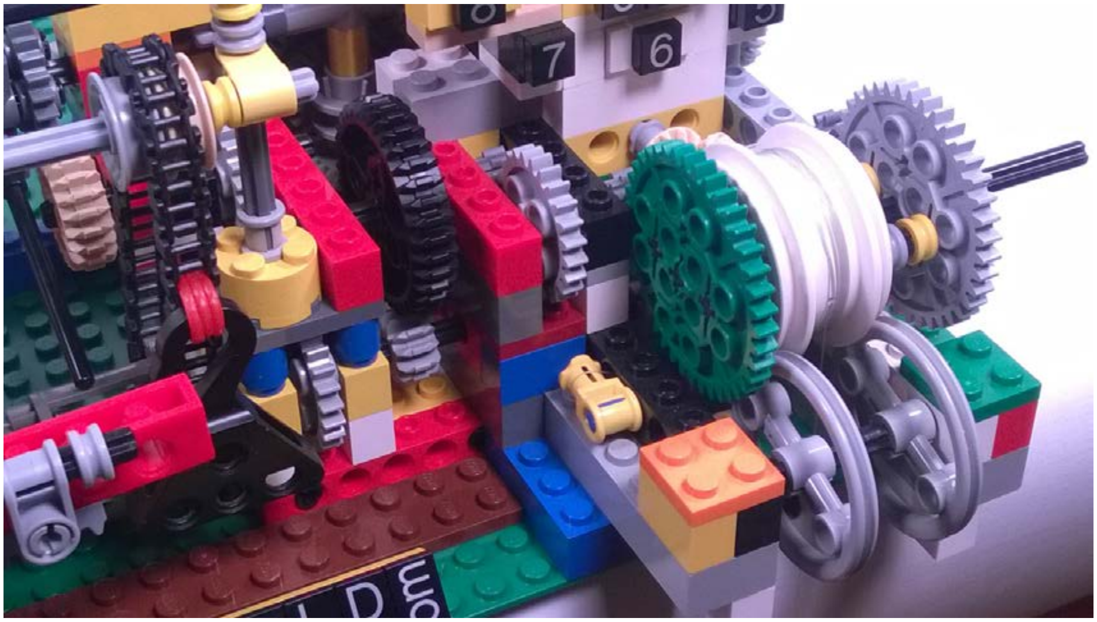


The pendulum rod is thin and weak except in the swing plane. The bob is made from weights used for ballast in Lego boats. Original plans for an aerodynamically smooth rod were discarded after it added too much rod weight and raised the pendulum center of gravity. Suspending the bob with a string was also considered but rejected in order to have a solid rod to support the escapement pallets and some timing correction weights. Having a one piece pendulum/escapement eliminated the need for a 2nd knife-edge pivot. Building the pendulum rod out of Lego plates (bumpy) also allows the pendulum to be quickly shortened to show the effect on the swing period. Small Lego pieces (as weights) can be added to the bob or a flat table above the pendulum center of gravity in order to alter the pendulum timing. To permanently change the pendulum to one of three shorter lengths with faster swings requires only changing just one 24 tooth gear to a 16, 12, or 8 tooth gear and rewinding the clock more often. At its full length of just over 1 meter, the pendulum has a semi-arc swing of less than 2.5 degrees which reduces the impact of circular error.

Pendulum with pivot, bob, 1x2 showing center of gravity (white), and 1x2 showing one meter (gray).

Power Source - The power source is a 3 pound weight that drops 30 inches in 24 hours. Lego weights could have been used again but in the spirit of making JS3 less expensive, I now use nickel coin rolls in a Lego holder. It is cheaper to power the clock using money instead of Lego parts! The coin rolls and the fishing line for safety are the only non-Lego parts. A falling weight turns a gear attached to a spool that rests on 4 roller bearings, an idea gleaned from Harrison's clocks. 3 pounds is too much weight for a single Lego plastic axle to bear so that weight is first divided in half with a simple pulley, then the remaining 1.5 pounds is spread across 4 rollers on 2 axles. The rollers are prevented from bending inward under the weight on their axles because their rims are held in place by the spool. The spool can be lifted off the rollers to rewind the clock in 20 seconds while the remontoire provides maintaining power. The gear train was designed to position the pendulum and main weight to be hanging over the shelf edge while keeping the spool center of gravity on the shelf to prevent tipping.

Main weight reel (white) on 4 roller bearings with two 40 tooth gears for stability.



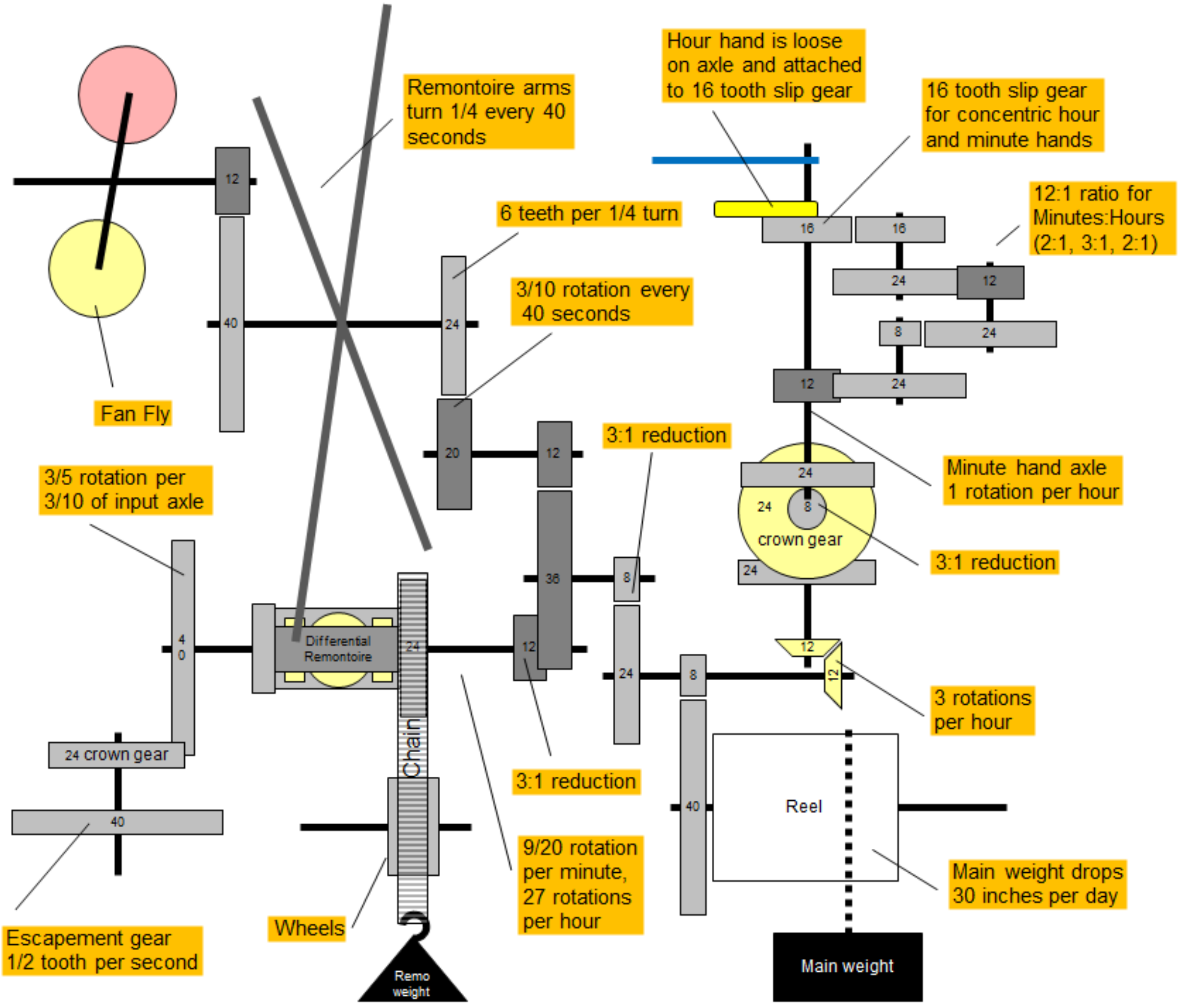
Lego holder for less expensive main weight made from 8 nickel rolls.

Display – I designed the Lego Astronomical Clock to display both civil cycles and natural cycles. Certain displays like 24 mean hours in a day and a 7 day week are civil cycles. The front of the clock is used for the hours and minutes and the top of the clock for longer duration events and orrery-like astronomical complications. The clock face has concentric hands for minutes and hours with numerals in a traditional round layout. A design decision to use the natural cycle of a lunar month instead of a civil calendar month first established it as an astronomical clock. As such, the clock can be used to teach astronomical science as well as gear train math concepts and physics topics like gravity and friction. On the top of the clock is an earth model (from a Lego captain's globe) that rotates once every 24 hours. The day-of-the-week indicator showing the initial letter of each day is a wheel rotating 1/7 per day using a 14 tooth bevel gear meshed with a worm gear driven from the hour hand.

Lego Clock astronomical complications: (clockwise) earth globe 24 hour, 1x2 tide clock (blue), synodic month (b&w lunar phase), tropical month (moon orbit), days of the week, tropical year with earth tilt showing months and season colors, EoT, 1x2 sidereal day pointer (white).

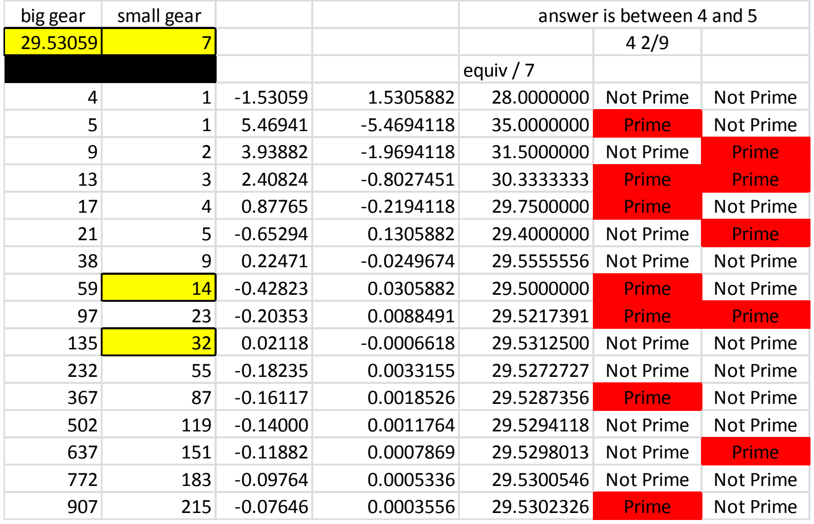
Gear Train – In this Lego clock, the gear train performs the usual rotation speed changes and ensures the gears align with standard Lego brick hole locations. The gear train also adds or subtracts rotations using differential gears. Epicyclical gears were considered instead of differentials since they are used in many historical astronomical clocks. In Lego, it is quite difficult to support long rotating arms holding epicyclical gears without creating lots of additional friction. So instead I used Lego differential gears whenever two angular velocities needed to be added or subtracted. Besides the differential used in the remontoire, there are four more differentials for the astronomical complications. Other than day-of-week, the gear train also has to ensure the displays and orbits rotate in the right direction. Changing plane orientation can only be done with limited bevel, contrate, and crown Lego gears.

Lego Clock gear diagram for lower clock (escapement, remontoire, fan fly, main weight, minutes, hours)



Starting with synodic month, the gear trains had to approximate irrational numbers. To find the gear train for the synodic month I created a Stern-Brocot method spreadsheet to find non-prime combinations that were possible with Lego gears (mostly multiple of 4 teeth). Coming off the 7 day week wheel, the fraction 135/32 factors well and yields a synodic month of 29.53 just using 6 gears (20:16, 24:16, 36:16).

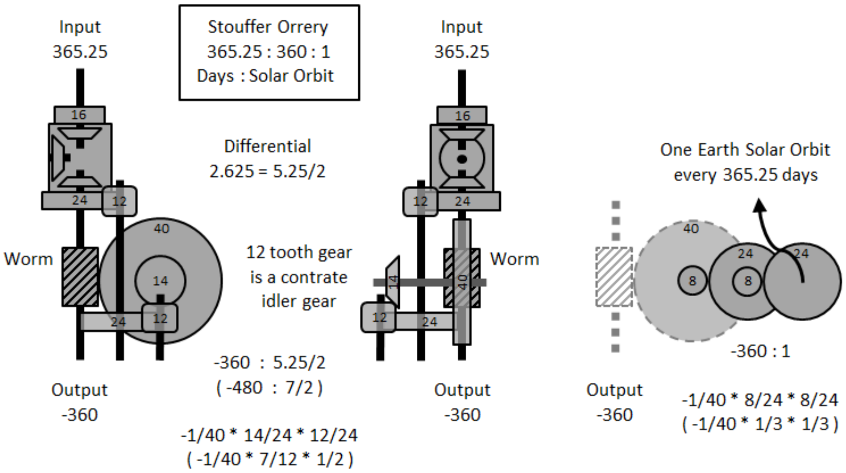
Stern-Brocot spreadsheet showing non-primes 135/32 achieving synodic month in 29.53125 days



big gear	small gear			answer is between 4 and 5		
29.53059	7				4 2/9	
				equiv / 7		
4	1	-1.53059	1.5305882	28.0000000	Not Prime	Not Prime
5	1	5.46941	-5.4694118	35.0000000	Prime	Not Prime
9	2	3.93882	-1.9694118	31.5000000	Not Prime	Prime
13	3	2.40824	-0.8027451	30.3333333	Prime	Prime
17	4	0.87765	-0.2194118	29.7500000	Prime	Not Prime
21	5	-0.65294	0.1305882	29.4000000	Not Prime	Prime
38	9	0.22471	-0.0249674	29.5555556	Not Prime	Not Prime
59	14	-0.42823	0.0305882	29.5000000	Prime	Not Prime
97	23	-0.20353	0.0088491	29.5217391	Prime	Prime
135	32	0.02118	-0.0006618	29.5312500	Not Prime	Not Prime
232	55	-0.18235	0.0033155	29.5272727	Not Prime	Not Prime
367	87	-0.16117	0.0018526	29.5287356	Prime	Not Prime
502	119	-0.14000	0.0011764	29.5294118	Not Prime	Not Prime
637	151	-0.11882	0.0007869	29.5298013	Not Prime	Prime
772	183	-0.09764	0.0005336	29.5300546	Not Prime	Not Prime
907	215	-0.07646	0.0003556	29.5302326	Prime	Not Prime

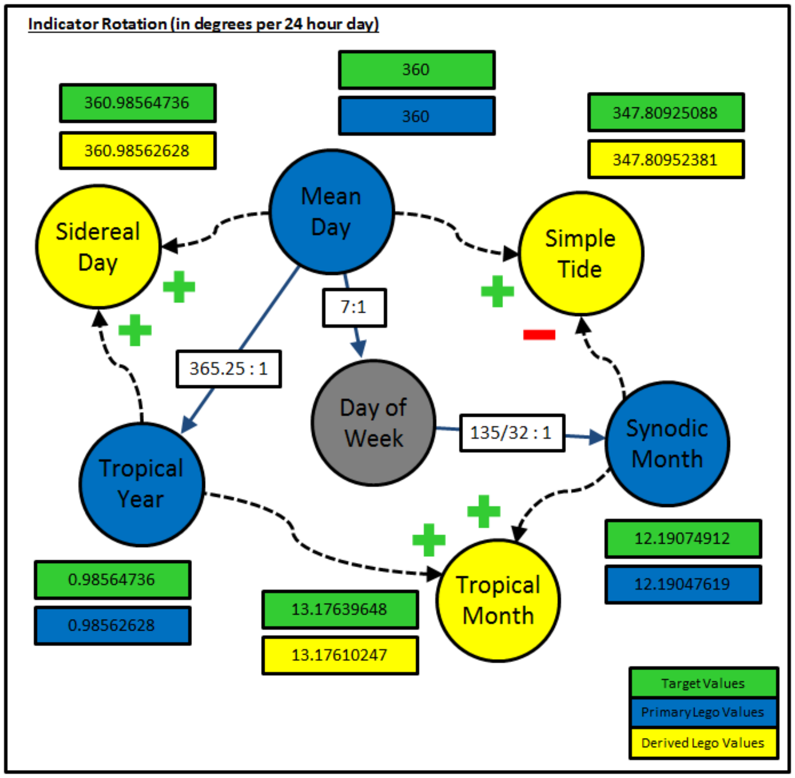
The Stern-Brocot spreadsheet did not yield any good Lego gear train candidates for the annual earth orbit around the sun in 365.242 days. Another approach was needed. Settling for accuracy of 365.25 days to match the civil cycle of leap years, I thought a differential could again be used as an addition & subtraction machine. If some portion of the 365.25 day rotations could be subtracted continuously during the year then the remaining amount could be converted to one earth orbit. Using a differential, I created a mechanism that takes an input of 365.25 days and outputs exactly one 360 degree rotation. Remember that a differential can have one input and two outputs (or vice versa). The annual orbit differential splits the input of 365.25 day rotations by routing 5.25 through the differential frame output and 360 to the output axle. The two outputs (frame and axle) are locked together in a ratio of 480:7 (which equals 360/5.25) preventing anything other than this ratio. The 360 output axle rotations are converted to a one 360 degree rotation with a 40:1 worm and two 3:1 reductions that drive a model of the earth orbiting around the sun showing months and seasons. The earth axis tilt is maintained throughout the orbit by a Ferguson paradox-like arm mechanism.

Mechanism for creating 360 degree earth orbit from input of 365.25 day rotations.



The challenge of having limited Lego gears is that there are very few gear trains that work well for many typical complications. My solution was to create three "easier" complication rotations then derive three more difficult rotations using differentials to add or subtract angular velocities. With a satisfactorily accurate 24 hour mean day, 29.53 day synodic month, and a 365.25 day earth orbit, combinations of these three primary rotations could directly produce three additional astronomical complications: tropical month, simple tide (lunar day), and sidereal day. To my knowledge using these three primary rotations to derive three more complications this way has not been done before. That may be because historical clocks don't have the gear teeth constraints and tend to use individual gear trains for complications instead of combining final rotations.

3 primary complication rotations and 3 derived complication rotations

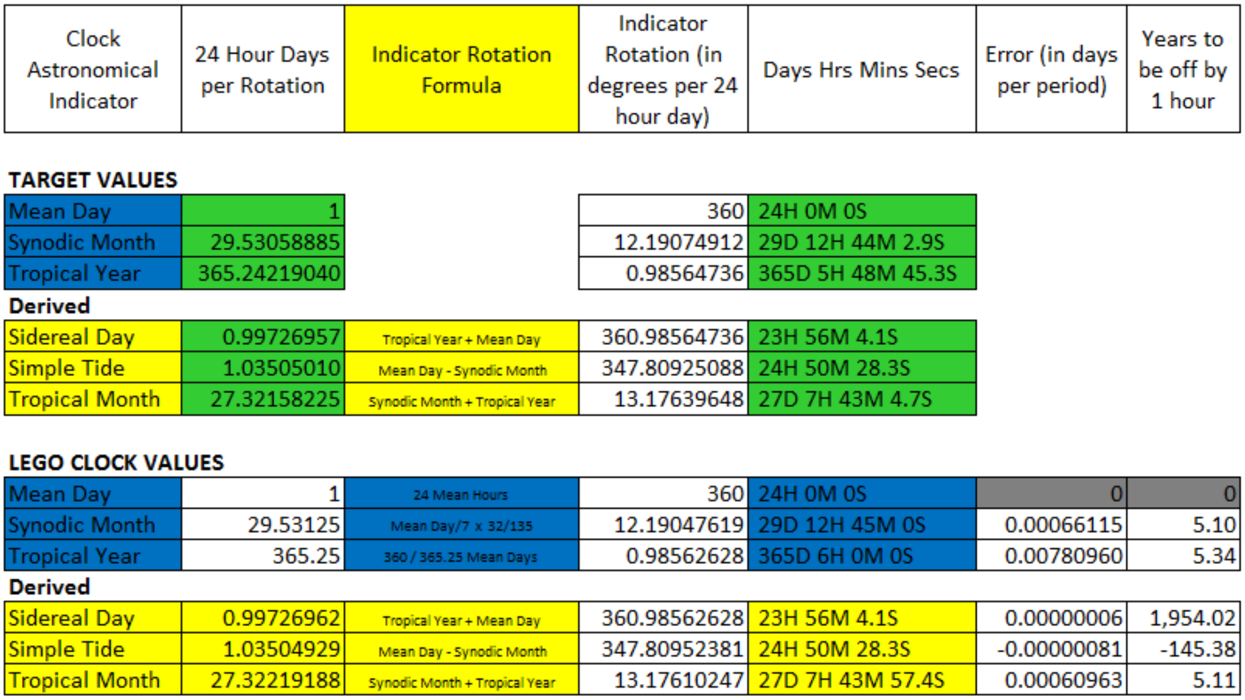


Each of the three derived complications is combined from the rotation of two primary complication rotations using a differential:

Sidereal Day = Mean Day + Tropical Year
Simple Tide (Lunar Day) = Mean Day - Synodic Month
Tropical Month = Synodic Month + Tropical Year

The accuracy of the three derived complications could be improved by increasing the accuracy of the primary three. The error of around one hour in 5 years for the derived Tropical Month comes from the error in the primary Synodic Month and Tropical Year.

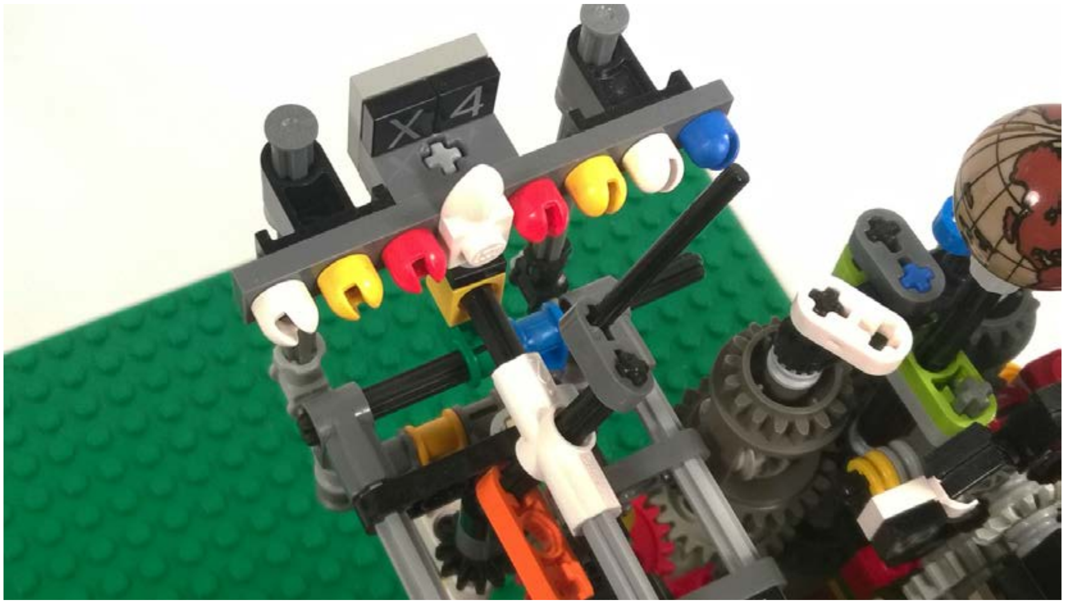
Target values (green), Lego primary values (blue) and secondary derived values (yellow).



Clock Astronomical Indicator	24 Hour Days per Rotation	Indicator Rotation Formula	Indicator Rotation (in degrees per 24 hour day)	Days Hrs Mins Secs	Error (in days per period)	Years to be off by 1 hour
TARGET VALUES						
Mean Day	1		360	24H 0M 0S		
Synodic Month	29.53058885		12.19074912	29D 12H 44M 2.9S		
Tropical Year	365.24219040		0.98564736	365D 5H 48M 45.3S		
Derived						
Sidereal Day	0.99726957	Tropical Year + Mean Day	360.98564736	23H 56M 4.1S		
Simple Tide	1.03505010	Mean Day - Synodic Month	347.80925088	24H 50M 28.3S		
Tropical Month	27.32158225	Synodic Month + Tropical Year	13.17639648	27D 7H 43M 4.7S		
LEGO CLOCK VALUES						
Mean Day	1	24 Mean Hours	360	24H 0M 0S	0	0
Synodic Month	29.53125	Mean Day/7 x 32/135	12.19047619	29D 12H 45M 0S	0.00066115	5.10
Tropical Year	365.25	360 / 365.25 Mean Days	0.98562628	365D 6H 0M 0S	0.00780960	5.34
Derived						
Sidereal Day	0.99726962	Tropical Year + Mean Day	360.98562628	23H 56M 4.1S	0.00000006	1,954.02
Simple Tide	1.03504929	Mean Day - Synodic Month	347.80952381	24H 50M 28.3S	-0.00000081	-145.38
Tropical Month	27.32219188	Synodic Month + Tropical Year	13.17610247	27D 7H 43M 57.4S	0.00060963	5.11

The final complication on the JS3 Lego clock is an Equation of Time (EoT) indicator that also shows solstice, equinox, aphelion, and perihelion. At its simplest, the traditional EoT kidney shaped cam is a function of the sum of two sinusoid waves representing the earth's eccentricity and obliquity on a 2:1 rotation ratio with slightly offset periods and very different amplitudes. Lego doesn't have a kidney shaped EoT cam like that used in many equation clocks. So I went back to basics and invented a new EoT solution by modifying an ancient mechanism, the whippletree (a.k.a. whiffletree).

Scale for EoT pointer showing (X4) blue on right representing 16 and white on far left representing 12.

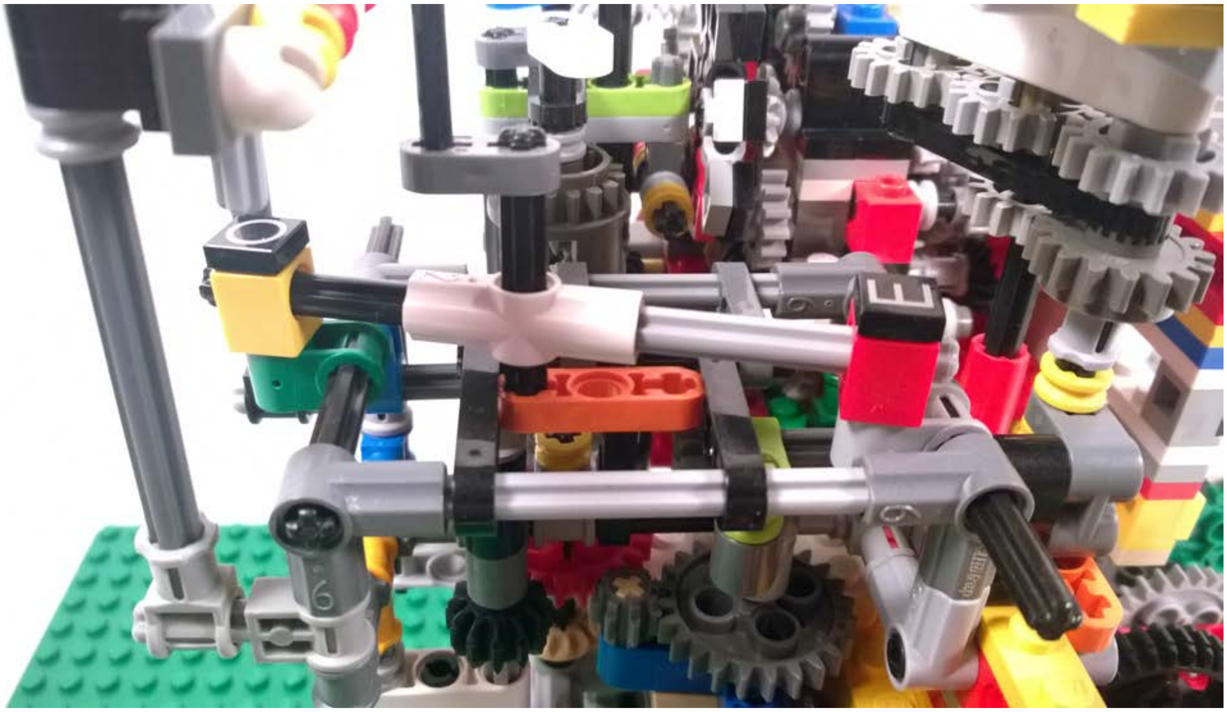


The Lego EoT mechanism uses the sinusoid wave created by isolating a single X or Y motion of a point on a rotating wheel. Two different sine wave periods are generated from Lego 24 and 12 tooth gears. These two sine waves are then added together using a new "parallel whippletree". A traditional whippletree has been used in diverse applications such as tethering oxen of different strengths, for a WWII airplane payload mechanical calculator, and on the IBM Selectric typewriter. All those implementations ignore the small error caused by the two input shafts converging and diverging due to the varying angle of the summing lever. In my Lego EoT mechanism, the sine input shafts always remain parallel thereby eliminating this error. The ends of the summing lever can slip through each input shaft end connector. The summing lever remains fixed at a "middle" point that divides the summing lever into two portions representing the desired ratio of the input amplitudes. Since the amplitude of the obliquity sine wave is larger than the eccentricity amplitude, the fixed point of the summing bar is closer to the obliquity input shaft giving it a greater contribution to the EoT sum.

Math to determine fixed "middle" point of parallel whippletree summation bar.

Element	Amplitude	Contribution	Distance	Teeth	Period
Obliquity	9.87	56.30%	3.496	12	2
Eccentricity	7.66	43.70%	4.504	24	1
Total	17.53	1	8		

Parallel Whippletree Equation of Time mechanism with red drive gear, black 12 tooth gear, and gray 24 tooth gear connected through 8 tooth idler gear. Eccentricity (E) sine shaft extended toward camera and Obliquity (O) sine shaft extended away from camera. Summing lever is fixed by orange pivot in "middle" and slides through O and E 1x1 bricks connected to the sine shafts.



There are several mechanical functions involved in creating and summing the sine wave inputs using this EoT mechanism. Wave frequency is controlled by the 2:1 ratio of the gear teeth (12 & 24). The period start offsets are adjusted first by whole tooth engagement and then by the idler gear tooth mesh with a fine adjustment for distances less than one tooth. Addition of the two sine waves is accomplished through the parallel whippletree summing lever. Amplitude of each wave is equivalent to the ratio created by the "middle" fixed point of the whippletree summing lever. Multiplication of the small resulting summation motion is done through a pointer lever that traces a display range points from -14 to +16 on a straight scale. The earth orbit display also has certain months at "corners" roughly showing equinoxes and solstices. Even more accurate equinox and solstice indication is when the 12 tooth obliquity (O) sine wave bar is centered (zero). Aphelion and Perihelion are when the 24 tooth eccentricity (E) sine wave bar is centered.

Since the astronomical complications move too slowly to be noticed, some clutches have been built in to the clock to separate mechanisms and allow for a demonstration mode and setting mode. Lifting a crown gear clutch separates the power from the 12:1 minutes/hours gear train allowing the clock time to be easily adjusted. Hidden behind the clock face numeral 4 is a lock that disengages the timekeeping from the rotating globe day mechanism and everything longer than one day. In demonstration mode, a crank on the right side of the clock can be manually rotated showing the complications moving quickly. A third clutch separates the earth orbit from the EoT mechanism in order to align both these items.

One of three clutches (blue) is hidden behind the clock numeral 4 separating time functions from astronomical functions. The demonstration mode crank (brown) is inserted.

Several other complications were considered and prototyped before being discarded. A perpetual calendar was designed but it was such a large mechanism that it doubled the size of the Lego clock. Hourly chimes (bells) were considered but also were too large and more suitable to a different themed clock. A seconds hand was implemented but removed since it demanded too much power and required changes to the remontoire weight and shape. An odometer (with Pascaline automatic carry) was also created to represent the calendar year, Saros eclipse cycle, or another counting event. It may be added back later. I hope other horologists and Lego builders take on the challenge of adding these and other complications into their clocks.

More information is available at BuildSTEAM.com, my web site devoted to bringing these hands-on mechanisms to the next generation. Our motto is “Inspiring Young Innovators”. In addition to the clock there are Lego working models of a “steam” engine, mechanical logic gates (the basis of modern computers), phonograph, key locks and combination locks models. A working Lego sextant helps complete the longitude story. Like the clock, these Lego machines do more than just look the part. They perform the function of the real machines.

With these models, I hope to inspire three groups: children, mentors, and experts. For children, I want them to learn to love and understand mechanisms and engineering and appreciate their historical impact. They should gain the confidence that complex processes can be studied and understood. I want them to become makers and inventors, confident in using the tools of math and science. For teachers/mentors/parents, I want to create models and collaborate on workshop lesson plan materials to help them foster tinkering. For experts, I want to provide a platform where they can share their knowledge with the next generation and add supporting information to supplement the hands-on Lego models.

I want to provide more details in future HSN articles, especially the EoT mechanism, the 365.25 conversion gear train, and using Stern-Brocot for deriving gear trains for complications. I look forward to the online discussions from the horology experts, feedback from teachers, and the ideas that will come from the Lego builder community.