2022 Midwest State Machine Design Competition

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Abstract:

A mechanical clock has been designed by Valparaiso University's team: Lauren, Jonathan, and Llovizna with the assistance of Prof. Andrew Gutshall. The "crazy clock" effect was made for the production *All in the Timing*.
The clock has 3 hands: second, minute, and hour. It can complete two conditions.

The first condition has the seconds hand moving at an angular velocity of 3 revolutions per second; at which, the minute hand moves a total of 6^o per each single second revolution. The hour hand then moves a total of 30^o per each revolution of the minute hand. All hands move in clockwise direction.

On the contrary, during the second condition, the second and hour hand move in counterclockwise direction, only the minute hand moves in the clockwise direction. Each single revolution of the second-hand results in a total of 18^o movement of the minute which ascend the hour hand to moves a total of 60^o. The conditions are interchangeable given that a backstage crew member switched the magnet up or down. Any further manufacturing and bill of materials are attached below.

Research:

The following have been used in various forms to assist in the learning of a clock mechanism and design specifications. What we learned about clocks and material science in each resource below is listed next to it.

“How a Mechanical Watch Works”: Setting jumper is used to lock the crown mechanism in place. A crown, similar to a pusher, is used to re-adjust setting and time. A mainspring, connected to a mainspring barrel, exerts force on the gears, creating a change in motion. The spring is then connected to the wheel train - a set of gears connected to one another and attached to the hands. Cannon pinions help reduce speed from gears. In between the gears and hands, there are jewel bearings which help keep internal parts in good condition. The heart of the mechanism comes from a pallet form and escape wheel where the balance wheel moves in a precise rhythm making the fork move back and forth, which then, turns the escape wheel releasing mainspring power in small increments. In aggreiance to Hooke’s Law, a possible source of power can come from the change of distance in a spring.

“How A Mechanical Clock Works”: Similar reiteration as previous resource; however, this video does show the physical components and the manual assembly.

“How a watch works; Mechanical Movement”: A quick run-down of the overall line of assembly: energy, wheels, escapement, controller, and time indicator.

Gear Ratios & Compound Gear Ratios This website provided a run down for calculating compound and simple gear ratios as well as a reminder of shaft spacing.

Torque and Speed Relationships in Gear: A refresher on torque, and its effect on moment. The example most helpful to us consisted of a motor and block.

Further research on sound waves noise cancellation was done and is listed on the cited list.

All members used their knowledge and notes from Valparaiso University’s Material Science course to determine what material would be utilized. Credit to the professor is listed on the cited list.

Brainstorming:

- 1st: Make the system removable by allowing the 1st gear train to be removed and then placing the second one.
  - Cons: Gears may fall. It may take too long.
- 2nd: Use a spring to power the gears.
  - Cons: More calculations resulting in a higher risk of failure and higher maintenance. High risk of injury if spring dislocates and uncoils.
- 3rd: The system can be hand mechanized with a crank.
  - Cons: The timing of the cranking would be arduous.
- 4th: The clock can run by a pendulum.
  - Cons: Runs out of power quickly and massive.
    - Difficult to run the second hand in 3rpms.
- 5th: Remove specific gear while keeping majority.
  - Cons: May become uneven or pieces may get lost.

Care and Noise Reduction:

Safety: The entire system will weight > 5lb. If deciding to carry it oneself, do it under the discretion of one's physical ability to do so. Safety gloves are recommended as the hands, plates, and face are made of plywood. We do expect safety glasses to be worn – working with small parts can results in pieces falling out when not handled correctly. We do suggest that durable shoes are worn as the falling off the clock may cause injury. **Before using the clock, make sure all gears and (dividers/platforms) are not dislocated**. When moving the gears around, make sure the motor is off. As there are a high number of gears, the risk of finger pinching is high. When not in use, keep the clock stored independently as collision with other props may damage the gears and other miniscule components.

Set-Up: Depending on the need of the clock, it can be placed on a wall or on a flat surface. The gears will be covered with a closed box. The closed box will have a hole which can be hooked onto to place the clock in higher altitudes. For the competition, the clock will be placed on a 3D-printed base which will stand on a flat surface.

Maintenance:

- Efficient and safe cleaners for all the components of the mechanism – approved by CDC Guidelines and EPA's list of Disinfectant for Use Against SARS-CoV-1 (COVID-19) and overall cleaning tips.
  - Clorox or Lysol Disinfecting Wipes.
  - Lysol or Clorox Disinfectant Spray.
  - Cleaners containing: Alkyl (50% C14, 40% C12, 10% C16) Dimethyl Benzyl Ammonium Saccharinate (also called Quaternary ammonium)
  - Cleaners containing: (optional) Ethanol or Ethyl alcohol

Noise Reduction: One of our focuses was noise reduction due to the reflection of soundwaves which results as audio points towards a flat surface. Consequently, there will be either echoes or reverberation. This is because our gears, designed to be as linear planes, transmit noise to the back surface of the clock assembly. Listed below are possible noise reductors:

- Oiling the coincident between the axel and gear - reduces friction which then minimizes sound.
- Create a vacuum – extracts all air thwarting sound to travel.
- Insulate the clock with a noise reduction cover made of dynamat or mass loaded vinyl – traps sound from leaving a space.
- Add mass and make the assembly compacted – less space for sounds to travel.

We agreed that insulating the box is an option, but we'll most likely go with oiling.

Detailed Logistics:

When testing out materials, a ¼"x12"x12" piece of plywood was used to test out how well the gears would cut out. Using a laser cutter of 500Hz and 4 passes with 20% speed and 100% power, caused the teeth of the gears to deteriorate. When we changed the speed to 10%, the teeth of the gear had twice as less wood ash, but the teeth were still slightly uneven. Due to inconsistency, it was decided to utilize acetal instead. Acetal sheets refine cuts and dampen sound.

Due to time constraints of 20 minutes, it was decided to make 2 gear trains. The 2 gear trains are the two layers in Figure 3.1 and Figure 3.2. Each represent one of the two conditions. A shifter mechanism, as shown in Figure 4.0, is used to run either the 1st or 2nd layer. A magnet holds the gear in place thwarting it from falling. The idea is that a crew member would be able to switch the condition by moving the magnet; by doing so, the first condition or second gets triggered. The clock hands must connect to two different sets of gear trains depending on the desired mode. However, a traditional shifter is problematic in this capacity, since while shifting, the shifter experiences backlash while the halves of the shifter catch up to each other. Because the hour hand moves so slowly, a low backlash system was necessary to begin movement immediately upon clock startup.

To engage immediately, we decided to use the friction between the shifter plate and the gear to power the shaft, as shown in Figure 5.0. A circular magnet around the shaft holds the steel shifter plate in contact with the gear. An adjustable counterweight allows the weight of the plywood hands to be offset.

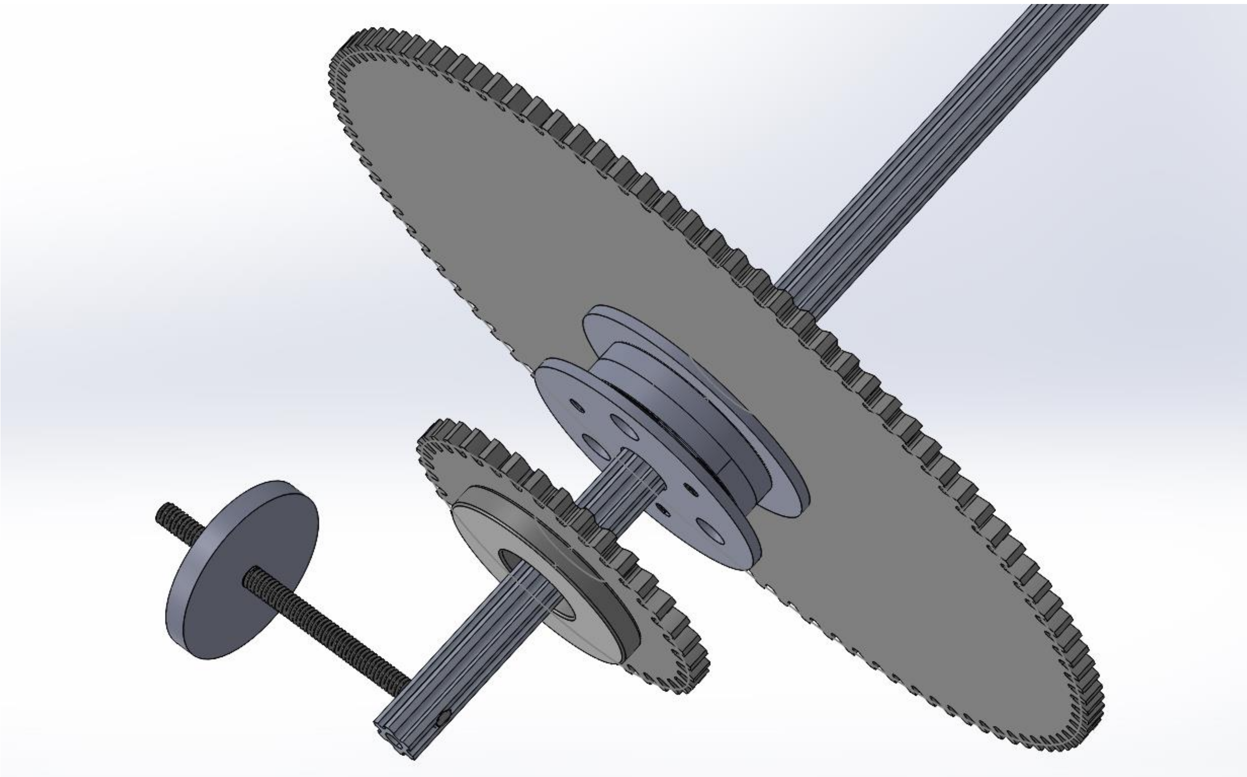


Figure 4.0:

The counterweight is threaded with a light thread locker onto the threaded rod. This allows us to balance the hand shafts around the axis of rotation. We do not anticipate balance in the other axis to be an issue since the shaft will be supported with bearings at several points. The threaded rod will be threaded into the shaft with a permanent thread locker. We don't think that the hands will weigh too much, so a small metal weight should be capable of balancing them out.

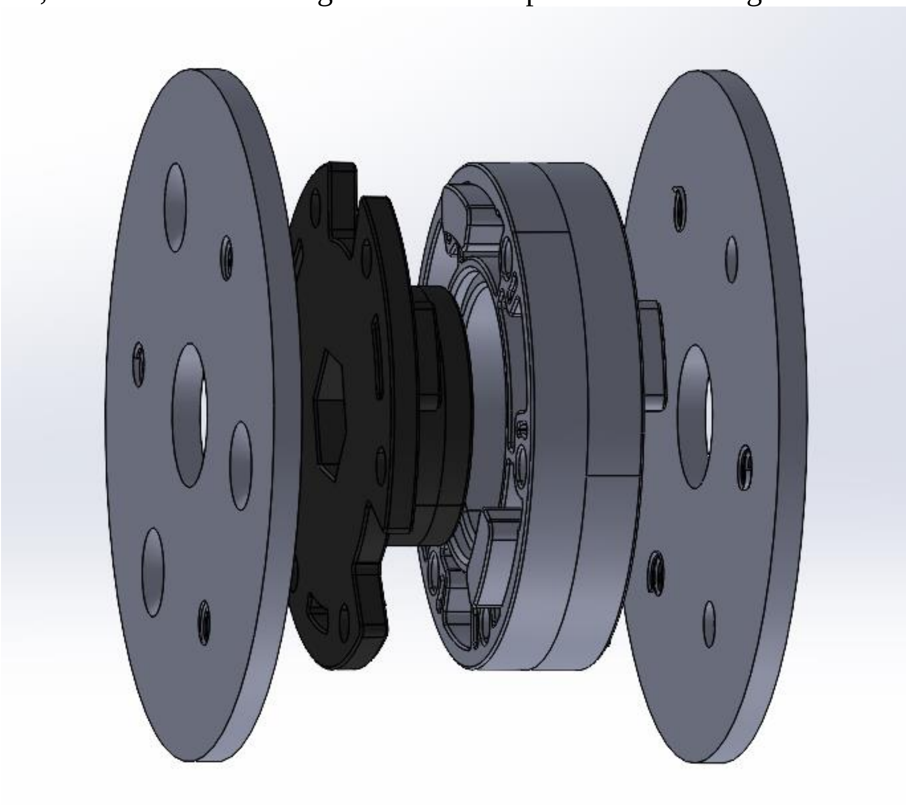


Figure 5.0

The moving part of the shifter itself, Figure 6.0, is made up of four main components. Two drilled and tapped steel plates make up the end caps held on by countersunk screws. These parts are attracted by the magnets on the gears to provide the friction force between the shifter and the gears. A plastic hex hub and spacer from VEX allow for torque transfer to the hex axle and spacing for the control plate to move the mechanism.

When putting things all together, the gear train system was much larger, we reduced and compacted the gears. This reduces the noise and becomes cost-efficient. The Figure 6.0 is in an example of the previous sketch.

Condition 1:

Our clock mechanism is divided into two layers as shown in Figure 3.1. The first layer, closer to the front face of the clock, starts off with the gearbox axle holding an 18-teeth gear which connects to the second hand with 2 gears attached. One gear is a 55-teeth, and the other is a 20-teeth gear. The 20-teeth gear gets coincident to the 100-teeth gear attached to the first axle, which runs the 36-teeth gear. The 36-teeth gear is then routed to the second axle where it gets connected to the 72-teeth gear that's attached to a 20-teeth gear. The 20-teeth gear is attached to a 60-teeth gear which falls on the minute hand. That gear attaches itself to a 60-teeth gear that's on a 4th axle. It then turns a 30-teeth gear that's connected to a 60-teeth gear on 5th axle. A 20-teeth gear is on the same axle which coincident to a 60-teeth gear that runs a 30-teeth gear. Finally, the last gear is attached to a 60-teeth gear that runs the hour hand.

The system is designed to have a 60:1 gear ratio between the seconds and minute hand. The minute and hour hand then have a 12:1 gear ratio.

Now, we've noticed that the front face has direct contact with the first layer which will increase friction. To resolve this, we would be adding spacers, or washers, in between.

Condition 2:

The second layer, above the first layer, starts off with the gearbox axle holding an 18-teeth which connects to the 7th axle with a 55-teeth gear that runs a 20-teeth gear. The 20-teeth gear connects with a 60-teeth gear that aligns with the second hand. The gear helps run a 30-teeth gear that's attached to the 8th axle's 60-teeth gear that runs a 20-teeth gear. The same routine occurs with the 9th axle, minute hand, 4th axle, 5th axle, and finally the hour hand.

The system is designed to have a 20:1 gear ratio between the second and minute hand. The minute and hour hand then have a 6:1 gear ratio.

Green - Clockwise
Red - Counterclockwise

Gear Ratios for Condition 1

Condition 1

Gearbox	Second hand	Ax1	Ax2	Ax3	Minute hand	Ax4	Ax5	Ax6	Hour hand
18	55								
	20	100							
		36	72						
			30	60					
				20	60	60			
						30	60		
							20	60	
								30	60

	Calculations			Ratio	Speed (rev/s)
Motor					110
Gear Box	(110/12)			12	9.166666667
Second	Gear speed *(18/55)			3.055555556	3
Minute	Second hand *(20/100)*(36/72)*(30/60)*(20/60)			60	0.05
Hour	Minute hand *(30/60)*(20/60)*(30/60)			12	0.004166666667

Figure 1.0

Gear Ratio for Condition 2

Condition 2								
Gearbox	Ax7	Second hand	Ax8	Ax9	Minute hand	Ax4	Ax5	Hour hand
18	55							
	20	60						
		30	60					
			20	100				
				36	72	72		
						20	60	
							30	60

	Calculations			Ratio	Speed (rev/s)
Motor					110
Gear Box	(110/12)			12	9.166666667
Second	Gear speed *(18/55)*(20/60)			9.166666667	1
Minute	Second hand *(30/60)*(20/100)*(36/72)			20	0.05
Hour	Minute hand *(20/60)*(30/60)			6	0.008333333333

Figure 1.2

Bill Of Materials

Object	Material	Cost/Amount per cost	Vendor	Quantity	Length necessary (in)	Thickness (in)
Axle	Steel	$6/36in	HomeDepot	11	16.5	1/4
Steel Sheet	A36 Steel	$12/1	Amazon	1	9x6	0.125
Countersunk Screws	Own	---	---	---	---	---
Filament	Own	---	---	---	---	---
Bearings	Own	---	---	---	---	---
Washers	Own	---	---	---	---	---
Plywood	Plywood	Own				1/4
Churro	Aluminum	$18/72in	AndyMarks	4	16	1/4
Motor	Multi	Own	VexU	1	---	---
Magnet	Ferromagnetic	$1.50/1	Magnet Shop	4	---	---
VersaHub	Plastic	$8/1	VexU	3	---	.5
Spacers	Plastic	$3.29/20	VexU	3	---	.5
Acetal Sheet	Acetal	$19/ 12"x12"	ePlastics	8	---	¼
Gearbox	Own	$60/1	VexU or AndyMark	---	---	---
Cover for Back Face of Clock	Own	---	---	---	---	---
					Area necessary (in^2)	Dims
Clock Face	Plywood			3	1728	6ft-2ft
Gears	---	---	---			
18 tooth	---	---	---	2	8	
20 tooth	---	---	---	6	29.04	
30 tooth	---	---	---	5	51.2	
36 tooth	---	---	---	2	28.88	
55 tooth	---	---	---	2	64.98	
60 tooth	---	---	---	10	384.4	
72 tooth	---	---	---	3	164.28	
100 tooth	---	---	---	2	208.08	
					938.86	2ft-4ft

Figure 2.0

--- = Not Needed/Null

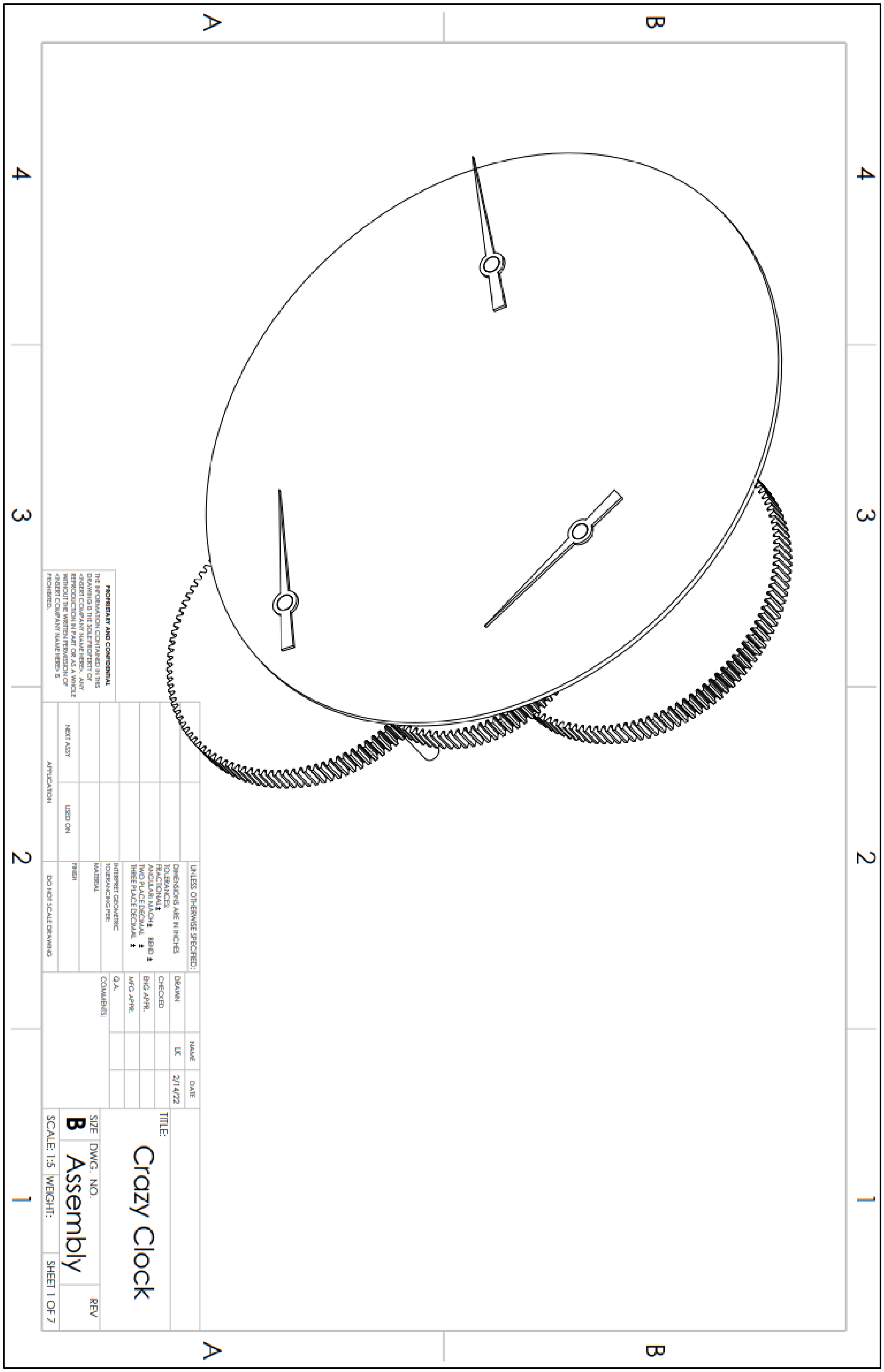
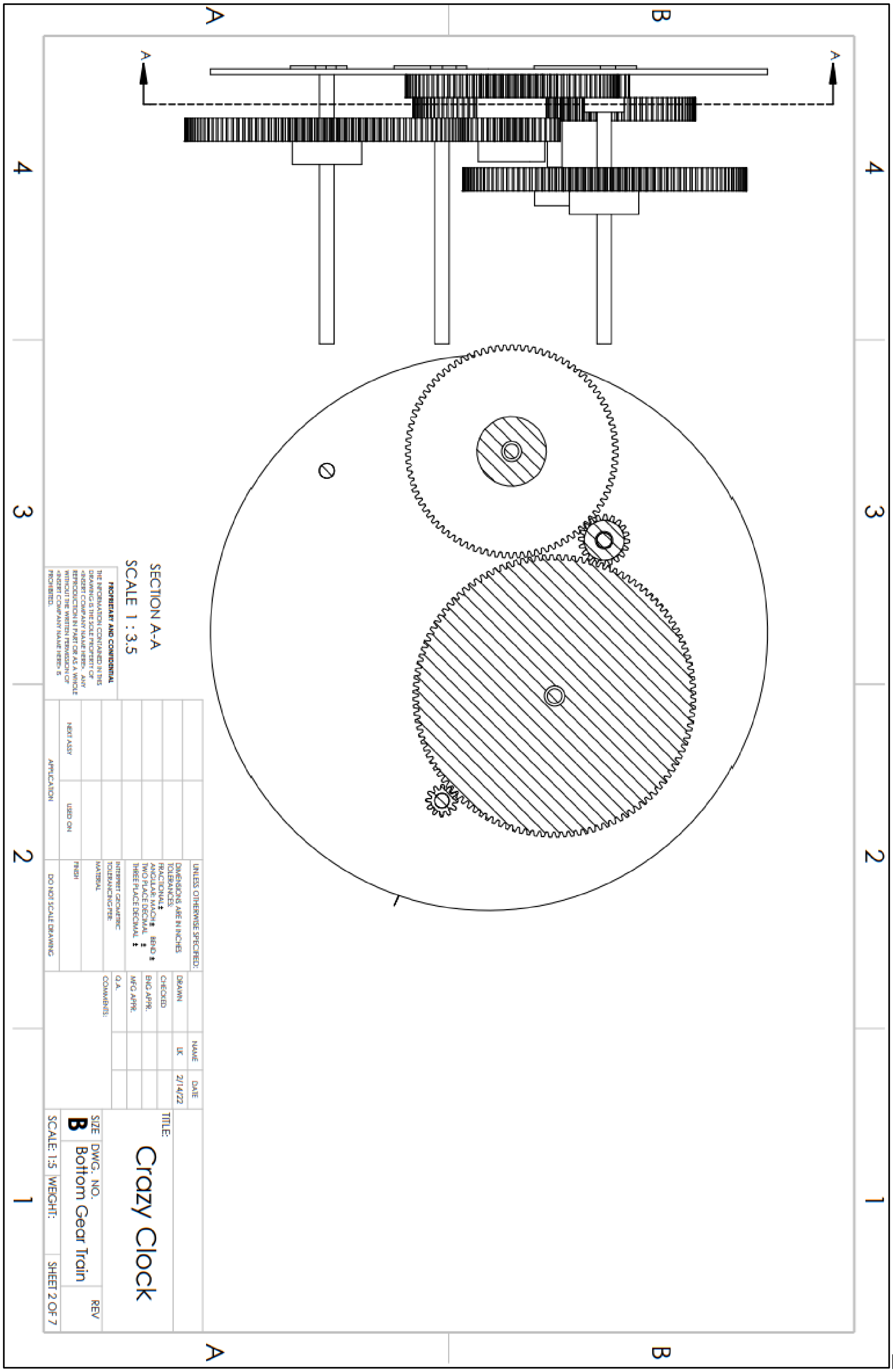


Figure 3.0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SCALE 1 : 3.5
PROPRIETARY AND CONFIDENTIAL
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
DRAWN
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
NAME
DATE
2/14/22
TITLE:
Crazy Clock
SIZE
B
DWG. NO.
Bottom Gear Train
REV
SCALE: 1:5
WEIGHT:
SHEET 2 OF 7
NEXT ASSY
USED ON
APPLICATION
DO NOT SCALE DRAWING

Figure 3.1

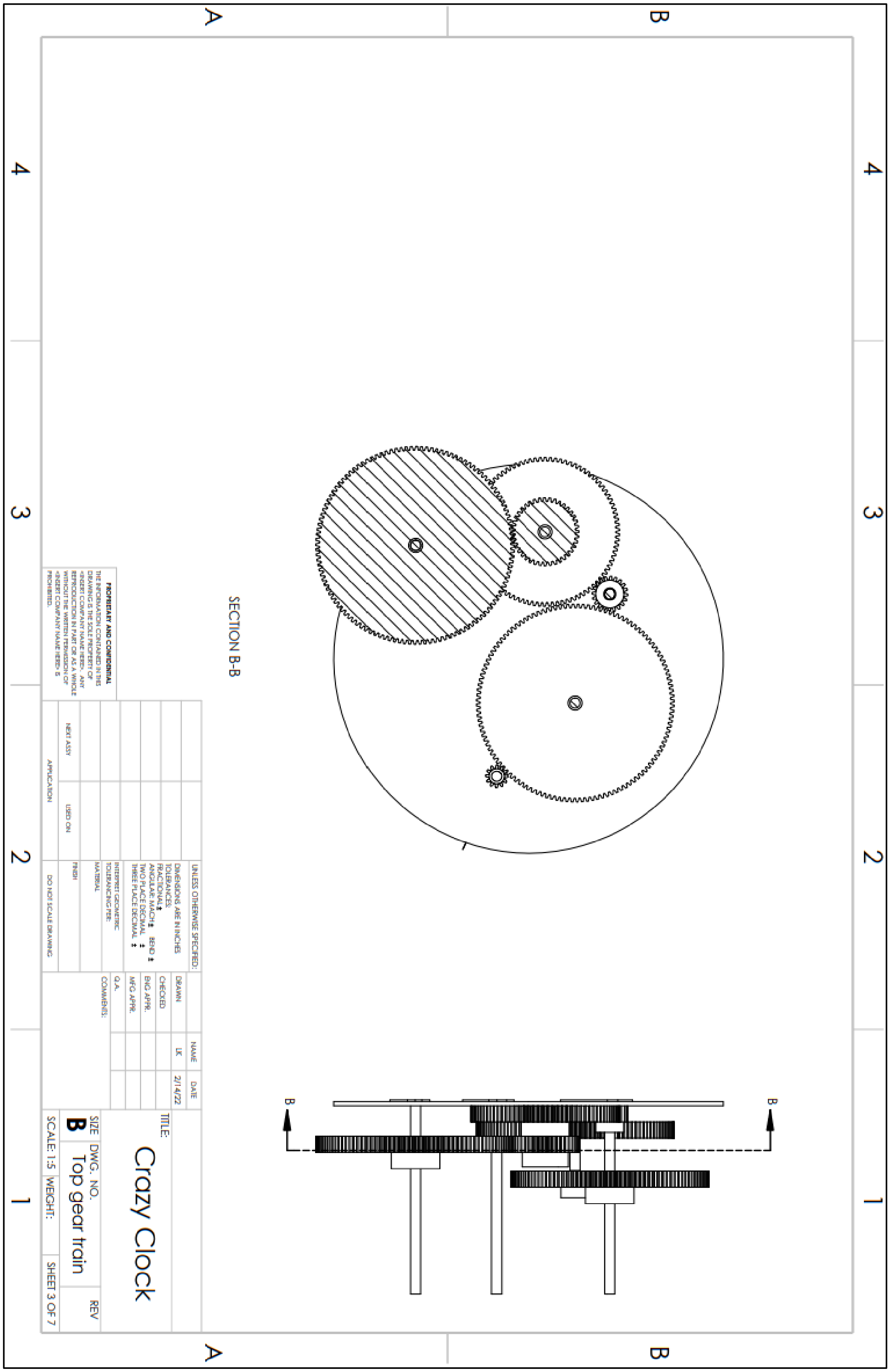

SECTION B-B
TITLE:
Crazy Clock
SIZE
B
DWG. NO.
Top gear train
REV
SCALE: 1:5
WEIGHT:
SHEET 3 OF 7
UNLESS OTHERWISE SPECIFIED:
DRAWN
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
NAME
DATE
2/14/22
MATERIAL
FINISH
NEXT ASSY
USED ON
APPLICATION
DO NOT SCALE DRAWING
PROPRIETARY AND CONFIDENTIAL

Figure 3.2

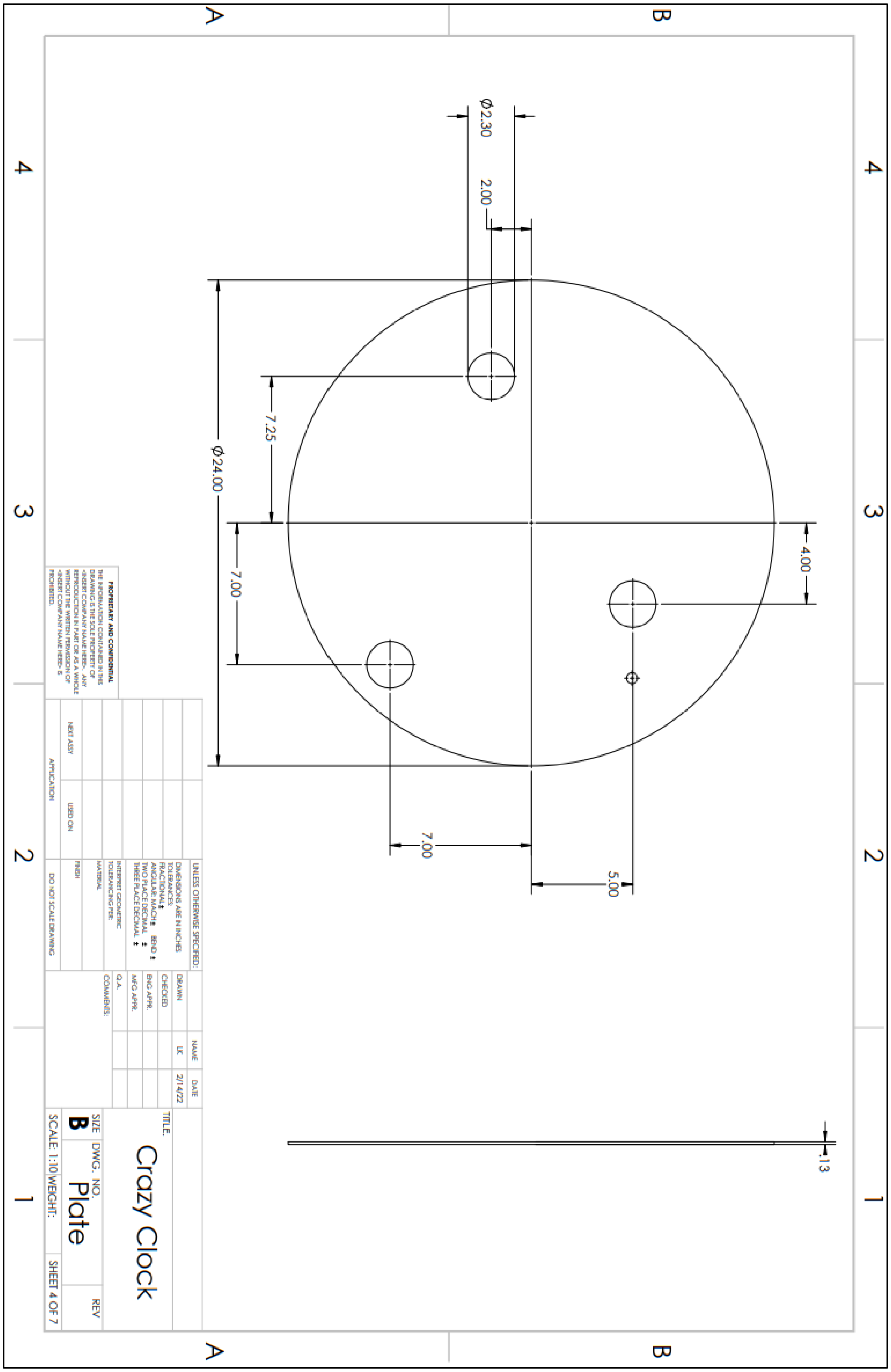

Ø2.30
2.00
Ø24.00
7.25
7.00
4.00
7.00
5.00
.13
UNLESS OTHERWISE SPECIFIED:
DRAWN
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
NAME
DATE
LK
2/14/22
TITLE:
Crazy Clock
SIZE
B
DWG. NO.
Plate
REV
SCALE: 1:10
WEIGHT:
SHEET 4 OF 7
NEXT ASSY
USED ON
APPLICATION
FINISH
MATERIAL
DO NOT SCALE DRAWING
PROPRIETARY AND CONFIDENTIAL

Figure 3.3

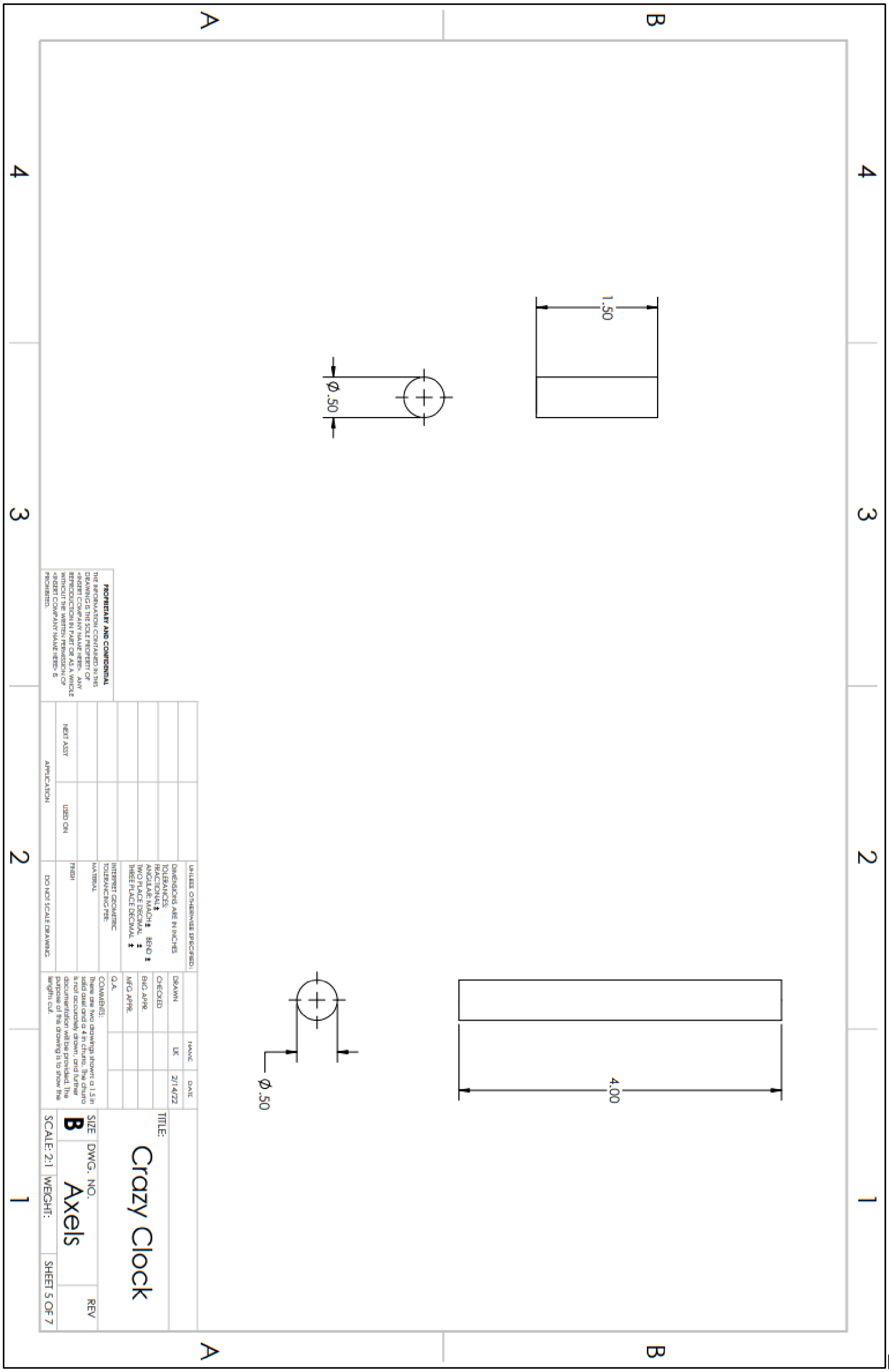


Figure 3.4

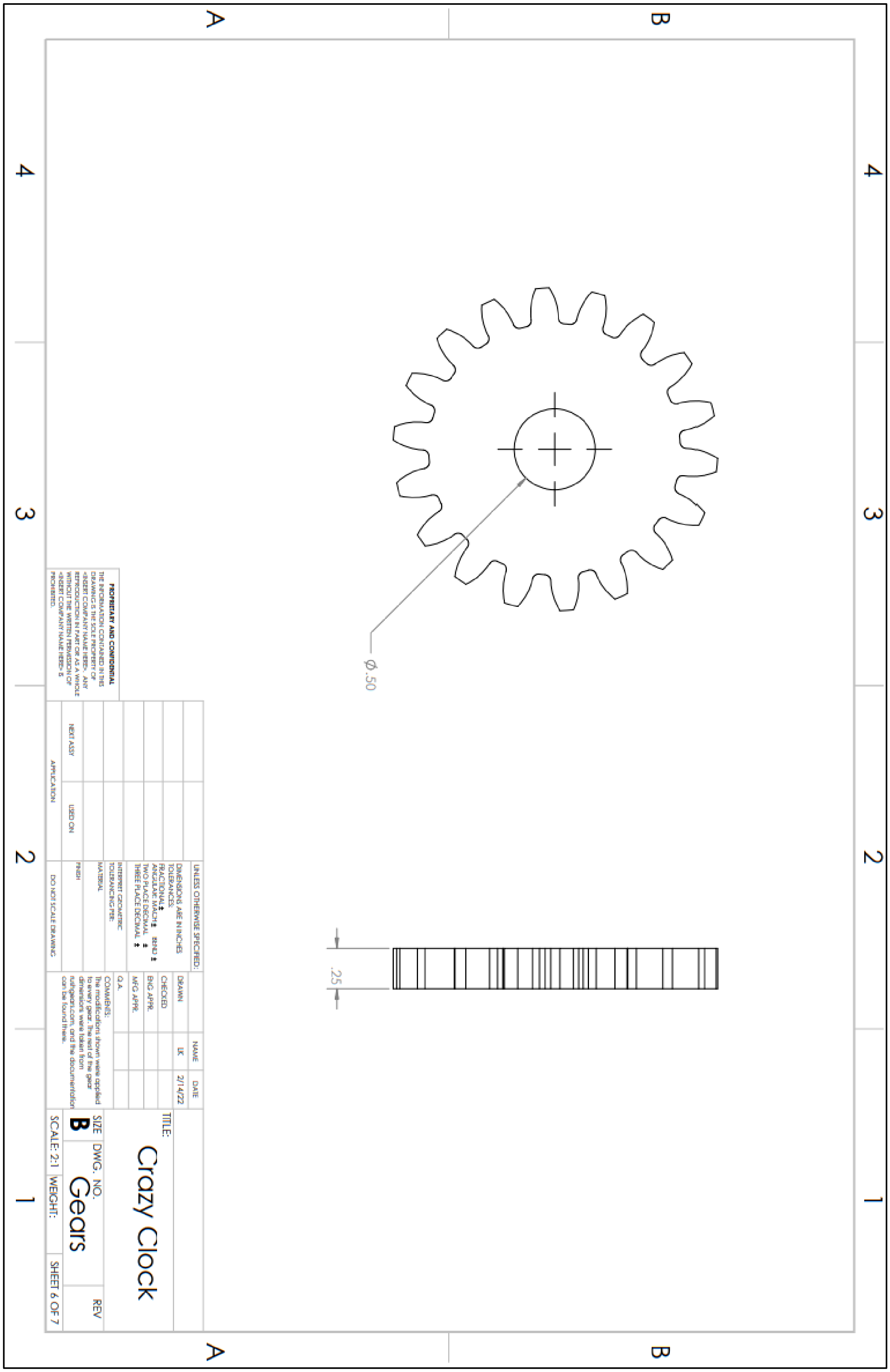
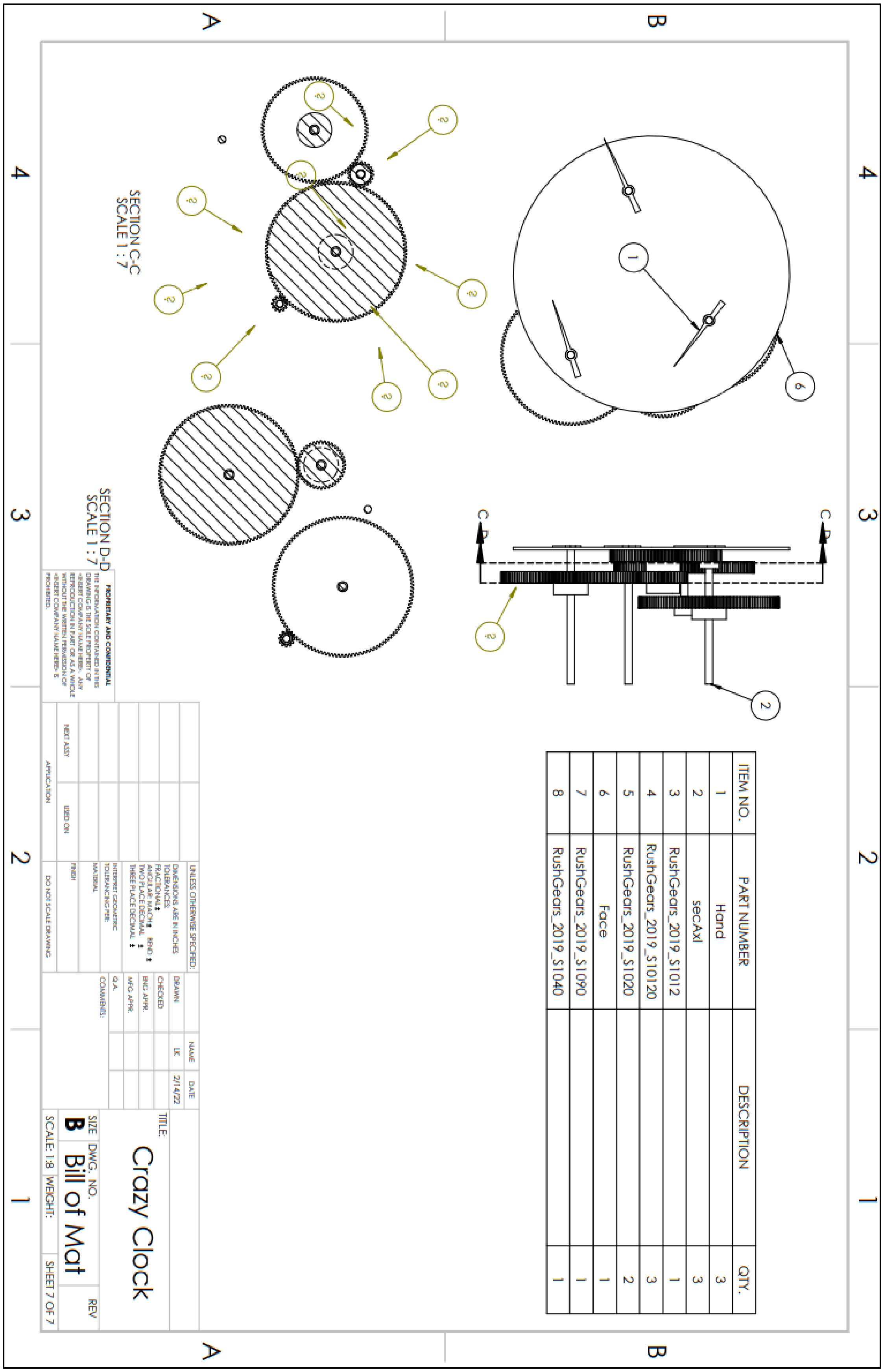

Crazy Clock
TITLE:
DWG. NO.
Gears
SIZE
B
REV
SCALE: 2:1
WEIGHT:
SHEET 6 OF 7
Ø.50
.25
UNLESS OTHERWISE SPECIFIED:
DRAWN
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
NAME
DATE
2/14/22
NEXT ASSY
USED ON
APPLICATION
DO NOT SCALE DRAWING
PROPRIETARY AND CONFIDENTIAL

Figure 3.5



SECTION C-C
SCALE 1 : 7
SECTION D-D
SCALE 1 : 7
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PART NUMBER
DESCRIPTION
QTY.
1 Hand 3
2 secAxl 3
3 RushGears_2019_S1012 1
4 RushGears_2019_S10120 3
5 RushGears_2019_S1020 2
6 Face 1
7 RushGears_2019_S1090 1
8 RushGears_2019_S1040 1
UNLESS OTHERWISE SPECIFIED:
DRAWN
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
NAME
DATE
LK
2/14/22
TITLE:
Crazy Clock
SIZE
B
DWG. NO.
Bill of Mat
REV
SCALE: 1:8
WEIGHT:
SHEET 7 OF 7
PROPRIETARY AND CONFIDENTIAL
NEXT ASSY
USED ON
APPLICATION
DO NOT SCALE DRAWING

Figure 3.6

Citations:

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