THE REVERSE ENGINEERING OF A MECHANICAL ALARM CLOCK

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EXECUTIVE SUMMARY

Team ECM^2 performed a reverse engineering of a mechanical alarm clock. The project included an analysis of the clock and a proposal for a modification that would serve the needs of a specific client. The client assigned to the team was a college student who lost his hearing last year. The client needed an alarm clock that could wake him up in time for his college classes.

To start the reverse engineering process the team documented the clock in its assembled state. The team then disassembled the clock and labeled and classified all of its parts. Each part was classified as being either standard or custom and assigned a unique part code. Each part was modeled in Solid Edge to facilitate the production of individual part and assembly drawings. A functional analysis was performed to determine how the various systems of the clock interact. The analysis concluded with the production of a gearbox schematic and functional decomposition spreadsheet. Finally, the notes taken during the disassembly process were reversed to produce assembly instructions, which were revised when the team reassembled the clock.

With the analysis complete the team used a Pugh's matrix to brainstorm possible ways to wake the client from sleep. The possibilities included optical stimulation with a strobe light, temperature alteration with a heating blanket, mild electrical stimulation, or physical disruption with a vibrating platform. After carefully considering the possibilities and their side effects it was decided the most logical method to wake the client was via physical disruption with a vibrating platform.

The vibrating platform would be placed beneath the client's mattress and be powered by a standard 120 volt Edison outlet. A limit switch would be added to the gearbox of the clock in such a way that it would be activated when the alarm is triggered. The limit switch would send a signal to an electronic controller that would activate the vibrating platform, waking the client.

Based on the assumption that the proper physical disruption will wake a person from sleep, the team concluded that the modification was an effective solution that would meet the needs of the client. This was further confirmed by the conclusion that disabling or resetting the vibrating platform would be no more complicated than disabling or resetting the alarm on the clock. The most significant complication identified by the team was the fact that the client, when winding the alarm on the clock, would have to be careful not to leave the limit switch in the activated position. This could, however, be avoided by taking the proper provisions in the programming written for the electronic controller.

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PROBLEM STATEMENT

This report presents team ECM^2's reverse engineering of a mechanical alarm clock. This problem statement provides a description of the project and the scope of the procedure that the team followed.

Project Description

The requirements of the reverse engineering project were presented to the team by the faculty of the Watson School of Engineering and the Engineering Design Division. The project required the team to analyze the clock and modify it to serve the needs of a client unable to hear the clock's alarm. The process the team followed consisted of the following:

- Documenting the assembled clock
- Disassembling the clock
    - Creating disassembly instructions
    - Numbering and classifying parts
- Identifying standard parts and custom part materials
- Modeling custom parts in Solid Edge
- Creating orthographic drawings of custom parts
- Creating assembly drawings with accompanying bill of materials
- Completing a functional decomposition of the clock
    - Creating a gearbox schematic
    - Creating a decomposition spreadsheet
- Drafting assembly instructions by reassembling the clock
- Modification of the clock to meet needs of client
    - Updating drawings, schematic, and spreadsheet with modification

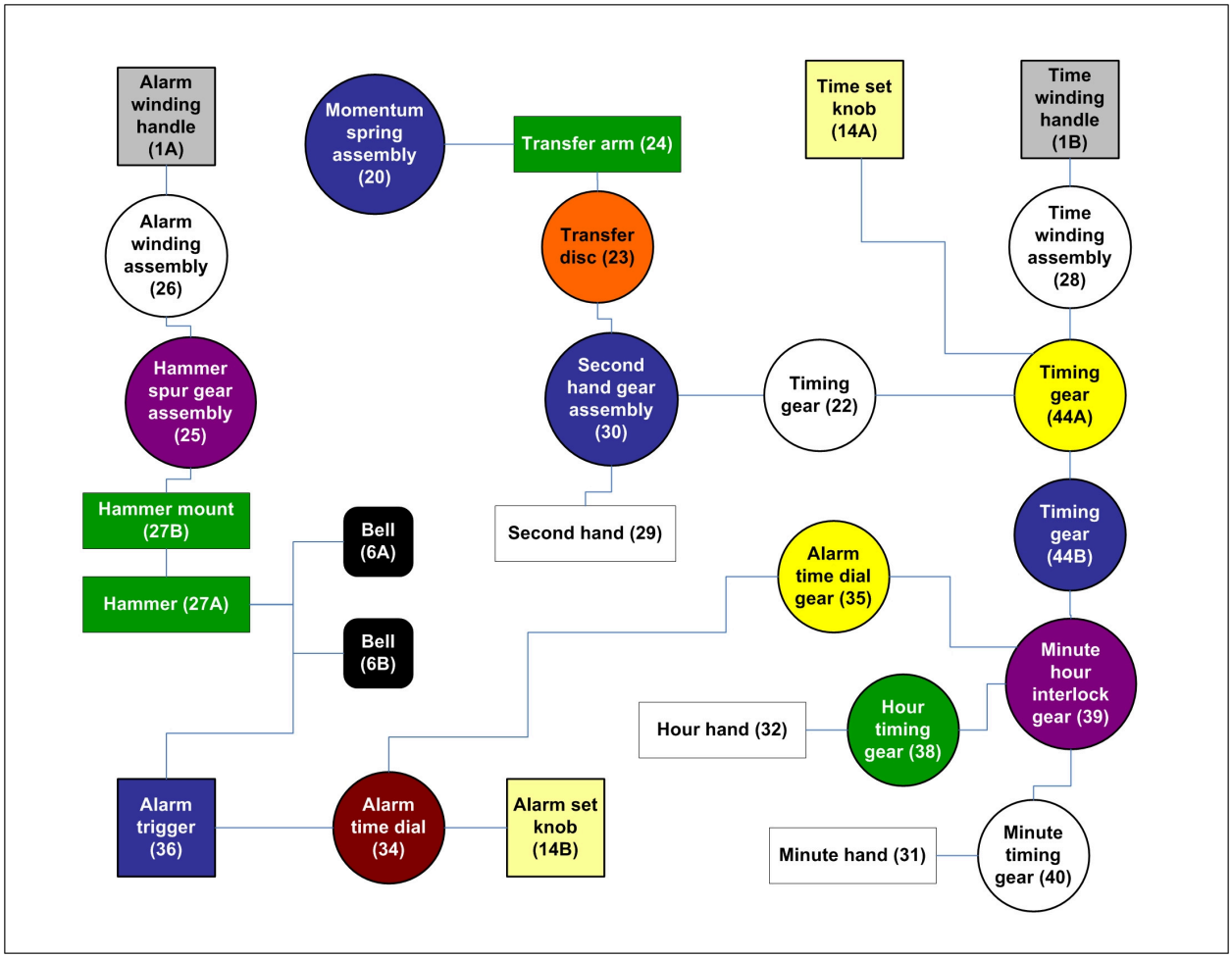
Scope of Project

From October 9, 2006 through December 6, 2006 team ECM^2 met in the freshman lab, student machine shop, engineering classroom, and library of Binghamton University. The team met at least three times each week for 1-3 hours per meeting. A team website and digital drop box were also established to collectively store and share files. The team completed all aspects of the project as outlined in the Project Description. At the end of the process the team presented its findings to the section 53 class and compiled all of its work in this report.

FUNCTIONAL DECOMPOSITION

The numbers appearing in parentheses in the device schematic and decomposition spreadsheet refer to the part numbers listed in the Bill of Materials in Appendix B.

Device Schematic



Decomposition Spreadsheet

Device	Inputs		Function	Output	
	Specific	General		Specific	General
Alarm winding handle (1A)	Rotational motion	Mechanical energy	Winds alarm winding spring, transfers motion from user to alarm winding assembly (26)	Rotational motion	Mechanical energy
Alarm winding assembly (26)	Rotational motion	Mechanical energy	Stores energy to power alarm mechanism	Rotational motion	Mechanical energy
Hammer gear assembly (25)	Rotational motion	Mechanical energy	Transfers motion from alarm winding assembly (26) to hammer assembly (27)	Rotational motion	Mechanical energy
Hammer assembly (27)	Rotational motion	Mechanical energy	Oscillates hammer (27A) between bells (6)	Oscillating motion	Mechanical energy
Bells (6)	Oscillating motion	Mechanical energy	Resonate, produce sound	Sound	Compression waves
Momentum spring assembly (20)	Rotational motion	Mechanical energy	Counts each second	Oscillating motion	Mechanical energy
Green transfer arm (24)	Oscillating motion	Mechanical energy	Transfers motion of momentum spring assembly (20) to orange transfer disc (23)	Oscillating motion	Mechanical energy
Orange transfer disc (23)	Oscillating motion	Mechanical energy	Transfers motion from green transfer arm (24) to second hand gear assembly (30)	Rotational motion	Mechanical energy
Second hand gear assembly (30)	Rotational motion	Mechanical energy	Transfers motion from orange spur gear (23) to second hand (29) and white timing gear (22)	Rotational motion	Mechanical energy
Second hand (29)	Rotational motion	Mechanical energy	Indicates second to the user	Visual reference	Information
White timing gear (22)	Rotational motion	Mechanical energy	Transfers motion from second hand gear assembly (30) to yellow timing gear (44A)	Rotational motion	Mechanical energy

Device	Inputs		Function	Output	
	Specific	General		Specific	General
Time winding handle (1B)	Rotational motion	Mechanical energy	Winds time winding spring, transfers motion from user to time winding assembly (28)	Rotational motion	Mechanical energy
Time winding assembly (28)	Rotational motion	Mechanical energy	Powers the timing mechanism, transfers motion to yellow timing gear (44A)	Rotational motion	Mechanical energy
Time adjustment knob (14A)	Rotational motion	Mechanical energy	Transfers motion from user to yellow timing gear (44A)	Rotational motion	Mechanical energy
Yellow timing gear (44A)	Rotational motion	Mechanical energy	Transfers motion from time winding assembly (28) to blue timing gear (44B)	Rotational motion	Mechanical energy
Blue timing gear (44B)	Rotational motion	Mechanical energy	Transfers motion from yellow spur gear (44A) to purple spur gear (38)	Rotational motion	Mechanical energy
Purple minute-hour interlock gear (39)	Rotational motion	Mechanical energy	Transfers motion from blue timing gear (44B) to white minute timing gear (40), green hour timing gear (38), and yellow timing gear (39)	Rotational motion	Mechanical energy
Green hour timing gear (38)	Rotational motion	Mechanical energy	Transfers motion from purple minute-hour interlock gear (39) to hour hand (32)	Rotational motion	Mechanical energy
Hour hand (32)	Rotational motion	Mechanical energy	Indicates hour to the user	Visual reference	Information
White minute timing gear (40)	Rotational motion	Mechanical energy	Transfers motion from purple minute-hour interlock gear (39) to minute hand (31)	Rotational motion	Mechanical energy
Minute hand (31)	Rotational motion	Mechanical energy	Indicates minute to the user	Visual reference	Information
Yellow alarm time dial gear (39)	Rotational motion	Mechanical energy	Transfers motion from purple minute-hour interlock gear (39) to alarm trigger (36)	Linear motion	Mechanical energy

Device	Inputs		Function	Output	
	Specific	**General**		**Specific**	**General**
Alarm trigger (36)	Linear motion	Mechanical energy	Releases hammer assembly (27), triggers alarm	Linear motion	Mechanical energy
Alarm adjustment knob (14B)	Rotational motion	Mechanical energy	Sets position of the alarm time dial (34), transfers motion from user to alarm time dial (34)	Rotational motion	Mechanical energy
Alarm time dial (34)	Rotational motion	Mechanical energy	Sets the time of alarm discharge	Linear motion	Mechanical energy

ASSEMBLY INSTRUCTIONS

The assembly process requires the use of a small Phillips head screw driver and a pair of needle nose pliers. Part names are shown in italics and are followed by their associated part number in parentheses. Refer to the Bill of Materials in Appendix B during the assembly process. Figures 1 and 2 illustrate the directions referred to within the assembly instructions. The instructions rely heavily on placing parts with respect to the *gearbox front panel assembly* (44). For this reason, Figures 3 and 4 identify each feature of the *gearbox front panel assembly* (44) as referred to in the assembly instructions.

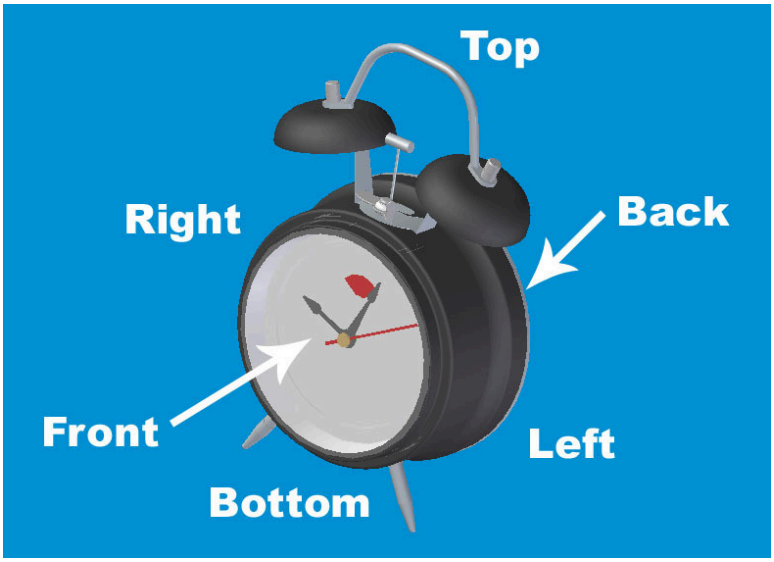


Figure 1 – Clock assembly

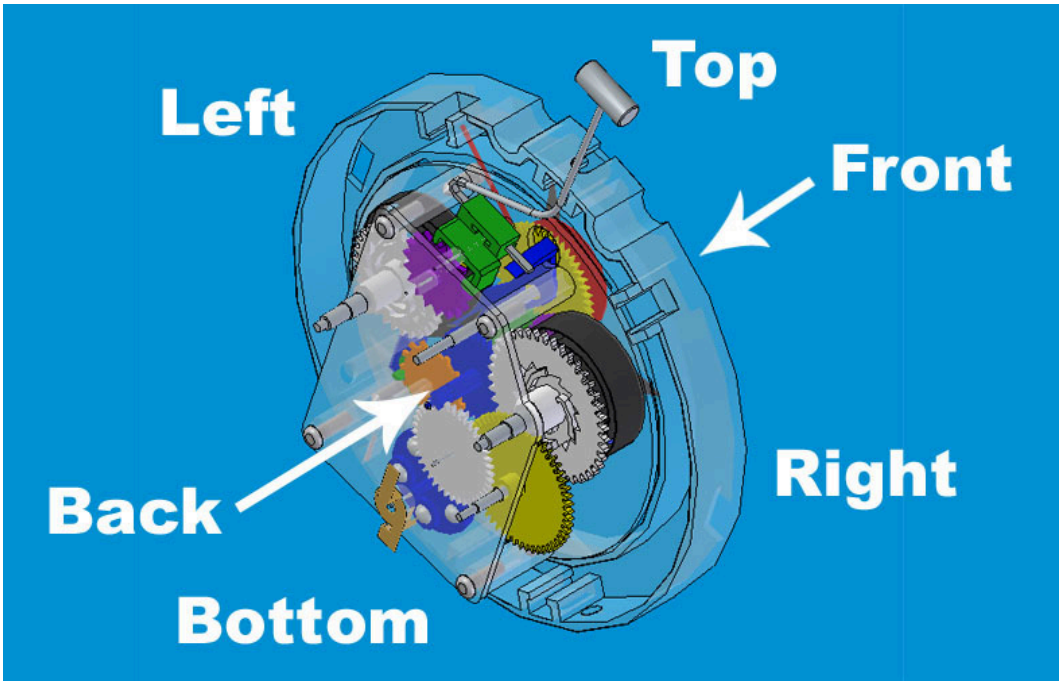


Figure 2 – Inner assembly

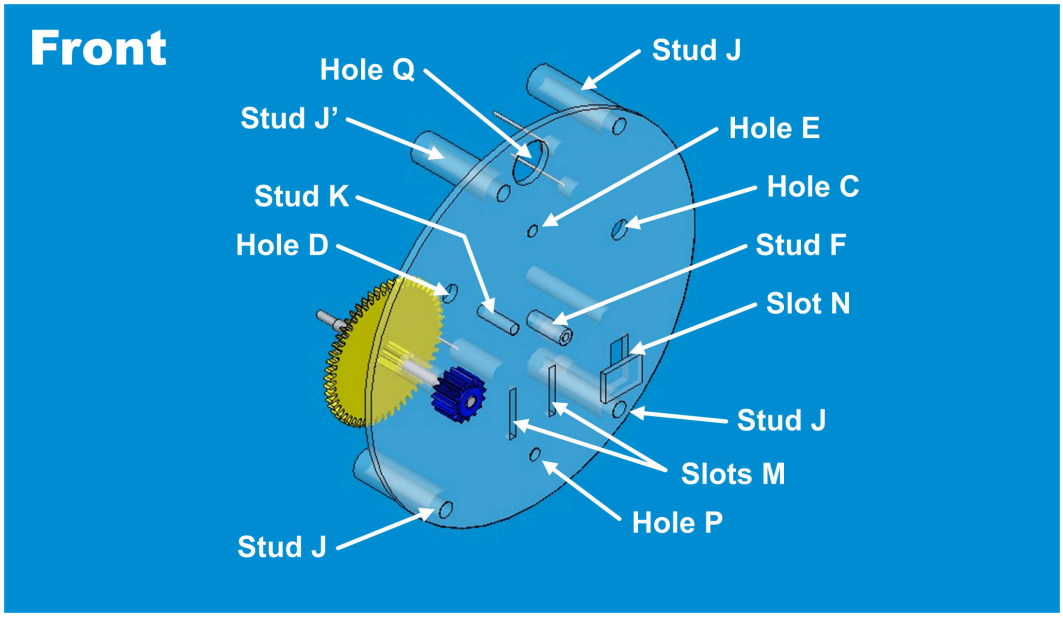


Figure 3 – Part 44 front

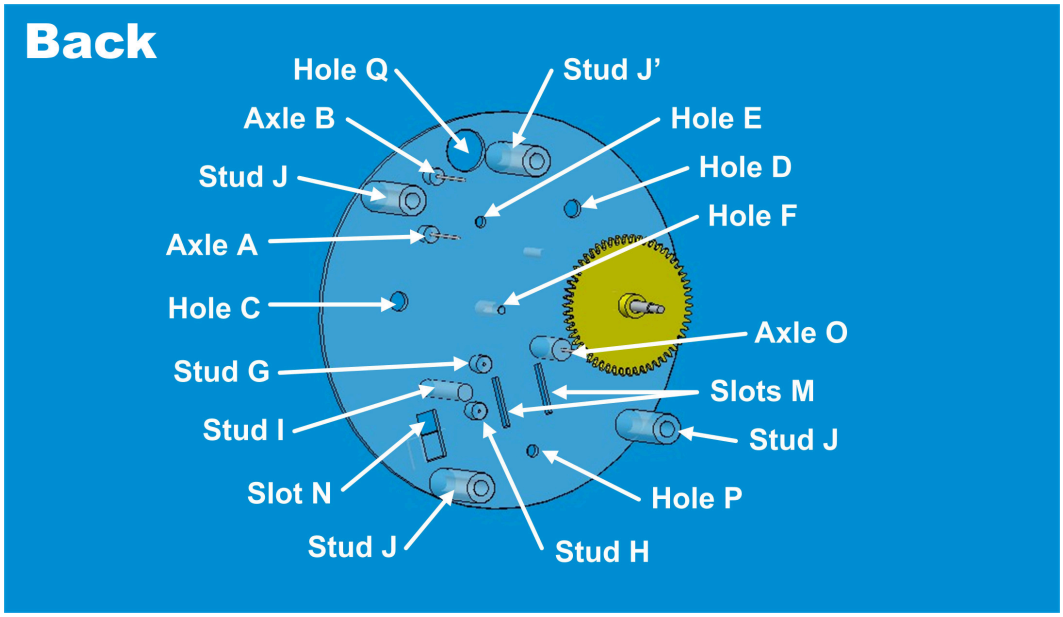


Figure 4 – Part 44 back

1. Use a pair of needle-nose pliers to thread the *momentum spring base* (43) into Hole P from the front side of the *gearbox front panel assembly* (44).
2. Align the *gearbox union ring* (42) and the *gearbox front panel assembly* (44) as shown in Figure 5. Place the *gearbox front panel screws* (41 A-C) through the front side of the *gearbox union ring* (42) and into the holes of Studs J on the *gearbox front panel assembly* (44). Use a Phillips head screw driver to secure the screws.

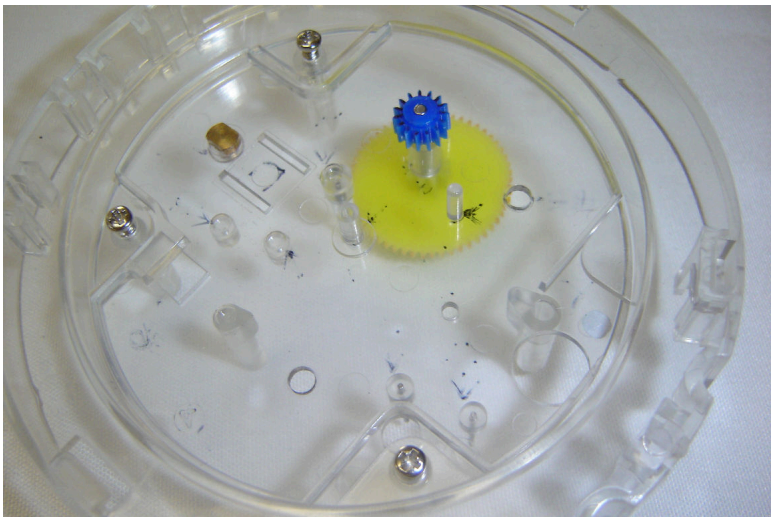


Figure 5 – Assembly step 2

3. Place the white *minute timing gear* (40) on Stud F of the *gearbox front panel assembly* (44). The toothed end of the *minute timing gear* (40) should be placed closest to the *gearbox front panel assembly* (44).
4. Place the purple *minute-hour interlock gear* (39) on Stud K of the *gearbox front panel assembly* (44). The larger diameter side of the *minute-hour interlock gear* (39) should be placed closest to the *gearbox front panel assembly* (44).
5. Place the green *hour timing gear* (38) on top of the white *minute timing gear* (40). The *hour timing gear* (38) should be oriented the same way as the *minute timing gear* (40) and should mesh with the purple *minute-hour interlock gear* (39).
6. Insert the tabs of the white *support arm* (37) into Slots M from the front side of the *gearbox front panel assembly* (44). The shafts of the green *hour timing gear* (38) and white *minute timing gear* (40) pass through the hole of the *support arm* (37).
7. Slide the tab at the end of the blue *alarm trigger* (36) into Slot N from the front side of the *gearbox front panel assembly* (44). The tip of the *alarm trigger* (36) should point into Hole Q on the *gearbox front panel assembly* (44).

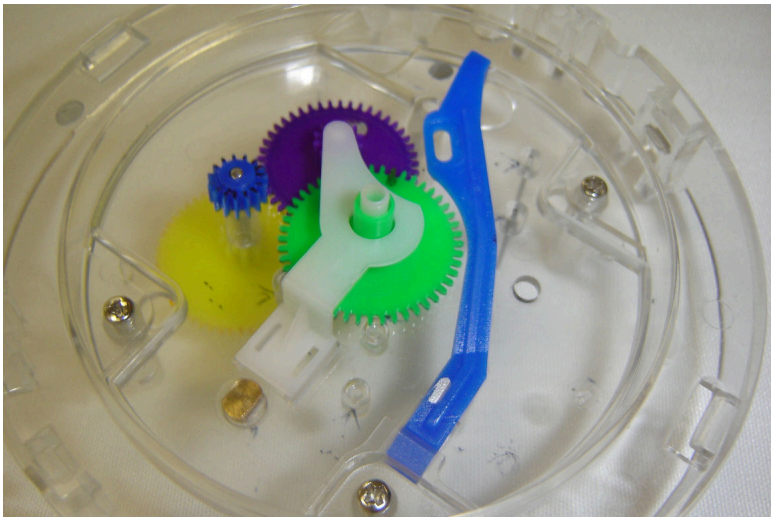


Figure 6 – Assembly steps 3-7

8. Place the yellow *alarm time dial gear* (35) on the shaft of the *alarm time dial* (34). The side of the *alarm time dial gear* (35) with the curving protrusion should face the *alarm time dial* (34).
9. Insert the *alarm time dial* (34) and the yellow *alarm time dial gear* (35) through Hole E on the front side of the *gearbox front panel assembly* (44). As shown in Figure 8, the shaft of the *alarm time dial* (34) should pass through the cutout in the blue *alarm trigger* (36) before passing through Hole E.

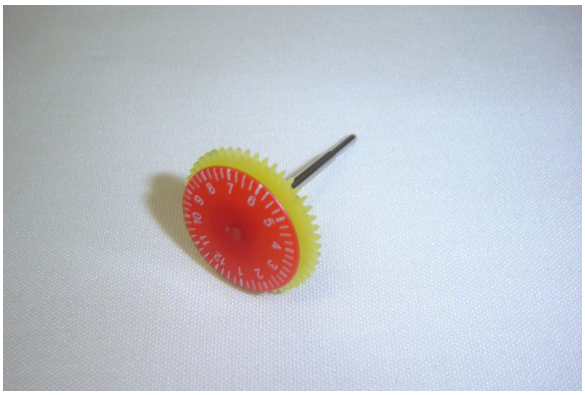


Figure 7 – Assembly step 8

Figure 8 – Assembly step 9

10. Place the *clock face* (33) on the front surface of the *gearbox union ring* (42). The green *hour timing gear* (38) and the white *minute timing gear* (40) should pass through the hole in the center of the *clock face* (33). The cutouts on the *clock face* (33) fit in the tabs on the left and right sides of the *gearbox union ring* (42). Be sure the red *alarm time dial* (34) is visible through the cutout beneath the "12" in the *clock face* (33). Refer to Figure 10.
11. Place the *hour hand* (32) on the face of the clock by pressing it down onto the shaft of the green *hour timing gear* (38). Place the *minute hand* (31) on the face of the clock by pressing it down onto the shaft of the white *minute timing gear* (40). The black side of each hand should face away from the *clock face* (33). Refer to Figure 10.
12. Place the axle end of the blue *second hand gear assembly* (30) into Hole F from the back side of the *gearbox front panel assembly* (44).

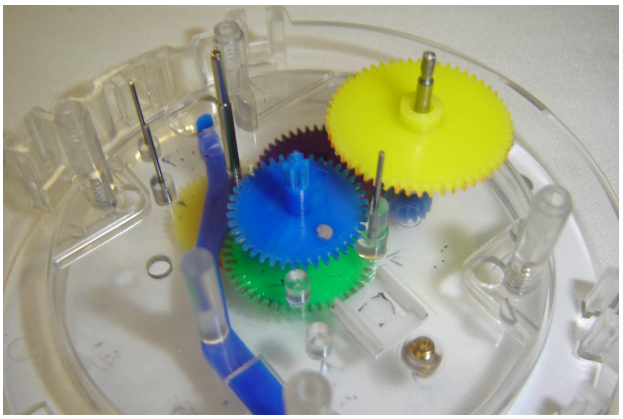


Figure 9 – Assembly step 12

Figure 5.1

13. On the front side of the clock, the axle of the blue *second hand gear assembly* (30) will be visible inside the center of the white *minute timing gear* (40). Press the axle of the *second hand* (29) down onto the axle of the blue *second hand gear assembly* (30).

Figure 10 – Assembly step 13

14. Place the axle of the *time winding assembly* (28) into Hole D as shown in Figure 11. Secure the end of the spring by hooking it around the shaft of Stud J. Make sure the spring is not caught on the *gearbox union ring* (42) and that all of its loops are pushed out the right side of the gearbox.

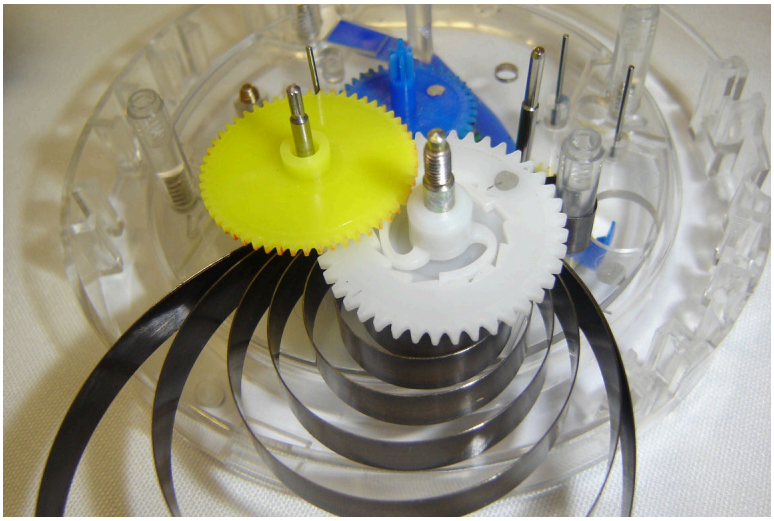


Figure 11 – Assembly step 14

15. Place the *hammer assembly* (27) on Axle B as shown in Figure 12.
16. Place the axle of the *alarm winding assembly* (26) into Hole C as shown in Figure 12. Secure the end of the spring by hooking it around the shaft of Stud I. Make sure the spring is not caught on the *gearbox union ring* (42) and that all of its loops are pushed

toward the left side of the gearbox.

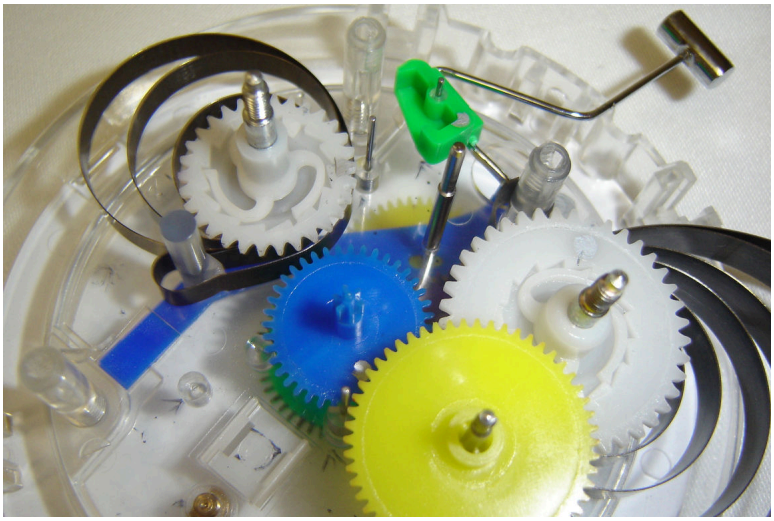


Figure 12 – Assembly steps 15-16

17. Place the *hammer gear assembly* (25) on Axle A. The side of the gear assembly with the yellow tooth faces down. Be sure that the yellow tooth is not resting inside the spring coils of the *alarm winding assembly* (26). The hammer gear assembly should mesh with the white gear of the *alarm winding assembly* (26) and rest inside the notch in the *hammer mount* (27B) of the *hammer assembly* (27).
18. Insert the pin on the bottom side of the green *transfer arm* (24) in the hole on Stud H. The slender end of the *transfer arm* (24) should point toward the *momentum spring base* (43). Refer to Figure 13.
19. Place the pin on the bottom side of the orange *transfer disk* (23) into the hole on Stud G. The bottom side of the orange *transfer disk* (23) is the side with the smaller diameter gear. The smaller diameter gear of the disk should mesh with the blue *second hand gear assembly* (30). The teeth on the larger diameter gear of the disk should mesh with the protrusions on the green *transfer arm* (24). Refer to Figure 14.

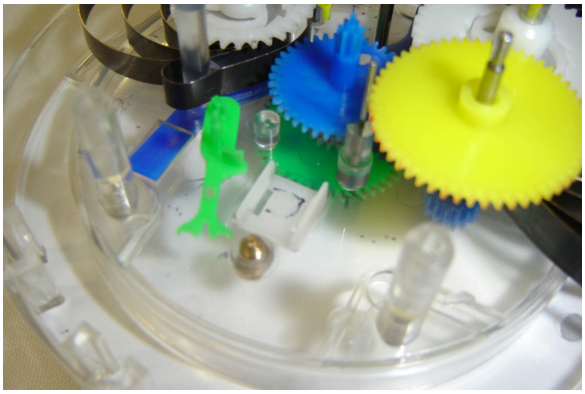


Figure 13 – Assembly step 18

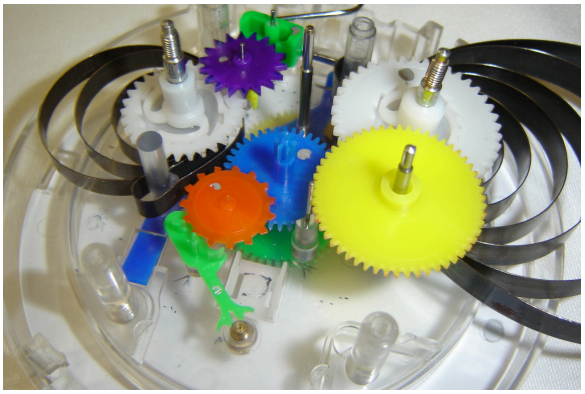


Figure 14 – Assembly step 19

20. Place the white *timing gear* (22) on Axle O. Orient the *timing gear* (22) in such a way that it meshes with both the blue *second hand gear assembly* (30) and the yellow *timing*

gear (44A).

21. Gently place the *gearbox back panel assembly* (21) on top of Studs J being careful not to disturb the gears beneath it. Be sure that all of the parts and axles of the gearbox line up with their corresponding holes in the *gearbox back panel assembly* (21).

Figure 15 – Assembly step 21

22. Gently insert the *momentum spring assembly* (20) using a pair of needle-nose pliers. Be advised, this is one of the most difficult steps in the entire assembly process, read all instructions before proceeding: The *momentum spring assembly* rests in between the *momentum spring base* (43) and the corresponding stud on the *gearbox back panel assembly* (21). It may be necessary to partially remove the *gearbox back panel assembly* (21) in order to insert the *momentum spring assembly* (20). Be very careful not to disrupt any of the parts of the gearbox while doing this. Be sure the notch in the end of the green *transfer arm* (24) is centered on the small blue axle on the bottom side of the *momentum spring assembly* (20). Refer to Figure 16. Be sure the *momentum spring assembly* (20) spins freely and that it oscillates the green *transfer arm* (24) when it spins.
23. Insert the *gearbox back panel screws* (19 A-D) by placing them through the holes in the corners of the *gearbox back panel assembly* (21) and into the holes in Studs J. Secure the screws using a Phillips head screw driver.
24. Use a pair of needle-nose pliers to thread the end of the spiral spring of the *momentum spring assembly* (20) through the thin slot in the brass part of the *gearbox back panel assembly* (21). Refer to Figure 16.
25. Using a pair of needle-nose pliers, insert the end of the spiral spring into the small hole on the *gearbox back panel assembly* (21). Insert the end of the spring no farther than the length of the hole. Secure the spring in the hole with the *momentum spring anchor pin* (18). The smaller diameter end of the pin is meant to point into the hole.

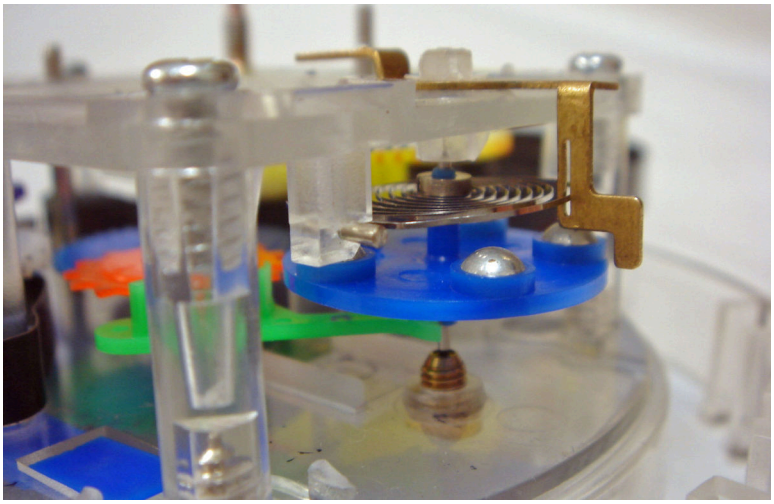


Figure 16 – Assembly steps 22,24,25

26. Wind the *time winding assembly* (28). Use a pair of pliers to grip the shaft of the assembly and rotate it counter-clockwise to wind the assembly.
27. Spin the *momentum spring assembly* (20) gently but quickly. If the gearbox was assembled correctly the *momentum spring assembly* (20) should continue to spin back and forth and not decay to a stop. The green *transfer arm* (24) and the orange *transfer disk* (23) should work with one another to rotate the blue *second hand gear assembly* (30).
28. Place the *clock face plate* (16) inside the small diameter end of the *clock housing* (17).
29. Place the *face plate ring* (15) inside the *clock housing* (17) and against the *clock face plate* (16). The smaller diameter side of the *face plate ring* (15) should face toward the back of the clock, or away from the *clock face plate* (16).
30. Press the *time adjustment knob* (14A) and *alarm adjustment knob* (14B) down onto the axles of the *timing gear assembly* (44AB) and the *alarm time dial* (34), respectively. The star shape end of each axle should fit into the star shaped cutout in the bottom of each knob. It may be necessary to apply pressure to the red surface of the *alarm time dial* (34) while pressing the *alarm adjustment knob* (14B) down onto its axle. If the *alarm adjustment knob* (14B) is not pressed all the way down onto its axle the *alarm trigger* (36) will not discharge properly.
31. Place the entire gearbox into the *clock housing* (17) as shown in Figure 18. The *hammer* (27A) must be passed through the small rounded cutout in the clock housing.

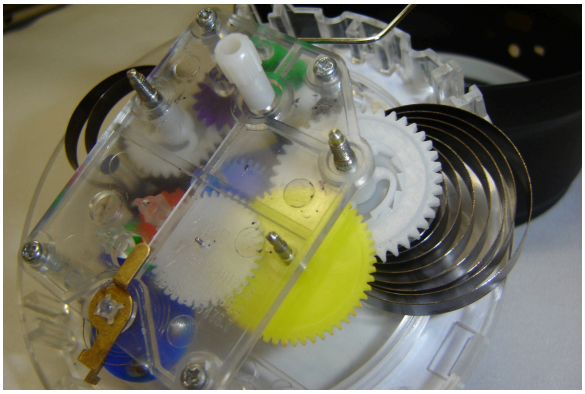


Figure 17 – Assembly step 30

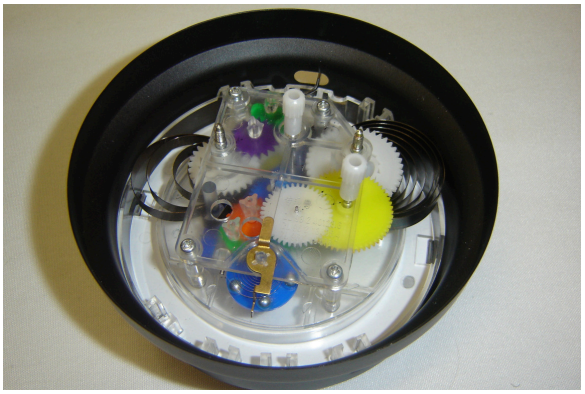


Figure 18 – Assembly step 31

32. Slide the *leg washers* (13A-B) onto the shafts of the *legs* (11A-B). Insert the *leg nuts* (12A-B) into the two slots on the bottom of the *gearbox union ring* (42). Insert the *legs* (11A-B), with *washers* (13A-B), into the holes on the bottom of the *clock housing* (17). Thread the *legs* (11A-B) into the *leg nuts* (12A-B).

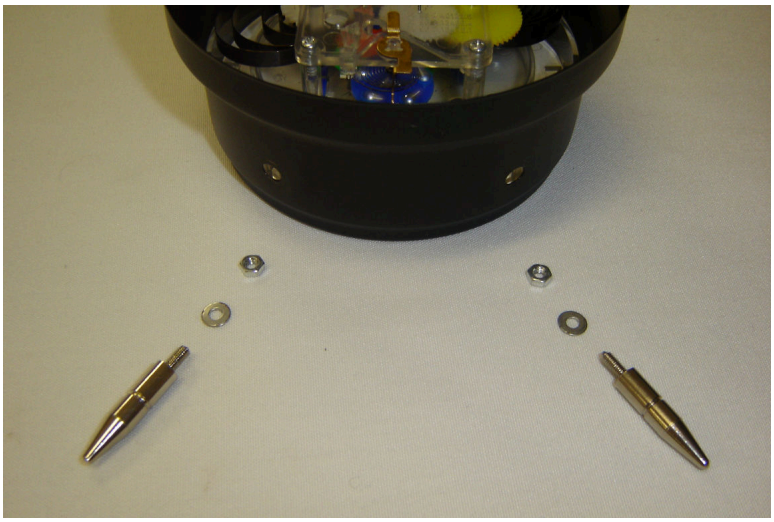


Figure 19 – Assembly step 32

33. Attach the *bell support arm* (10) to the top of *clock housing* (17). The small tabs in the bottom of the support arm fit into the cutouts on the top of the clock housing. Refer to Figure 20.
34. Insert the *hammer lock nut* (9) into the slot on the top of the *gearbox union ring* (42). Pass the *hammer lock screw* (7) through the *hammer lock* (8), the hole in the center of the *bell support arm* (10), and the hole in the top of the *clock housing* (17). Thread the *hammer lock screw* (7) into the *hammer lock nut* (9)

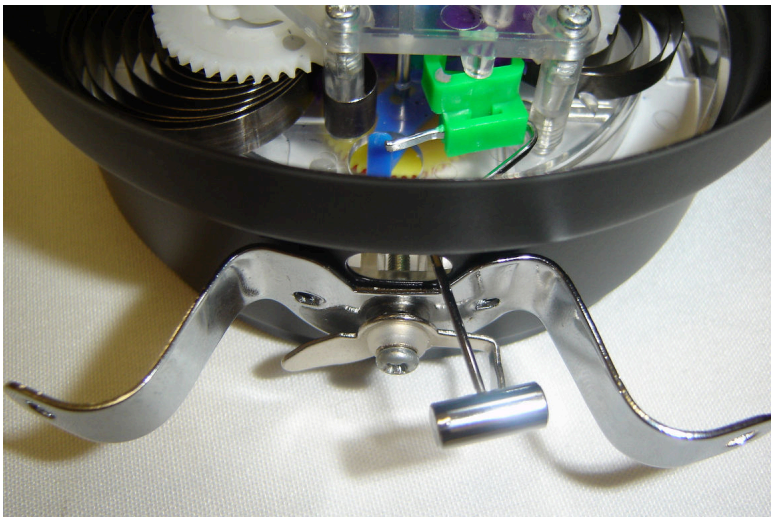


Figure 20 – Assembly step 33-34

35. Place each *bell* (6A-B) on the *bell support arm* (10) and line up the holes in each. Place the *bell handle* (5) on top of the *bells* (6A, B) and line up the holes in each. Place the *bell pins* (3A-B) through the *bell handle* (5), the *bells* (6A-B) and the *bell support arm* (10). Reaching underneath each *bell* (6A-B), thread the *bell nuts* (4A-B) onto the *bell pins* (3A-B) using a pair of needle-nose pliers.

Figure 21 – Assembly step 35

36. Insert the *back panel* (2) by placing it into the open back of *clock housing* (17). Line the holes in the *back panel* (2) up with the *adjustment knobs* (14A-B) protruding from the back of the *gearbox back panel assembly* (21).
37. Attach the *alarm winding handle* (1A) and *time winding handle* (1B) by rotating each in its direction of winding.

RESULTS AND ANALYSIS

The project required that the mechanical alarm clock be modified to meet the needs of a nineteen year old client who lost his hearing last year and is waiting for surgery that might correct his condition. The client is a college student and has recently been arriving to class late or not at all. The client is in need of an alarm clock that can effectively wake him from sleep. Furthermore, he is a heavy sleeper, often places his alarm clock across the room, and has no roommate to wake him.

The team determined the best way to meet the needs of the client was to give the clock the capability of triggering an external electrical device that could wake the client. The possibilities for the external device were considered in the Pugh's matrix found in Appendix D. Some of the possibilities included optical stimulation with a strobe light, temperature alteration with a heating blanket, mild electrical stimulation, or physical disruption with a vibrating platform. All of these possibilities would require equal operation by the user and be reasonably simple to install. Some of the possibilities, however, would be more portable than others. For example, the heating blanket or strobe light would be much easier to transport than the vibrating platform.

After carefully considering the possibilities and their side affects it was decided the most logical method to wake the client was via physical disruption with a vibrating platform. The other possibilities were dismissed because they were found to be either potentially ineffective due to uncontrollable factors or because of the risk that they might cause unforeseen physiological side. For example, the strobe light was not chosen because it would be easy for the client to cover his eyes unintentionally during sleep. The heat blanket and mild electrical stimulation were not chosen due to the unforeseen side effects that temperature or electricity might have on the client. Though the vibrating platform was not the most portable, light weight, or inexpensive design the primary concern of the team was effectively waking the client.

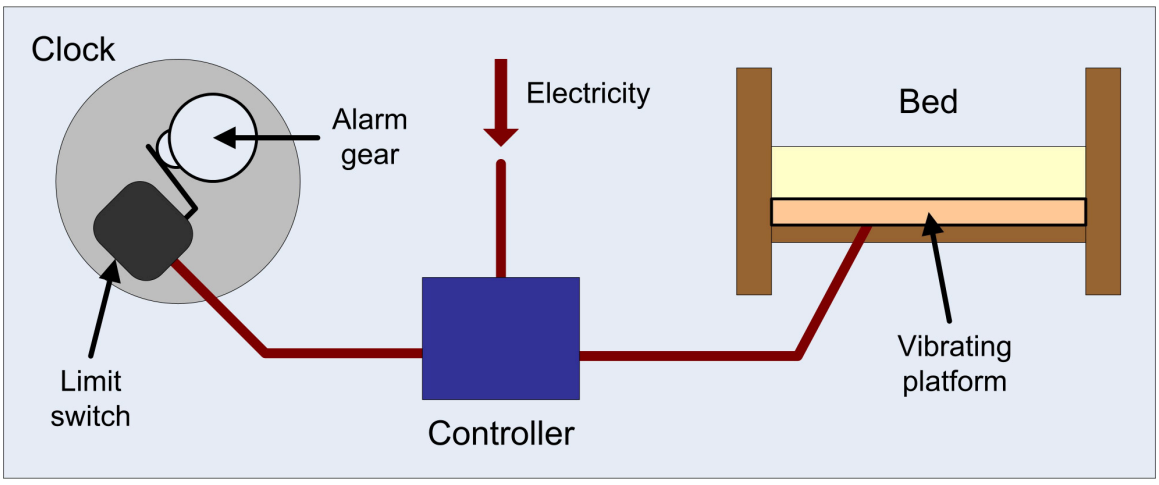


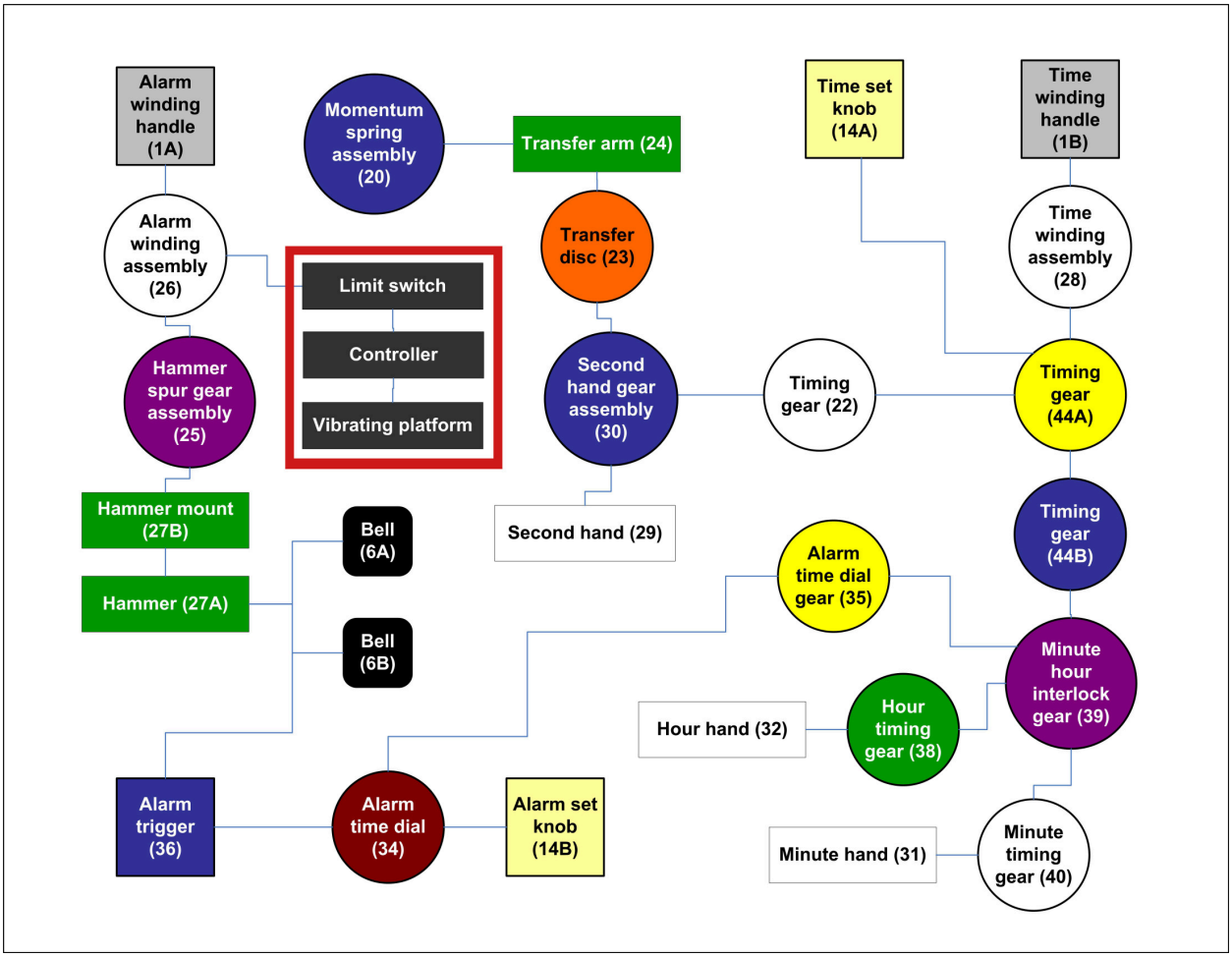
Figure 22 – Modification concept diagram

The vibrating platform would be placed beneath the client's mattress as shown in Figure 23. The platform would consist of electrically driven motors powered by a standard 120 volt Edison outlet. The platform would be triggered by a controller that receives a signal from a limit switch inside the clock. When the alarm is triggered a protrusion on the shaft of the *alarm winding assembly* (26) would contact the limit switch triggering the device. This modification required the design of a custom bracket on which to mount the limit switch. The bracket would be molded out of High Density Polyethylene similar to the other plastic parts inside the clock. The bracket and switch would be mounted with self tapping screws similar to parts E and F in the Standard Parts Table in Appendix B.

Drawing M-1, the modified exploded assembly view, details the modifications made to the gearbox of the clock. The modification to the *alarm winding assembly* (26) and the design of the custom bracket are detailed in drawings M-2 and M-3. The modified device schematic and functional decomposition illustrate how the modification would interact with the existing parts of the clock.

The numbers appearing in parentheses in the modified device schematic and decomposition spreadsheet refer to the part numbers listed in the Bill of Materials in Appendix B.

Modified Device Schematic



Modified Decomposition Spreadsheet

Device	Inputs		Function	Output	
	Specific	General		Specific	General
Alarm winding handle (1A)	Rotational motion	Mechanical energy	Winds alarm winding spring, transfers motion from user to alarm winding assembly (26)	Rotational motion	Mechanical energy
Alarm winding assembly (26)	Rotational motion	Mechanical energy	Stores energy to power alarm mechanism and triggers limit switch	Rotational motion	Mechanical energy
Limit switch	Rotational motion	Mechanical energy	Completes circuit, sends signal to vibrating platform controller	Electrical signal	Information/ Electrical energy
Hammer gear assembly (25)	Rotational motion	Mechanical energy	Transfers motion from alarm winding assembly (26) to hammer assembly (27)	Rotational motion	Mechanical energy
Hammer assembly (27)	Rotational motion	Mechanical energy	Oscillates hammer (27A) between bells (6)	Oscillating motion	Mechanical energy
Bells (6)	Oscillating motion	Mechanical energy	Resonate, produce sound	Sound	Compression waves
Momentum spring assembly (20)	Rotational motion	Mechanical energy	Counts each second	Oscillating motion	Mechanical energy
Green transfer arm (24)	Oscillating motion	Mechanical energy	Transfers motion of momentum spring assembly (20) to orange transfer disc (23)	Oscillating motion	Mechanical energy
Orange transfer disc (23)	Oscillating motion	Mechanical energy	Transfers motion from green transfer arm (24) to second hand gear assembly (30)	Rotational motion	Mechanical energy
Second hand gear assembly (30)	Rotational motion	Mechanical energy	Transfers motion from orange spur gear (23) to second hand (29) and white timing gear (22)	Rotational motion	Mechanical energy
Second hand (29)	Rotational motion	Mechanical energy	Indicates second to the user	Visual reference	Information

Device	Inputs		Function	Output	
	Specific	General		Specific	General
White timing gear (22)	Rotational motion	Mechanical energy	Transfers motion from second hand gear assembly (30) to yellow timing gear (44A)	Rotational motion	Mechanical energy
Time winding handle (1B)	Rotational motion	Mechanical energy	Winds time winding spring, transfers motion from user to time winding assembly (28)	Rotational motion	Mechanical energy
Time winding assembly (28)	Rotational motion	Mechanical energy	Powers the timing mechanism, transfers motion to yellow timing gear (44A)	Rotational motion	Mechanical energy
Time adjustment knob (14A)	Rotational motion	Mechanical energy	Transfers motion from user to yellow timing gear (44A)	Rotational motion	Mechanical energy
Yellow timing gear (44A)	Rotational motion	Mechanical energy	Transfers motion from time winding assembly (28) to blue timing gear (44B)	Rotational motion	Mechanical energy
Blue timing gear (44B)	Rotational motion	Mechanical energy	Transfers motion from yellow spur gear (44A) to purple spur gear (38)	Rotational motion	Mechanical energy
Purple minute-hour interlock gear (39)	Rotational motion	Mechanical energy	Transfers motion from blue timing gear (44B) to white minute timing gear (40), green hour timing gear (38), and yellow timing gear (39)	Rotational motion	Mechanical energy
Green hour timing gear (38)	Rotational motion	Mechanical energy	Transfers motion from purple minute-hour interlock gear (39) to hour hand (32)	Rotational motion	Mechanical energy
Hour hand (32)	Rotational motion	Mechanical energy	Indicates hour to the user	Visual reference	Information
White minute timing gear (40)	Rotational motion	Mechanical energy	Transfers motion from purple minute-hour interlock gear (39) to minute hand (31)	Rotational motion	Mechanical energy
Minute hand (31)	Rotational motion	Mechanical energy	Indicates minute to the user	Visual reference	Information

Device	Inputs		Function	Output	
	Specific	General		Specific	General
Yellow alarm time dial gear (39)	Rotational motion	Mechanical energy	Transfers motion from purple minute-hour interlock gear (39) to alarm trigger (36)	Linear motion	Mechanical energy
Alarm trigger (36)	Linear motion	Mechanical energy	Releases hammer assembly (27), triggers alarm	Linear motion	Mechanical energy
Alarm adjustment knob (14B)	Rotational motion	Mechanical energy	Sets position of the alarm time dial (34), transfers motion from user to alarm time dial (34)	Rotational motion	Mechanical energy
Alarm time dial (34)	Rotational motion	Mechanical energy	Sets the time of alarm discharge	Linear motion	Mechanical energy

CONCLUSION

Modification Effectiveness

Although no actual experiments were conducted, it is believed by the team that the proper type and duration of physical disruption would wake the client from sleep. Because the vibrating platform would cover the entire surface area of the mattress it would not be possible for the client to escape the vibration as long as he is in bed. Due to the simplicity of the interface between the clock and the switch, the vibrating platform would always be activated as long as the alarm is triggered. This assumes that electricity is always available to the vibrating platform and that the controller and the platform are in good working order. The vibrating platform would be easy to deactivate as it would only require disabling and rewinding the alarm. The most significant complication identified by the team was the fact that the client, when winding the alarm on the clock, would have to be careful not to leave the limit switch in the activated position. This could, however, be avoided by taking the proper provisions in the programming written for the electronic controller.

Team Experience

The reverse engineering project has provided many lessons with its completion. The experience of the project has shown each member the value of working productively as a team. Each team member has learned how to accommodate the individual abilities, work ethics, and methods of learning of the other members. Each team member has learned to trust one another to be responsible and complete work on time. The team has learned collectively discovered how to organize projects and prepare technical documents efficiently. This is evidenced by the simple fact that the team arrived at each major checkpoint in its original schedule on time. Minor problems along the way, such as losing photos to an FTP transfer error, have also demonstrated the need to plan extra time into the schedule to overcome any problems that might arise along the way.

APPENDIX A

Exploded View Assembly Drawings

APPENDIX B

Bill of Materials

Bill of Materials

Each part in the table has been assigned a unique part code. The part code consists of a number and, if multiple parts share the same number, a letter. Each part has also been classified by its type (custom, standard, or assembly). Refer to the Standard Parts Table following the Bill of Materials for the specifications of the standard parts. Note the following:

- Parts with identical numbers in their part codes, and that appear in the same row (such as 6A and 6B), are identical parts.
- Parts with identical numbers in their part codes, and that appear in different rows (such as 27, 27A and 27B) are related by an assembly.

Code	Name	Type	Material
1A, 1B	Alarm winding handle, time winding handle	Custom	AISI 1020 Carbon steel
2	Back panel	Custom	AISI 1020 Carbon steel
3A, 3B	Bell pins	Custom	AISI 1020 Zinc-plated carbon steel
4A, 4B	Bell nuts	Standard	See standard part table, Part A
5	Handle	Custom	AISI 1020 Chrome-plated carbon steel
6A, 6B	Bells	Custom	AISI 1020 Carbon steel
7	Hammer lock screw	Standard	See standard part table, Part B
8	Hammer lock	Assembly	Multiple materials
9	Hammer lock nut	Standard	See standard part table, Part A
10	Bell support arm	Custom	AISI 1020 Chrome-plated carbon steel
11A, 11B	Legs	Custom	AISI 1020 Zinc-plated carbon steel
12A, 12B	Leg nuts	Standard	See standard part table, Part A
13A, 13B	Leg washers	Standard	See standard part table, Part C
14A, 14B	Time adjustment knob, alarm adjustment knob	Custom	High density polyethylene
15	Face plate ring	Custom	High density polyethylene
16	Face plate	Custom	Glass, .07” Thickness
17	Clock housing	Custom	AISI 1020 Carbon steel
18	Momentum spring anchor pin	Standard	See standard part table, Part D
19 (A-D)	Gearbox back panel screws	Standard	See standard part table, Part E
20	Momentum spring assembly	Assembly	Multiple materials
21	Gearbox back panel assembly	Assembly	Multiple materials
22	Timing gear (white)	Custom	High density polyethylene
23	Transfer disc (orange)	Custom	High density polyethylene
24	Transfer arm (green)	Custom	High density polyethylene
25	Hammer gear assembly	Custom	High density polyethylene
26	Alarm winding assembly	Assembly	Multiple materials
27	Hammer assembly	Assembly	Multiple materials
27A	Hammer	Custom	AISI 1020 Chrome-plated carbon steel
27B	Hammer mount (green)	Custom	High density polyethylene
28	Time winding assembly	Assembly	Multiple materials

Code	Name	Type	Material
29	Second hand	Assembly	Multiple materials
30	Second hand gear assembly (blue)	Assembly	Multiple materials
31	Minute hand	Custom	AISI 1020 Carbon steel
32	Hour hand	Custom	AISI 1020 Carbon steel
33	Clock face	Custom	Paper
34	Alarm time dial	Assembly	Multiple materials
35	Alarm time dial gear (yellow)	Custom	High density polyethylene
36	Alarm trigger (blue)	Custom	High density polyethylene
37	Support arm (white)	Custom	High density polyethylene
38	Hour timing gear (green)	Custom	High density polyethylene
39	Minute hour interlock gear (purple)	Custom	High density polyethylene
40	Minute timing gear (white)	Custom	High density polyethylene
41 (A-C)	Gearbox front panel screws	Standard	See standard part table, Part F
42	Gearbox union ring	Custom	High density polyethylene
43	Momentum spring base	Custom	Brass-plated steel
44	Gearbox front panel assembly	Assembly	Multiple materials
44AB	Timing gear assembly	Assembly	Multiple materials
44A	Timing gear (yellow)	Custom	High density polyethylene
44B	Timing gear (blue)	Custom	High density polyethylene

Standard Parts Table

All standard parts were identified using the *Machinery's Handbook, 22nd Revised Edition*.

Part	Specification	Material
A	Style 2, Metric hex nut – M 3 x ½	AISI 1020 Zinc-plated carbon steel
B	M 3 x ½, Type I Cross-recess head machine screw	AISI 1020 Carbon steel
C	Plain washer, 3 mm, narrow, soft	AISI 1020 Carbon steel
D	Standard taper pin - .045" Major diameter	AISI 1211 Steel
E	3-28 Type B, Type I Cross-recess Pan Head Tapping Screw	AISI 1020 Carbon steel
F	3-28 Type AB, Type I Cross-recess Pan Head Tapping Screw	AISI 1020 Carbon steel

APPENDIX C

Part Drawings

APPENDIX D

Modification Brainstorming

Pugh's Matrix

	Clock	**Vibrating Platform**	**Strobe Light**	**Heat Blanket**	**Electrical Stimulation**	**Bed Tilt**	**Frequency Generator**	**Mechanical Swatter**	**Sound Vibration**
Cost	S	-	-	-	-	-	-	-	-
Size	S	-	S	-	S	-	S	-	-
Reliability	S	S	-	S	S	+	+	+	S
Weight	S	-	-	-	-	-	-	-	-
Customer Appeal	S	S	S	-	-	-	S	-	S
Durability	S	S	+	S	S	S	+	S	+
Efficiency	S	+	+	+	+	+	+	+	+
Side Effects	S	-	-	-	-	-	-	-	-
Easy Installation	S	-	S	S	S	-	S	-	S
Portability	S	-	S	S	S	-	S	-	-
Easy to Use	S	S	S	S	S	S	S	S	S
Power Requirement	S	-	-	-	-	-	-	-	-
Pluses	0	1	2	1	1	2	3	2	2
Same As	12	4	5	5	6	2	5	2	4
Minuses	0	7	5	6	5	8	4	8	6