GET ACTIVE GAMING SYSTEM

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Abstract

This document describes the Get Active Gaming System, a device developed to increase the amount of exercise users get in a day. The system consists of three components: a heart rate monitor, a jumping jack game, and a game similar to Whack-a-Mole. The individual components communicate via IR transmission with a Central Hub module and take in various user inputs to allow for a more interactive game experience. The gaming system was a success in that each module functioned as specified by original project goals and communicated quickly with each other to offer reasonable feedback to the user via the Central Hub. The project was developed for the Electrical and Computer Engineering Senior Design course at the University of Illinois at Urbana-Champaign in Fall 2018 and has the potential to scale to public use.

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1. Introduction
In this age of technology, electronic devices surround us. Both adults and children alike are glued to these devices. In any spare time we have, we pick electronic devices up reflectively, either to check social media or play games. It is also easy for tired parents to hand their children electronic device to entertain them. All of this screen time is dangerous, and there are consequences of using so much interactive technology at such a young age. Researchers have found that children are starting to get attached more to objects instead of their parents. When using screen devices, their surrounding environment gets blocked out, resulting in girls and boys not learning social skills and conversational manners [1]. Using devices excessively limits time for physical activities, which can cause many problems in the future. It is getting harder to motivate kids to exercise and be active because of technology. With the use of electronic devices, there is no need to move around in order for kids to tire themselves out in order to entertain themselves. It is much easier to sit in one spot and stare at a screen. Also for adults, the increased use of electronic devices in this age has taken time away from getting active. Between checking emails, and keeping tabs on people, it is important for adults to put down their phones once in a while.

1.1 Objective
Our goal is to provide entertainment that does not involve screen devices and motivates people to get active. We will create a small box that allows people to be active right in their homes. It will feel like a video game, but eliminates the use of a screen. The box will be small and lightweight, so the users can set it up in a variety of places such as in a home, office, or retirement center. There will be three functionalities, consisting of two games and a heart rate monitor. The first game works similar to whack-a-mole, where four devices using pressure sensors will be placed around the user's environment and light up to prompt the user to press it. The next game is a get active test, where accelerometers will be placed in arms bands and put on the user and then they have to keep moving for a certain amount of time. The heart rate monitor keeps track of the users heart rate during these games.

1.2 Background
There have been other devices that try to promote activity outside of screen devices. Video game devices like Microsoft Kinect or Wii incorporate physical activities into their games, but a TV screen is still used. Kinect uses RGB, a depth sensor, and a microphone in order to detect the user's motions, and Wii uses a controller as the interface [2][3]. Our game would incorporate all of the fun and physical activity these other technologies use, but it would also have the feature of no screen, helping people to cut down on screen time. With no screen needed, there is more mobility and flexibility in the placement of the box and locations it can be played.

2 Design Procedure and Details

The block diagram, shown in Figure 1, portrays the four components of the Get Active Gaming System and their connections. The Central Hub contains the majority of the Get Active Gaming System's functionality and logic. The Central Hub is important in deciphering IR remote button presses when the user selects which setting they would like to activate. The Central Hub initiates relevant modules, receives information from the modules upon calculation or game completion, and displays resulting information to the user. The use of IR LEDs and IR receivers in each module allows for clear communication between the components and maintains signal integrity. Figure 1 also outlines the subcomponents of the Whack-a-Mole game, the Get Moving Game, and the Heart Rate Monitor.

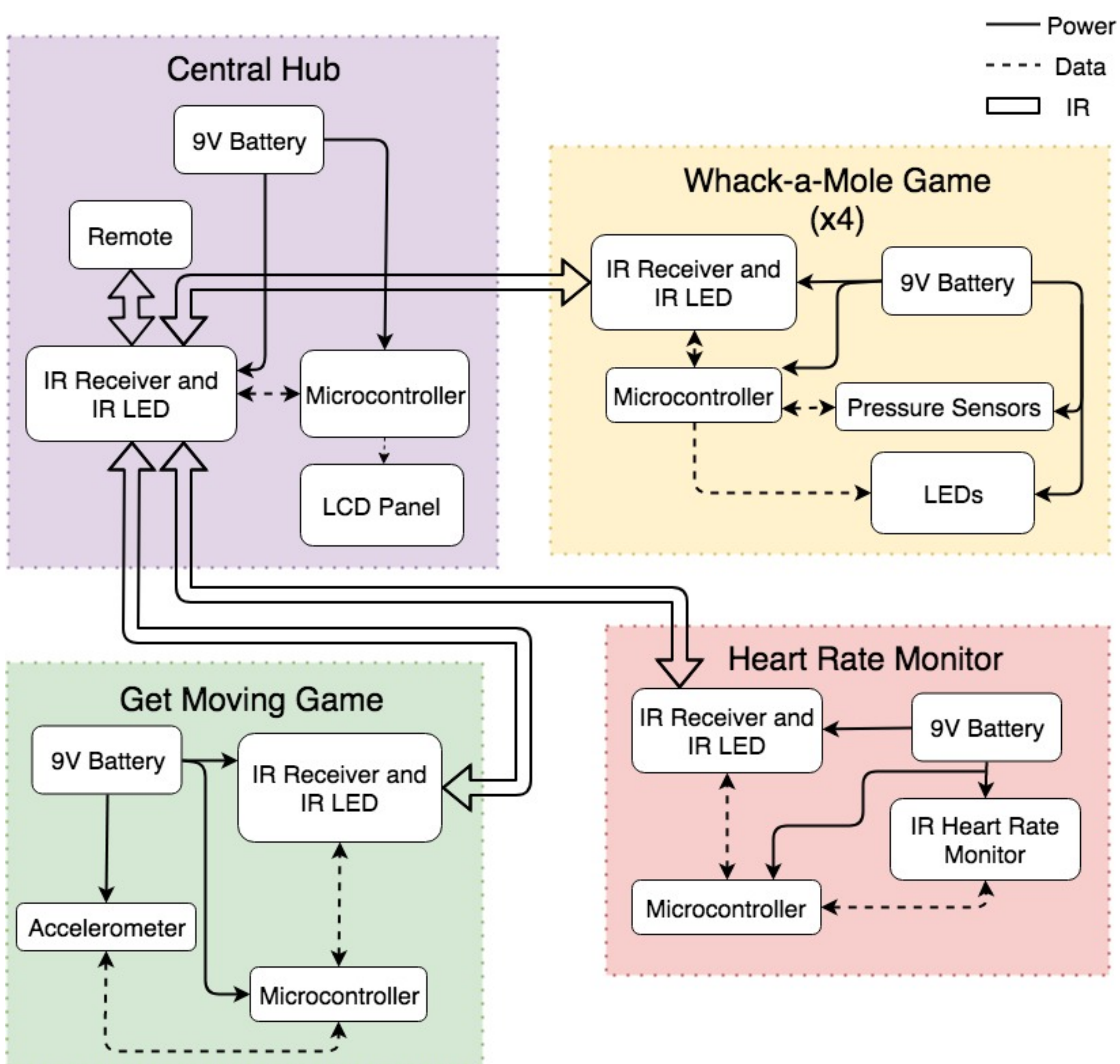

Figure 1. Overall block diagram of the Get Active Gaming System.

2.1 Central Hub

The Central Hub contains the major electrical components and logic for the Get Active Gaming System. Players are able to select which game they would like to play, see their game score, and monitor their heart rate. The Central Hub is the central unit that all of the wireless devices connect to and provides instructions to the devices regarding when to activate or remain idle. A voltage regulator is used to decrease the 9 V battery input to 5 V to be used by the microcontroller and the IR receiver. A 16 MHz crystal oscillator is used to run the microcontroller at adequate speed. The IR LED and IR receiver are used to send and receive signals between the Central Hub and peripheral modules. The LCD Panel is used to provide game information and feedback to the player. Figure 2 shows the circuit schematic for the Central Hub.

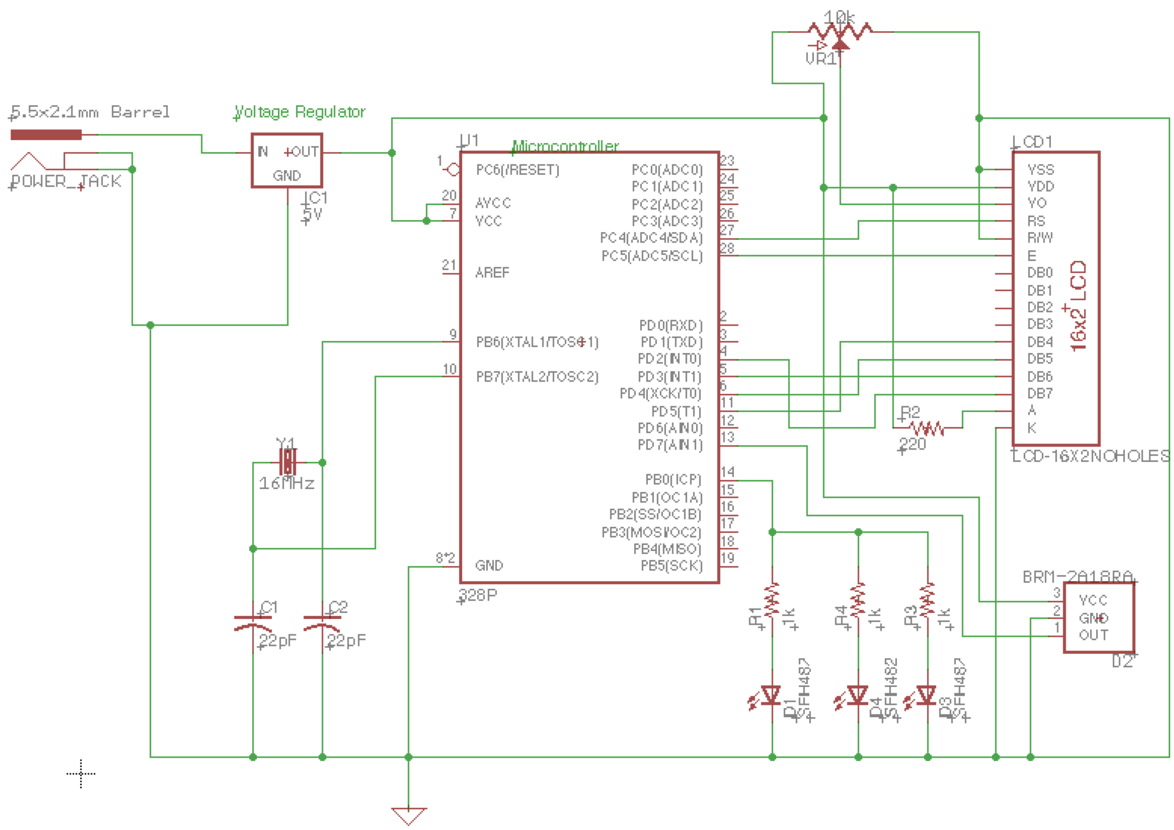

Figure 2. Central Hub circuit schematic.

2.1.1 IR Remote

The IR remote sends signals to the Central Hub to change game mode. We chose the SparkFun IR remote because it is lightweight and contains enough buttons with unique IR signals for choosing at least three game modes. This remote was a good choice because its transmission distance is over 78 feet by our measurements. This ensures that the remote can be used to control the system in a very large room.

2.1.2 9 V Battery

The 9 V battery is the source of power to the module. 9 V batteries were chosen as our main sources of power because they could be connected to 5 V regulators, which allow for a steady 5 V to be supplied to submodules.

2.1.3 Microcontroller

The ATMEGA328P microcontroller was chosen to run the control software for each of our modules because it has enough ports to control all our submodule components, runs on 5 V, and is compatible with Arduino for easy programming.

2.1.4 IR Receiver and LED

The IR Receiver and LED are controlled by the module's microcontroller and detect and send IR signals to and from other modules. The transmission distance of the SparkFun LEDs was rated at 45 feet but ended up being around 17 feet due to electrical current limitations. The receiver was able to detect signals from at least 81 feet (limited by us running into a wall during testing and unable to move further away). For our module communication, we also debated using RF or Bluetooth but chose IR because it seemed the most straightforward while still being able to meet our requirements. If we were to redesign our project, we may choose RF instead because it offers longer range of transmission while still maintaining unique signals.

2.1.5 LCD Panel

The LCD Panel was chosen to display the current game scores or mode. The small 16x2 display is just big enough for the user to be able to see their scores. We wanted the display to be small because the objective of this project was to eliminate the amount of time people spend looking at screens. The LCD can hold up to 32 characters, which is sufficient in displaying the necessary information for each module.

2.2 Whack-a-Mole Game

There are four Whack-a-Mole modules that can be placed around a room during game play and are able to communicate with the Central Hub. When the user decides they would like to play the Whack-a-Mole game and have selected it on the Central Hub, the four modules light up at various times determined by the Central Hub. The player then runs around the room to quickly hit the lit up modules before time is up. The Central Hub communicates with the modules via unique IR signals so that only one module lights up at a time. When the force sensor is pressed, the module then sends a confirmation signal back to the Central Hub which increments the game score and sends a new signal to tell the next module to light up. Figure 3 shows the circuitry within each Whack-a-Mole module.

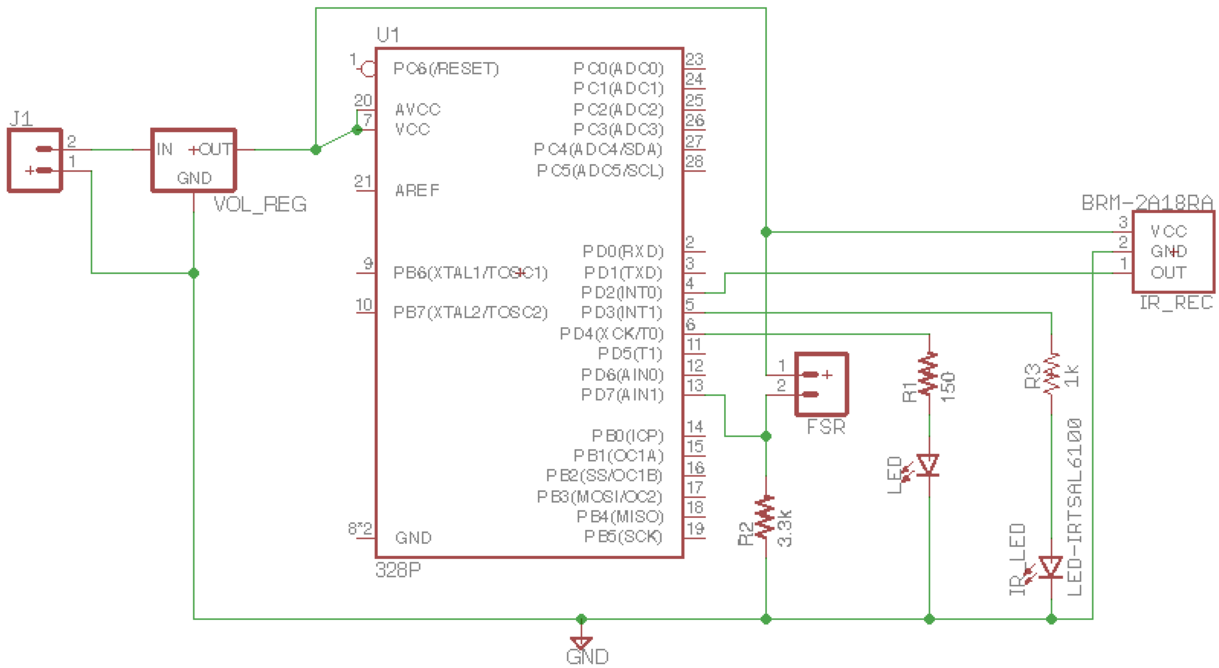

Figure 3. Whack-a-Mole Game circuit schematic.

2.2.1 9 V Battery

Refer to Section 2.1.2.

2.2.2 Microcontroller

Refer to Section 2.1.3.

2.2.3 IR Receiver and LED

Refer to Section 2.1.4.

2.2.4 Pressure Sensor

We chose to use the SEN-09376 Force Sensor Resistor which changes resistance depending on applied force. We chose this sensor because it can detect small to moderate amounts of force within the range of someone pressing it by hand with different pressures. The sensor is also 1.75" x 1.5" which seemed like a reasonable size for our game modules if someone were to run across the room and have to aim and hit it quickly.

2.2.5 LEDs

The LEDs on the Whack-a-Mole modules were included so the user would know which module to press. We used red LEDs in series with 220 Ω resistors to limit the current flow yet provide enough power so the LEDs would be visible to the user.

2.3 Get Moving Game

The Get Moving Game monitors how active the player is during a given amount of time. Accelerometers are attached to the player's arm and then the player is free to move (do jumping jacks, jog in place, etc.). After a start signal from the Central Hub, the Get Moving Game begins. After a certain amount of time, the accelerometer modules communicate back to the Central Hub which displays the calculated game score (number of jumping jacks). Figure 4 shows the circuit schematic for the Get Moving Game.

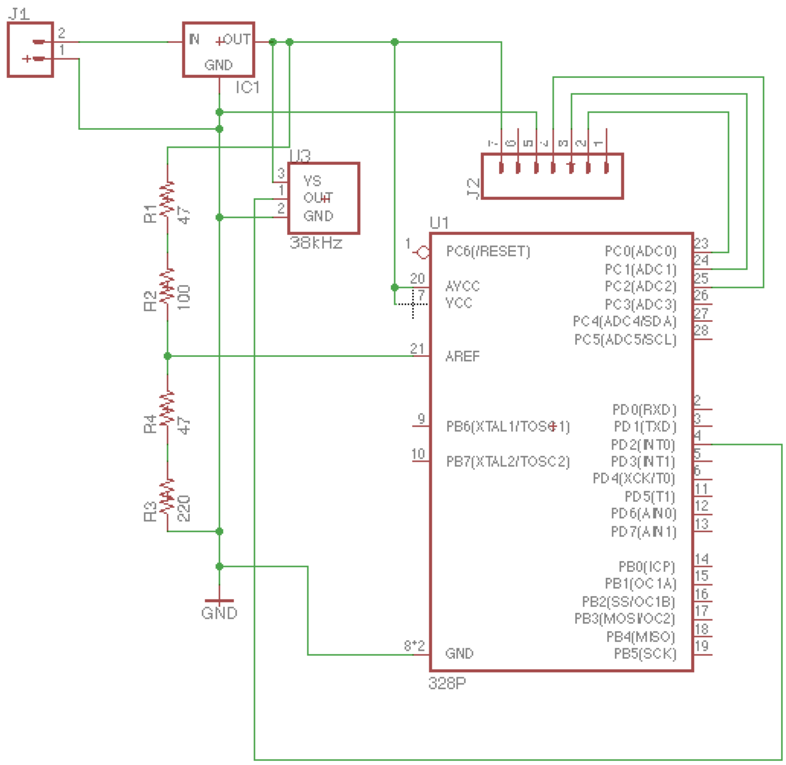

Figure 4. Get Moving Game circuit schematic.

2.3.1 9 V Battery

Refer to Section 2.1.2.

2.3.2 Microcontroller

Refer to Section 2.1.3.

2.3.3 IR Receiver and LED

Refer to Section 2.1.4.

2.3.4 Accelerometer

We chose to use accelerometer ADXL355 for the Get Moving Game because it is 3-axis sensing, and we need the accelerometer to be able to sense acceleration in the z direction. It is a very compact component, which is necessary so it is able to sit on the user's arm. It is also able to sense up to 3 Gs of acceleration, which is much faster than a person can move their arm in a jumping jack movement.

2.4 Heart Rate Monitor

The Heart Rate Monitor detects the player's heart rate and upon an IR remote button press, records then sends the current heart rate to the Central Hub. The heart rate is displayed on the Central Hub LCD panel to provide players with approximate feedback of how high or low their heart rate is. We originally planned to do filtering in the hardware but ended up using the digital signal processing library from Arduino [4].

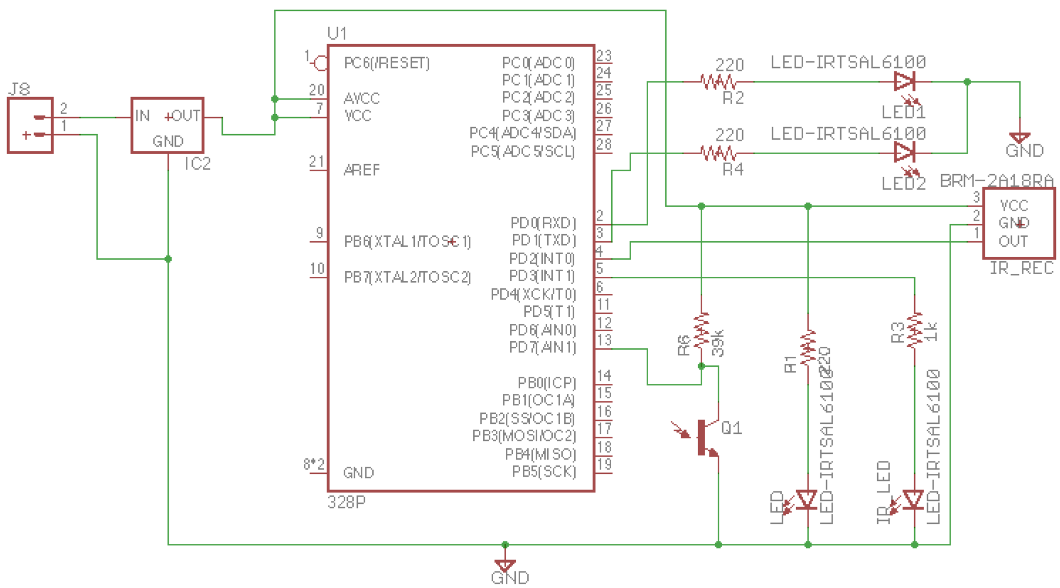

Figure 5. Heart Rate Monitor circuit schematic.

2.4.1 9V Battery

Refer to Section 2.1.2.

2.4.2 Microcontroller

Refer to Section 2.1.3.

2.4.3 IR Receiver and LED

Refer to Section 2.1.4.

2.4.4 LEDs

The Heart Rate Monitor has two LEDs: one that blinks in time with each heartbeat and one that indicates when the heart rate is being recorded. The LEDs were added to the Heart Rate Monitor to provide real-time feedback to the user. The heart rate (red) LED is useful because it allows the user to visually determine where their heart rate is at. The recording (green) LED is also useful to determine if the IR signal from the Central Hub was successfully received and whether the monitor is in a recording state and should be kept near the Central Hub for easier data transmission at the end of the recording period.

3. Design Verification

3.1 High-Level Requirements

3.1.1 Central Hub

Requirement: Module accurately sends and receives signals to and from the peripheral modules via IR.
Verification: The IR LED in the Central Hub correctly transmits signals to peripheral modules and starts the module's functionality. The IR receiver on the Central Hub is able to receive signals from the IR remote and peripheral modules, which causes the appropriate information to appear on the LCD panel.

Requirement: The microcontroller handles multiple game modes individually (not simultaneously).
Verification: The code is structured such that only one game is played at a time. The user must select a game using the IR remote. Then appropriate information including the game start screen and game score are displayed. After the game is complete, the user may select another game to play.

Requirement: The LCD panel displays output corresponding to the game being played.
Verification: The LCD panel correctly displays information needed for the game. The display has a home screen that is on unless a game is selected. When a game is selected the LCD panel displays the start screen for the game, game timer, and game score when appropriate.

Requirement: The IR remote is able to switch games and connect via IR with the microcontroller.
Verification: The IR remote uses distinct buttons to select each game. The IR remote sends a specific value through IR to the Central Hub, which is analyzed to start the appropriate game. This is clearly visible when the LCD panel displays information related to the chosen game.

3.1.2 Whack-A-Mole Game

Requirement: This module should send and receive IR signals from the Central Hub.
Verification: The Central Hub increments count whenever a Whack-a-Mole module is pressed, indicating correct transmission.

Requirement: The microcontroller receives input from force sensor presses.
Verification: The LED on the Whack-a-Mole module turns off when the force sensor is pressed, indicating that a value above 100 was detected on the force sensor.

Requirement: The microcontroller outputs a unique IR signal (via IR transmitter) back to the Central Hub.
Verification: Using a receiver connected to an Arduino board, unique IR signals were detected for each Whack-a-Mole module upon force sensor press.

Requirement: The module can be placed in any orientation within a 25'x25' room.
Verification: The module can receive IR signal from almost any direction, limited by the physical barriers on the module. The module also needs to be oriented such that the IR LED is facing towards the Central Hub to correctly send the IR signal.

Requirement: The pressure sensor values vary depending on applied force.
Verification: Using Arduino Serial Plotter, different values were observed upon different forces applied to the force sensor (Figure 6).

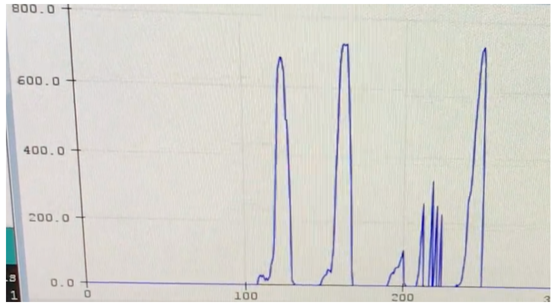

Figure 6. Force Sensor analog output displayed in Arduino Serial Plotter.

Requirement: Users can determine which module to hit based on the LED light attached to the module.
Verification: The LEDs light up only when they receive their unique IR signal pattern and displays brightly, verifying this requirement.

3.1.3 Get Moving Game

Requirement: The microcontroller can record accelerometer data from user's arm movements accurately.
Verification: This was verified first by using the Arduino and displaying the count on the serial monitor. After putting the code on the microcontroller, this was verified by watching the LCD panel output and making sure the number of jumping jacks increased.

Requirement: The microcontroller connects with the IR Receiver and must receive a certain IR signal for start and stop commands.
Verification: An LED was connected to the IR receiver in the Get Moving Game that lit up when a unique IR signal was received.

Requirement: The microcontroller connects with the IR LED and sends a unique IR signal back to the Central Hub.
Verification: This was verified by watching the LCD panel and making sure the appropriate count value was displayed.

Requirement: The module stays on the user's arm during movement.
Verification: This was tested by doing jumping jacks and making sure the module stayed on the user's arm. This was tested at faster arm speeds and was verified to be secure.

3.1.4 Heart Rate Monitor

Requirement: The module should accurately (+/- 10 beats/min) record the user's heart rate.
Verification: This was verified by watching the red LED on the module, which blinked upon every heartbeat detection, and by checking the blinking light rate against the user's pulse. The pulse was also verified using Arduino Serial Plotter to observe the IR receiver values (Figure 7).

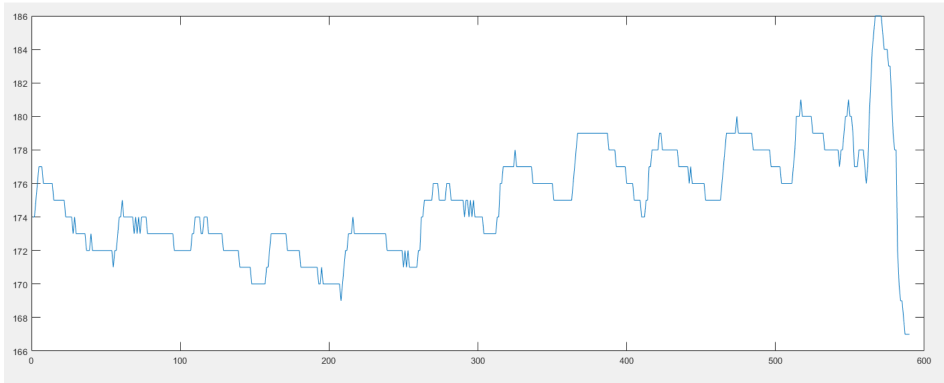

Figure 7. Heart Rate Monitor output in Arduino Serial Plotter.

Requirement: The microcontroller sends the score back to Central Hub (via IR communication).
Verification: The Central Hub successfully receives the heart rate count, verified by correct display.

Requirement: The module can fit on a variety of user finger sizes.
Verification: The clip allowed for the heart rate monitor to fit on multiple finger sizes.

Requirement: The module stays on the user's finger.
Verification: The clip allowed for comfortable attachment to the user's finger. The clip was tight enough to stay on but not so much as to cause discomfort.

3.2 Low-Level Requirements

All except three of our low-level requirements were met. Refer to Appendix A for a complete list of requirements. Below describes the requirements that were not met.

The IR LEDs were only able to transmit a signal 17 feet, rather than 25 feet. This was limited by the max current ratings of the IR LEDs. When we purchased the IR LEDs, they were supposed to transmit up to 45 feet at max current, which we tried to supply using BJTs. However, at this current, they started to burn. Ultimately, we had to run the LEDs with a smaller current and sacrifice further transmission distance.

We ended up not using the coin cell batteries and used 9 V batteries instead to supply a consistent 5 V to the modules.

The accelerometer sensitivity/step size was 550-833 mV rather than our 250-350 mV requirement. This, however, did not affect our overall design because we just needed to detect changes from negative to positive acceleration to count as a jumping jack.

4. Costs

4.1 Parts

Table 1 Parts Costs

Part #	Mft.	Description	Module	Price	Qty	Subtotal
TSOP38238	Adafruit	IR Receiver	All	$1.95	7	$13.65
ATMEGA328-PU	Mouser Electronics	Microcontroller	All	$1.96	7	$13.72
LCD1602	Newegg	LCD Panel	Central Hub	$2.99	1	$2.99
COM-14865	SparkFun	Remote	Central Hub	$3.95	1	$3.95
E522	Energizer	9V Batteries	All	$14.49	1	$14.49
SSL-LX5093IT	Lumex	LEDs	Whack-a-Mole	$0.19	4	$0.76
RB-Spa-463	SparkFun	IR LEDs (pack of 25)	All	$7.95	1	$7.95
SEN-09376	SparkFun	Pressure Sensor	Whack-a-Mole	$11.25	4	$45.00
ADXL375	Digi-Key	Accelerometer	Get Moving Game	$37.50	1	$37.50
MCF 0.25W 220R	Newark	220Ω Resistor	Heart Rate	$0.09	1	$0.09
7078937	Allied Electronics and Automation	39kΩ Resistor	Heart Rate	$0.05	1	$0.05
CF1/4W683JRC	Jameco Valuepro	68kΩ Resistor	Heart Rate	$0.10	2	$0.20
7078902	Allied Electronics and Automation	8.2kΩ Resistor	Heart Rate	$0.05	1	$0.05
MCF 0.25W 220R	Newark	1kΩ Resistor	Heart Rate	$0.09	1	$0.09
NTE-QW147	Vetco Electronics	470kΩ Resistor	Heart Rate	$0.29	1	$0.29
HW218	Vetco Electronics	1.8kΩ Resistor	Heart Rate	$0.22	1	$0.22
K104K15X7RF53L2	Allied Electronics and Automation	0.1uF Capacitor	Heart Rate	$0.07	2	$0.14
RA1/25-R	Jameco Valuepro	1uF Capacitor	Heart Rate	$0.15	1	$0.15
B00MS4DM24	Kikkerland	Clip	Heart Rate	$3.99	1	$3.99
				TOTAL		**$145.82**

4.2 Labor

We estimate ECE Grad earns average of $67,000 (2014-2015) and believe $27 per hour is a fair hourly rate for our work.

$27/hour * 2.5 * 10hrs/week * 9 weeks * 3 workers = $7,290

Per person: $2,430

5. Conclusion

5.1 Accomplishments

We were able to successfully implement the four modules of the Get Moving Gaming System, with reliable communication between all of the modules. The Central Hub is able to transmit signals, receive data, then display the information on the LCD panel. The Whack-a-Mole modules light up independently and at a reasonable rate for the user to hit each one. The Central Hub then records the number of times the user hit a Whack-a-Mole module in the time period, and displays the final score upon game completion. The Get Moving Game successfully records the number of jumping jacks the user does in a certain amount of time, and then sends that number back to the Central Hub when the timer runs out. The Heart Rate Monitor displays the user's pulse on an LED, blinking whenever a heartbeat is detected. It is then able to send this number back to the Central Hub so the user can see what their heart rate is.

5.2 Uncertainties

There are some uncertainties regarding the IR communication when the distance increases. This may affect the user's experience with the game because if the receiver does not receive the correct signal being sent, it interferes with the score being displayed on the LCD panel in the Central Hub. Seen in figure 8 below, the accuracy of the signal being sent and received declines when the distance increases. From 2 feet away, the receiver easily detects the correct signal from the IR LED. From 5 feet away, the receiver only detects the correct signal at a 35° angle from the line perpendicular to the LED. When the IR LED is 13 feet away, this angle is reduced to 15° and, from 17 feet away, the receiver no longer obtains the correct signal at any angle. At all of these distances, the receiver is still able to get a signal from the LED, but if it is not within the angles specified above, the signal is not guaranteed to be correct.

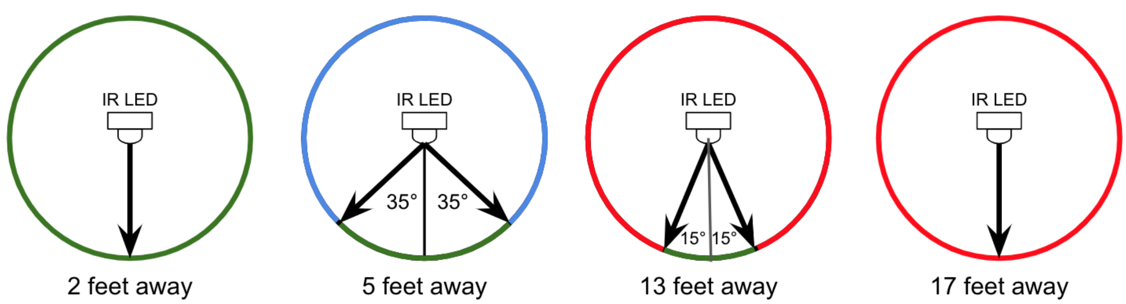

Figure 8. IR LED Transmission Range

We also experimented quite a bit with an IR remote, and observed that the receiver at a distance of approximately 81 feet easily captures the signal sent out by the IR remote. Figuring out how this IR remote is built and what kind of IR LED is being used is essential for future work of this project so the distance between the modules and Central Hub will not be an issue when playing the games.

5.3 Ethics and Safety

5.3.1 Ethical Considerations

We had little trouble in following the IEEE and ACM Codes of Ethics [5][6]. The general purpose of the ethical guides is to promote invention based around benefiting society and prevention of harm. Our product does not gather any personal information from the user except for their heart rates (which are not saved, only calculated and displayed), so this does not violate confidentiality or privacy (ACM Code of Ethics, #1.6 and #1.7). Our goal with this project is to promote well-being of users and encourage them to get more active in life. We aim to improve user wellness and will do so in a game-like manner. This interface is fun and attractive to users of all ages and appeals to a wide audience. Overall, the Get Active Gaming System provides users with a simple yet encouraging way to spend a few minutes a day not sitting down or staring at a screen and enhances quality of life.

We discussed this with our TA and one consideration we kept in mind during our project was to create a unique design for the heart rate monitor, so as to not violate IEEE Code of Ethics, #2 which states we must "avoid real or perceived conflicts of interest whenever possible" [5]. There are many designs along the lines of "DIY IR pulse recorder" online that we planned to learn from, but did not copy.

5.3.2 Safety Considerations

IEEE Code of Ethics, #2 states that we must "hold paramount the safety, health, and welfare of the public" [5] which applies to all of our safety considerations mentioned below.

Our project uses 9 V batteries as power sources, so we needed to ensure that our circuits were created properly to eliminate the risk of any shocks. Ideally, everything we made would be contained and the only exposed wires may be to the sensors (IR, pressure, etc.). Currently, there is no formal packaging encasing each module, but all wires were properly insulated and do not pose any more risk than normal power cords. Additionally, batteries can corrode after a long period of time; however, with regular use the user should drain the battery and replace it before this poses an issue.

During design, we needed to consider our audience. One demographic we targeted was children so we needed to make sure the box and components are child-proof. If a kid is running around the room pressing sensors, there is a concern of them tripping on exposed wires or falling on or near the box. For this reason, we needed to make sure our circuits are contained so no loose wires are exposed and make the box such that it can be placed on a table or away from where the player will be running around. We hid the wires, which is beneficial if users have a pet at home or if the system will be placed in a retirement home where people may be in wheelchairs. Furthermore, using IR eliminated the need for wire to connect each module to the Central Hub, making the system even safer.

Another issue we encountered is with the heart rate monitor portion of our project. According to the ACM Code of Ethics, #2.3, we must "know and respect existing rules pertaining to professional work" [6]. The heart rate monitor uses an IR transmitter and receiver and can be classified as a Class I or II medical device by the FDA since it is interacting with humans and measuring a part of the body [7]. However, we did not need to register it because similar devices exist in hospitals and are pre-approved so our system could be "grandfathered" [8]. We only need to gain approval from the FDA if we were to put our project on the market. The heart rate monitor also does not pose a serious threat to humans because the IR sensors we are using will come from SparkFun, which we assume has passed human safety tests.

If we were to put our product on the market, we would want to run user tests with volunteer subjects. This would ensure our game can detect everyone's heart rates and arm movements accurately. To do so, we would need research subjects and need to get IRB human testing approval [9]. It should be relatively easy to get approval for human testing because there are not many risks to a user.

5.4 Future Work

There is a lot of potential growth for this project. Since we made the game system modular, there is the possibility of expanding the amount of games available. This can be done as long as the IR remote used for the game has enough buttons to send a different IR signal for each game. We would also like to make the games much more compact. For the Get Moving Game and Heart Rate Monitor especially, we want to make those as small as possible so the user is not affected by the weight when they are playing. We also want to look more into the IR LED range. This would be done by looking more into the IR remote used for the game and seeing what type of LED is used there. Another possibility would be to try other IR LEDs that can handle more current so that the range would improve.

References

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Appendix A Requirements and Verification Table

Table 2 System Requirements and Verifications

Component	Requirement	Verification	Verification Status (Y or N)
Power Supply	1. Convert 4.5-5.5V from AC to DC	1. a. Connect the plugged in power supply to a breadboard b. Measure the voltage across the power supply using the multimeter by placing the red probe on pin with voltage and placing the black probe on ground.	1. Y
IR Receiver	1. Detects IR transmissions within 1 second of IR signal being sent from a distance of up to 25 feet. 2. Detects unique IR patterns and can display. timing and frequency of pulses (within 20% accuracy) on microcontroller console.	1. a. Point IR remote at sensor, press button, and observe if LED lights up within 1 second of button presses 2. a. Use test code from Adafruit's "Using an IR sensor" to display unique IR pattern on microcontroller console and check that the pattern is within 20% of the actual IR remote's pattern (found online)	1. Y 2. Y

IR LED	1. Transmission range > 25 feet. 2. 850 nm +/- 100 nm wavelength (low IR range). 3. Operates at less than 100 mA of continuous forward current. 4. Forward voltage between less than 1.7 V. 5. Power dissipation at or below 150 mW.	1. a. Place the IR LED and IR receiver 25 feet apart. b. Observe, using Adafruit code, whether the IR receiver displays different output when the LED is connected and disconnected 2. a. Using the digital video mode on a cell phone, record the LED b. Turn the LED on and off, if it is transmitting light in the infrared range (850 nm +/- 100 nm), a purple glow will appear on the video screen 3. Using a multimeter, connect in series and record the current passing through the LED when Vdd is connected to the microcontroller's voltage output and ensure it is at or below 100mA 4. Using a multimeter, connect in parallel and record the voltage drop across the LED when Vdd is connected to the microcontroller's voltage output and ensure it is at or below 1.7 V. 5. Using the values computed in verifications 2 and 3, calculate the power across the LED and ensure it is at or below 150 mW.	1. N 2. Y 3. Y 4. Y 5. Y

Microcontroller	1. Run off of 1.8-5.5V. 2. Delivers signals through the IR LED and IR receiver faster than 1 second.	1. Use a multimeter to measure the voltage by placing one probe on the VCC pin and the other probe on the ground pin of the microcontroller chip. 2. a. Set up the microcontroller to light up an LED that is controlled by an IR LED and IR receiver pair. b. Count how many times the LED lights up in a 10 second period. c. If the total count is larger than 10, the microcontroller has met this requirement.	1. Y 2. Y
LCD Panel	1. Must have dimensions less than 100mm x 100mm to make user friendly. 2. Power supplied around 4.5-5.5V. 3. Must be able to transmit data at a speed of less than 1 second.	1. a. Measure dimensions with ruler. b. Confirm the dimensions are less than 100mm x 100mm. 2. a. Probe input and output to find voltage using a multimeter. b. Confirm this value is `between 4.5-5.5V. 3. a. Send data to LCD panel and observe time it takes for LEDs to light up. b. Confirm LED lights up 1 second or less.	1. Y 2. Y 3. Y

Remote	1. Transmit IR signal > 25 feet 2. Transmit 3-10 different IR patterns 3. Run off coin cell battery for at least 50 hours	1. a. Set up the IR receiver press buttons on the remote from 25 feet away b. Using the Adafruit test code, observe if the microcontroller console displays output upon button press 2. Same as verification 1 except also ensure that the IR patterns displayed on the console are unique for each button press 3. Determine the power consumption (mAh) and current drawn (mA) in the remote and divide the power by the current to get the approximate lifetime.	1. Y 2. Y 3. Y
Coin Cell Batteries	1. Needs to supply between 1.5-4V into the system. 2. Weigh no more than 5g. 3. Volume no more than 2 cm^3, has to be able to fit in all aspects.	1. a. Probe positive (outer circle) and negative (inner circle) terminals. b. Use multimeter to measure the voltage across the battery. c. Confirm that this output voltage is 1.5-4V. 2. a. Use a scale to weigh coin cell battery. b. Ensure that it is less than 5g. 3. a. Measure radius distance. b. Use $V=\pi r^2 h$ to get the volume. c. Confirm that the volume is less than 2 cm^3 .	Not used

Pressure Sensors	1. Detect force less than 10 kg 2. Resistance must be 2 kOhm with heavy pressure (10 kg +/- 0.5 kg)	1. a. Attach the pressure sensor to an ohmmeter. a. Apply weights varying from 0 to 10 kg to the pressure sensor and verify that the resistance decreases with increasing pressure. 2. a. Attach the force sensor to an ohmmeter. b. Read the resistance with no pressure applied and verify it is above 1 MOhm. c. Apply 8 kg +/- 0.5 kg pressure (with weight) and verify resistance is below 2 kOhm.	1. Y 2. Y
LED	1. Must be bright enough for the user to see it up to 25 feet away.	1. a. Attach LED to IR receiver circuit b. Supply power and observe from 25 feet away if the LED is visible	1. Y

Accelerometer	1. Needs to be able to collect information of user's movements accurately and in all directions. 2. Display output data in less than 1 second. 3. Needs to be able to receive 2g (43mph) of acceleration. 4. Sensitivity of accelerometer should be between 250-350mV/g.	1. a. Set voltage of V_s into ST pin, which shoots an electrostatic force into accelerometer beam. b. Observe output on xyz axis. c. Make sure an there is an output of -1 to -1.25g in the x-axis, 1-1.25g in the y-axis, and 1.5-2g in the z-axis. 2. a. Using the previous verification test, observe the time it takes for the output to display. b. Confirm it takes less than 1 second to display the output 3. a. Move the accelerometer as fast as we can. b. Confirm that the accelerometer is able to detect the speed. c. Also check to ensure that the output is able to reach 2g. 4. a. Input 1g (21.9mph) into accelerometer b. Observe output display c. Confirm it gives an output voltage of 0.200-0.400V.	1. Y 2. Y 3. Y 4. N

IR Heart Rate Monitor	1. Pulse is transmitted to the output of the circuit at every heartbeat with an error of max 10 beats/minute.	1. a. Attach the Signal output from the IR receiver and transmitter heart rate circuit to the A0 pin of the microcontroller. b. Place the IR receiver and transmitter against the user's thumb. c. Using code provided by "Make:" tutorials, observe the console output and verify that the frequency matches the user's heart rate (determined by checking pulse with finger on user's throat or wrist).	1. Y

Appendix B EAGLE Printed Circuit Board Layouts

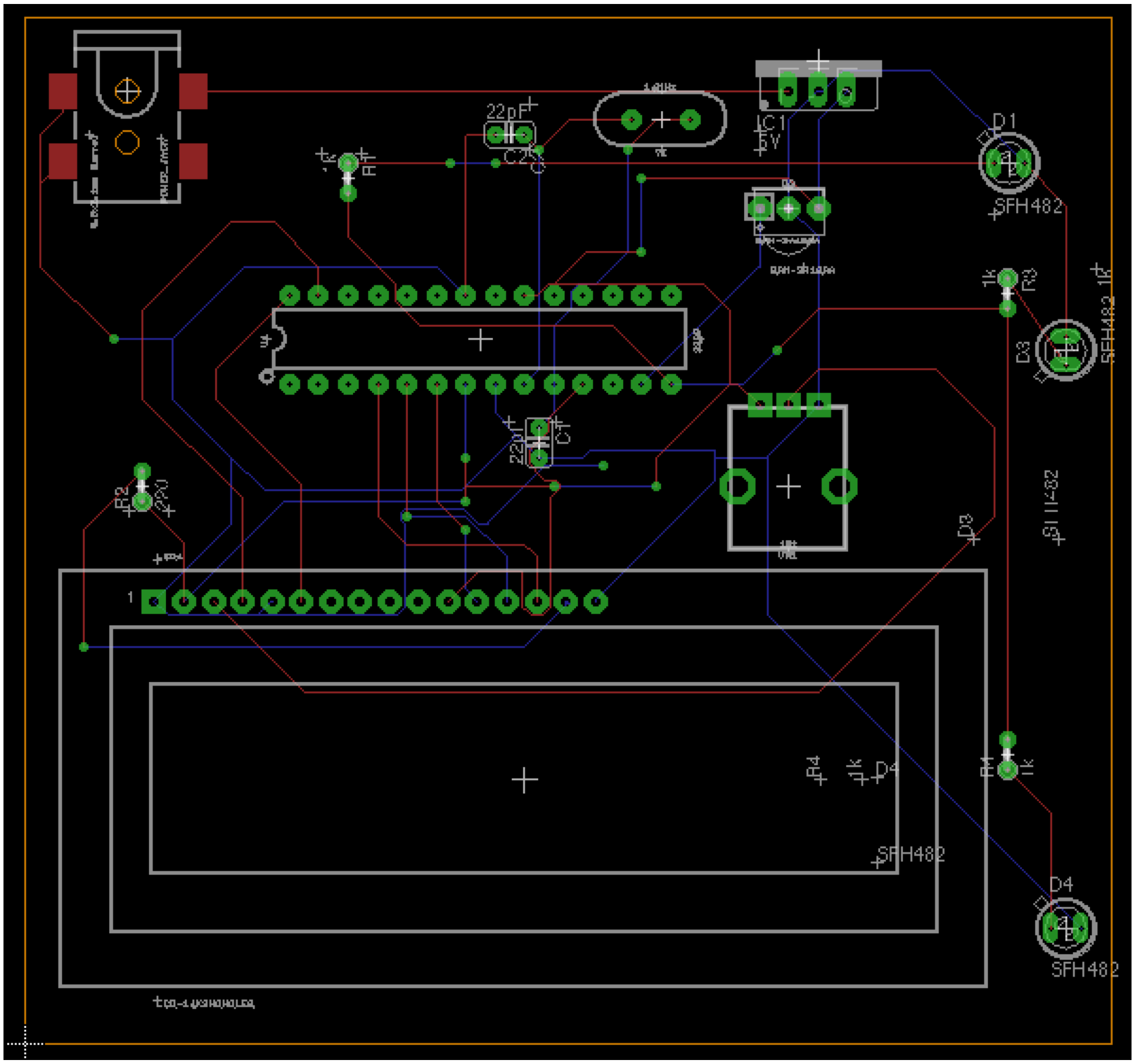

Figure 9. Central Hub PCB layout.

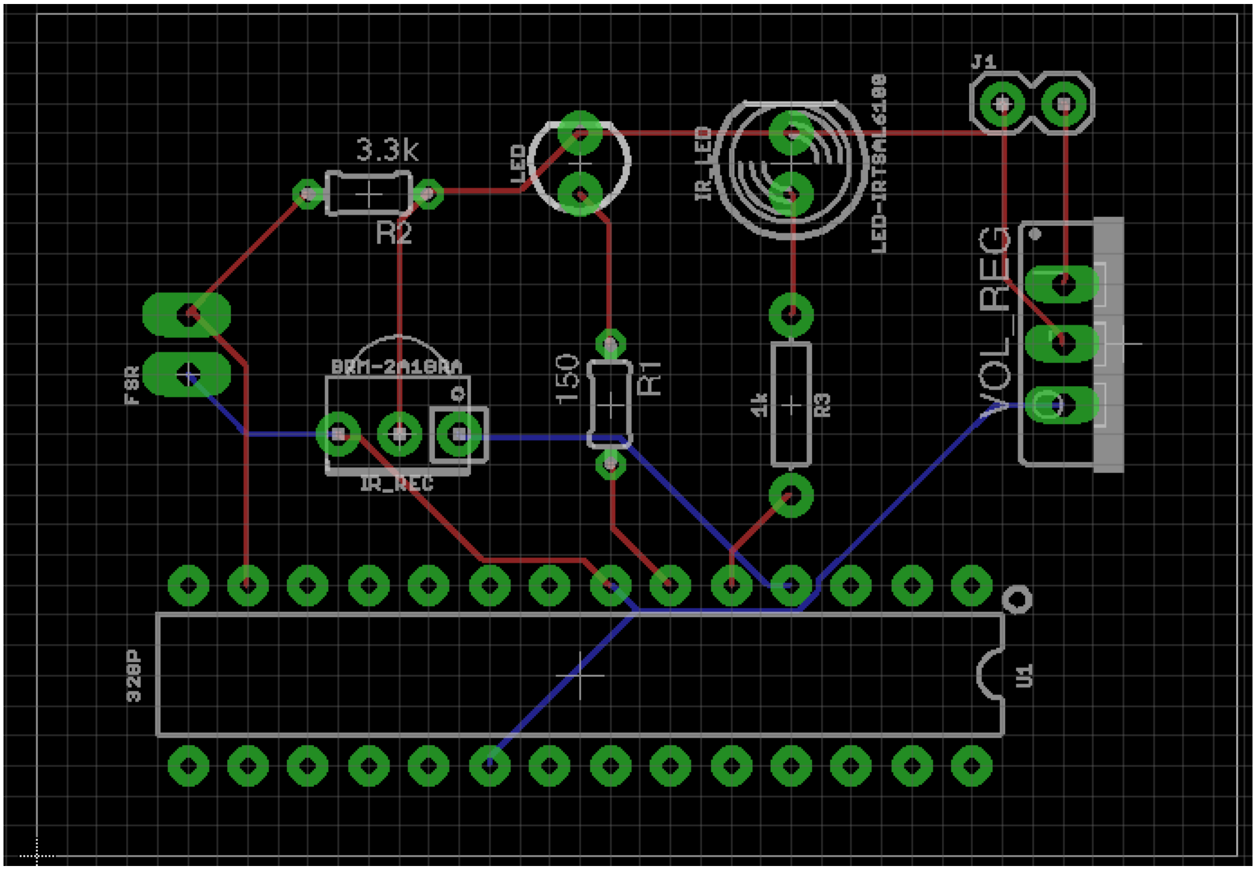

Figure 10. Whack-a-Mole PCB layout.

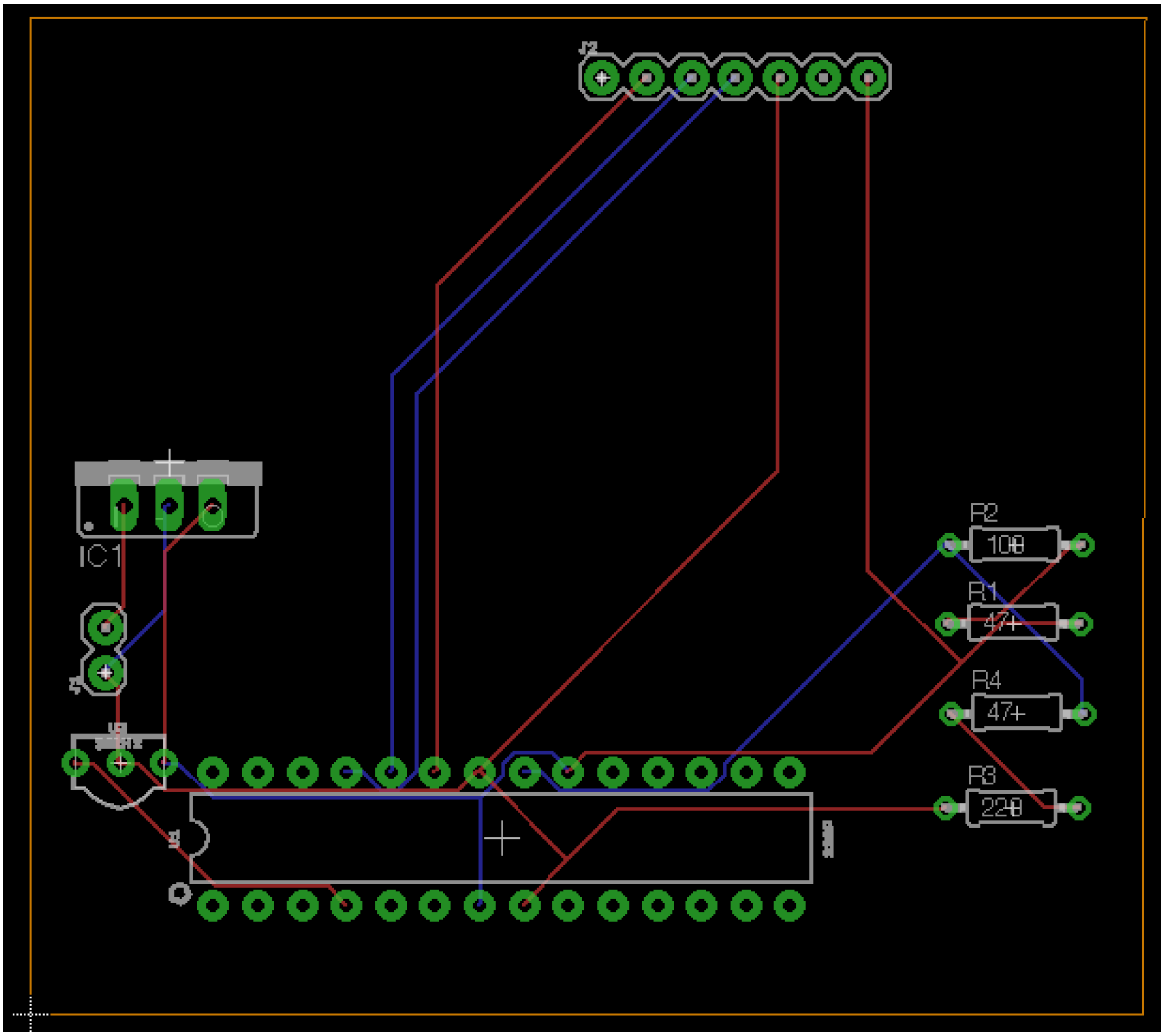

Figure 11. Get Moving Game PCB layout.

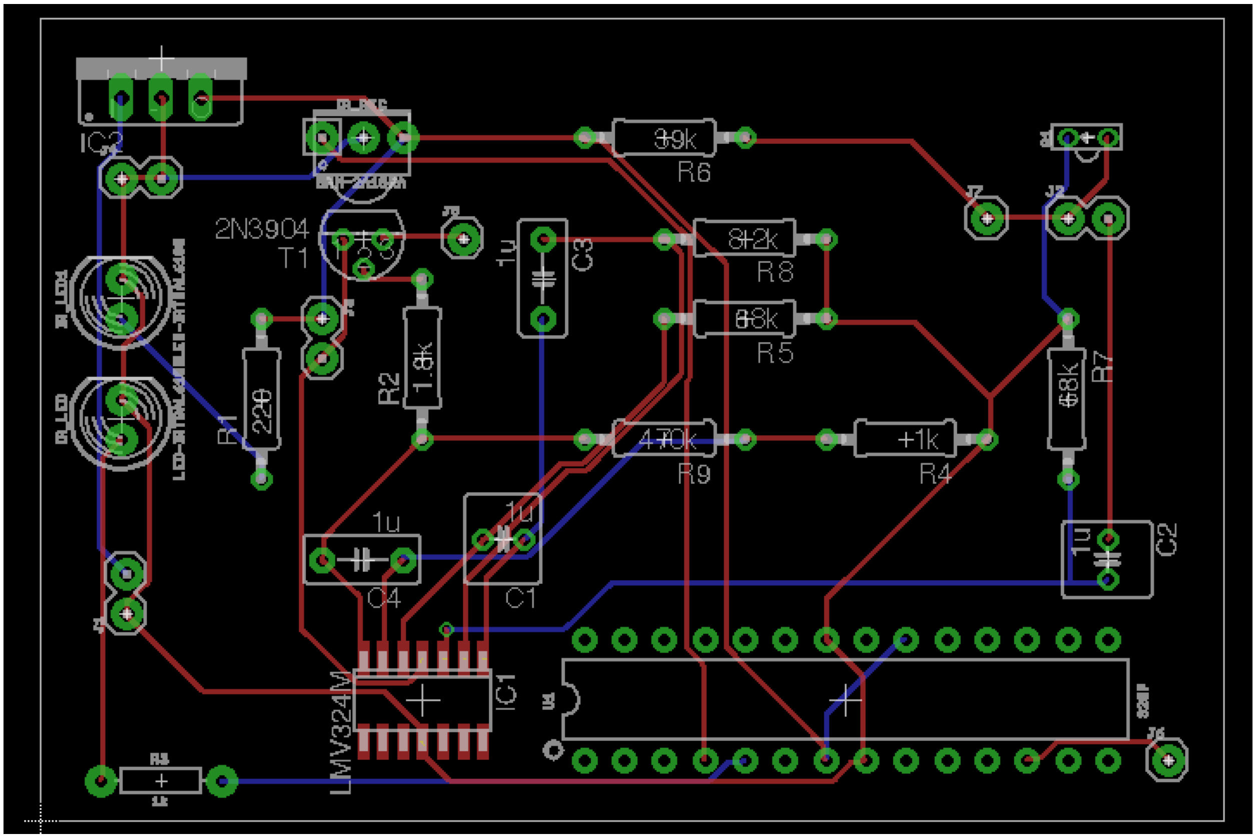

Figure 12. Heart Rate Monitor PCB layout.