Bar Watch

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ECE 445 Design Document - Spring 2021

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1 Introduction

1.1 Objective

Responsible drinking has been a concern for a long time. In 2020, despite COVID restrictions, drunk drivers caused an average of 29 deaths every day and 28% of all traffic deaths [1]. In 2016, over one million drivers received DUIs - and that’s just 1% of the self-reported cases [1]. As a result, 43 of the 50 states have adopted the Dram Shop Law, which can hold bars liable for drunk driving accidents [1]. In most states, this also extends to within the bar if any accidents occur. Patrons are now able to hold bars liable and file Dram Shop Cases for reasons ranging from recklessness to intentional conduct [2]. Therefore, it is in the best interest of the bars and public to find a way to actively track alcohol consumption.

Our goal with Bar Watch is to facilitate safe drinking and also offer a more COVID-safe experience. It is a reusable accessory that bars can use to monitor their patrons’ alcohol consumption and purchases. This device will be given to customers upon entry. It will be able to interact with different dispensers and track the user’s purchases. This has the added benefit of contact-free delivery and reduced waiting times for consumers. Each device will be connected to a central database through a wireless communication module. The database contains the different prices and alcohol information, and tracks the user’s consumption. If a patron reaches a dangerous level of alcohol consumed as determined by their physical features and time between drinks, the bar is alerted to offer ride services if necessary. When the customer leaves, the device is returned and sanitized for use again. This endeavor would be a big first step towards responsible drinking and making the experience COVID-safe.

1.2 Background

There have been efforts to track alcohol consumption and automate dispensers, but none have sought to combine the two into an ergonomic, multipurpose wristband. With COVID still a threat, our solution's features appear to be even more valued.

With regards to dispensers, Smartender is the closest product that mirrors this notion of automated dispensing [3]. Taproom bars also offer cards that patrons can use at dispensers without contacting a bartender. However, what they do not have is a BAC-tracking system to notify both the bar and patron about their alcohol consumption. Such features exist separately in downloadable apps that do not properly hold individuals accountable. By notifying bar employees, our product gives them the tools to ensure those under the influence are properly guided to potential ride services or otherwise taken care of appropriately. In addition to this, patron information is added to the wristband and database until they exit bar. In the event of any altercation or emergency on premise, the necessary information is ready on hand without delay.

To put it more succinctly, our product seeks to unify two different products (automated dispensing and BAC-tracking) into one solution, while incorporating a payment feature to further reduce human interaction. Going further, we wish to add a safety feature that allows for patrons to use the wristbands as a call for help. With a single pushable button, the bar employee can be quietly made aware of a person's distress and step in. Our goal in designing Bar Watch is to make drinking at bars a safer interaction and take into consideration the COVID threat present today.

1.3 Physical Design

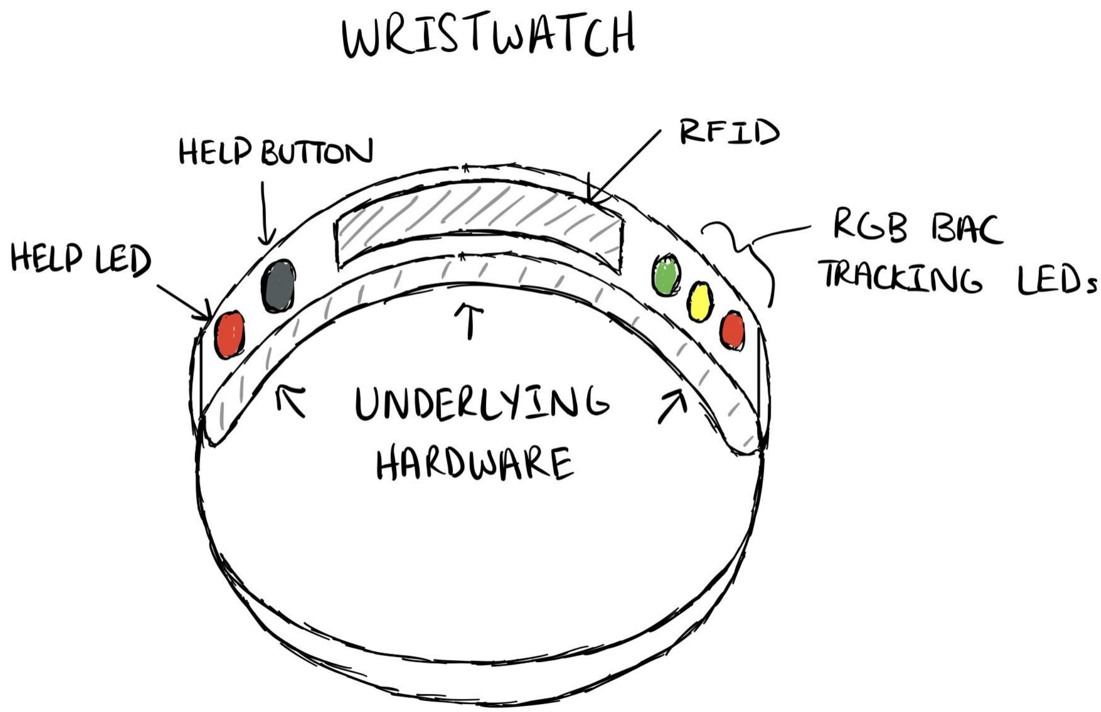

Figure 1.3a: Wristwatch Physical Design

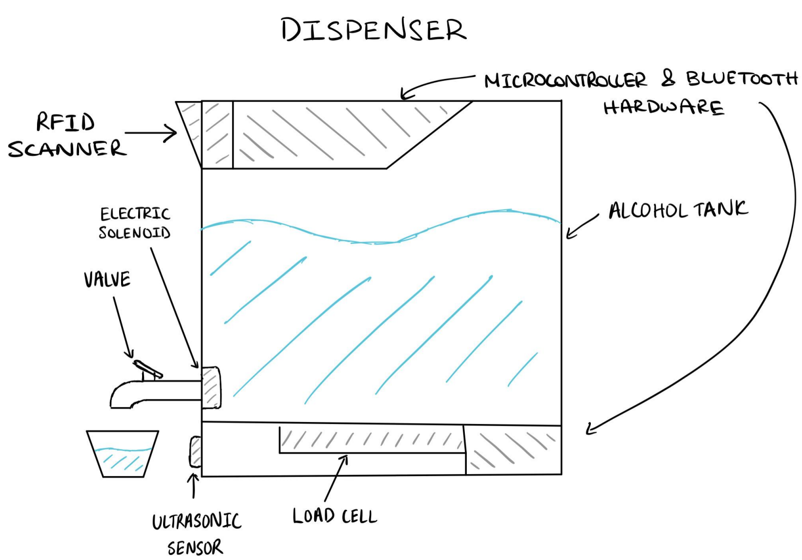

Figure 1.3b: Dispenser Physical Design

1.4 High-Level Requirements

- ❖ Measure volume of alcohol poured within 1-5% of actual volume and up to 16 fluid ounces poured so that we can estimate Blood Alcohol Content/Concentration (BAC), based on customer biometrics and volume of alcohol.
- ❖ When a customer uses the wristwatch at the dispenser or presses the 'Help' button, the purchase/status is reflected in the database under the customer's entry within 1 second.
- ❖ Provide visual feedback via a 5 second long LED indication after purchase to customers and customer summary to bar staff within 5 seconds of request.

2 Design

2.1 Functional Overview and Block Diagram

As seen in **Figure 2a**, there are three main components to the Bar Watch Design. They are the Bar Watch Wristwatch, the Bar Watch Dispenser, and the Computer. The dispenser will be connected to the computer via bluetooth connection and send data from the microcontroller. It will gather data on the amount of alcohol purchased by each customer and send it to the computer to calculate the BAC level of the customer. It will also read the RFID from each wristwatch and allow the user to pour drinks as long as it recognizes the RFID and the RFID has been activated. Visual feedback to employees on alcohol levels of customers is shown through the computer, while each patron will have a simple LED level to approximate if they are near the legal limit.

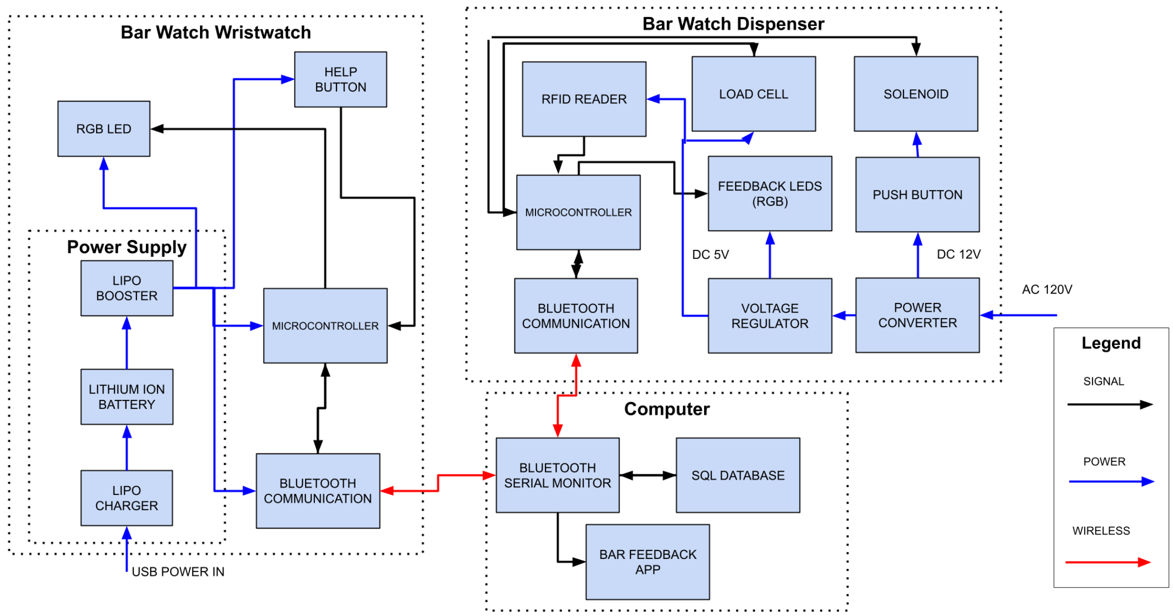

Figure 2a: Block Diagram of Design

Block Level Requirements

2.2 Power Supply

Converts our AC wall voltage to a 12V DC voltage which will be in the input voltage range for our step-down voltage regulator so that we can power the components for our drink dispenser. 12V will also make it easy for us to open our solenoid because it will stay closed until 6-12V is applied across it's terminal, so it will allow us to use a simple relay circuit.

2.2.1 Watch Battery

For our watch battery, we decided to use a 3.7V lithium-ion battery. This battery will power all the components in the watch such as the bluetooth module, the ATMega328P microcontroller, and the LEDs. The battery's output voltage ranges from 3.3V to 3.7V when fully charged. The battery has 1Ah capacity, so it should be able to power the watch for over 7 hours which is plenty of time for a bar to be open.

2.2.2 LiPo Charger/Booster

The LiPo charger/booster will allow us to connect our 3.7V lithium-ion battery to this component and get an output voltage of 5V at 1 amp. It will also allow us to charge a lithium-ion battery safely from a micro-usb charger. The charging module consumes about 500mA.

Requirements	**Verification**
Fully charge battery	❖ Use a micro-usb charger to charge the battery until the LED indicates it's fully charged then check that the battery is outputting 3.7V.
Reliably output 5V +/- 5% at 1 Amp +/- 5%	❖ Measure the output voltage from the booster and ensure that it's outputting 5V with a current of 1A.

2.3 Control Module

2.3.1 Microcontroller

For our circuits, we are using the ATMega328P. It will be used to collect and transmit data using the I2C standard and then send this data through bluetooth to the computer using USART. This microcontroller will be programmed using the arduino IDE.

Requirements	Verification
Sends a signal below or above 2V to the inverted logic relay module.	❖ Have the microcontroller send the same signal that would be sent when we're trying to dispense and use an oscilloscope to check that it's a step signal with an amplitude less than 2V.
Receive and verify RFID data via the USART communication.	❖ Scan RFID tag and use a serial monitor to make sure that the correct UID of the RFID tag is being displayed.
Send and receive information to the bluetooth module via USART communication.	❖ Send a few test characters from a smartphone via bluetooth and use a serial monitor to make sure that the correct character is received by the bluetooth module.

2.3.2 12V Electric Solenoid

We use a 12V normally-closed solenoid to dispense drinks. This solenoid will start dispensing drinks when we apply 12V across it's two terminals. This solenoid is perfect because it only allows liquid to flow through one direction and it has a wide pressure range, so we can choose a suitable pressure that will allow us to dispense drinks in a timely manner without any kind of backsplash.

2.3.3 Load Cell and Load Cell Amplifier

The load cell that we are using allows us to measure forces from 0-5kg which will be suitable for our uses because our largest cup will be 16oz which translates to a maximum weight of 0.45 kg. Additionally, the load cell has a range of error of only +/- 0.0015kg, so we will be able to have good accuracy. The load cell amplifier will amplify our load cell signals to report them to our microcontroller.

Requirements	**Verification**
Read weight with a range of error within +/- 0.0015kg	❖ Calibrate our weight cell using a simple Arduino circuit and weigh an object of known weight and use the Arduino IDE to check if the reading from our load cell is within the range of error.
Transmit the weight to the microcontroller via USART.	❖ Weigh an object of known weight and use a serial monitor to see if the weight is communicated successfully.

2.4 Wireless Communication

2.4.1 Bluetooth Module

The dispenser and the wristwatch will need to be constantly connected to the computer to provide and receive data for each unique user. One such solution to this would be to connect via wireless bluetooth. This allows us to wirelessly send data such as drinks purchased, alcohol consumption, and help signals via the USART on our microcontroller.

Requirement	Verification
Send and receive information to the bluetooth module via USART communication.	❖ Send a few test characters from a smartphone via bluetooth and use a serial monitor to make sure that the correct character is received.

2.4.2 RFID Tag & RFID Reader

The RFID tag has a unique identifier that is used to identify each specific user. When a watch is activated, the dispenser will be able to identify the user, and link any purchases and the amount of alcohol consumed to their account. The RFID reader reads the unique identifier of the tag.

2.5 Case

The bar environment is prone to spills and other accidents with beverages. As such, the wristband and dispenser hardware require a case that passes IP26 environmental standards.

Requirements	Verification
Passes IP26 environmental standards	❖ Touch wristwatch and dispenser with bare hands ❖ Spray case with water for 30 sec ❖ Ensure parts function as intended

2.6 Software

The software portion of our project connects the different components of the design (wristwatch, dispenser, database, etc) and determines how they interact with each other. The flow chart seen in **Figure 2.6** summarizes this logic.

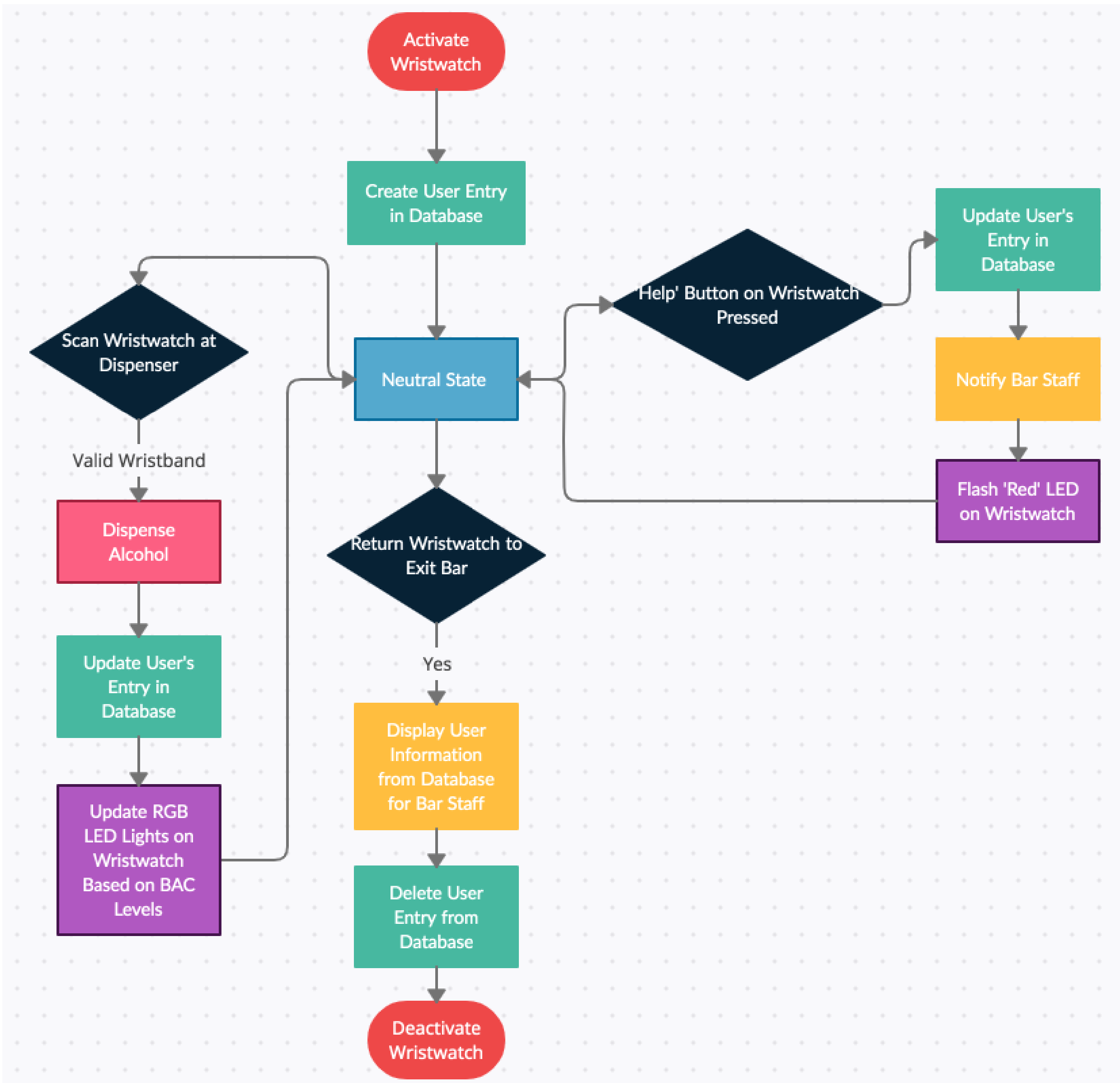

Figure 2.6: Logic Flowchart

Data collected from the dispenser is used to update user information regarding purchases and alcohol consumption. The wristwatch's data is used to determine if the user requires assistance. By using this information, the software updates the database as needed and notifies the bar staff if any action is required from them. It ensures patrons have a contact-free experience.

2.6.1 Data Transmission

Information from the wristwatch and dispenser is transmitted wirelessly via bluetooth to the computer. In return, the computer communicates wirelessly with the wristwatch only.

Requirements	**Verification**
Data is transmitted to computer from wristwatch/dispenser	❖ Press 'Help' button on wristwatch and verify signal is received by computer ❖ Use wristwatch on dispenser and verify weight sensor data & wristwatch user information is received by computer
Data is transmitted to wristwatch from computer	❖ Manually set user's BAC status to 'red' and ensure wristwatch LED is 'red'

2.6.2 Data Storage

Sensor and signal data will be received wirelessly and transferred to a MySQL server. This will enable proper storage of vast amounts of information. Over time, the information added here will need to be updated and deleted.

*Note: ‘Activating’ a wristwatch means scanning the wristwatch w/ RFID to put the user's first entry in the database. ‘Deactivating’ a wristwatch would entail scanning the wristwatch w/ RFID to delete the user’s entry in the database.

Requirements	**Verification**
Data is added to database	❖ ‘Activate’ wristwatch and ensure user information is added to the database
Data is updated in database	❖ Use wristwatch on dispenser and ensure user information is updated in database
Data is deleted from database	❖ ‘Deactivate’ wristwatch and ensure user information is deleted from the database

2.6.3 Logic Processing

The stored data will need to be processed to determine the current statuses of the user. Following this, the information within the database will need to be updated.

Requirements	Verification
When wristwatch is scanned by dispenser, must update the user's information in database	❖ Use wristwatch on dispenser and ensure user information is updated in database
When 'Help' button is pressed, must update the user's information in the database and flash LED on wristwatch 'red'	❖ Press 'Help' button on the wristwatch ❖ Ensure database updates with this information ❖ Ensure LED on wristwatch flashes 'red'

2.7 User Feedback

An essential component to the design will be the visual feedback. This allows the user and bar employees to receive information from the wristwatch, dispenser, and computer. For the user, it allows them to quickly glance at their wrist and determine how much they drank. This will allow them to make a more informed decision on how much more they want to drink. It will also allow bar employees to examine the wristwatch - when the user returns it - and suggest rideshare services if the user is over-inebriated. Additionally, bar employees may be alerted to emergency situations within the bar.

2.7.1 RGB LEDs

The LEDs will be located in the user's wristwatch and the dispenser. The LEDs on the wristwatch give a rough estimate of how much alcohol the user has consumed. The dispenser LEDs will give feedback of when it is ready to read the watch and when it is ready to dispense.

Requirements	**Verification**
RGB lights must change depending on user's BAC levels	❖ Modify the user's database entry for amount of alcohol consumed and ensure all 3 RGB lights are functional based on corresponding BAC level

2.7.2 Help Button

The Help Button on the wristwatch is also essential to making the bar a safer environment. It will be able to quickly alert employees to any potential emergencies as well as ensure that users still feel safe if they ever encounter a dangerous situation. Because people will be drinking and enjoying themselves, it is important that this feature is not accidentally pushed and only used when the user intends it to be.

Requirements	**Verification**
Button must be depressed for at least 3 seconds	❖ Accidental press of the ‘Help’ button does not activate the ‘Help’ subroutine
Wristwatch must flash red	❖ Press ‘Help’ button on the wristwatch and ensure the LED light flashes ‘red’
Database must be updated	❖ Press ‘Help’ button on the wristwatch and ensure the user’s database entry is updated
Computer must display an update	❖ Press ‘Help’ button on the wristwatch and ensure the computer displays a notification for the bar staff

2.8 Circuit Schematics

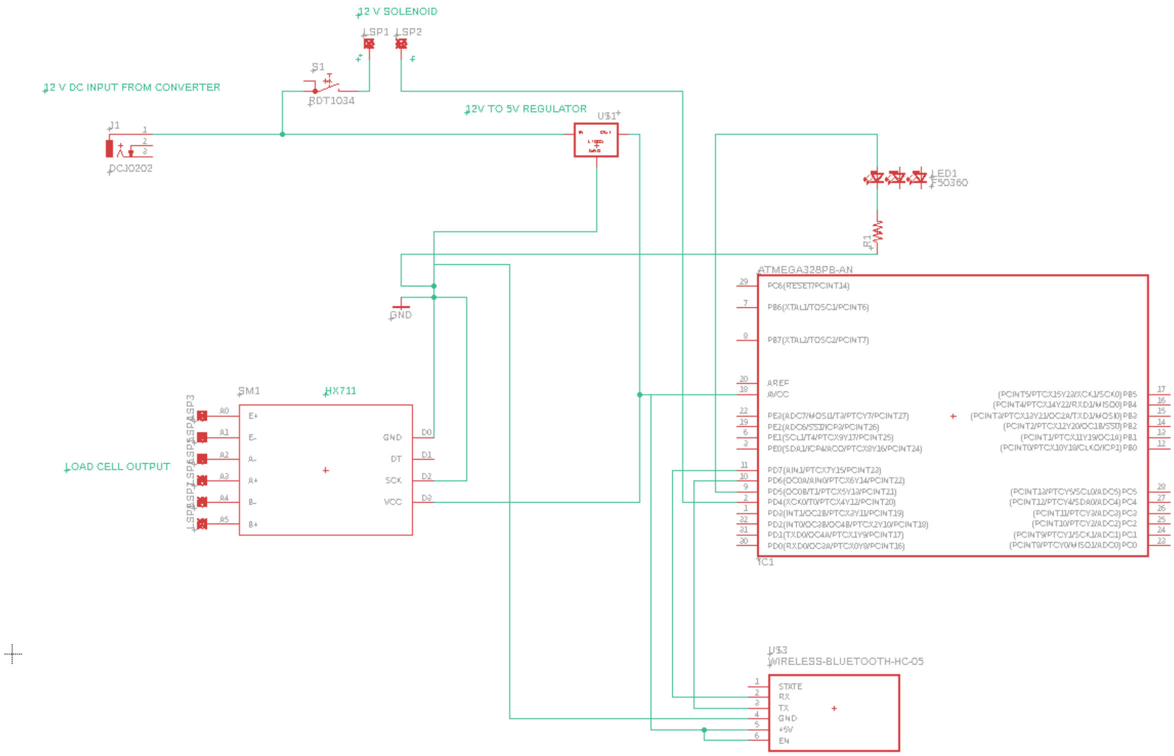

Figure 2.8a: Dispenser Circuit Schematic

Figure 2.8a the connections between the microcontroller, load cell and ADC, voltage regulator, RGB LEDs, and Bluetooth module of the dispenser.

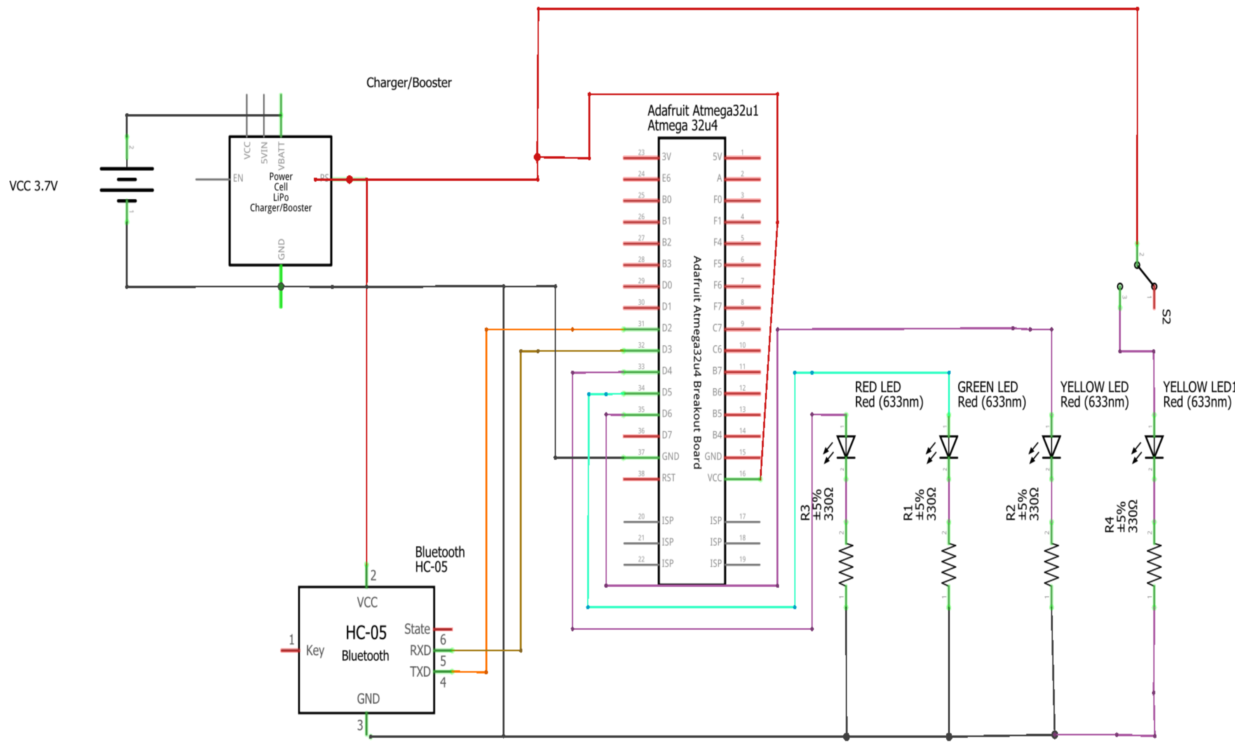

Figure 2.8b: Watch Circuit Schematic

Figure 2.8b shows a schematic of the watch module. It shows connections between the microcontroller, bluetooth module, LEDs, and power components.

2.9 Tolerance Analysis

One of the most important components to the design is the accuracy of the load cell sensor. Not only will this need to be precise to gain an accurate estimation of a customer's BAC level, but it will also determine the cost of each drink pour. If the load cell is constantly under-measuring the amount of alcohol poured, it could possibly give customers a false sense of security that they are still able to drive home. Additionally, the bar owner will be losing money on each pour of alcohol. The high-level requirement that this sensor will be used to meet is the measuring of the alcohol poured within 1% for up to 16 fluid ounces poured. Using the mass of the liquid poured, the ATMega328P will be able to convert the mass to a volume and send it to the computer for further use. To ensure that this will always be within 1%, the load cell calculation will be performed for the worst case scenario.

The load cell is a type of transducer that converts the force exerted on it into an electrical signal. From the load cell datasheet, the formula to calculate the measured force of the load cell is:

$$Measured\ Force = A * Measured\ \frac{mV}{V} + B\ (offset)$$ [4]

A is a constant that is equal to the $\frac{Capacity}{Rated\ Output}$. The rated output of the load cell is $1.0 \pm 0.15 \frac{mV}{V}$, and the capacity is 5 kg. Additionally, each load cell needs to be calibrated before use, which is where B, the offset is introduced. Because this variable can be calibrated, it will not be considered in the risk analysis. Instead, a range of which forces can be measured will be shown in **Table 2.9**.

	Max Rated Output ($\frac{mV}{V}$)	Max Measured Force (kg)
Low end	0.85	4.25
Average	1.00	5.00
High end	1.15	5.75

Table 2.9: Load Cell range

For testing purposes, water will be used, which can be converted from kg to fluid ounces using the following formula in the worst case scenario.

$$4.25\ kg * 1000\ \frac{g}{kg} * 1 \frac{cm^3}{g} * 29.5735 \frac{fl\ oz}{cm^3} = 125687\ fluid\ oz$$

As can be seen, the load cell can easily tell weights up to 16 fluid ounces. To save on costs, a 1 kg sensor will be able to reach that maximum weight as well. Because this is a bar environment, it may be better to go with the 5 kg sensor if it is more tolerant to people pushing down on it. However, to determine if it is precise enough, more analysis must be done.

The load cell output circuit is shown in **Figure 2.9.**

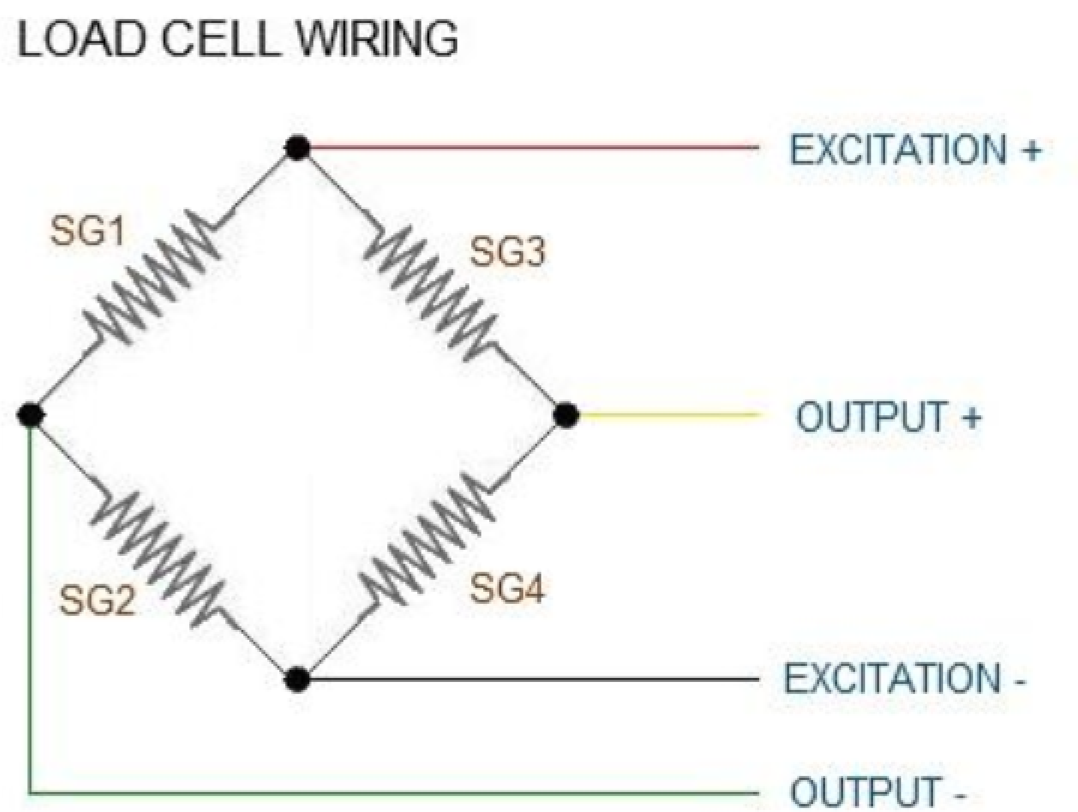

Figure 2.9: Load Cell Circuit Diagram

The outputs from the load cell will be connected to an HX711 chip, which will be the interface from the load cell to the microcontroller. It will take the analog differential voltage output of the load cell and convert it to a digital 24 bit number that corresponds to the mass measured. This chip has a small typical input noise range of 50 to 90 nanovolts. [5] Additionally, based on the load cell input, the circuit will be measuring the input differential between the excitation and the output voltages, which are changed by the amount of force on the load cell itself. Under typical 5V supply which will be used in this project, the full-scale differential input covers up to 20 mV in the worst-case scenario [5], which is well above the differential output of the load-cell circuit.

3 Cost and Schedule

3.1 Cost Analysis

For any project to be successful, it is necessary to run a cost analysis to determine how much the labor and materials will cost. This is essential because the product ultimately needs to create a profit for the company to have an impact and be used in society. If there is no incentive for a producer to manufacture a product, it will never be created. Additionally, a cost analysis can show which parts of the product are driving the margins down the most, and if these parts can be switched for a cheaper alternative that still works.

3.1.1 Labor

The average annual starting salary for Illinois Electrical Engineering graduates is $79,714 [6]. Assuming that the engineer works 40 hours a week, for 52 weeks a year, the average hourly salary is $38.32. From the date of approval, February 11th, to the last date of the semester for this course, May 6th, there are 12 weeks. Because there are three engineers, the total cost for labor this semester is:

$$12\,weeks\ *\ 40\,\frac{hours}{week} * 38.32\,\frac{\$}{hour} * 3\ =\ \$55,180.80$$

3.1.2 Parts

All parts will be priced based on the prototype. A table of parts is shown below in **Table 3.1.2**.

Part	Amount	Price per part	Total Price
HC-05 Bluetooth Module	2	$7.99	$15.98
Lithium-Ion Battery	1	$7.29	$7.29
Charging Module	1	$15.95	$15.95
Load Cell and HX711	1	$12.99	$12.99
ATmega328P	2	$4.46	$8.92
RFID Reader and Chip	1	$6.99	$6.99
12V 0.5 inch Solenoid	1	$25.99	$25.99
Dispenser Wall to 12V DC Converter	1	$8.95	$8.95
Normally Open Push Button Switch	1	$4.94	$4.94
L7805 5V Voltage Regulator	1	$0.30	$0.30
RGB LED	5	$0.90	$4.50
Total			$112.80

Table 3.1.2: Parts list

3.2 Schedule

A general schedule of what work will be completed each week is included in **Table 3.2** below. Week 1 is the week that the project was approved, with week 12 being the final week.

Week	Work Completed
Weeks 1-3 (Week of February 8th to week of March 1st)	Begin design document and process. Refine High-level requirements. Create physical diagrams, block diagram, and circuit schematics for design solution. Determine parts to use and purchase in design.
Week 4 (Week of March 8th)	Review design and edit any issues. Purchase parts and finalize physical design with the machine shop. Deliver any arrived purchased parts to the machine shop.
Week 5 (Week of March 15th)	Finalize circuit schematics and order PCBs. Deliver any remaining parts to the machine shop.
Weeks 6-8 (Week of March 22 to week of April 5th)	Solder and debug circuit and circuit components. Redesign and reorder PCBs if necessary. Begin writing software for ATMega328P microcontrollers on the Wristwatch and Dispenser. Begin writing software for the computer to be able to store the database of customers.
Week 9 (Week of April 12th)	Finish debugging and finalizing the circuit. Begin writing Final Report.

	Prepare for Mock Demo the next week. Ensure that the circuit meets high level requirements.
Weeks 10-12 (Week of April 19th to Week of May 3rd)	Demonstrate final project to the TAs and Professors. Finish editing and writing Final Report. Present final project.

Table 3.2:Weekly Schedule

4 Ethics and Safety

Our project has several potential safety hazards. The watch will be powered by a lithium-ion battery which poses the risk of causing a fire or the leaking of combustible by-products if overcharged [7]. To circumvent this, we will incorporate a battery protection IC to protect the battery from overcharge, overdischarge, and/or overcurrent. As the watch will be worn on the user's wrist, there is also the possibility that the user will wash their hands or spill their drink with it on, so we will also make sure to make the watch as water resistant as we possibly can.

According to ACM Code of Ethics Rule 2.9, we must "design and implement systems that are robustly and usably secure" [8]. To be compliant with this we opted to make the information about the user fully anonymous by storing no personally identifiable information about the user. No data about the user is recorded since the information that the system monitors is tied to a unique identifier on the watch. Upon turning in the watch, the data is also deleted. Ethically, there is also the danger of other patrons in the bar knowing how intoxicated, and thus, vulnerable that the user is. However, since multiple security personnel will have access to this information and there will be a dedicated 'help' button on the watch, we are hoping that those risks are mitigated by security personnel's active monitoring of the intoxication levels of the users. Additionally, the watches will be returned when the customer goes to pay, which gives bar staff a chance to intervene or help if a customer needs it.

5 References

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