18-549 Capstone

Project Proposal

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Table of Contents

1. Project Description

The body's needs for water is unrelenting. Consuming an adequate amount of water every day is necessary and important to ensure that the body has enough water to carry out its many functions such as regulating body temperature and maintaining nutrient metabolism. Despite the importance of drinking water, studies reveal that almost two thirds of Americans do not drink enough water on a regular basis. Currently, many products exist on the market to monitor a user's fitness patterns throughout the day to encourage people to be more active and on the move but few products exist that encourage users to also maintain and develop healthy water drinking habits. Bødtle aims to remedy this problem.

Bødtle is a device designed to monitor a user's water consumption and give the user timely reminders throughout the day to keep his/her water consumption in check and on track. To accomplish this task, Bødtle uses a sensor unit that the user can attach to his/her water bottle that can detect the quantity of water the user is consuming throughout the day. Bødtle also features a mobile application which interfaces with the sensor unit to track and display information regarding the user's water consumption. Users can use the mobile application to set goals for how much water they would like to drink in a day and the mobile application will deliver push notifications to the user at appropriate times throughout the day to remind him/her to drink enough water in order to reach that goal.

The purpose of Bødtle is to provide a low cost and user friendly way for users to develop better water consumption habits. Hopefully with this product, people will become more aware of the importance of drinking water and become encouraged to develop better health and wellness habits as a whole.

2. Design requirements

The Bødtle system consists of two main components: the sensor unit to be attached to the water bottle and the mobile app with which the user and the sensor will interact. The system's design requirements are spread across the two components as noted below:

2.1 Sensor Unit (SU)

- The SU shall be composed of the following parts:
    - an accelerometer to detect movement and tilt of water bottle
    - a timer to time how long the water bottle is tilted for to determine if the tilt is due to the user drinking water from the bottle
    - a temperature sensor to detect bottle refills
    - a battery unit
    - an led to signal battery charge

- The SU shall communicate with the mobile app over bluetooth to supply the following information:
    - quantity of water the user is consuming
    - when the bottle is refilled
- The SU shall measure water consumption within 20% error
- The SU shall measure no more than 3” inches wide and 3” inches long
- The SU shall attach securely to water bottles of a variety of sizes
- The SU shall have low power consumption
- The SU shall be rechargeable
- The SU shall maintain a battery life of a minimum of 5 days between charges

2.2 Mobile App (App)

- The App shall communicate with the SU over bluetooth to pull the data specified above
- The App shall display real time information about the user’s water consumption
- The App shall notify/remind users at appropriate times to drink water
- The App shall use minimal battery usage

3. Functional Architecture

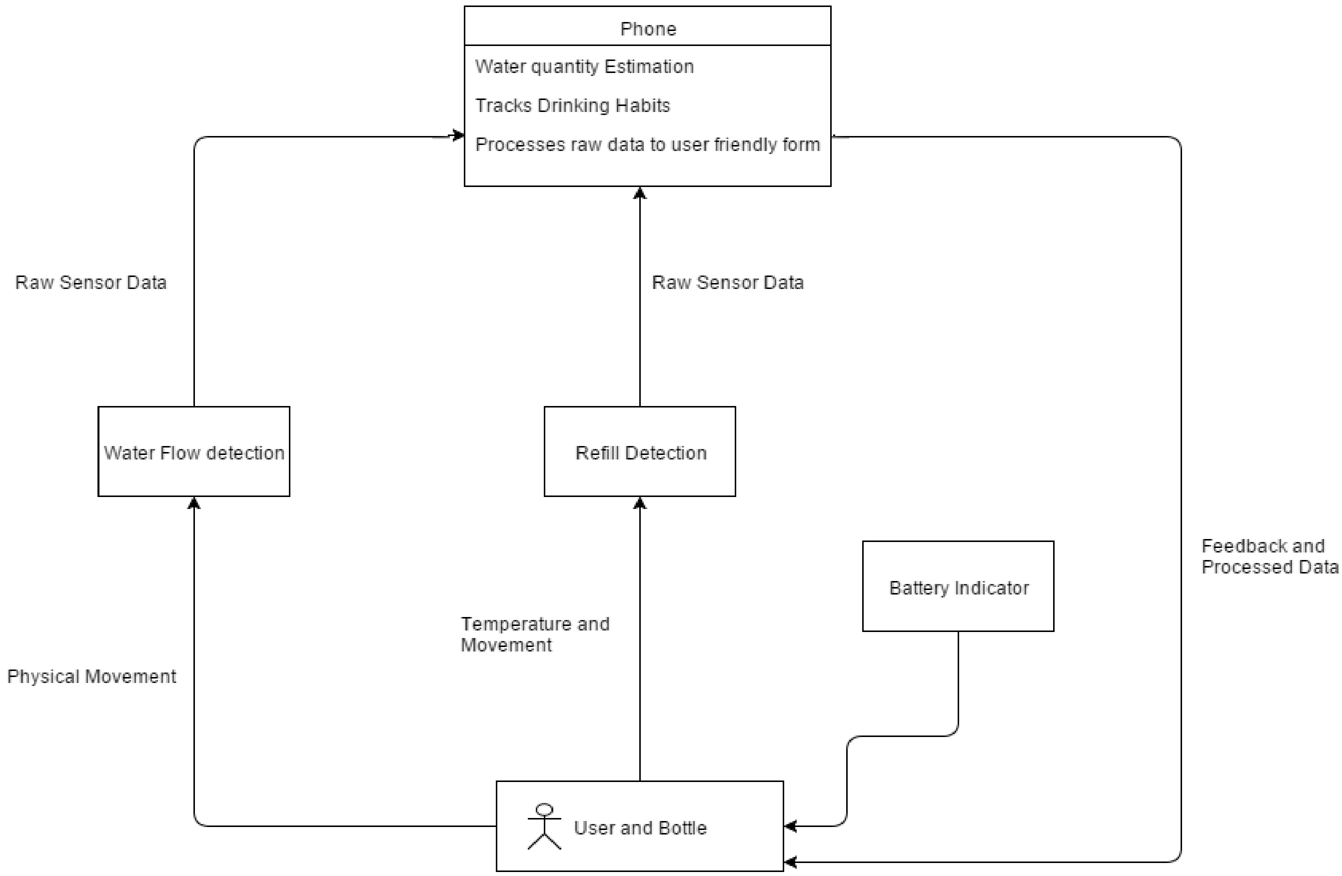


Figure 3.1: High level architecture of our system.

The above figure shows the interaction between the user, our sensing systems, and our phone application. Water inflow (refills) and outflow from the bottle are captured and measured with our detection systems. The systems communicate to our phone application the respective data. The phone processes and organizes the data. The phone has to estimate how quickly and how long water is drank. Additionally, the phone has to figure out when a recorded measurement is the user drinking and when a measurement is physical noise. The phone then interacts with the user to provide notifications and organized data on drinking habits. Lastly, we have a battery indicator to notify the user when the Bødtle's battery needs to be changed or charged.

4. Design trade studies

4.0 *Custom Bottle Design vs Aftermarket Attachment*

In looking to create a smart water bottle there are two different designs that must be considered thoroughly, namely creating a custom smart bottle versus having an aftermarket attachment to an existing water bottle. The factors to be considered are as follows

4.0.1 Compatibility/Price

- The custom bottle would require a completely new purchase and would render all existing bottles useless. This drastically increases the price for users, as new bottles must be purchased to replace all old ones.
- The attachment device would allow a cheap alternative, as this it can be placed on an existing product provided the bottle adheres to certain requirements (non-vacuum). This also allow the user to provide and switch smart functionality to different bottles with no hassle.

4.0.2 Accuracy

- Custom bottles allow exact bottle dimensions and specifications which provide reliable data from sensors. Sensors can also be strategically placed to provide accurate readings since sensor locations are static and reliable.
- Attachments would substitute weight sensors for temperature sensors to provide data that may be less accurate but greater variety of uses.

4.0.3 Innovation

Existing products focus on custom bottles, since they require less research and development and thus companies are able to drastically cut down cost. Custom bottles on the market provide inelegant solutions that further complicate the problem, by creating heavy, inaccurate and more restrictive products. However no other company has created anything that may be attached to any existing product, which allows Bødtle to be the first of it's kind instead of adding to the already enormous amount of similar products.

After careful consideration it was decided that an attachment would be a better fit, since it allows the creation of a completely revolutionary product while also working with existing products. Furthermore, accuracy lost in hardware can be compensated with software, giving the attachment design an edge over the custom bottle design.

4.1 How and where to attach the Bødtle

Figuring out how and where to attach the Bødtle to the user's bottle was the first design decision to make. The position would have a large effect on the available sensors that can be attached and used for water flow and refill detection.

The two options considered were bottom and side mounted. A side mounted device could accommodate for bottles of most sizes, but would interfere with the aesthetic and profile of the bottle. A top mounted device would better match the profile of the water bottle, but could only fit very specific bottle shapes. It was decided on making the Bødtle side mounted since sacrificing the bottle's profile was deemed as acceptable for increased flexibility.

4.2 Sensors for water flow

The three goals for sensing water flow were minimizing error, detecting false measurements, and ease of use. The possible design choices reviewed were motion based sensors, internal sensors, and weight based sensors.

A motion sensor system would approximate when and how quickly the user is drinking based on the Bødtle's movement. This type of system would record suspected drinks as soon as they happen. However, because there's no way to detect actual water flow, motion based sensing is less accurate. Additionally, the system must distinguish between actual drinking motions and similar, but false, motions.

Internal sensors would be inside the bottle or or attached to the bottom of a screw on cap. Because the sensors need to be physically attached to the rest of the device (PCB, battery, etc.), there would be hard space constraints; attachable internal sensors would not be feasible. Additionally, having multiple sensors would require more battery and extra communication hardware, which further complicates the problem.

A weight based sensor would record measurements based on the weight of the entire bottle. Given the weight and density of water, a phone app could easily figure out changes in water levels. Weight based sensors require the user to place the bottle upright and still, which means possibly delays in water measurement. Weight sensors, though accurate, would be difficult to keep flush against many types of water bottle bottoms.

It was decided that this project would focus on using a motion sensor system because it worked the best with the flexibility of a side mounted device. The decisions for sensor system and mounting location were tightly coupled. Even though the motion sensor system is the only one compatible with side mounting, other mounting and sensor combinations were all thoroughly discussed.

4.3 Sensors for refill

With a retrofit, external device, it is difficult to correctly measure when a refill occurs and how much water was added. Using a weight sensor would accurately measure both; however, the same limitations are present as mentioned in the previous section (5.2). Instead, it decided to use a temperature sensor. Drastic changes in the temperature of a non-insulated bottle would signify a refill. Unfortunately, we cannot measure how much water flows in. We have to make two large assumptions: a refill only occurs when the bottle is empty and fills the bottle to maximum capacity. However, as the user uses the bottle more, the software would then compensate for the user's habits to allow a more accurate reading and assumptions.

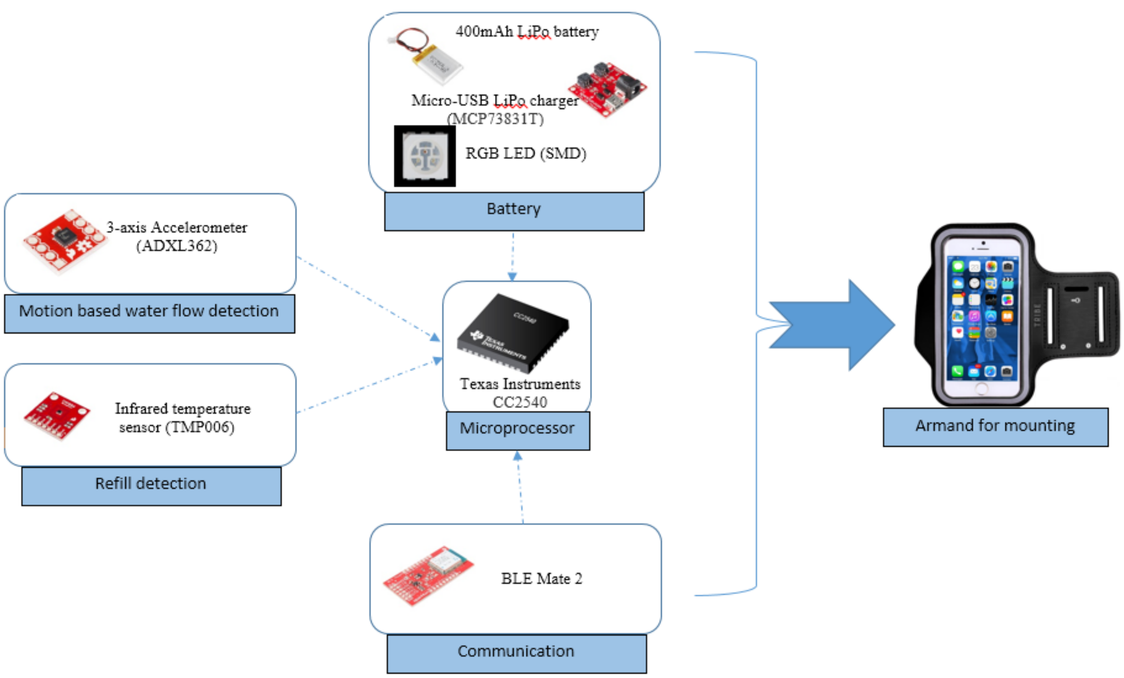
4.4 Replaceable vs. rechargeable battery

We decided on using a rechargeable battery because our device can be easily removed and does not have to be waterproof. While a replaceable battery would be more portable, our device would be constrained by common battery sizes and dimensions. Additionally, our device would have to be very low power to prevent constant battery changing (months before changing). With a rechargeable battery, however, we have more flexibility with battery size, dimension, weight, and capacity. We believe that a battery lasting approximately a week would not substantially lower ease of use.

4.5 Android vs. iOS app

The team has both Android and iOS development and usage experience. However, because most of the team don't have an Apple computer, it would be difficult for to develop in Swift. Therefore, it was decided that an android application would be a reasonable solution.

5. System Description



Because Bødtle is attached to a water bottle, it needs to be light and small. The components selected were partially chosen given their size and weight. Additionally, the sensors had to be precise (more bits) because fine grain measurements were necessary to better estimate water flow. Lastly, the components must have low power consumption or the ability to be toggled on and off.

Bødtle contains the following systems:

5.1 Communications

Communications between a mobile device and the Bødtle can be achieved in three ways, NFC, Bluetooth and Wi-Fi. Although NFC would allow passive communication between the phone and the Bødtle system, it requires power to rewrite the NFC sticker, while also being very limited in range. Wi-Fi allows communications via very long distances with great speeds, which is great, however Wi-fi also cost a significant amount and consumes more power than Bluetooth. Bluetooth communication is shorter in range than Wi-Fi, however using Bluetooth 4.0, power consumption can be drastically decreased. Additionally, since security is not an issue in the Bødtle system, Bluetooth allow us a cheaper, and low power alternative to Wi-Fi, which is critical when using a small onboard battery powered device.

5.2 Water Flow Detection

Water flow can be detected using a variety of sensors, such as line sensors and accelerometers. Using a line sensor, no assumptions need to be made about whether a person is really drinking versus a false movement that may seem like a drink. The problem with this is that, although it allows the sensing of when water passes through a certain point, there is no way to tell the rate the water flows out of the bottle since measurements of angles and velocity are not calculated. However, an accelerometer allows the calculation of angle and velocity to accurately predict the flow of water out of a bottle given its specification. The tradeoff here is that it must be assumed that certain angles and movements always mean drinking, and false movements can not be detected without sophisticated software components. However, since flow rate is the core of the Bødtle, it makes sense that an accelerometer is a better option than a linebreak or other IR sensors.

5.3 Water Refill Detection

Water refill detection can be done using two different sensors, temperature and weight. Weight sensor allows an accurate measurement of the water volume in the bottle, however this comes at the price of having the weight sensor at the bottom of any bottle, thus making it only compatible with certain bottle shapes and sizes. Although less accurate, a temperature sensor allows the Bødtle device to sense when water is being added to the bottle by calculation the change in temperature and the presence of sudden or faster than normal temperature changes.

5.4 Power

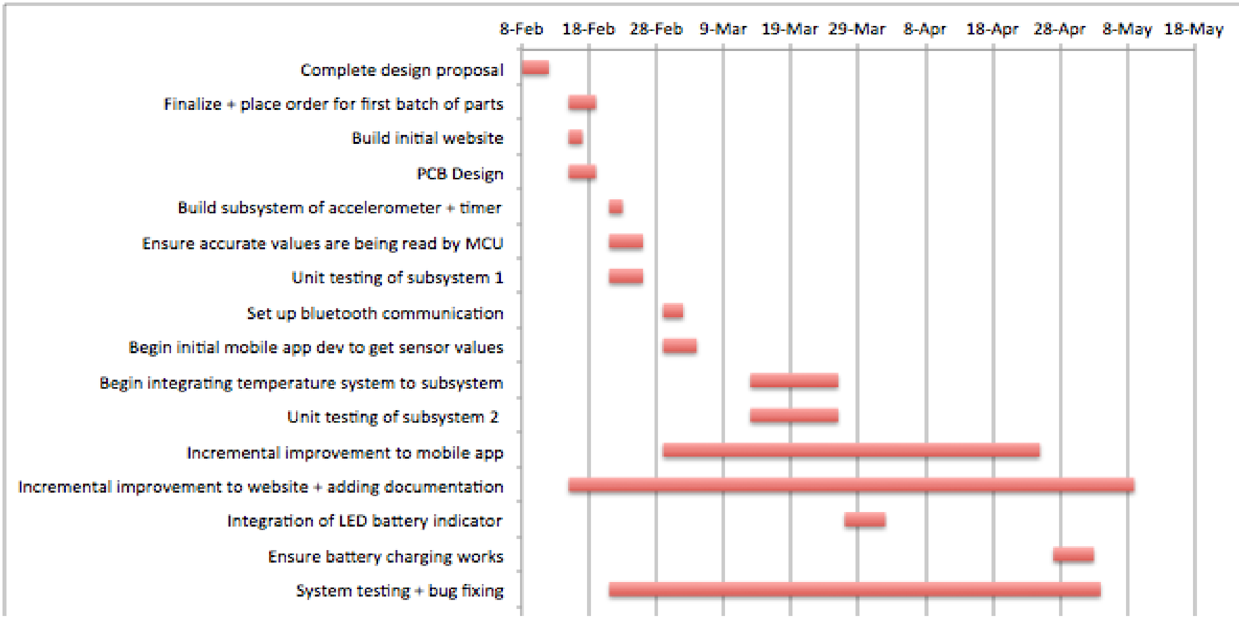
The system used to power the device must be rechargable, since it makes no sense to constantly change batteries to power the device. Thus a rechargeable Lithium battery would make the most sense. The capacity of the battery must be also taken into account, since a larger battery last longer, but also comes as a cost of having a bigger and heavier device. Thus, it was determined that the battery should only be large enough to power the device for about a week, which we estimated to be in the ballpark of 400mAh, since other sizes being sold were too small or too big for the purposes of Bødtle.

6. Project management

6.1 Project Schedule

Week	Dates	Tasks	Comments
1	2/7 - 2/13	• Finalize parts list and place order for first batch	• Team Proposal Presentation on 2/10
2	2/14 - 2/20	• Build initial website • Begin PCB design • Begin testing and experimenting with sensors	• Website check 1 on 2/19
3	2/21 - 2/27	• Build subsystem of only accelerometer and timer to send accurate values to MCU • Unit testing	• System demo 1 on 2/24
4	2/28 - 3/5	• Set up bluetooth communication • Begin mobile app development including bluetooth communication • Transmit accelerometer + timer data and to mobile app	• Peer evaluation 1 3/3
5	3/6 - 3/12	-	-
6	3/13 - 3/19	• Attach temperature sensor to subsystem • Ensure accurate values are being transmitted with each “refill”	• System demo 2 on 3/16
7	3/20 - 3/26	• Add logic to mobile app such that it records the time of user refill, and the frequency	• System demo 3 on 3/23
8	3/27 - 4/2	• Refine existing subsystems and finetune the accuracy on the readings • More testing • Add to website • Work on battery indicator, recharging	• System demo 4 on 3/30 • Website check 2 on 4/1

9	4/3 - 4/9	• Repair existing bugs • Refine mobile app, add more logic such that it knows how to learn from the user's habits • If needed, continue work on battery indicator and recharge	• System demo 5 on 4/6
10	4/10 - 4/16	• Testing on subsystem	• System demo 6 on 4/13
11	4/17 - 4/23	• Figure out how to make the system more compact / as aesthetically pleasing as possible • Polish up last glaring bugs in apps and system, system testing	• System demo 7 on 4/20
12	4/24 - 4/30	• More system testing • Ensure system will reliably work during the final demo	• Final system demo on 4/27
13	5/1 - 5/7	• More system testing, ensure nothing breaks during public demo • Finalize documentation in report	• Public demo on 5/4 • Final report due 5/6 • Final peer evaluation 5/7
14	5/8 - 5/14	• Clean up and finish website	• Final website check 5/9



6.2 Team Member Responsibilities

Project Component	Primary Responsibility	Secondary Responsibility
Smartphone Application	Cathy	Robert
Website	Sijia	Hao
Accelerometer + Timing Subsystem	Hao	Cathy
Temperature Subsystem	Robert	Sijia
Communication between MCU and mobile via bluetooth	Hao	Robert

6.3 Budget

Team #: 10				
Part Name / ID	Quantity	Cost	Vendor	Purchasing Link
SparkFun BLE Mate 2	1	$29.95	Sparkfun	https://www.spark
LED - SMD RGB	1	$0.50	Sparkfun	https://www.spark
SparkFun Triple Axis Accelerometer Breakout - ADXL362	1	$14.95	Sparkfun	https://www.spark
SimpleLink Bluetooth Smart Wireless MCU with USB (CC2540F128RHAR)	1	$5.85	Digi-Key	http://www.digike
Polymer Lithium Ion Battery - 400mAh	1	$6.95	Sparkfun	https://www.spark
SparkFun USB LiPoly Charger - Single Cell	1	$14.95	Sparkfun	https://www.spark
Tribe AB37 Premium Water Resistant Sports Armband	1	$9.88	Amazon	http://www.amazo
SparkFun Infrared Temperature Breakout - TMP006	1	$14.95	Sparkfun	https://www.spark
CamelBak eddy .75L Water Bottle (Rain)	1	$10.93	Amazon	http://www.amazo
Nalgene Tritan Wide Mouth BPA-Free Water Bottle, 1-Quart (Slate Blue)	1	$9.85	Amazon	http://www.amazo
Total Price		**128.76**		

The total cost of our initial design is $128.76, but we expect to use more of the remaining budget to test different sensors and solve future problems we encounter.

7.4 Risk Management

7.4.1 Design Risks

Risk: A design that is too large and clunky and/or not aesthetically pleasing

Mitigation Strategy: We aim to use very small parts and design a compact PCB such that the part does not stick out too much on the bottle. We aim to hide all of the parts within the sleeve and ensure that no wires stick out.

7.4.2. Resource Risks

Risk: Sensors do not provide enough or accurate readings

Mitigation Strategy: In the case where some sensors may not perform ideally (i.e. temperature sensor), we may have to either rethink the sensor, make up for the sensor's less accurate results by adjusting the software, or include a button for the user to tap each time he/she refills.

Risk: Team is software-oriented and not too hardware-oriented

Mitigation Strategy: Because our team is mostly software-based, we may encounter some issues dealing with hardware problems such as proper PCB or system design. To mitigate this issue, we plan to simplify our project in case a hardware-related issue prevents us from making progress. For example, if we end up having problems with our temperature sensor, we may eliminate it completely and replace it with a button that notifies via Bluetooth every time a user refills their bottle.

7.4.3. Scheduling Risks

Risk: Falling behind in one area, which will create a domino effect on all other areas
Mitigation Strategy: We plan to divide and conquer the work such that we are split up into two groups doing tasks concurrently. By doing so, if one group of two gets stuck, the other will not be impacted. We plan on meeting regularly with our assigned TA so that we can get guidance as soon as we get stuck.

7. Related Work

There are multiple competitors offering water bottles with similar functionality. However, there are no retrofit, mounted devices that track daily hydration. Pictures of the three products are shown below the descriptions.

7.1 Thermos Nissan Intak

The Intak tracks the number of bottles drank by having the user physically turn a dial after each refill. There are no sensors or companion app, but this product is the least expensive ($10).

7.2 Sportline Hydracoach

The Hydracoach has a button interface and screen built into the bottle. It is not clear how the bottle senses water flow, and currently costs $25. It is also not clear how old the technology is, but we estimate the Hydracoach was introduced a decade ago.

7.3 Thermos Bottle w/ Smart Lid

The Thermos Bottle w/ Smart Lid calculates and suggests a hydration goal based on personal data. The bottle has a 12 day battery life, works with Fitbit products, and costs $60. Temperature and volume are located in the "sensor tube". We estimate this product was introduced in late 2015, which makes it the youngest competitor product.

Figure 8.1: (Left to right) Thermos Nissan Intak, Sportline Hydracoach, Thermos Bottle w/ Smart Lid

9. References

Texas Instruments CC2540 Reference sheet:
http://www.ti.com/general/docs/lit/getliterature.tsp?genericPartNumber=cc2540&fileType=pdf

Thermos Nissan Intak
http://www.thermos.com/products/intak-purple-24-oz-hydration-bottle.aspx

Sportline Hydracoach:
http://www.hydracoach.com/applications/index.html

Thermos Bottle with Smart Lid
http://www.thermos.com/smartlid.aspx