# Hydrowatch
# High Level Design

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# 1 Introduction

The world is full of wearable devices. Recent devices of interest, such as the fitbit and Apple Watch, provide the user with information regarding their heart rate and movement throughout the day. With these devices, users receive quantitative and qualitative information regarding their health. A key component of health is hydration. The prevention of dehydration has always been a vital part of survival, but a practical wearable device that is able to inform an individual of their hydration level does not currently exist. We propose the construction of a wearable device that, based on a baseline measurement, communicates to the user a relative hydration level and advises the user when to drink water to rectify low hydration levels. We will determine relative hydration based on optical properties and the capillary refill rate of the skin, process this data within the device on a microcontroller, and communicate the results to the user.

# 2 Problem Statement and Proposed Solution

In order for life to be sustained, water must be present within the body. Humans can only survive for a few days without water, which is required by our organs for operation. When one contains a sufficient amount of water in their tissue, they are considered to be hydrated. Currently there are no noninvasive practical wearable systems that can provide information about hydration levels to a user. An additional issue is that many people wait until they are thirsty to drink water. At that point, however, the body is already dehydrated and has begun to shift water to vital organs. In fact, the general population of people do not know how to assess their own hydration level. Dehydration can lead to numerous health problems and complications including: exhaustion, lack of strength, and rapid heartbeat. We seek to design a device that will inform a user when a drop below an established level of hydration is noted and suggest consumption of water.

This device will consist of three components. The first is the detection of hydration in the body. This detection will be implemented through the use of LEDs to optically measure the amount of water, electrolytes, and other substances present in the tissue, which change based on the hydration of the user. We will test the system on a phantom, which mimics the optical properties of tissue to allow for consistent tests to be performed on a material that has set properties. The second component is the processing that will be done on the device through a microcontroller, which will analyze the received data and produce an indicator based on the results. The third and final stage will be alerting the user to their hydration level.

# 3 System Requirements

The basis of the system relies on the detection of absorbed light by water, deoxyhemoglobin, and oxyhemoglobin. We must design a system that is able to process multiple LEDS and capture real time data of the absorbency. At the center of this project is an AFE4490 which will have the follow requirements:

- Microcontroller talks to AFE4490 through SPI interface
- AFE sets LED blink rates converts analog signals from photodetector
- The AFE4490 needs to be able to communicate to the LEDs to set a blinking rate as well as the period of time for photodetection. After the photodiode detects the light from the LEDs, the data is tested to see if it is above of below acceptable limits. (see below)

On this first prototype design, we will process the data via MATLAB. We need to send data through bluetooth to an external GUI, which is run in MATLAB and also send user alerts either using MATLAB or a Bluetooth signal to the user's phone.

In order to ensure that our system has operating parameters and thresholds that represent "healthy" nominal levels of hydration, we need to conduct test measurements on different classmates, professors, and colleagues to accumulate enough data to be confident in our hydration thresholds.

In choosing a Bluetooth chip to complete data transfers, there will be significant dependence on distance between the transmitter and receiver, as Bluetooth has a much reduced range compared to WiFi or satellite signals. Because of this, we should expect to have the receiver of the Bluetooth communications reasonably close to the transmitter and should also try our best to combat possible noise in a busy room with many other Bluetooth devices available.

Note that at this stage, this device not intended for continuous wear and use, but rather will be used only when measurement desired, so powering with a batteries acceptable for the main board. The use of batteries also ensures that there is sufficient power to run the microcontroller as well as the LEDs at the specific wavelengths needed for detection. An acceptable time for the batteries to last on the system would be at least half a year.

We should be fine in terms of unsafe voltages and/or currents, and we will have no exposed wires. This is a device that will have contact with the skin. Thus, we have to have low current to not harm the user. The device will be lightweight, and has to fit and feel comfortable on a wrist or finger.

# 4 System Block Diagram

## 4.1 Overall System:

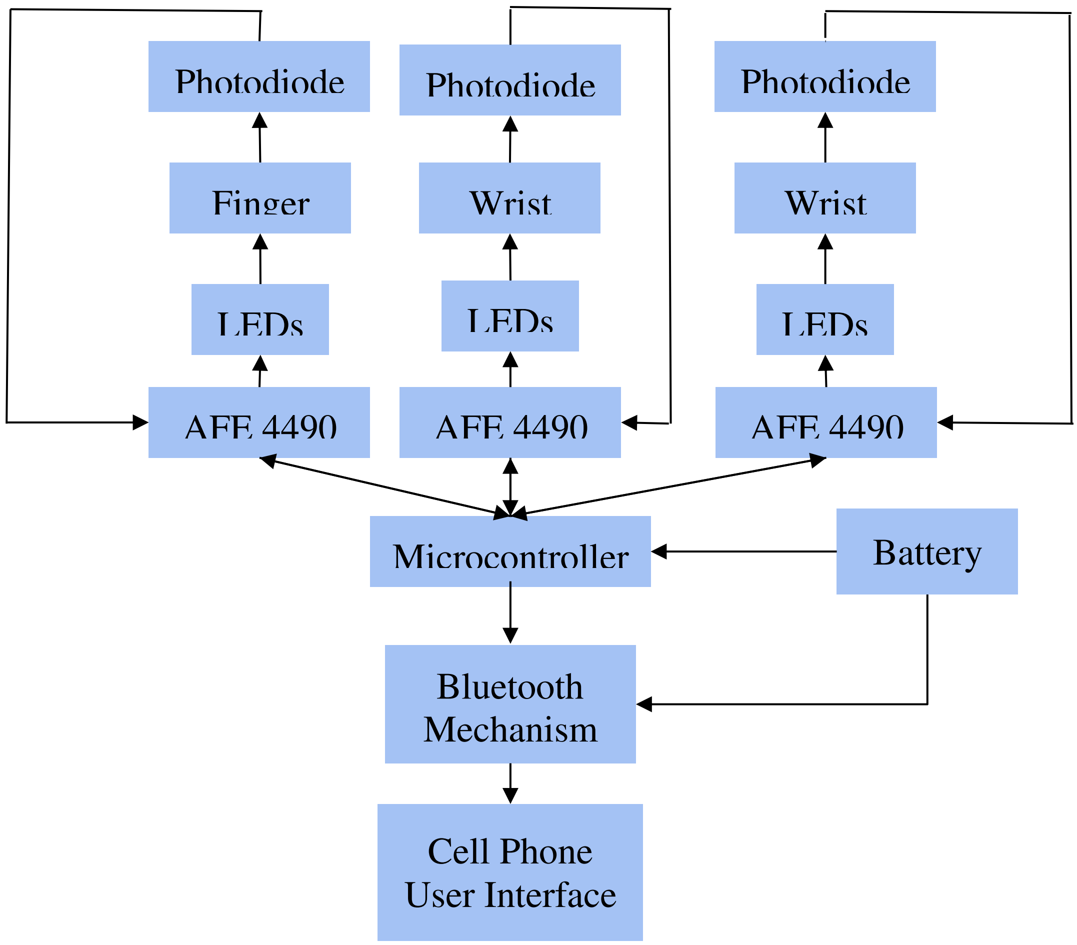


Figure 1: Block Diagram of the HydroWatch

## 4.2 Subsystem and Interface Requirements:

**Microcontroller determines LED flash rates**: Through SPI commands, the microcontroller will be able to set how fast the LEDs will flash at alternating times to get different absorptions of different wavelengths of light in the skin. Intensity should be enough to get past the epidermis and run through this layer and be absorbed again at another point.

**Photodiode captures light:** The photodiodes absorb the light from the LEDs that was sent through the skin and converts this light into a current. We require a rather sensitive photodiode, such that any small fluctuations in light intensity should become apparent.

**Microcontroller receives signal from photodiode**: The AFE will be able to provide the microcontroller with the photodiode current reading through SPI communications and reading out the appropriate data.

**Bluetooth mechanism:** After receiving the current measurements, we could use a Bluetooth SOC that would allow us to send out the required data from the microcontroller and send that data to our desired phone user interface (and in the future possibly a computer interface for data processing).

**Physical data storage:** To ensure that we capture all of our required data from the photodiodes, it would be advantageous to have on-board storage in the form of an SD card. This also serves as a backup in the unlikely event that wireless communications do not function as desired.

**Battery:** The AFE chip requires somewhere between 2 V and 3.6 V to operate, and our LEDs and photodiodes also will require some minimum voltage and current. Because of this, we should aim to have a battery that has slightly more capacity than we would think to provide for leakage currents and other miscellaneous losses

**MATLAB Software:** Post-processing of data once received whether through BlueTooth or SD card data. GUI will also be present in MATLAB to present graphical data. Following MATLAB processing, the user will be emailed a message with their hydration state.

**User interface/alert:** Be able to communicate to the user that an abnormal reading has occurred, which could be in the form of a push notification or opening an app and allowing a Bluetooth communication to send an alert. Another option for user alert could be a red LED on the wrist board when a threshold level has not been met for hydration. The final option for user alert is to have the MATLAB processing send an email to the user.

## 4.3 Future Enhancement Requirements

In the future, given more time and resources, some components could be enhanced to make the device more user friendly. On of these components is the complete wireless transmission of data that is collected by the photodiode to the user interface rather than (storing it on a flash or SD card) filtering through the data with the micro controller and only sending a push notification or flashing an LED. Another enhancement would be to make the device a continuous wear device and make the battery rechargeable. Another component that could be enhanced is the user interface. The user interface could be developed into a full phone application to display the data that is wirelessly transmitted from the microcontroller. This way the interface could provide daily hydration level reports rather than just notifying the user when they are dehydrated.

# 5 High Level Design Decisions

**Microcontroller selection:**
Given our group's exposure to the PIC microcontroller and lack of experience with the RSL10 system on a chip, we think that it would be prudent to select the PIC32 that we have used in the fall semester and in Embedded Systems to control the rest of our board. We are confident in understanding SPI communications as well as controlling other chips that may need to be interfaced with SPI and I2C communications protocols. Also, the lack of understanding how to

develop code for the RSL10 as well as unfamiliarity with how to set pins and various other peripheral configuration bits leads to us deciding to likely continue with the PIC32.

**Communicating to the AFE4490 (Setting LED rates and Reading current values):**
PIC microcontroller provides the required SPI interfaces to the AFE chips, runs on the same required input voltage range as the AFE chips, and also has the capability to be connected to another possible Bluetooth chip that could be used for the data transfer.

**LEDs and photodiode:**
We have chosen to use a standard silicon photodiode because it has a spectral range of roughly 430nm~1100nm which covers the spectrum we plan to use, and it is a low cost device. The absorption band for water that we have decided to use is at 980 nm because the next higher band is out of the range of the photodiode. To measure absorption at this band, two IR emitters at 940 nm and 950 nm will be used as they are readily available. The absorption band for hemoglobin is around 660 nm. For this band, we found suitable LEDs at 629 nm and 660 nm. A blue LED at 458 nm will be used to determine if the device is in proper contact with the skin by measuring the absorption of melanin. Melanin has high absorption near 450nm; if the device is in contact, almost none of the blue light will reach the photodiode. If not in good contact, the photodiode will sense the blue light.

**Storage mode (SD)**
**Microcontroller stores the data on a physical storage component:** Possibly a microSD card, with at least 32 GB of storage for many test runs. Since we are not assuming that the user will be continuously wearing this device, it isn't entirely critical that a large amount of storage space be available all at once, but rather just small chunks when the testing occurs.

**Bluetooth mechanism**
There exists systems on a chip like the CC2540 2.4 GHz Bluetooth® SoC, which would allow us to control the wireless communications from the microcontroller using an SPI interface. By dropping in a comparatively inexpensive SOC such as this, we could also find a development or kit board for these systems and try to get communications started without having to actually create a board for ourselves. This type of rapid prototyping and problem solving will likely serve a crucial role as we move forward with subsystem development and integration.

**Type of battery/power supply for development**
Due to size constraints and the need for a lightweight solution, we have decided that a smaller battery, likely placed on the main board, will be sufficient to power the system. A possible battery solution would be a 5V coin battery, which would be relatively cheap and very replaceable for our system. This slightly higher voltage would also provide us enough tolerance for slight over and under voltages.

**Software requirements**
We will do post processing in MATLAB. Our data will be sent from our device to a local device such as a laptop. Using absorption of water, deoxyhemoglobin, and oxyhemoglobin we will estimate if the user is at a reasonably hydrated state. If the user is hydrated, they will be sent an email stating the fact.

# 6 Open Questions

- What are the most effective wavelengths for measuring dehydration using only surface measurements?
- How fast do we need to allow the LEDs to flash to get the measurements we desire?
- How easy is it to handle programming and taking inputs from multiple AFE chips at once?
- What will the post-processing look like and what data do we hope to convey to the user?
- What is the optimal placement of the LEDs for getting light measurements?
- How bright of a light/how intense of a light to get a measurable quantity?
- Do we need to do any analog amplification of currents from the photodiodes?
- How do we write to the storage devices (should we choose to implement them)?
- Is there a significant time delay in attempting to send data wirelessly/writing to storage devices?

# 7 Major Component Costs

- Multiple LEDs (458nm, 629nm, 660nm, 940nm, 950nm) ~ $1 each
- Photodiodes (430nm-1100nm) ~ $1 each
- OpAmp ~ $5
- AFE4490 microcontroller (3) ~$20 each
- LCD screen for results ~ $3
- Circuit board ~ $50
- Bluetooth System on a Chip ~$5
- Evaluation board for RSL 10 and AFE4490
- Phantoms (2) ~ $20
- SD card ~$10 for 32GB microSD card

# 8 Conclusions

HydroWatch will give the general population access to a device that simply and accurately measures the users hydration level. With the wide range of wearable devices on the market today for heart rate and movement, this device will add a unique functionality to the lives of many. Various LEDs and photodetectors will measure multiple tissue components to determine a level of water content in the body relative to pre-established level. Hydrowatch will help users stay healthy and hydrated with alerts when water levels drop below that individual's threshold.