HEAT EXHAUSTION DETECTOR

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February 9, 2023

ECE-445

1.Introduction

1.1.The Problem

Heat related illnesses such as heat stress, heat exhaustion and heat stroke are a serious problem for everyone but especially individuals who perform hard labor in harsh environments. With global temperatures rising early estimates from the Center for Disease Control and Prevention have estimates that heat related deaths have increased by 56% between 2018 and 2012 [1]. Workers such as construction workers, roofers and even factory line workers have an increased chance of experiencing one of these illnesses. Unfortunately for these people there is not something that can provide these people an early warning detection to alert them that they are at risk of experiencing one of those heat related illnesses and should remove themselves from the environment and hydrate as soon as possible.

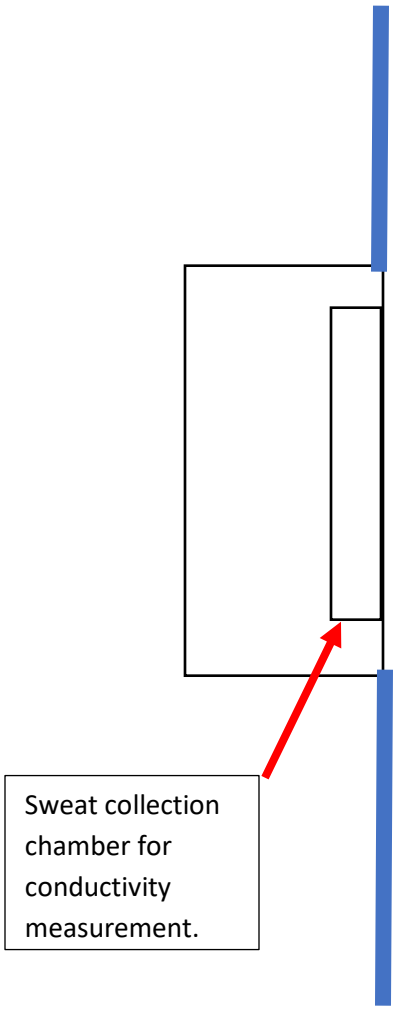
1.2. Solution

The solution to this problem is to design a wearable device that can measure several different factors and provide an alert to the user and those around them that they should be removed from the environment. To implement this the device will use a humidity and temperature sensor in order to provide data on the environment the individual is working in. This will provide the information necessary to determine the heat index and the danger level of the environment the person is working in. A gyroscope and accelerometer will be used in order to measure the individual's activity level. A conductivity measurement will be used to monitor the chloride concentration of the individuals sweat. According to a study in the Journal of Taiba University Medical Sciences patients experiencing one of the heat related illnesses showed a marked decrease in the sweat chloride concentration as the illness got worse [2]. The device will take these measurements and produce a visual and audible alert to the wearer and surrounding workers such that action can be taken to remove the individual from the environment to cool down and hydrate

1.3. Requirements

HIGH LEVEL REQUIREMENTS

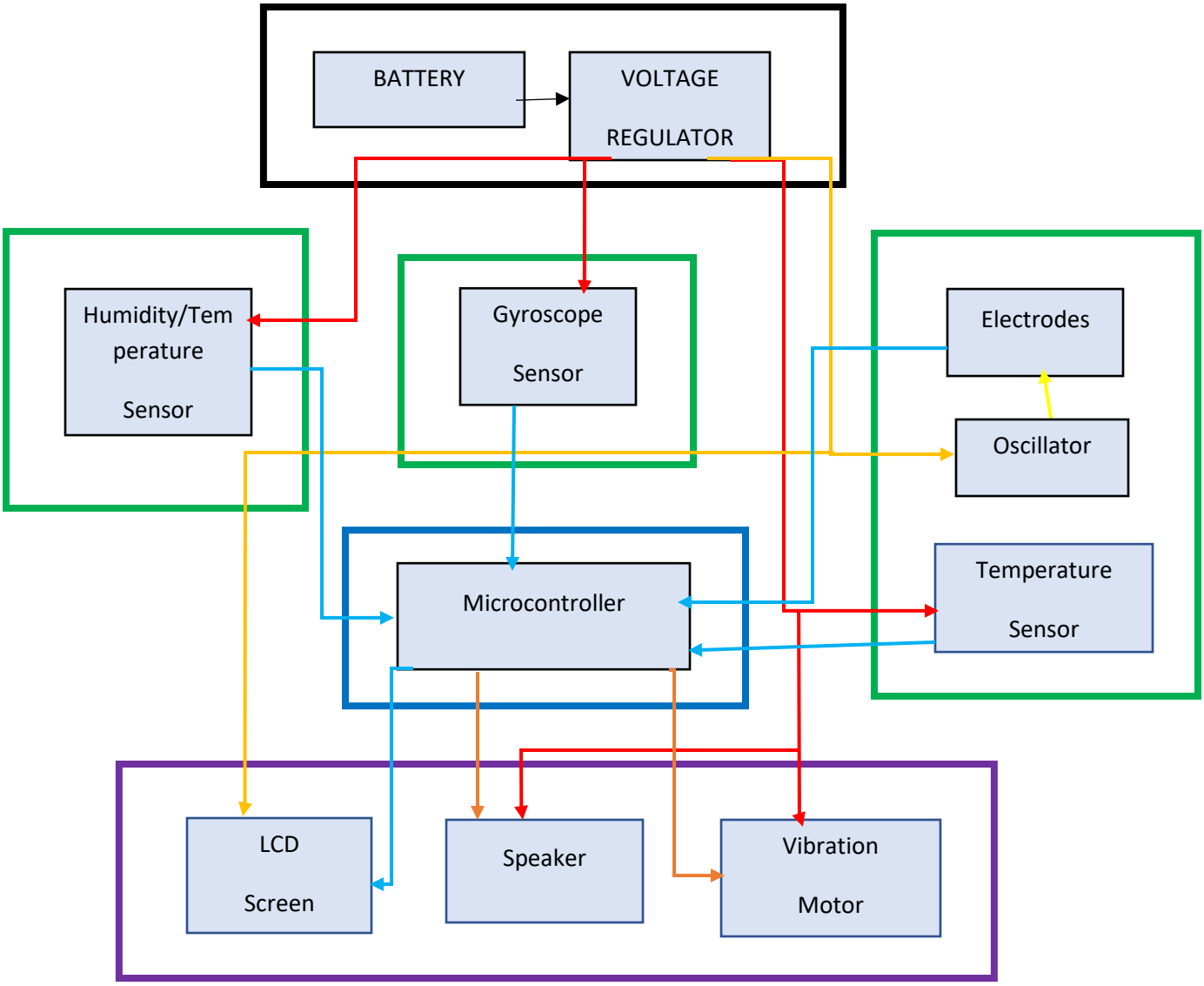
- Accurately measure the chloride concentration through a conductivity measurement within +/- 1.5mmol/L
- Produce an alert that can be acknowledged in bright or noisy work environments.
- The device packaging must be durable enough to be worn on construction sites and not interfere with the individual's work performance.




RISK LEVEL: HIGH
Alarm speaker

2.Design

2.1. Block Diagram



3.3V		Power System	
5V		Sensors	
1kHz square wave		Control	
Data		User Interface	
Actuation		LEGEND	

2.2. Power System

- The power system Provides the voltage and current to the subsequent subsystems such as the sensors, microcontroller and components of the user interface

2.2.1. Battery

  - The battery will provide the voltage and current for the 5V components such as the LCD screen and the oscillator for the conductivity sensor. The battery will also provide the voltage and current for the other sensors and user interface items
  - Requirement 1: Battery must be large enough to provide power to the device for a sustained period of time such that constant changing of batteries is not necessary
  - Requirement 2: Battery must me small enough in size such that the device can maintain a small and compact packaging

2.2.2. Voltage Regulator

  - AP2127K-3.3TRG1
  - The voltage regulator will maintain the 3.3V to the temperature and humidity sensor as well as the accelerometer and the low voltage user interface components. The voltage regulator must also provide 5V to the LCD screen and the oscillator of the conductivity sensor.
  - Requirement 1: Maintain the supply voltage to 5V components with a +/- 0.2V margin of error.
  - Requirement 2: Maintain the supply voltage to 3.3V components with a +/- 0.2V margin of error.

2.3. Sensors

- The sensor blocks will detect the necessary data to determine the danger level of the environment, activity of the individual as well as chloride concentration of the wearers sweat.

2.3.1. Gyroscope and Accelerometer

- The gyroscope and accelerometer, chosen to be LSM6DSMTR, is capable of providing 3-axis accelerometer and gyroscopic measurements as well as a pedometer to detect the number of steps.
- Requirement 1: The gyroscope and accelerometer must be able to provide adequate data which can be used by the microcontroller to determine the level of physical activity the wearer is engaged in

2.3.2. Temperature and Humidity

- The temperature and humidity sensor, chosen to be the SHT4x Sensor, is capable of measuring the relative humidity with +/-2% accuracy and temperature with an accuracy of +/-0.2 degrees Celsius.
- Requirement 1: Provide an accurate measurement of the outside temperature and relative humidity, within the component's tolerance range, for heat index calculations by the microcontroller

2.3.3. Conductivity

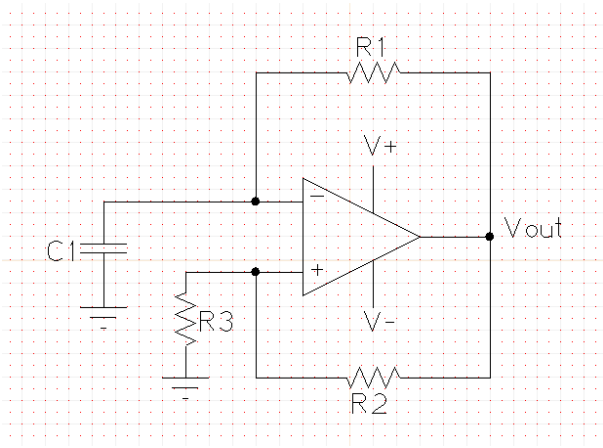
- AS321KTR-G1
- The conductivity sensor will utilize a relaxation oscillator which will provide an AC square wave signal to the electrodes at a frequency of 1kHz to prevent ionization of the

sweat sample. The resulting current will be sent to the microcontroller's analog to digital converter for measurement reading.

- Requirement 1: Provide a conductivity measurement that can be used to calculate the chloride concentration of the individuals sweat within +/-1.5mmol/L.

2.3.4. Oscillator

- The oscillator will utilize the 5V power supply and an Op-amp in order to produce a square wave at a frequency of 1kHz to the electrodes for conductivity measurement



- Requirement 1: Produce a square wave at 1kHz with a +/- 100Hz margin of error.

2.3.5. Temperature Sensor

- The temperature sensor for the conductivity measurement is necessary to calculate the temperature compensated measurement
- Requirement 1: Measure the temperature of the sweat sample with +/- 0.2 degrees Celsius margin of error.

2.4. Control

- The control unit is responsible for performing the necessary calculations for conductivity and assessing the current risk level based on the sensor input. The control unit will also actuate the alarm systems of the user interface subsystem.

2.4.1. Microcontroller

- ATMEGA808-XUR
- The ATMEGA microcontroller was chosen because it offers an analog to digital converter for the conductivity measurements as well as several general IO pins for the accelerometer, temperature and humidity sensor readings.
- Requirement 1: Perform calculations using the following equations for conductivity measurements

$$K = \frac{D}{A} \tag{2.1}$$

Equation 2.1 calculates the cell constant where K is the cell constant, D is the distance between the electrodes and A is the area of the electrode.

$$\sigma = C_{measured} * K \tag{2.2}$$

$$G = \frac{\sigma}{1 + \alpha(t - t_r)} \tag{2.3}$$

Equation 2.2 and 2.3 are used to standardize the conductivity measurement where $C_{measured}$ is the measured conductivity value and σ is the adjusted conductivity value taking into account the cell constant. The next equation dictates the temperature compensation where G is the standardized conductivity reading, t is the temperature of the sample, t_r is the reference temperature which is 25 degrees Celsius and α is the temperature compensation factor

- Requirement 2: During an alarming condition where the users sweat chloride concentration reaches 25mmol/L actuate the vibration motor and speaker to alert the wearer.

2.5. User Interface

- The user interface is responsible for providing the user with visual, audible and physical feedback as to their current condition and alert them when approaching heat exhaustion.

2.5.1. LCD Screen

- NHD-0216K1Z-NS(RGB)-FBW-REV1
- The LCD screen will be able to provide information to the wearer about the heat index and chloride concentration of sweat
- Requirement 1: Display the chloride concentration and heat index of the environment to the wearer
- Requirement 2: Provide an alarming indicating light when chloride concentration is measured below the threshold.

2.5.2. Speaker

- PRT-20660
- The speaker will produce an audible alarm when the detected chloride concentration reaches below the threshold
- Requirement 1: The speaker should be able to produce an alarm that could be acknowledged in a loud environment

2.5.3. Vibration Motor

- VZ32TL2B2882008D
- The vibration motor will vibrate the casing in order to provide a physical alarm.
- Requirement 1: The vibration motor will vibrate the device casing during an alarm condition such that in the case the visual and audible alarms cannot be seen or heard the wearer can still be alerted

2.6. Risk Analysis

- The block that will pose the greatest difficulty to implement would be the conductivity sensor. The block is heavily reliant on the signaling and analog digital converter of the microcontroller. The conductivity measurement must also take into account the physical dimensions of the electrodes used. The conductivity sensor must be able to generate strong enough signals in order to be read by the microcontroller and use small enough potentials such that the wearer is not affected by the measurements.

3.Ethics and Safety

This project is meant to address the safety risks that are involved with workers who have to work in harsh environments. As stated in section 1.1 there has been an increase in heat related illnesses which can not only result in death but can also result in work place accidents. According to the CDC the symptoms of heat exhaustion can include dizziness, weakness and even fainting [7]. Experiencing one of these symptoms while operating a large piece of machinery, working around rotating equipment or working at a high elevation can be very dangerous not only for the individual but the other workers in the area. Following section I.1 of the IEEE code of ethics to hold paramount the safety, health, and welfare of the public, this project aims to provide workers an extra layer of safety by alerting them to the potential risk of experiencing a heat related illness [5]. The device itself does not pose any safety risk to the wearer as the majority of the electronics will be sealed in the casing and not exposed to the wearer. Although the device itself poses no risk to the user there is a potential that by wearing the device around rotating equipment could present a potential risk to the wearer. The device should be worn around the forearm which will mitigate those risks but for an added measure the casing supporting the straps should be strong enough to support the device but not so strong that it presents a hazard while at work.

4.References

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