IN-SUIT CARBON DIOXIDE SENSOR

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Overview

The main objective of this project is to develop a CO_2 sensor that can be placed inside a space-suit. The CO_2 sensor is the largest bottleneck in the development of an in-suit analysis and transmission system for real-time metabolic rate characterization. This system is important because it allows for quantifying the energy expenditure of astronauts and also monitors the safety of the in-suit air environment. Developing an in-suit version of this system is important because it will reduce the footprint of this system and allow for monitoring in cases where the suit is not connected to an umbilical. Time and funding permitting, the stretch goal of this project is to design a prototype of this in-suit metabolic analysis system by integrating the data from the CO_2 sensor with data from a flow-rate sensor.

Requirements and Specifications

Requirements	
Name	In-suit carbon dioxide sensor.
Purpose	In-suit air environment monitor; Component in in-suit real-time metabolic rate characterization system.
Inputs	Constantly circulating mixture of O_2 and CO_2.
Outputs	CO_2 concentration in parts-per-million. This info must be reported to the user wirelessly.
Performance	Must accurately sample CO_2 concentration at a rate of at least 10 Hz and a pressure of 19 psia. Must have a CO_2 measurement range of at least 0 to 7%, as that is the range typically seen in NASA's current metabolic rate characterization system.
Safety	Must meet all materials compatibility and safety standards required by NASA.
Power	The device must run for at least four hours on batteries.
Physical Size and Weight	Must have a minimal footprint, able to fit inside a space-suit unobtrusively. Must
Placement	Any sensors placed within the gas flow path must result in no change to nominal suited operations or EVA hardware configurations.

Components and System Design

Hardware

SprintIR 0-10% NDIR CO_2 Sensor: The SprintIR is a relatively small (~20 mm tall) CO_2 sensor that has a sampling rate of 20 Hz. There are several different models with different ranges; the range needed for this project is 0-10%, as specified by the NASA mentor. In active mode, the sensor operates at 3.3V and consumes ~35 mW of power; when turning on or exiting low power mode, the sensor take about ~1.2 seconds to warm up, so the sensor must remain in active mode to be useful in a metabolic analysis system. The default sampling method is diffusion, but the sensor can be fitted with an adapter to allow for flow through sampling. Since the O_2 and CO_2 in the space-suit are constantly circulating, the flow through adapter may be preferred. However, the adapter does add ~10 mm to the height. This sensor reports its readings over a UART serial connection at 9600 baud, and can be configured to correct for non-standard pressures.

TI MSP-EXP430F5438A Experimenter Board: The microcontroller for the system will be MSP430 based, and for prototyping purposes the experimenter board will be used initially for the sake of ease and availability. The microcontroller will interface with the CO2 sensor over a UART serial connection operating at a baud rate of 9600, and will use this connection to configure the sensor and read sensor data. If the functionality of the wireless module is included on this same microcontroller, then the data will then be transmitted wirelessly to the user; otherwise, the CO2 sensor microcontroller will send the data to the wireless module microcontroller, either using a serial or I2C. If the data cannot be sent for whatever reason, then it will be stored in the flash memory of the microcontroller, either until it is transmitted or until the data is no longer valid.

Battery: At 3.3 V and 35 mW, the SprintIR sensor will consume 42 mAh in a four hour period. A 1s LiPo battery would easily be able to supply the required power and would take up a very minimal amount of space. Lithium batteries are also easier to charge, but they are also more prone to explode if not handled and charged properly. These are all important considerations, but not as much so for this early prototyping stage.

Integration Board: A custom PCB may be designed to connect the sensor, microcontroller, and battery in a tidy, compact package. However, initial prototyping will be done on a solderless breadboard.

System Enclosure: Putting the system in a smooth enclosure would protect the space-suit from any components which may be sharp.

Software

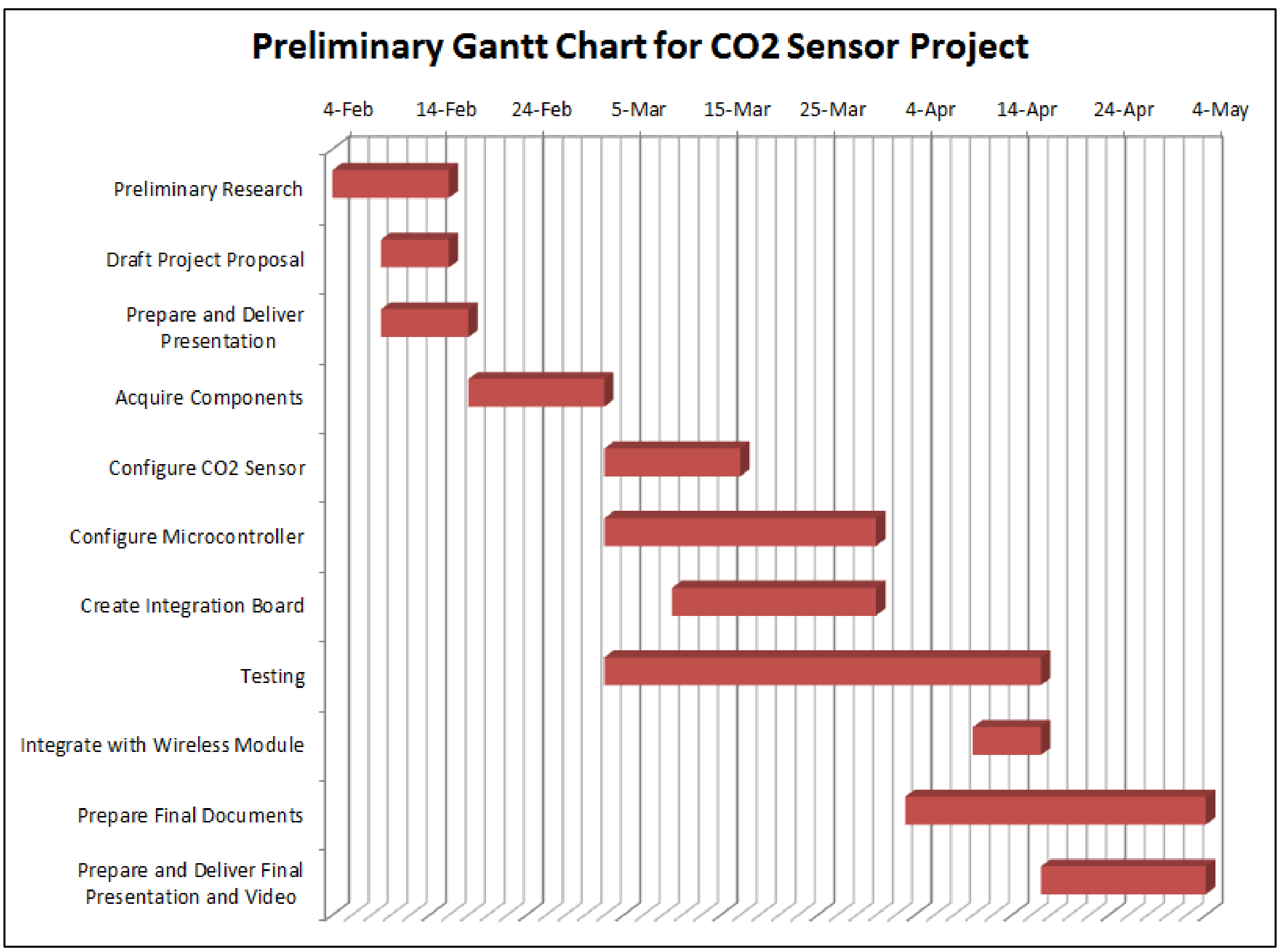
CrossStudio for MSP43: Software package for programming the MSP430. It is already available for student use at UAF, and is the programming method we are most familiar with.

Difficulties

1. For NDIR style CO2 sensors, decreasing or increasing the pressure of the input gas either decreases or increases the CO2 concentration reading, respectively. The SprintIR is calibrated for pressure at sea level, 14.7 psia, so the sensor will yield incorrect readings at the specified pressure of 19 psia.

    a. Luckily, this error can be closely represented by certain mathematical relationships, and the SprintIR can be configured to account for different pressures.
2. To test the CO2 sensor at the specified pressure of 19 psia, a specialized testing chamber would have to be created.
    a. Instead of creating a testing chamber, a potential solution to this issue is to just test the device at the ambient pressure of 14.7 psia and then correct the issue in software.
3. CO2 sensor requires wireless module being developed by the In-Suit Wireless Data Transfer group.
    a. Will have to coordinate with that group to make sure that their module will be compatible with the formatting of our data. If possible, we may be able to select a microcontroller that can handle both gas sensor processing and the wireless processing, making more efficient use of hardware.
4. Every team member has busy schedules with different times of availability, limiting the amount of time we can meet and collaborate.
    a. In addition to being able to meet during lab time, we have set aside time every Friday to meet and work on the project. For work such as writing reports and other documents, we can collaborate remotely via Google documents, email, and telephone.

Project Plan



References

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