Team 310 – Preliminary Detailed Design

March 28, 2024

# Introduction

Spacesuit design is currently an active area of research, as engineers and scientists work to improve current missions in space, as well as prepare for long-term missions on the moon and on Mars. Working in a pressurized suit thousands of miles from Earth obviously presents a range of challenges and dangers, including monitoring the in-suit environment and the astronaut’s health. A sensor system shall be developed by Team 310 for the purpose of monitoring some of these variables, as discussed below.

The project shall be a proof-of-concept design that measures an astronaut’s vital signs and environment in a spacesuit. In general, the device shall measure selected variables, store the measurements locally, and provide a means of transmitting the data to an external device.

The final deliverable shall be a prototype for a sensor unit that could be used during an extravehicular activity (EVA) mission. The device shall also transmit the collected and interpreted data.

# Selected Concept

The chosen design shall be a suite of biomedical sensors capable of monitoring an astronaut's vital signs and spacesuit environment during EVA missions. The suite shall be a wearable sock that is able to transmit the sensor data to the main communications system, implemented in C++, via a serial interface, I2C, and detect abnormal readings that consequently trigger the appropriate alarms.

The suite shall feature a heart rate sensor, on-toe pulse oximeter, thermometer, and Galvanic skin response sensor to monitor the internal vitals of the wearer. External to the sock shall be a suite of environmental sensors, including a CO2 sensor, pressure sensor, and humidity sensor. The sensor data shall be sampled, timestamped, and logged in CSV format for transmission to another device via a wired serial connection.

# Sensor Processing Circuit Card Assembly

The sensor processing board’s main function shall be to receive any data from the sensors, analyze and display it in an organized format, to be sent to the Informatics Interface that shall deliver any outside indicators of the data, such as alarms. The processing unit contains the microcontroller, RFID reader, and SD card reader. The microcontroller shall process the data being sent to the unit from the environmental sensors and biomedical sensors. This data shall then be converted to I2C format to be inputted into the microcontroller. The data shall then be stored onto the SD card inserted into the SD reader. The RFID reader can be scanned with an RFID tag and data showing which alarms have been triggered shall be loaded onto the tag.

The data received from the sensors shall be processed and analyzed through the Sensor Processing Circuit Card containing the STM32 microcontroller, SD Card reader, and I2C connectors and displayed in a meaningful way for accurate reading and response. The program shall be implemented in C++ developed in Code Composer Studio. The program shall sample the sensor data with timestamps, log and display real-time readings from each sensor in graphical format and detect when abnormal levels are reached from any sensor to then trigger a visual and auditory alert to the wearer and their supervisor.

# Environmental Sensor Unit

The environmental sensing dynamics of the sock include a multitude of sensors. These sensors include CO2, pressure, and humidity sensors with the direct intention of monitoring the astronaut’s isolated environment within their spacesuit. It is self-evident that the environment shall be monitored at all times while the device (sock) is in use. There were multiple sensors up for selection that underwent scrutiny amongst the team; two to three sensors were researched and selected as candidates for their respective categories. The selection process included elements such as price, sampling rate, I/O interface(s), power consumption, data format, etc. In addition, applicability and lead time was another critical element that is considered. All of the dictating elements were used in the selection process for determining which of candidate sensors would be chosen as the utilized sensor in the design.

For the first of the environmental sensors was the CO2 which consisted of 3 candidates: the USEQGSEAC82180, T6793-5K, and PASCO2V01BUMA1 CO2 sensors. Each of them met the requirements for I/O output (I2C) and the power consumption rates. The dictating factor for the chosen sensor was the range of how much CO2 was in the system it operated in; options 1 and 3 both worked in the 250-4000 ppm range while option 2 was capable of ranges from 0-5000ppm of CO2. This was the deciding factor for its selection, additionally its short lead time of 3 weeks compared to its respective counterparts.

The barometric air pressure sensor proved to be difficult in finding a small-scale application that fitted the requirements of the design. However, after researching, two candidates were looked at and underwent the decision process: The Bosch BMP280 and the AITRIP pressure sensors. After decision making process the BMP280 sensor was selected due to its capability to be integrated with an I2C connection as well as the voltage operation range. The counterpart was very similar in regard to performance however lacked the I2C attribute thus its rejection in use for the project.

Lastly the humidity sensor selection was conducted and consisted of two options that gave promising potential. The SHT85 and the CC2D33S-SIP humidity sensors were very similar with respect to performance – they both had I2C I/O interfaces, digital outputs, power consumptions, and physical size. The deciding factors were lead time and output data rates; the chosen sensor was the SHT85 which has 16-bit output at 8 sec/sample with a 8-week lead time versus a 14 bit output at 7 sec/sample with a 13-week lead time.

# Biomedical sensor Unit

The biomedical sensor suite shall be comprised of a pulse-oximeter, thermometer, and galvanic skin response sensor. Each of these sensors shall be integrated into the sock and have each of their signals conglomerated into one connection so it can be exported outside of the internal pressure suit. Each type of sensor had multiple contenders for our project. We selected each sensor based on their price, sampling rate, I/O interface(s), power consumption, and data format.

The first biomedical sensor, the pulse-oximeter, had an extremely small pool to select from. The sensor we chose was the MAXREFDES117. The advantage of this sensor is that it is a highly integrated small-size sensor, non-chest based, and ultra-low power consumption. The small board size of 12.7mm x 12.7mm is useful for this wearable sock application where size is a crucial factor.

The second biomedical sensor, body temperature reader, was the most expensive sensor in our project. The sensor chosen is the MAX30205. This device converts the temperature measurements to digital form using a high-resolution, sigma-delta, analog-to-digital converter (ADC). The accuracy of this sensor meets clinical thermometry specification. The sensor has a 2.7V to 3.3V supply voltage range, low 600µA supply current, and an I2C compatible interface that make it ideal for medical applications.

The third biomedical sensor, the galvanic skin sensor, was chosen for its I2C interface. The sensor chosen is the MIKROE-4500. This sensor’s main features include low-noise analog front end, highly accurate GSR acquisition, blood pressure measurements, long operating period and more.

# Summary

Team 310 has proposed a space suit sensor design system that will be used by astronauts during extravehicular activity. This sensor system has two main systems which will measure the astronaut’s vital signs as well as the in-suit environment of the spacesuit. This system of sensors will be incorporated into a wearable sock that the astronaut will wear. The environment sensors include CO2, pressure, and humidity sensors to monitor the astronaut's environment within their spacesuit. The biomedical sensors will incorporate a pulse-oximeter, thermometer, and galvanic skin response sensor together to monitor the health of the astronaut. These sensor readings will be processed by a microcontroller. The data will be outputted, and any breaches of normal threshold values of the sensors will set off an alarm.

A diagram of a circuit board

Description automatically generated