Pilot Biometrics

ECG Waveform captures

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Revised: 10/15/2017 – V1

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ECG - Electrocardiography - the process of recording the electrical activity of the heart over a period of time.

ADC - Analog to Digital Converter - device used to convert an analog signal to a digital signal

HIPAA - Health Insurance Portability and Accountability Act - regulates how medical information must be secured and stored

1 Introduction

1.1 Acknowledgement

Rockwell Collins has provided much assistance in terms of resources and Connections.

JR Spidell proved to be extremely beneficial with his guidance and background experience.

The Operator's Performance Lab (OPL) from the University of Iowa allowed use of their facilities for the purpose of testing.

1.2 Problem and Project Statement

When military pilots are in flight, they experience a range of forces and conditions. This environment can quickly affect the health of the pilot. Real-time health information is critical for trainers and health officers on the ground to make decisions about the safety of a pilot during training exercises. This information is critical in determining whether the pilot can safely continue a training mission, and whether the pilot will continue to be physically fit to fly.

Our project aims to provide this critical information using an ECG sensor harness. The device will actively monitor the ECG waveform of a pilot in flight, analyze the waveform to detect when a pilot is in distress, and communicate this information to decision makers on the ground. The device will be capable of running continually for 4-5 hours and store all of the operational data for later review.

1.3 operational Environment

The ECG sensors will be attached to a pilot via harness in fighter jet test flights. It will experience rough shaking, inconsistent vibrations, movements from the pilot, and high-g maneuvers. We expect conditions inside the cockpit to be clean, the cabin partially pressurized, and within a reasonable range of temperatures. Our device will not come into contact with water or weather conditions and humidity in the cockpit will be minimal.

1.4 Intended Users and uses

Our product will be worn by fighter pilot trainees. Extracted data will be read by people on the ground in order for them to help pilots better understand how flying affects their body.

1.5 Assumptions and Limitations

Assumptions

- Pilots have already gone through stringent health checks
- Pilots will not have any previously known abnormal heart conditions
- Product will be designed mainly for use in training exercises
- Only one person will be using device

Limitations

- 4-5 hours of battery life
- Testing will be minimal
- Testing product durability will not be performed
- Processed data may be delayed by 3-8 seconds
- Final product will not inhibit any other action performed by pilot

1.6 Expected End Product and Deliverables

The end product is a wearable harness-mounted system capable of accurately reading the ECG of a fighter pilot for the duration of the flight. The product will also send readings to the ground where professionals can access the pilot's health and stress levels. The ECG sensor system has a continuous operational lifetime of 4-5 hours and can also store 4-5 hours of operational data. The system is capable of transmitting the ECG waveform data in real time, or only transmitting a distress signal.

- Delivery due on April 20th, 2017

2. Specifications and Analysis

We discussed implementing the filter on the actual hardware of the PCB, but we decided that we do not need such a short response time. Instead, we decided to implement the filter through the software and sacrifice a small amount of speed. We have been researching and planning until we receive all of the hardware that we need to begin the design process on the hardware. We can start developing code and testing it once we decide what kind of data we will observe, how to filter it and what the results tell us about the pilot's status. We are following the IEEE standards and Rockwell Collins specifications for quality. Our final design will not take credit for work that we did not do ourselves and we will deliver all deliverables upon the completion of our project in accordance with the agreement made with Rockwell Collins.

2.1 Proposed Design

We built a PCB which runs our algorithms to filter and monitor an ECG waveform. We have written code to provide feedback to ground operators on the status of the pilots. We designed a chest harness to mount the pilot biometrics unit to.

A complete list of functional and non-functional requirements is included below:

Functional
Accurately detect a pilot in distress
Capture ECG waveform of pilot in operation
Accurately identify distress based on waveform
4-5 hours of continuous operation
Consistent and reliable power supply
Notify pilot or ground station
Communicate danger to pilot without increasing distress
Communicate with ground teams
Store 4-5 hours of operational data
Operate in real time on an ARM microcontroller

Non-functional
Don't interfere with pilot's primary tasks
Flight operations
Emergency ejection
Don't interfere with pilot's safety harness
Don't interfere with pilot's normal communications

2.2 Design Analysis

We have considered a number of design options in our current implementation. Both a hardware and software filter were considered, and we have also considered using a combination of both. For power distribution, we considered a dedicated power supply from the cockpit, as well as an integrated battery. Finally, for data storage, we are currently exploring a number of options for saving 4-5 hours of operational data.

3 Testing and Implementation

Check circuit and ECG filter algorithm on pre-extracted ECG readings to check if the circuit and software are set up correctly.

Test ECG sensors with the validated software to make sure they are working correctly, induce stress on wearer to check if a difference in stress levels can be measured as expected.

Once system is set up on a harness, test the comfort, stability, and accuracy of entire system under extreme conditions.

3.1 Interface Specifications

To test the main algorithm in a controlled environment we will have to have consistent and accurate ECG readings. To do this we will write software that will mimic ECG readings. This will involve adding the functionality to mimic a pilot in distress or a pilot who is about to lose consciousness.

3.2 Hardware and software

STM32F767 Microcontroller from ST micro is used to interface with the ADC and interpret the data.

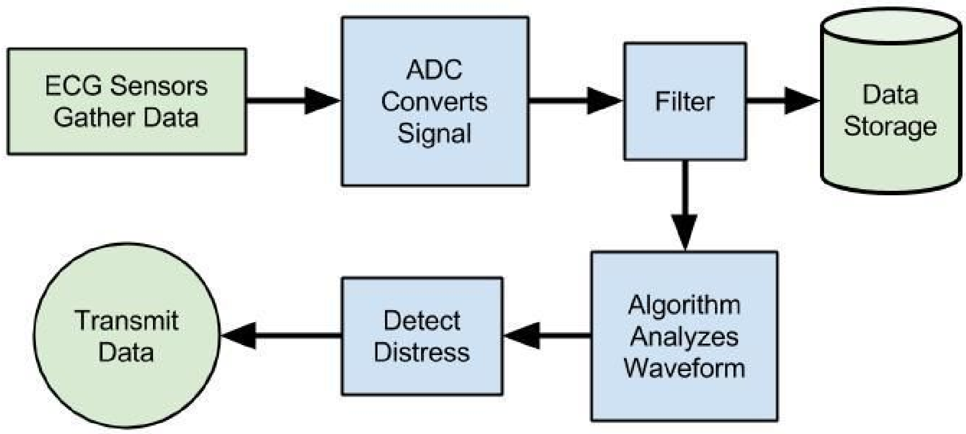
ADS1298RECGFE-PDK is an ADC used to convert the data received from our ECG sensors into data that our microcontroller can use.

ECG sensor ADS129R will read ECG waveforms from our user and then send it into our ADC.

3.3 Process

Our design begins with four ECG sensors creating an analog signal. The signal goes into an ADC to create a digital form of the waveform. The waveform data is then filtered to reduce noise. The filtered data is then stored for later use, and also analyzed to detect distress. Finally, the data is transmitted to observers on the ground.

Figure A.



3.4 Results

We have not completed any testing as of October 15th, 2017.

4 Closing Material

4.1 Conclusion

Our goal is to create a device capable of monitoring the health of a pilot during training operations and communicating critical data with ground teams. The device must be capable of running continuously for 4-5 hours and securely store 4-5 hours of operational data. The ECG harness system must not interfere with a pilot's primary tasks or ability to safely eject.

Our research suggests the best plan of action to achieve these goals is a system of four ECG sensors, connected to a harness. ECG sensor data is fed into an ADC, and then to a microcontroller for processing, data storage, and transmission. The system will use a dedicated battery pack and be designed to function under standards conditions inside an aircraft.

4.2 References

ECG Waveform Resources:

https://biomedical-engineering-online.biomedcentral.com/articles/10.1186/s12938-017-0371-6

https://ecglibrary.com/ecghome.php

https://physionet.org/physiotools/software-index.shtml

STM32 MCU Nucleo Microcontroller Resources:

http://www.st.com/en/evaluation-tools/stm32-mcu-nucleo.html?querycriteria=productId=LN1847

http://www.st.com/content/st_com/en/products/evaluation-tools/product-evaluation-tools/mcu-eval-tools/stm32-mcu-eval-tools/stm32-mcu-nucleo/nucleo-f767zi.html

4.3 Appendices

Figure B.