Pilot Biometrics
ECG Waveform Captures

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Team Members
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Advisor: Professor Tyagi
Client: Rockwell Collins

Purpose

Provide critical **medical information** to decision makers about the condition of **US Navy pilots** during training missions

Project Overview

Capture, monitor, and analyze Electrocardiograph (ECG) waveform

- Three ECG Sensors take voltage readings
- Filtering remove interference noise
- Analog to Digital Converter (ADC) converts signals
- ECG waveform data fed into microcontroller
    - Copy stored on device (4-5 hours)
    - Copy packaged for output
    - Input into artificial neural network for stress detection
- Battery and voltage regulator for 4-5 hours operation

Operational Environment

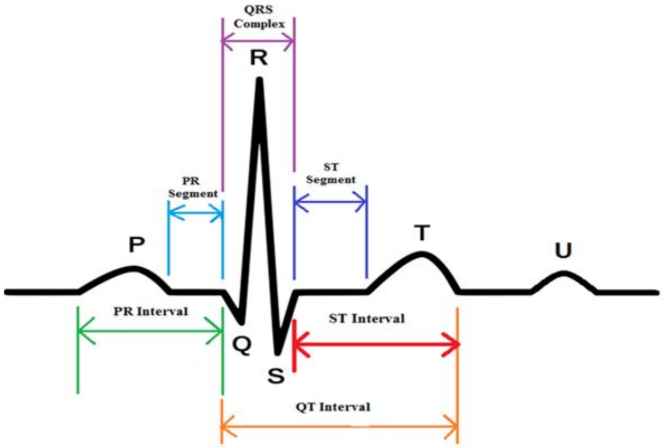
- ECG sensors attached to user via disposable pads under flight suit
- Used inside military aircraft cockpit
  - Rough shaking
  - Inconsistent vibrations
  - Movements from pilot
  - Unpredictable muscle contractions
  - High-g maneuvers
- Pressurized cabin
- Reasonable range of temperatures and humidity

Intended Users

- US Navy fighter pilots in training
  - Pilots already certified to operate aircraft
  - In good health and physical condition
- Practicing missions with multiple aircraft
- Extracted data can be transmitted to ground in real time
- Data used by training and health officers
  - Determine whether or not to continue mission
  - Confirm if pilot is fit to continue training
  - Identify health issues early

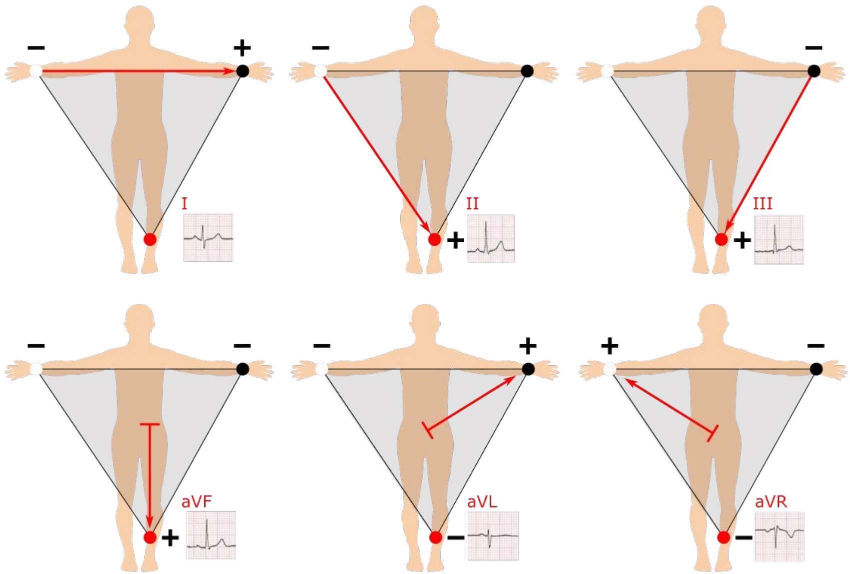
ECG Waveform

- Captured using 3-Leads
- R-Wave
  - Used to detect Heart-Rate
  - Easy to capture
- QT Interval
  - Time from start of R-wave to the end of T-wave
  - Not as reliable to capture

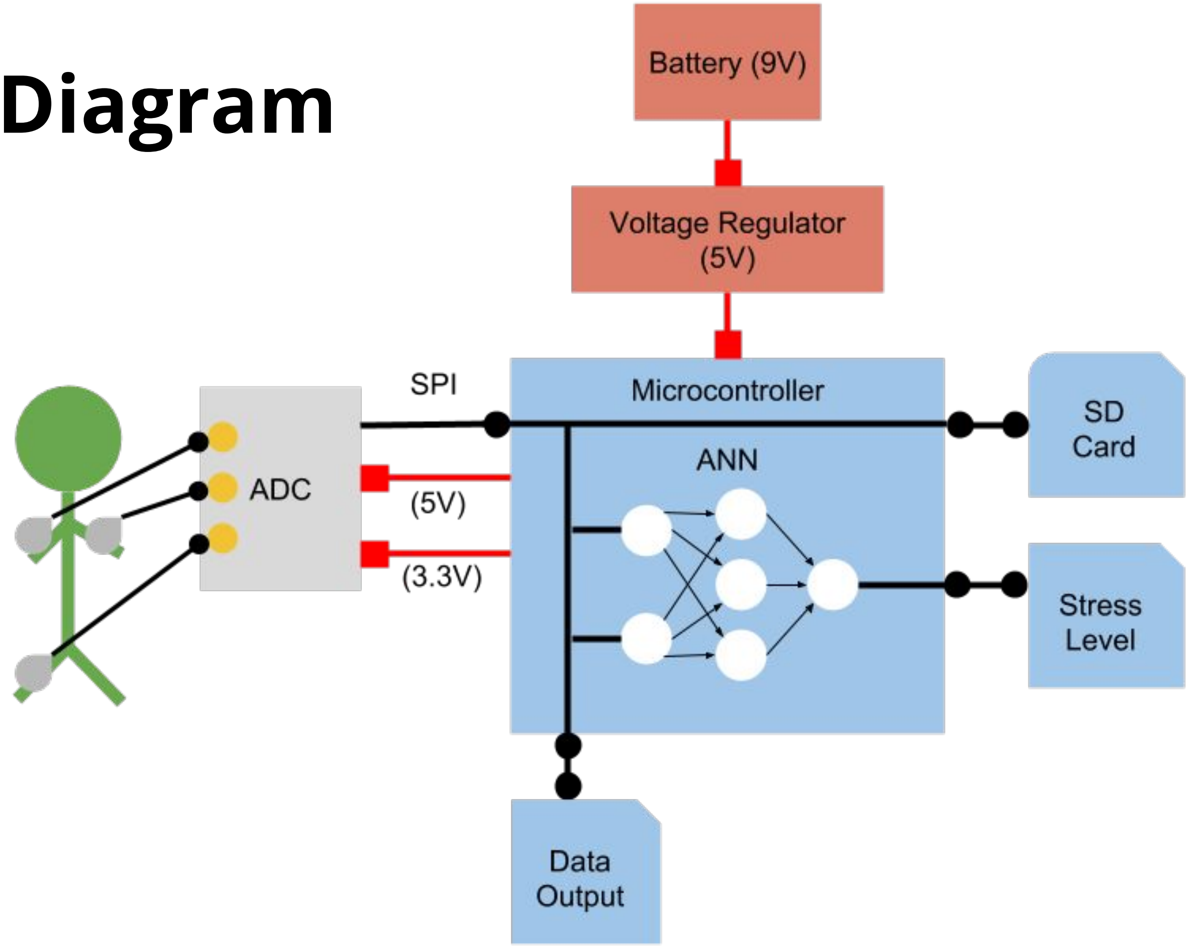


Detecting Stress

- Heart-Rate Variability
  - Measure variability between R-waves
  - Easily Implemented with ECG
  - High variability is indicator of stress
- QT Interval
  - Measurement of QT intervals
  - Difficult to implement accurately
  - Decreased interval indicates stress

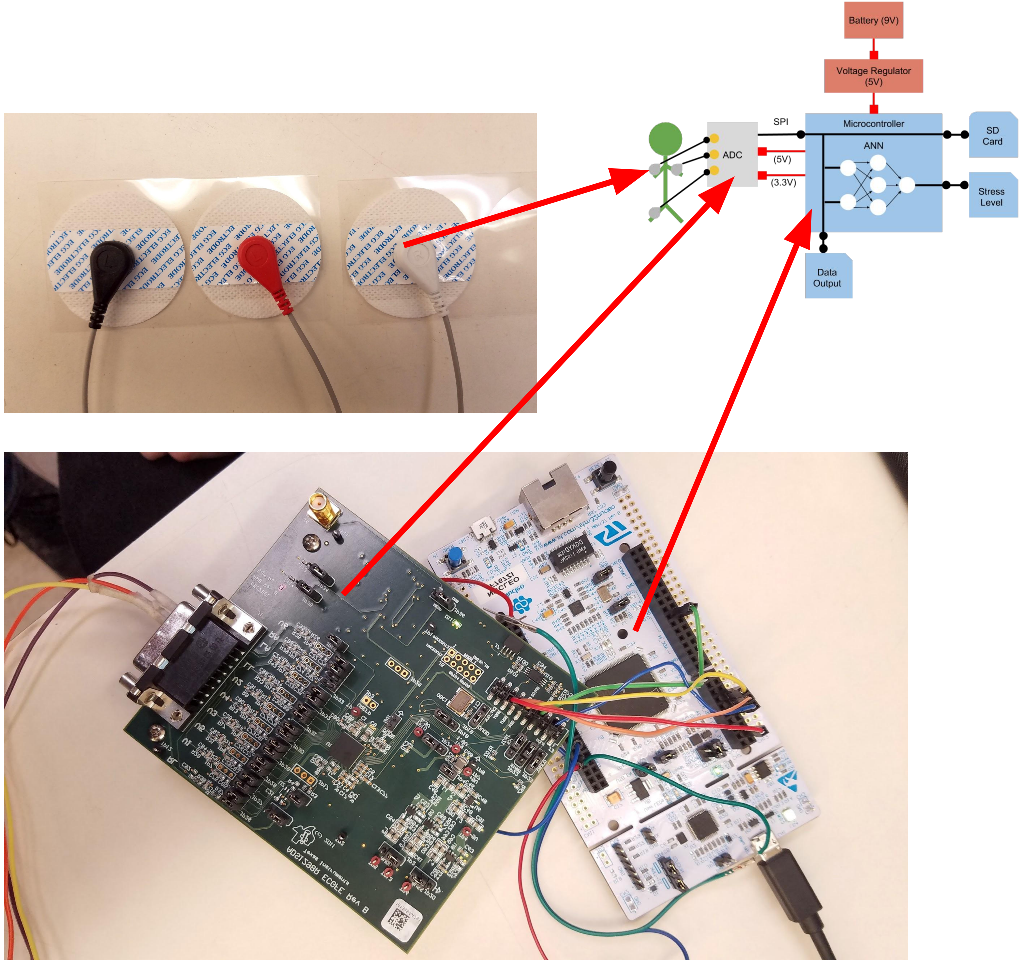


System Diagram

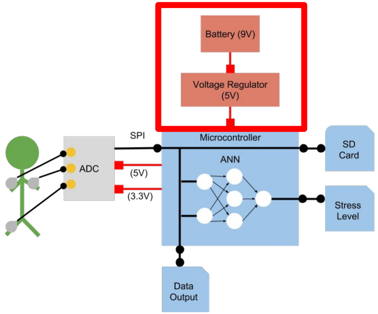


Hardware

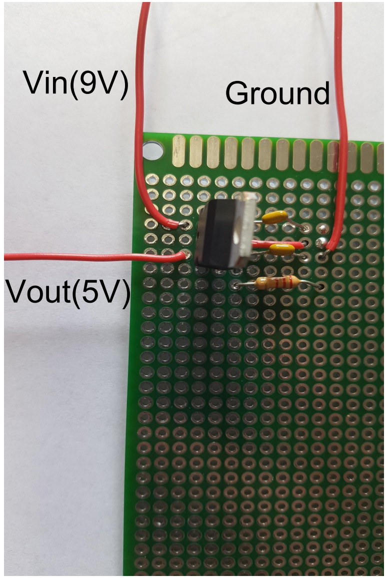
- ADS1298R (Pictured)
  - 24-bit ADC
  - Built in hardware frequency filter
- Nucleo-144 (Pictured)
  - Used in place of permanent microcontroller
  - Communicates over SPI
- ECG Leads (Pictured)
- STM32F746G Discovery



Voltage Regulator & Battery

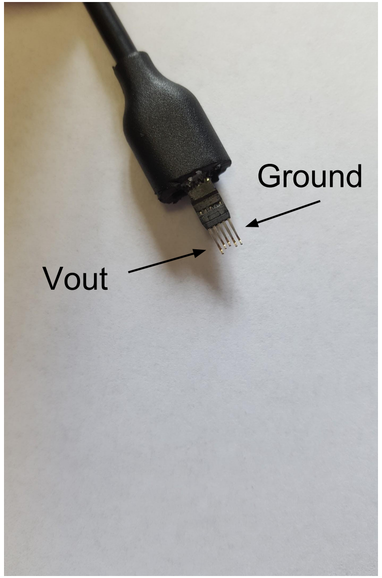


Voltage Regulator

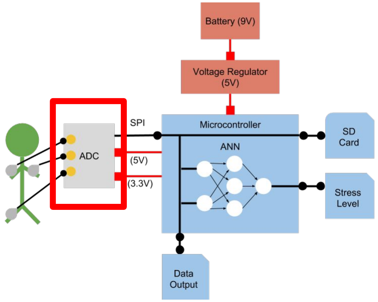


Battery

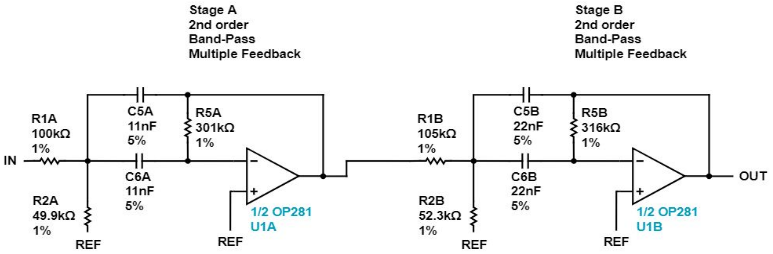
Power Cord

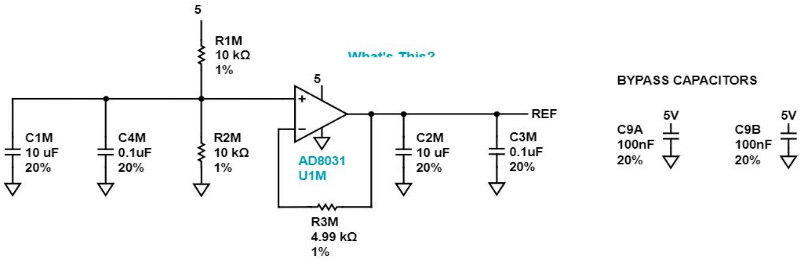


Filters



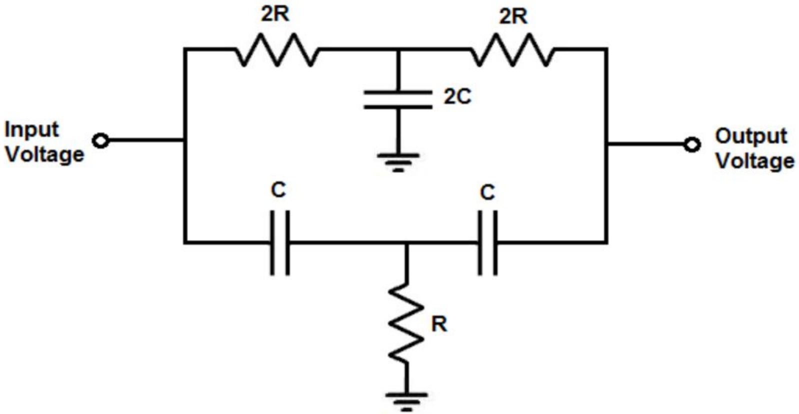
Bandpass Filter



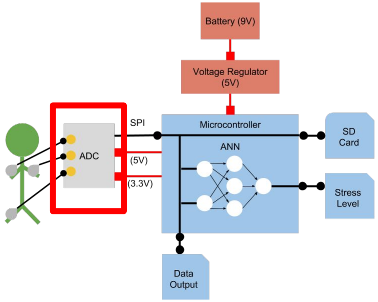


Offset Voltage

Notch Filter

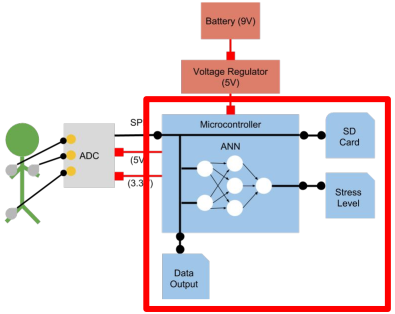


Analog to Digital Converter



- 24-bit ADC
- Communication with microcontroller over SPI
- Operating at 8,000 samples-per-second
- Using 3 leads for ECG detection
  - Disposable ECG sensor pads placed on skin
  - Return voltage readings
- Challenges
  - Evaluation module PCB designed for 12-lead system.
  - Evaluation module designed to work with companion board that is only compatible with Windows XP-7

Microcontroller



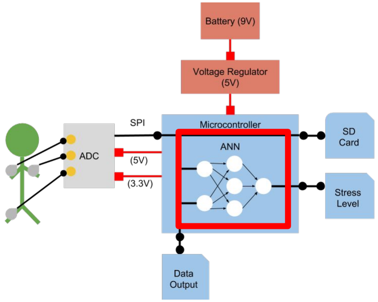
SPI Interface with ADC

- ADC output written to board registers
- C++ application reads registers and directs data flow

STM32F746G Discovery Board

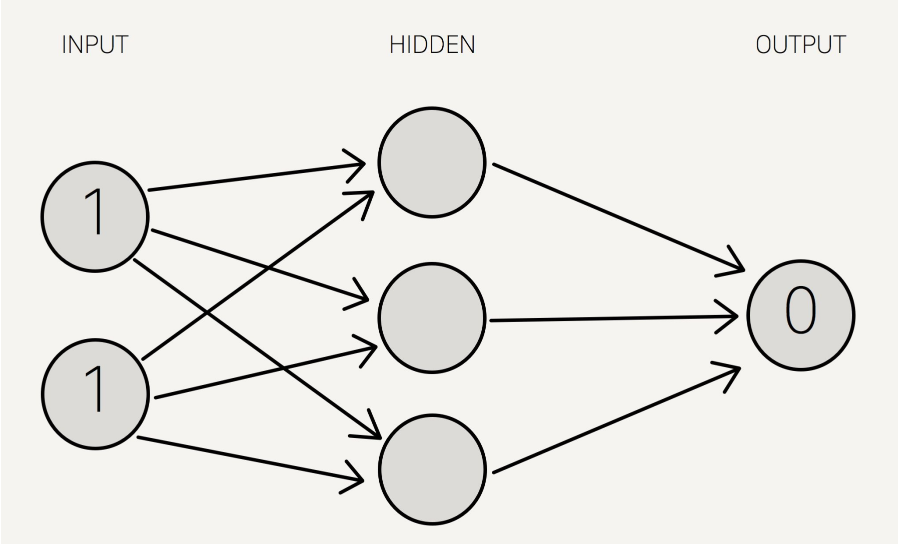
- Linux Development Environment
- Reconfigure u-boot and put uClinux on quad-SPI flash memory on board to boot
- Reconfigure uClinux image to use SPI and store to microSD card

Artificial Neural Network



Stress Detection

- Given a set of training data, will learn whether an individual is stressed or not
- Uses Heart Rate Variability as the metric to detect cognitive stress
  - Time domain measurement NN50
- Can tweek itself over time to with individual pilots



Data Collection

Control Data

- Measuring time between R-waves of user at rest
- Single task that is uncomplicated

Stressed Data

- Measuring time between R-waves of user doing mentally straining tasks until failure
- Starts with single spatial navigation task
- Additional cognitive tasks added until subject feels overly stressed

Testing

- Component Testing
  - Individually test hardware components
  - Test battery performance/lifetime and data storage requirements
- ECG Waveform Testing
  - Compare device output against sample ECG data
  - Test on multiple subjects for anomalies
- Artificial Neural Network Testing
  - Train with labeled data
  - Validate with test data and adjust weights for accuracy

Questions?

Team Members

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*Not presenting