EEE 489: Electrical Engineering Capstone Design Project 2025

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Sleep Sensing

Detect and Display heart rate and sleep phase information

Team 8: Sleep Sensing

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Introduction:

Sleep is vital to overall health, yet one in three adults in the U.S. report insufficient rest. Poor sleep quality is linked to cardiovascular disease, diabetes, and cognitive decline, while disorders such as obstructive sleep apnea affect nearly a third of adults and often go undiagnosed. Current consumer trackers rely heavily on motion detection, which misclassifies sleep stages with limited accuracy, while medical-grade studies require multiple sensors that cause discomfort and anxiety. These limitations leave a critical gap in accessible and reliable sleep monitoring.

Our Approach

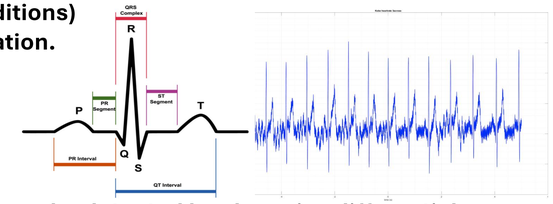
This project introduces a non-intrusive sleep sensing device that leverages heart rate (HR) and heart rate variability (HRV) to deliver precise sleep phase analysis. By combining physiological monitoring and a user-friendly mobile application. The goal is to bridge the gap between consumer convenience (inaccurate devices) and clinical reliability (lengthy, invasive testing), empowering everyday users to improve their sleep health while offering researchers richer datasets for identifying and studying sleep disorders with broader access to HR and HRV data.

Project Objective:

Develop a system capable of detecting heart rate (HR) [via Voltage present on skin], calculate heart rate variability (HRV) and then determine sleep phase changes over time from historical baseline of heart rate.

Benefits:

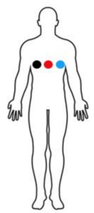
- Heart rate detected directly is more accurate than typical accelerometer-based approaches
- Information can be logged and shared for additional health analysis not just limited to sleep (e.g early detection of other heart conditions)
- Readily viewable with a mobile application.
- Data recorded for future insights
- Data available to share with providers



Theory Of Operation:

The electrical signals from the heart may be detected by observing differential signals across skin. Einthoven's triangle is a model used in electrocardiography (ECG) to represent where electrode sensors can be placed to detect these signals. By placing the electrodes at distant points (in an equilateral triangle) the electrical vector, created by the heart, across the body's conductive tissue becomes measurable.

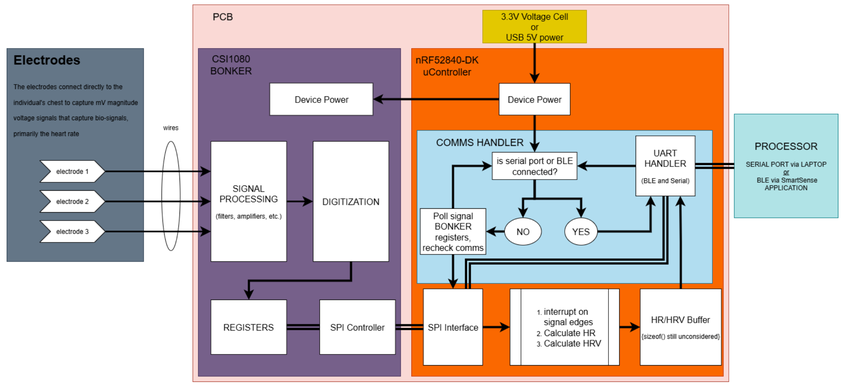
Once captured by polling the CSI080 chip the signal is digitized and stored with the microcontroller (MCU) and users HR and HRV can be calculated. Sleep phase is determined, and all information is transmitted over Bluetooth to mobile app where subject can view data and observe trends.

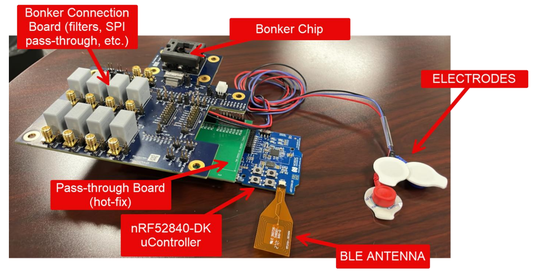


Cable Color	Signal
Black	RA (Right Arm)
Blue	LA (Left Arm)
Red	RL (Right Leg)

Sleep phases are determined with the following matrix:

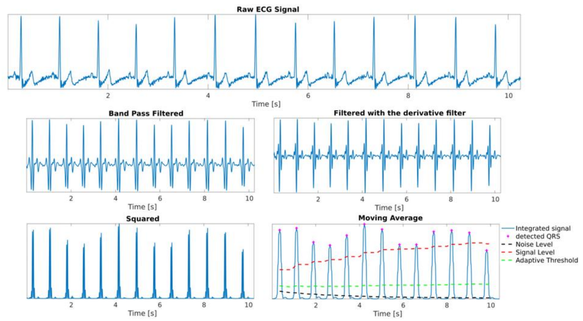
Sleep Stage	Heart Rate (HR)	Heart Rate Variability (HRV)	Note:
Awake	Baseline (~70bpm)	Baseline, is stable	Found by average of several days
Light Sleep	begins to drop	begins to increase	
Deep Sleep	below 70% baseline	increases but itself, is stable	Lowest HR of all stages
REM Sleep	below 80%, irregular	sharp increase, is irregular	Highest HRV of all stages





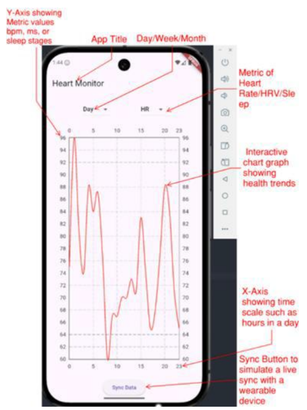
High Level System Flow Description:

- Electrodes interface with skin tissue and allow detection of voltage differences.
- CSI080 device captures these differential signals, filters, and amplifies them for processing.
- MCU controls data acquisition, processing, and communication.
- Critical Metrics (HR, HRV) are transmitted over Bluetooth BLE to mobile device.
- Mobile device displays heart rate, heart rate variability, and sleep information.



Example method for determining time between heart beats

- Simplest method use only Peak Detection to calculate the timing between two adjacent peaks in the measured signal
- Advanced methods include band pass filtered signals to remove noise and include average detection to track heart rate over time.



Conclusion and Usage:

Mobile Application:

Heart rate and Heart Rate variability plots are accessible with simple mobile application and lead to tracking of sleep phases. Information is easily accessible for user and can be logged and shared with medical providers if necessary.

Future Considerations:

Beyond its immediate application, the project serves as a foundation for future development of affordable, user-friendly sleep monitoring solutions that can empower individuals to better understand their sleep health while supporting clinical research into sleep disorders, and the data captured may also be useful for detection of other risk factors in cardiovascular health as the system may capture more information beyond just Heart Rate and Heart Rate Variability.