Real-time Electrocardiogram Monitoring

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Introduction

Arrhythmias are irregular heartbeats caused by faulty electrical signals in the heart. Premature ventricular contraction (PVC) is one of types of Arryhythmias. Consecutive PVCs could indicate ventricular tachycardia, a potentially life-threatening condition. This project expands on the 2016 senior capstone project work completed by Bamarouf, Crandell, and Tsuyuki[1].

Motivation

Holter monitors (current technology) only record electrocardiogram (ECG) data for later processing and review.
It does not allow for immediate notification of a PVC episode.

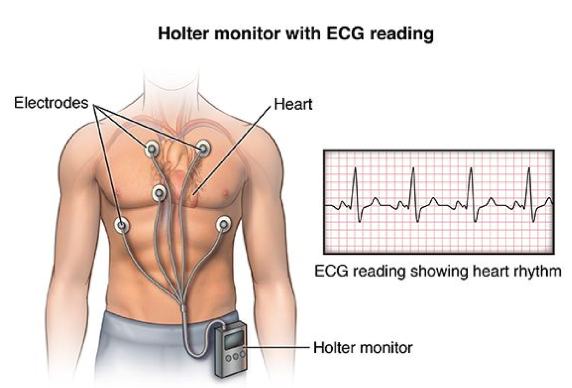

Figure 1 – Holter monitor setup[2]

Objectives

Design a standalone portable medical device which:

- Records and processes ECG data real-time
- Notifies the medical personnel wirelessly if PVC is detected

Quick Results

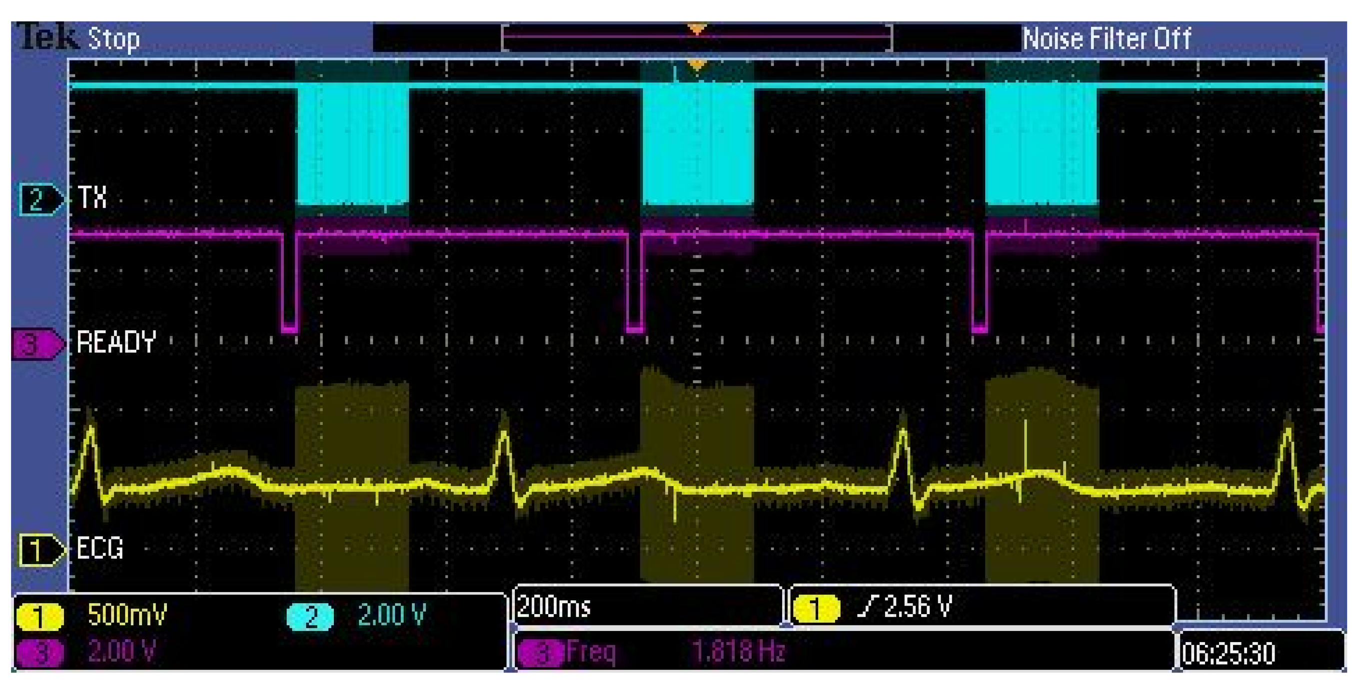

Figure 2 – Oscilliscope display(from top to down): Acquired binary data stream from DSP to embedded computer (blue), the markers for data active events (pink), and ECG reading (yellow)

System Overview

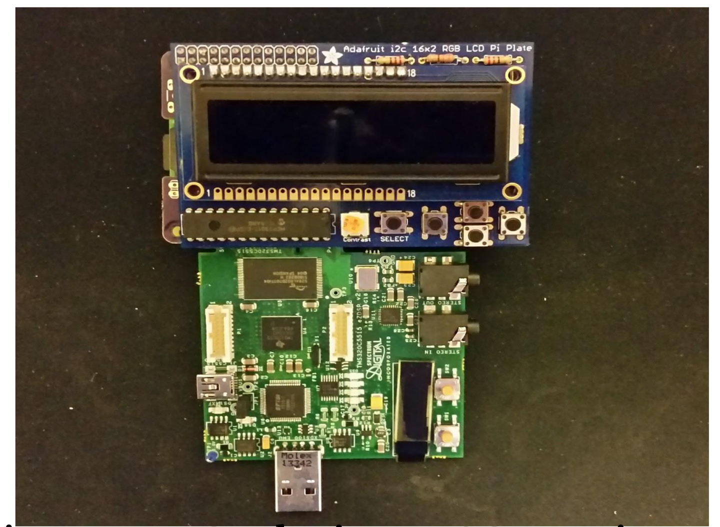

Figure 4 – Real-time ECG Monitor

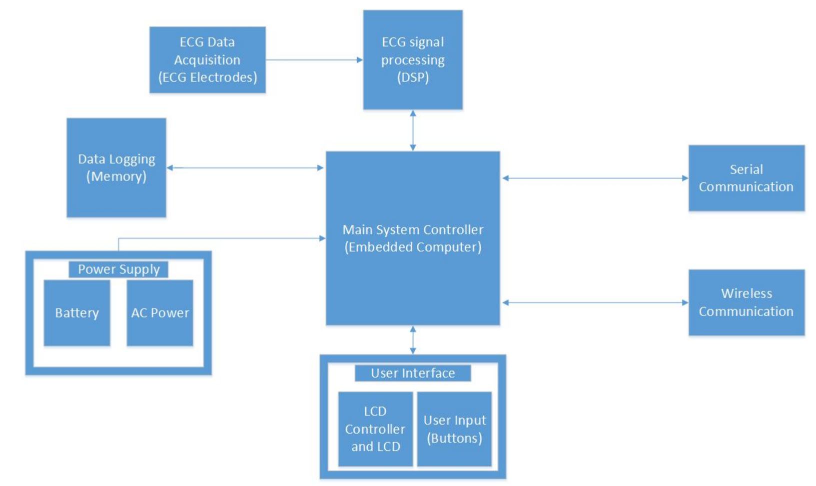

Figure 5 – System block diagram

ECG signals are sampled using three electrodes connected to a prefilter board. The digital signal processor samples the ECG at 360 samples per second. It processes the data and transmits the data to the embedded computer for recording and notification.

System Hardware

This device is built around the Raspberry Pi 3 embedded computer and the Texas Instruments CC5515 eZDSP. A custom printed circuit board has been developed to integrate the TI DSP and Raspberry Pi embedded computer together. The device is WiFi enabled to transmit messages, and supports web configuration. An LCD is also included for user interface.

Table 1 – Functional Description

Subsystem	Description
Main system controller	Controls functionality and data flow between all other subsystems; largely implemented on main microprocessor. User interface elements, wireless communication, and serial communication are implemented exclusively on this subsystem.
ECG data acquisition	Acquires ECG signal data from ECG sensor interface or stored benchmark data to provide to ECG Signal Processing subsystem. Raw ECG data may undergo prefiltering.
ECG signal processing	Processes and analyzes raw data ECG data; largely implemented as DSP hardware/software.
Serial communication	Interfaces main system controller and external computer for setting device parameters and viewing debug info.
Wireless communication	Sends event information from ECG signal analysis to client.
LCD controller	Interfaces with LCD to display system status and parameters, depending on selected system mode and user settings.
User input	Push buttons provide input to main system controller to select modes.
Data logging	Stores history of ECG signal data taken over specified time period in a rolling buffer; writes all system events to a logfile for debugging purposes.
Power supply	Selects between a battery or AC power supply and provides each subsystem with regulated power to the system.

ECG Algorithms

To detect PVC, the device must preprocess raw ECG data, detect heartbeats, and determine the presence of PVC. This implementation utilizes the Pan-Tompkins and Template-Matching algorithms.

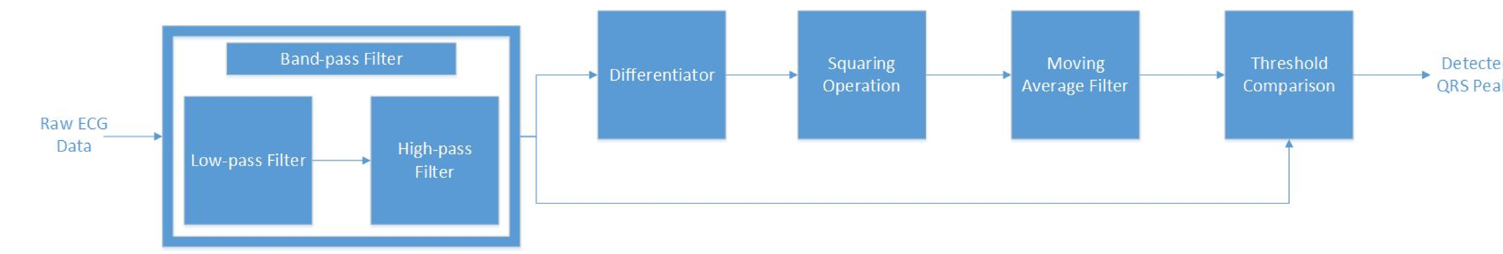

Figure 6 – Pan-Tompkins Algorithm Flowchart

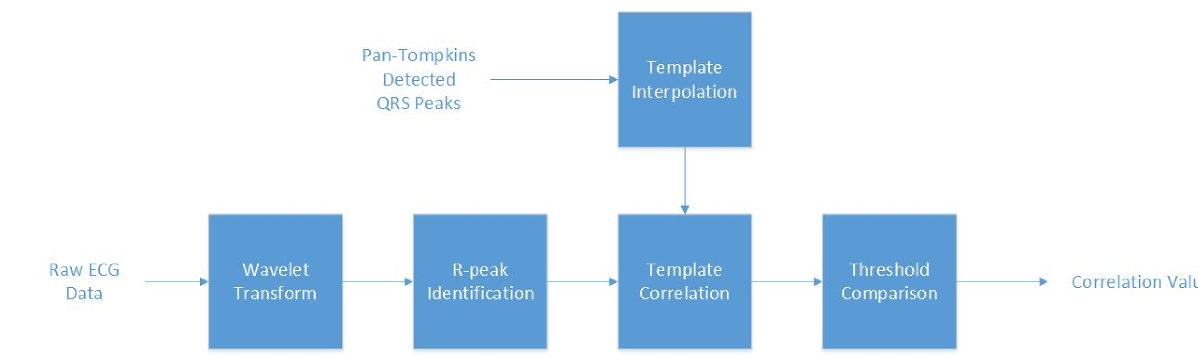

Figure 7 – Template Matching Algorithm Flowchart

Benchmark Result

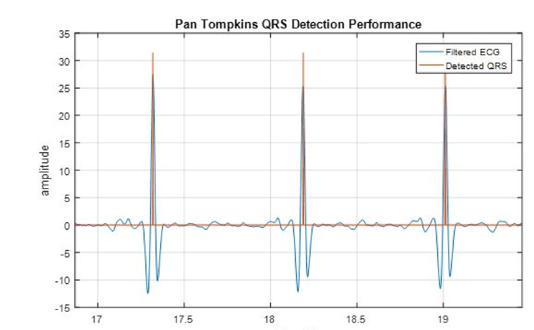

Figure 8 – An example of QRS detection

Benchmark ECG data from the MIT-BIH arrhythmia database have been evaluated in our simulation. An example of QRS detection is shown in Figure 8.

Conclusion

The system accurately samples ECG data, and processes it in real-time. The project has achieved these outcomes:

- Real-time sampling and processing of ECG data
- Timely logging and wireless notification of PVC
- Reliable interfacing between components
- Configuration through user interface
- Compact and portable design

This type of study may have a broad impact in wearable medical applications.

References

[1] F. Bamarouf, C. Crandell, and S. Tsuyuki, “Real-time heart monitoring and ECG signal processing,” Bradley University, May 2016.
[2] “acardio20140402v0005.jpg.” [Online]. Available: https://api.kramesstaywell.com/Content/ebd5aa86-5c85-4a95-a92a-a524015ce556/medical-illustrations/Images/acardio20140402v0005.jpg.