3rd year laboratory microprocessors proposal

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***Abstract*—This project aims to analyze using a PIC18 microprocessor the user's heartbeat data, captured through the ECG Module AD8232 detector. The system will output heart health parameters to an LCD screen and confront them with critical values, giving visual feedback with LED colors.**
The challenges of this project are interfacing the sensor with the ADC, on top of filtering and computing the data to give sensible outputs.

I. Introduction and motivation

CARDIAC monitoring is necessary for a variety of medical and fitness applications, from heart rate checking to advanced health diagnostics. Real-time pulse monitoring aids in early anomaly detection, enhances fitness optimization, and supports medical research evolution. A heartbeat sensor typically utilizes an infrared LED and a phototransistor to read pulse data. Though low-cost and simple to integrate, the raw data needs fairly complex processing to achieve accurate cardiac measurements and overall health scores. We saw the AD8232 heart monitor as the best fit for our needs. We recommend using the PIC18F87K22 microprocessor and its peripherals to meet this challenge. This microprocessor has a general set of features and high data processing capability, and it is ideal for raw analog sensor data processing (while concurrently visualizing the input stream on the oscilloscope) to extract heart health parameters for subsequent processing.

This project will create a stable interface between the sensor and microprocessor for precise pulse measurement, quality data for calculation, and immediate results. It has direct applications and future health monitoring and biofeedback possibilities. It is modular, allowing expansion with future sensors and data analysis methods. This enhances system performance and encourages innovation in health monitoring.

II. High level design

This project, due to its specificity, needs deep integration between hardware and software. The logic of the program is explained in Figure 1 while a sketch of how we aim to build the hardware part of the system can be found in Figure 2.

First of all, the user is required to set critical values for HRV (heart rate variance) and HC (heartbeat coherence) using the keypad. If input is not provided after 30 seconds, default values will be used (since the developers are both 21-year-old males of 75 kg, corresponding values will be set as default). The heartbeat raw data is taken from 3 pads positioned on the chest around the heart [1]; the data is then filtered on the chip using a band-pass filter (typically between 0.5 Hz and 3.5 Hz, which corresponds to about 30 and 210 BPM) to eliminate the noise. The filtered signal is then sent to the ADC, which converts it to a digital 12-bit signal using a fixed sampling frequency. The processor will then elaborate the signal detecting how far are the peaks between each other, thus estimating the RR-interval (length of a ventricular cardiac cycle). The array of intervals is then used for computing the calculations that will lead to the parameters of interest. The HRV is quite easy to compute as it is calculated as the standard deviation of the array; however, computing the coherence requires more complex calculations, as it is in fact defined as the ratio between the power (magnitude of the Fourier transform) in the lower band over the total power. Given the complications that using complex numbers and Fourier transforms on our PIC18 would add on the projects, we decided to keep operating in the time domain and adopted an algorithm to estimate the HC. The algorithm simply analyzes the regularity of R-R intervals around their mean and counts the

[1] see the documentation on the Github of the sensor for ulterior information.

number of intervals within a threshold ($k \times$ HRV), where k is a scaling factor. Thus the formula is:

$$\text{HC} = \frac{\text{Number of regular intervals}}{N} \times 10,$$

where N is the total number of intervals, and then it is normalised by multiplying by 10 (the HC is usually a number between 0 and 10). The calculated values and the current heartbeat frequency are then visible on the LCD screen; they are also confronted with the critical values, lighting up the green or the red LED if they are regular or irregular, respectively.

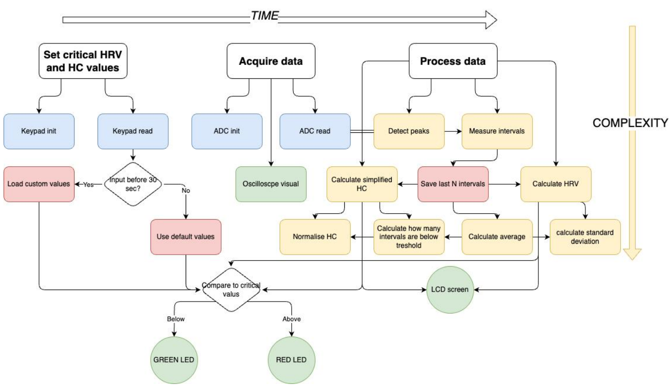

Figure 1: This flowchart sums up the structure of the software we aim to develop. The three main building blocks on top are sequential as indicated by the arrow, but data acquisition and processing will happen simultaneously. The chart is color coded as blue for input, green for output, red for data streams and yellow for elaboration routines. Such routines have been positioned in the y axis to have a complexity gradient explained by the corresponding arrow. Output and input routines have not been specified further (to avoid cluttering the chart) as they are standard but a reference can be found in the lecture slides.

III. Projected performance and assessment criteria

OUR Our project will be built to record two significant heartbeat variables: Heart rate variability (HRV) and coherence are key parameters for cardio-circulatory wellness. HRV measures the variation between beats, reflecting the body's response to stress and homeostasis. High

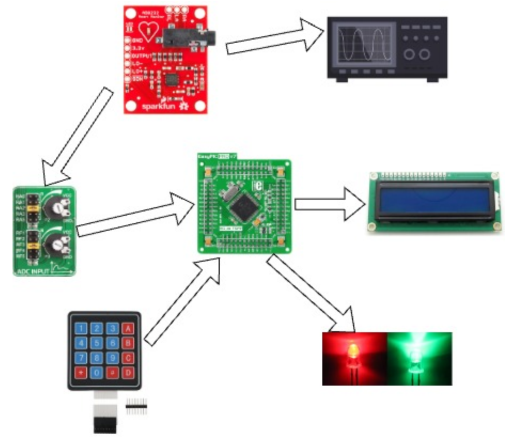

Figure 2: Hardware sketch. The ECG Module AD8232 heartbeat detector is the board with the red PCB, the ADC is the middle man between the sensor and the processor. The other components are the keypad, the oscilloscope, the 2x16 characters LCD screen and two LEDs. Arrows indicate the data flow between the components

HRV, reflects a healthy cardiovascular status and generally the capability of the heart to pace up or down according to external stimuli. Coherence is the synchronization of heart rhythm, respiration, and autonomic nervous system, expressed as a smooth trend in the R-R intervals. These metrics are applicable to biofeedback, stress reduction, and fitness training. A series of metrics will be evaluated for reliability and accuracy of performance. Heart rate (HR) and heart rate variability (HRV) accuracy will be assessed by comparing the system output with a tested heart rate monitor during resting, exercise, and recovery conditions. The HC will be verified by comparing the system output to recognized physiological states, i.e., relaxation (high coherence) and stress (low coherence), in order to verify that the coherence calculated is consistent with known norms.

IV. Conclusions

THIS proposal provides a preliminary framework for a real-time cardiac monitoring system using a PIC18F87K22 microcontroller and the AD8232 ECG module. The document presents foundations on which prototypes can be built and tested.