Lyne Petse
Szu-Po Wang
Wenting Zheng

6.111 Project Proposal (revised)

Overview:
Technology in the biomedical field has been advancing rapidly in the recent years, giving rise to a great deal of efficient, personalized and fast care for patients. There is still much to be done to make healthcare systems even better. One area is portability of medical electronics. Currently, a lot of medical machines that are used to monitor vital signs are heavy machines that confine patients within a certain space with limited mobility. For this project, we aim to develop a portable EKG device that will measure a patient's heartbeat, and then wirelessly transmit the information using an infrared transmitter to a remote location, where the information will be processed and displayed on a screen.

Our system is named D2H, which stands for "Dr House at Home". This system will have a base station and a portable EKG meter, and we will use IR to transmit data between them. The EKG meter is designed to be easily-carried by patients. Therefore, it only consists of a small FPGA board and the necessary circuits for EKG sensing and IR transmission. Moreover, the EKG meter could be powered by a battery in consideration of mobility and patient safety.

The base station would gather data from the IR receiver circuit and store them into its own FPGA board. The board could then display the EKG waveform on the monitor. Furthermore, the base station will use digital signal processing to retrieve patient information, like the heartbeat rate. Sound effects, such as the sound of a beating heart and a patient abnormality alarm, will also be included to enhance the monitoring efficiency. As a result, we could build a system that monitors patient's EKG data remotely.

IMPLEMENTATION

The D2H comprises several modules that will be used for data acquisition, transmission, signal processing and display. These modules are illustrated a block diagram (Fig. 1).

Data Acquisition and Transmission Block (Lyne)

The D2H will be used to take EKG data from patients and thus help monitor vital signs such as the heart rate. The D2H aims at being portable in other to allow patients heart rate to be monitored quickly, and more continuously. Because the transmitter will be used on people, a low voltage level is required (9V battery). We will also determine the limitations of IR transmission by testing how far from each other the transmitter and receiver can be.

ADC Conversion:
The first part of the project involves processing the analog signal from the EKG into a digital signal. The analog signal will range from 0 to 5V. This interval will be divided into 256 equal

intervals, and each interval will be represented by an 8-bit number. This analog to digital conversion will be done using the ADC0801 chip which will sample the analog data and return an 8-bit number for each sample. Sampling will be done continuously and the slow rate of the human heart allows us not to be concerned with bandwidth limitations.

IR-Transmitter:
The 8-bit output of the ADC0801 will be processed by the Nexus2 FPGA. For error detection and correction, we will modify the output using Cyclic Redundancy Check (CRC).The modified data will then be sent to the lab kit's FPGA through an IR transmission channel consisting of a simple circuit which comprises the Vishay TSKS5400S Infrared Emitting Diode (950 nm, GaAs), a 47ohm resistor, a 1K resistor, a 3.3µF capacitor and the 2N2222 Bipolar junction transistor; the circuit being power with the 5v battery.

IR-Receiver:
The data blocks sent through the IR channel will be received at the lab kit level, where error detection and correction will be performed for each block using CRC. When the receiver is done decoding and correcting a data block, it sends out a ready pulse to signal that data is ready for further processing. No significant memory storage will be required here because of the slow rate of the heart.

Data Acquisition test
In order to test our data acquisition, we will use a waveform from a function generator as our analog input signal and check that the signal is properly transmitted and that the data decoded at the receiver level matches the data that was sent.

Signal Processing Block (Wenting)

The signal processing block samples the signal from the IR receiver and processes it in such a way that will make it easy for the display block to show the necessary data. It performs some calculations and outputs data.

Peak detection:
This module's inputs are a one-bit ready signal and an 8-bit value. The output is a peak signal. The module uses a peak detection algorithm to detect the heartbeats. It takes in the values decoded from the signal decoding block and keeps track of the previous sampled values. When the module detects a peak, it will output peak signal to be 1. The peak detection module will store small amount of samples to keep track of when the peak appears.

Timer:
The timer module takes in a peak signal and outputs a time value and an expire signal. This module will start counting time when ready signal is asserted. On the next asserted ready signal, it will reset the clock to zero and output an appropriate time, along with an expire signal to tell the next module that the timer has finished counting.

Heartbeat Calculation:

The heartbeat calculation module takes in a ready signal and a time value. It will output an output_ready signal and an 8-bit heartbeat rate value. This module will use the peak detection module and timer module to count the heartbeat. When it has finished calculating the heartbeat, it will assert the output_ready signal and output the correct heart rate.

Patient abnormality detection:
This module will take in the output of the heartbeat calculation module. Since the heartbeat calculation module already performs the necessary calculation to output the beats per minute information, the patient abnormality module can simply use a threshold to determine the state of the patient. If the patient's heart has stopped, is beating too fast, or is slowing down significantly, the module should send out an alarm signal.

Testing:
The signal processing block can be tested in simulation using a pre-determined set of samples. The modules can be hooked up sequentially with the input samples. One will need to check to see if the outputs of each module are correct.

Display Block (Szu-Po)

The display block will take information of the patient and display it on VGA screen. Three types of information will be shown: EKG waveform, heartbeat rate, and heartbeat animation (Fig. 2). VGA signals for each of them will be generated by separated modules, and display logic will select the correct signal to send to the monitor.

VGA synchronization signal generation:
This module will generate the required synchronization signals for VGA display of 1024*768 pixels, and the coordinate of current pixel.

Display logic:
It will send the current position to each of the display modules. After that, it will select one of their outputs according to which region the current pixel belongs to, and send the RGB value to the VGA output.

Waveform module:
It takes the EKG samples, and return a colored pixel only if the sample (corresponding to the horizontal position) has exactly the same value as current vertical position. Since the EKG data is of 8-bit width, 256 pixels in vertical would be enough to display the waveform without distortion.

Waveform memory:
This module will use BRAM to store the EKG waveform from the data acquisition part. The waveform module can then read the stored values. As the writing and reading of data might happen simultaneously, a control logic which granting priority to reading will be used.

Character module:
Bitmap image of each character will be stored in a ROM. When this module takes in the

character to be displayed, the corresponding bit it stored will be sent out. This module may also change the size of the font by scaling the image proportionally.

Heartbeat module:
Multiple images of heart in different stage of beating will be stored in a ROM. When the signal processing block notify about which stage of heartbeat is the patient in, this module would take the information and send out corresponding image of heart.

Testing:
To test the display block, we can feed artificially-generated waveforms into the block, and check whether they are displayed correctly on the monitor. The character and heartbeat display can also be tested in the same way.

Sound Generation Block (Szu-Po)

The sound generation block generates the beating and alarm sounds. Two modules would be used to generate the two sounds, respectively. Those sounds will be added together and used AC97 audio chip to output to headphone.

Beating sound generation module:
This module takes the peak signal detected by the signal processing block. On each peak, this module would start playing a prerecorded heartbeat sound.

Alarm generation module:
If the signal processing block detected abnormality in any patient's EKG signal, this module will start to generate a siren sound. The sound will stop only when the signal becomes normal again, or someone manually stops the alarm through the FPGA board.

Testing:
The sound generation block only depends on the peak signal and abnormality signal. Therefore, we could manually input those signals by buttons and check if its operation is correct.

Possible functionality extensions

A possible extension for the project involves implementing a data acquisition scheme in which we would be able to get EKG data from multiple patients. If we were to use RF, we would be able to simultaneously transmit and receive data from multiples patients by using frequency modulation. However, the scope of this project doesn't allow us to use RF. Instead, we will emulate a multiple patient interface in which patient data is not sent simultaneously.

We could implement it at the transmission level, by having each transmitter encode data about the patient whose EKG is being measured. Each patient would need to have an ID that will be processed and relayed both at the transmitter, the receiver and the signal processing blick. We could also implement this functionality by having switches at the receiver which could be programmed to a specific patient ID so as to know which patient's data is currently being recorded; in this case, the transmitter, receiver and signal processing block would not need to handle patient ID. The display will indicate the patient ID in each case.

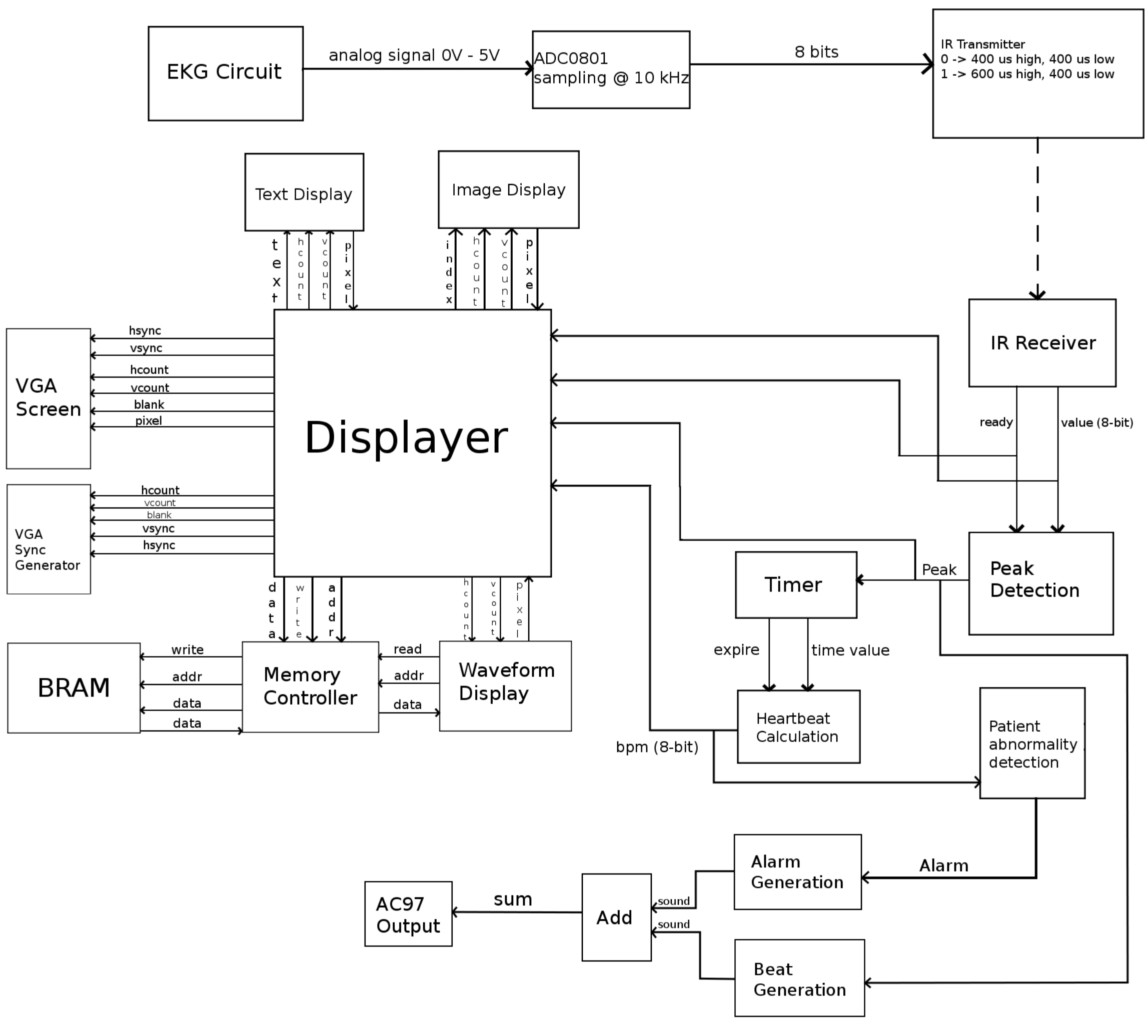

Figure 1. Block Diagram

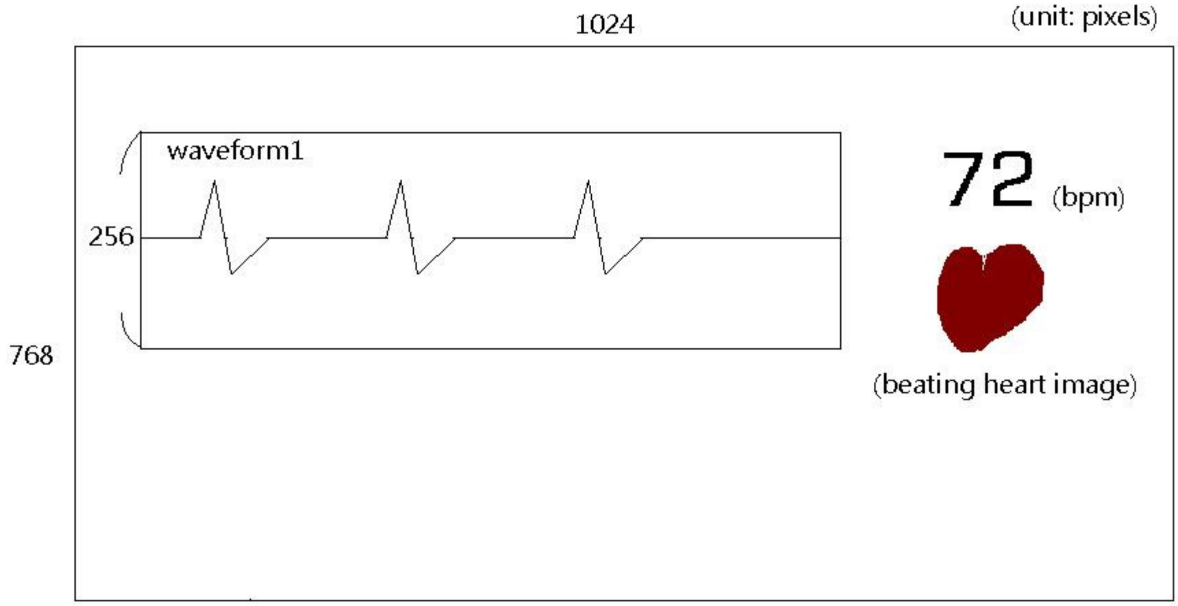

Figure 2. Sample video display