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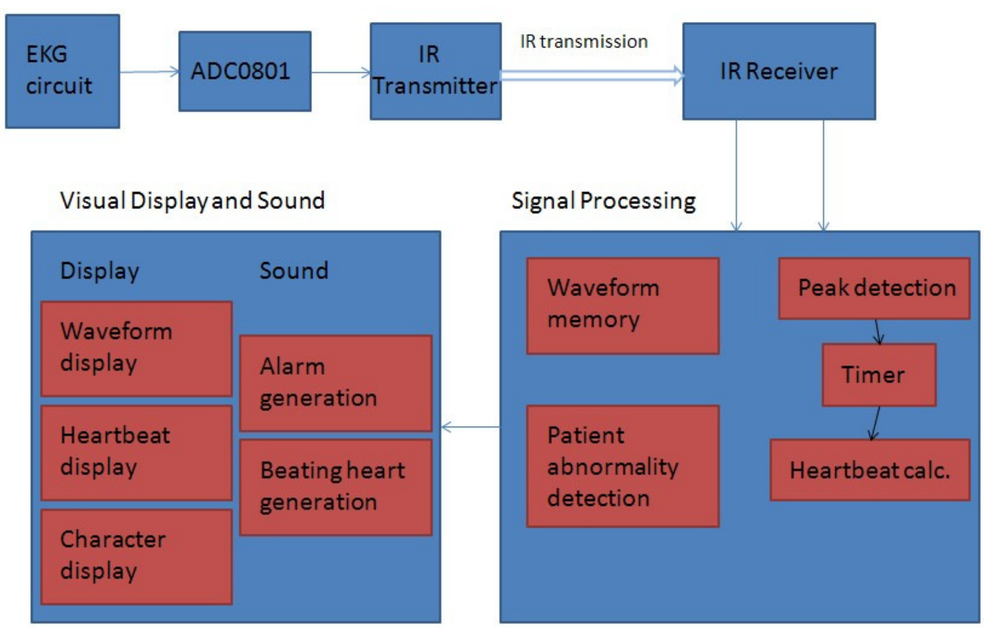
6.111 Project Proposal

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 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.

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 would be able to be powered by a battery in consideration of mobility and patient safety.
On the other hand, 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 effect 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



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. For our project, we use a 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 output of the ADC0801 will be processed by the Nexus2 FPGA in which each 8-bit data chunk will be modified using Cyclic Redundancy Check (CRC) in order to be able to detect and correct transmission errors due to noise. 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 is mainly responsible for appropriately sampling the signal from the IR receiver and processing it in such a way that will make it easy for the display block to show the necessary data.

Peak detection:
This module's inputs are a one-bit ready signal and an 8-bit value. The output is a peak signal. 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.

Waveform memory:
This module will take in the 8-bit output value from the IR receiver and store it in an accessible memory. The memory should have at least 256 by 8 bit space, which means that the mybram module will be enough. This memory can be accessed by other modules (such as the wavefrom display module).

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. Signal processing 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 waveform, store some samples, and detect for any abnormalities in a patient's heartbeat data. It can also take in the output of the heartbeat calculation module. If the patient's heart has stopped, is beating too fast, or is slowing down significantly, 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 takes inputs from the signal decoder, the signal processing block and the base station FPGA board, then output signal to VGA monitor. The signal decoder provides the EKG waveform data. Each time the decoder sends a new data point in, the display block will store it and display it on the monitor when appropriate. The signal processing block gives processed data, like number of beats per minute, peak position, etc. The display block would also display those data on screen. The base station board serves as a user interface, allowing users to send instructions to the display block, like scaling of waveform or choosing display modes.

There are several types of things that would be shown on the screen: waveform, character, and heartbeat animation. Each type of them will be dealt with a combinational module. Those modules take the current horizontal and vertical positions of current pixel, as well as the information (waveform, numbers, etc.) to be displayed, and generate the RGB intensities of the pixel. Their functions will be further explained below:

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.

Character module:
This module acts like a look-up table. Bitmap image of each character would be stored inside. When this module takes in the character to be displayed, it would send out the corresponding bit it stored. This module may also change the size of the font by scaling the image proportionally.

Heartbeat module:
This module also behaves as a look-up table. Multiple images of heart in different stage of beating would be stored. 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.

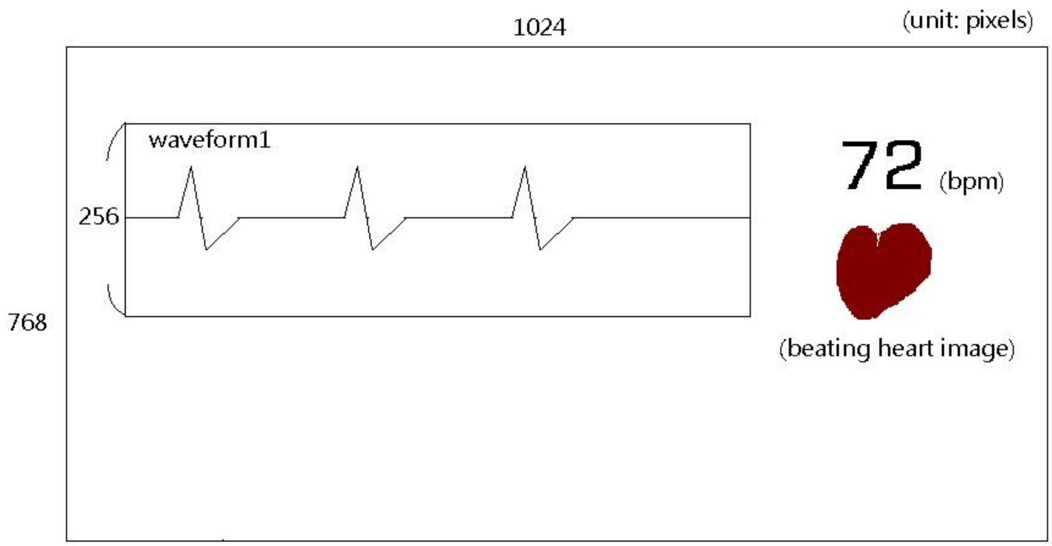
Sound Generation Block (Szu-Po)

Since it is impossible to have a person looking at the display screen at all time, having sound would make it much easier to monitor the patients' EKG signals. We plan to include two sounds in our design: a heart beating sound on each beat of the patient being monitored, and an alarm if we detected abnormality in EKG signal. The two 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:
Normally, this module will output silence. However, when the signal processing block detected abnormality in any patient's EKG signal, this module would take that information and 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.