Vellore Institute of Technology
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SCHOOL OF ELECTRONICS ENGINEERING

DEPARTMENT OF ELECTRONICS AND COMMUNICATION

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ECE1004-Signals and Systems

C2 Slot

DETECTION OF BREATHING AND INFANT SLEEP APNEA

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ABSTRACT-

Sleep apnea is a condition where people pause while breathing in their sleep; this can be of great concern for infants and premature babies. Current monitoring systems either require physical attachment to a user or may be unreliable. This project is meant to develop a device that can accurately detect breathing through sound and issue appropriate warnings upon its cessation. The device produced is meant to be a standalone device and thus was developed as an embedded systems project on a Xilinx Spartan 6 FPGA.

INTRODUCTION-

This project is a breath detection system; the particular aim of the project is to be able to detect the breathing of an infant. By being able to detect breathing you can notice when it stops and for how long, this is important due sleep apnea. Sleep apnea is a condition where people pause their breathing while sleeping. This can potentially be hazardous, especially for infant and premature babies where it is called apnea of prematurity if they are less than 37 weeks and apnea of infancy if they are older than 37 weeks. Apnea events are classified as cessation of breathing at least 20 seconds or longer. There is also a possible link between sleep apnea and sudden infant death syndrome, though it is debated. Various monitors already exist, some use attached electrical leads on the body to determine breathing and heart beats, while others are vibration sensors that detect movement of the baby. Monitors relying upon sensors attached to the body can be cumbersome and movement sensors are not always accurate. To this end a project was set out to build something that worked better without requiring direct contact with the body. Breath analysis is a broad subject and is mostly beyond the simple detection of a single breath to include characterization. Of course, these systems also use advanced techniques such as neural nets and genetic algorithms. For obvious reasons such advanced systems are impractical for compact, portable systems and thus were somewhat limited in aiding the project.

KEYWORDS-

Sleep apnea is a condition where people pause while breathing in their sleep; this can be of great concern for infants and premature babies. Attaching a lot of sensors to the body creates a lot of trouble for the patient. So instead of attaching sensors we can use microphone to record the sound of breathing and detect the delay between two successive breathing using programming and sent a message to the doctor whether the patient is having a sleep apnea or not.

Several **microphones** were used in the course of the project and any microphone should work given sufficient sensitivity and relatively low signal noise, though some calibration might be necessary. The final targeted microphone was a directional microphone from Audio Technica, the AT803 specifically, it does require a pre-amp and the ARTcessoires USB Dual Pre was used. In other testing a parabolic dish was used to help limit surrounding noise and may be helpful in nosier environments or to increase distance between patient and microphone.

System Requirements-

One of the crucial points of the device is that it be accurate, with extremely little chance of false negatives and few false positives while detecting apnea events. The device must be easy to operate and setup. No special training should be required to use or maintain the device and setup requirements should be minimal and unobtrusive. The device itself should be small in dimension not requiring large spaces and have few remote connections. The device should be powered from the wall with possible support for battery backup. To meet these needs some form of embedded system is desired

Hardware-

The main hardware for the project is the ATLYS project board from Digilent, as seen in Figure 2. This board features a Xilinx Spartan 6 LX45 FPGA, of special use to the project was the chips DSP48A1 slices which allows for efficient implementation of digital filters. The ATLYS board also features an AC'97 codec, National Semiconductor LM4550, which ideally would be used to sample incoming audio. It has a USB port used to power the USB pre-amp for the microphone system. Primary power is provided by a 20-watt AC to DC converter. The board does get warm so ventilation needs to be provided for in the packaging.

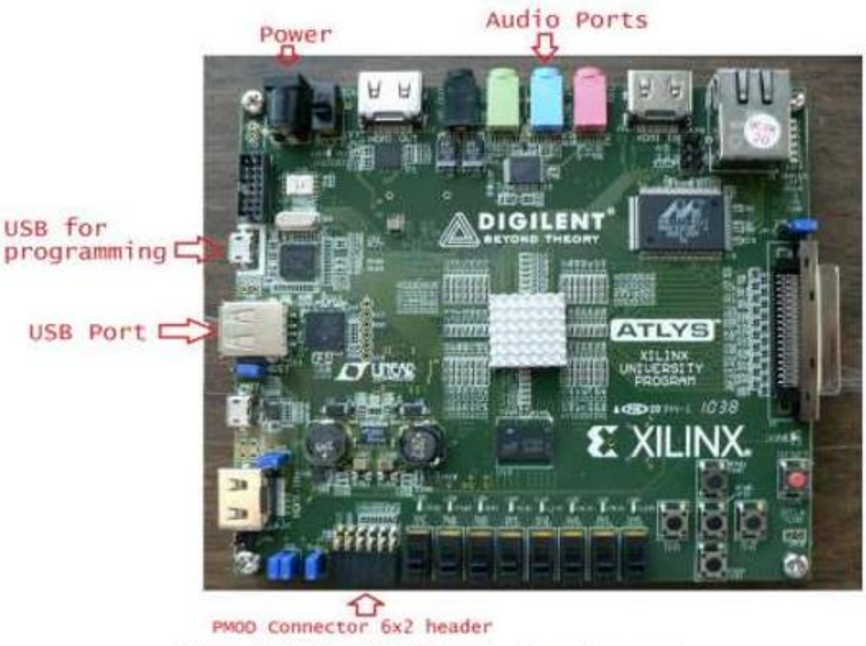
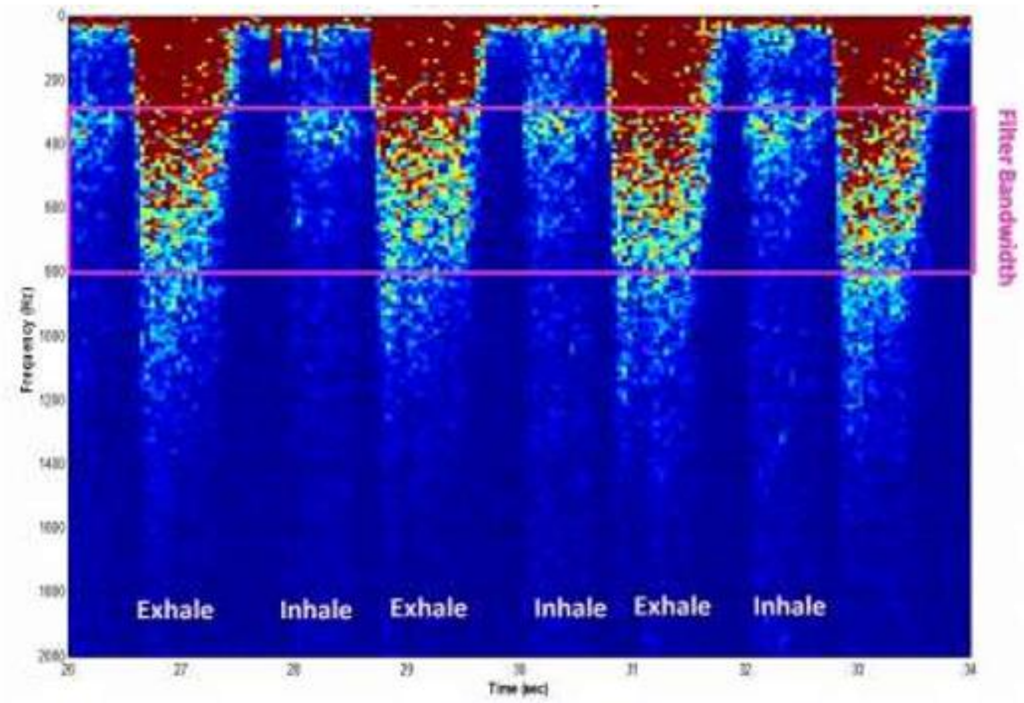


Figure 2 Digilent ATLYS board with ports marked

Due to difficulties in working with the AC'97 codec a separate analog to digital converter (ADC) was used, Digilent's PMOD AD1. This produces a 12 bit value representing the voltage read between 0 and 3.3 v (the voltage applied to the module). In addition the PMOD DA2 module, a 12 bit digital to analog converter (DAC), was used for testing and debugging purposes. Both of these devices run off 0 to 3.3 v provided from the board, however sound from a microphone has both positive and negative voltages. A level shifter was needed to shift the microphone output to all positive voltages so it could be read by the ADC, the circuit used can be seen in Figure 3 below. This simple circuit shifts the incoming voltage up by the reference voltage, and provides a gain of 2 to amplify the signal. Because we have only positive supply voltage an opamp capable of running without a negative voltage rail was required, an LM324 was used. This circuit also works to protect the analog converter, which cannot accept voltages outside 0 to 3.3 volts, by limiting output voltage from 0 to about 2 volts.

<u>VHDL Filter-</u>

A filter too complex for C to run in real time was desired but greater flexibility than a hardware filter was desired, as a compromise a VHDL filter was used. The first stage is a band pass filter for the 300 to 800 Hz range, as Figure 4 shows this is where there is clearly information sufficient to detect breathing but reduces the influence of external noise. Figure 4 Spectrogram of breathing.



The VHDL filter also provides the envelope of the signal rather than just a filtered waveform. This allows for simple peak detection to be done with software.

The envelope of a modulated sine wave can be seen clearly in yellow in Figure 5. Figure 5 Envelope filtering: Green is raw signal, yellow is the resulting envelope.

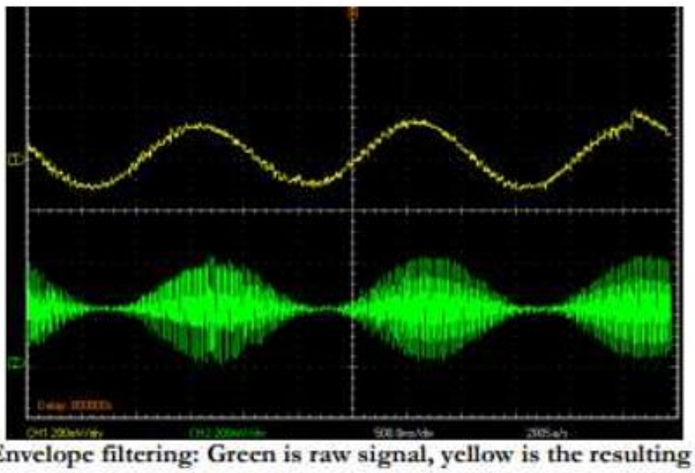
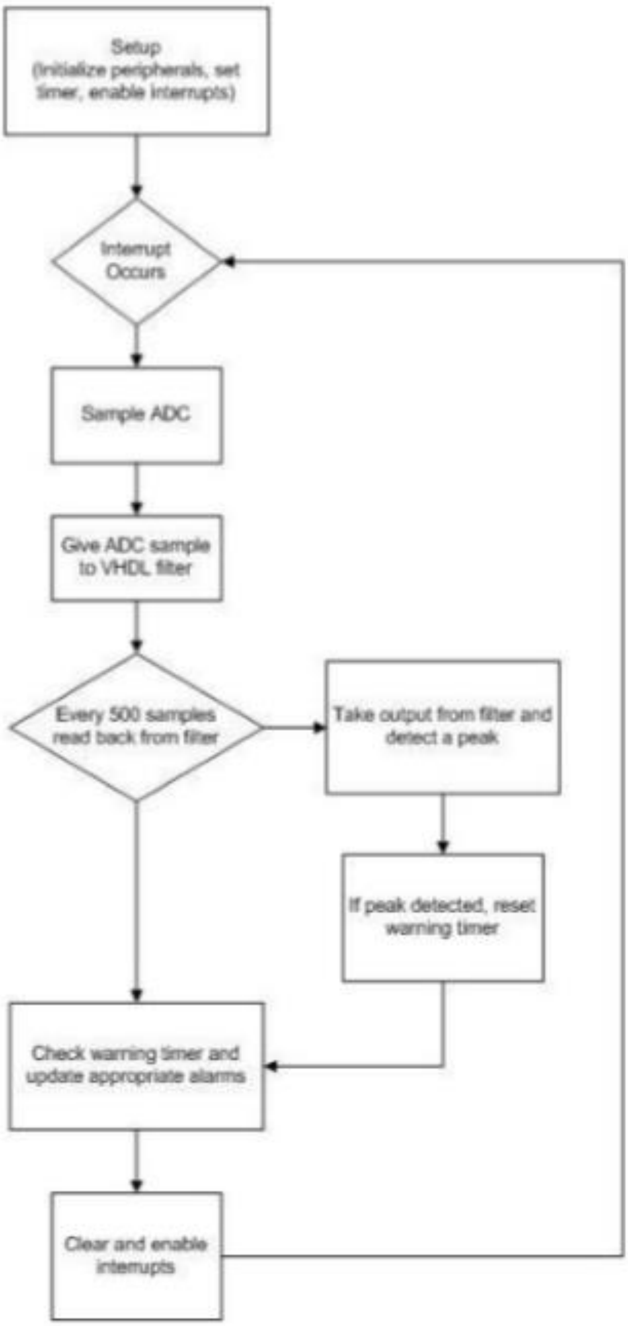


Figure 5 Envelope filtering: Green is raw signal, yellow is the resulting envelope

METHODOLOGY-

We will use the MATLAB code to develop the code to detect the breathing pattern of the individual and detect whether they have sleep apnea or not. But if we use Xilinx Board along with the VHDL filter we have to use C programming for proper working of the equipment.

BLOCK DIAGRAM



MATLAB CODE-

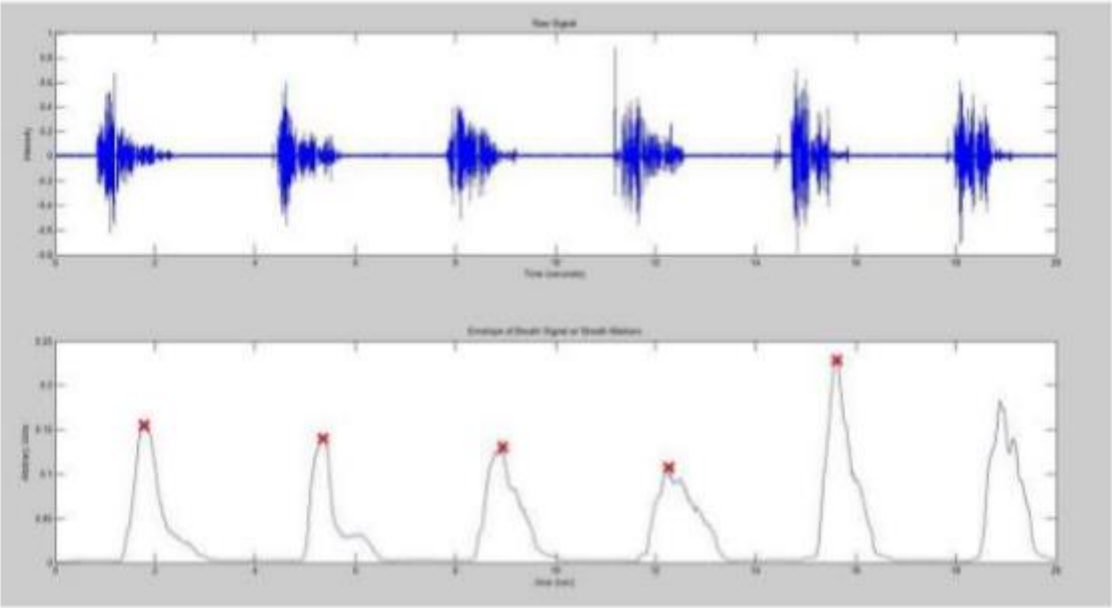
```
close all, clear all

%% Variables
low_stop = 300;
high_stop = 1000;
WindowEnvelope = 0.1;   % Length of envelope averaging filter window
(seconds)
MaximaWindow = 2.4;     % Length of window to find local maxima
(seconds)
DownSamp = 200;         % Frequency to downsampe envelope to (Hz)
Threshold = 0.2;        % Percentage of mean maxima value that a
breath must be above
Fs = 8000;              % Sampling Frequency
nbits = 8;              % Bits of Precision When Sampling
WindowTime = 5;         % Length of recorded time processed in each
batch (seconds)

%% Initialize
BreathCountTotal = 0;
y = audiorecorder(Fs,nbits,1);
meanbreath = 0;

%% Create Bandpass Filter
F=[(low_stop-100) low_stop high_stop (high_stop+100)];   % band limits
A=[0 1 0];                              % band type: 0='stop', 1='pass'
dev=[0.0001 10^(0.1/20)-1 0.0001];            % ripple/attenuation spec
[M,Wn,beta,typ]= kaiserord(F,A,dev,Fs);        % window parameters
b = fir1(M,Wn,typ,kaiser(M+1,beta),'noscale'); % filter design

%% Initialize
loopcount = 0;
EXIT = 1;
BreathTotal = [];

%% Initial Recoding
signal = zeros(1,Fs*WindowTime);
record(y)

while EXIT == 1
    %% Counter
    loopcount = loopcount + 1;

    %% Filter Signal
    signal_f = fftfilt(b,signal);
```

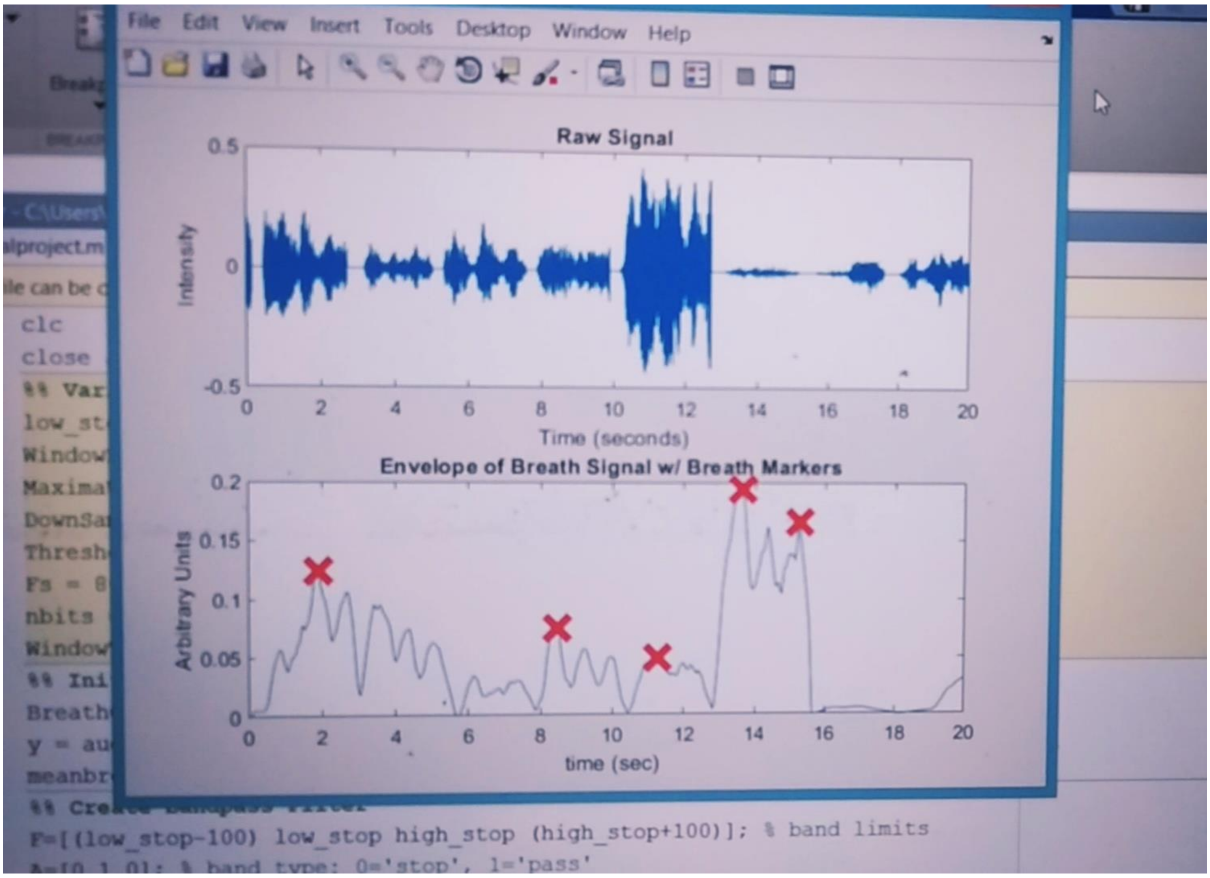
```
    %% Find Envelope
    signal_h = hilbert(signal_f); % Hilbert Transform
    envelope = sqrt(signal_h.*conj(signal_h));
    envelope_f =
filter(ones(1,round(Fs*WindowEnvelope))/round(Fs*.1),1,envelope);
    envelope_fDS = downsample(envelope_f,round(Fs*(1/DownSamp)));

    %% Find Local Maxima
    windowsize = DownSamp * MaximaWindow / 4;
    BreathCount = 0;
    Breath = [];
    for ix = 1:length(envelope_fDS) - windowsize
        maxima = max(envelope_fDS(ix:ix+windowsize));
        if loopcount < 2    % Ignore first 2 loops
        elseif loopcount < 100    % Use next 100 loops to get breath
threshold
            if maxima == envelope_fDS(ix+windowsize/2)
                BreathCount = BreathCount + 1;
                Breath(BreathCount) = ix + windowsize/2;
            end
        else    % Begin using and updating threshold
            if (maxima == envelope_fDS(ix+windowsize/2)) && maxima >
(Threshold * meanbreath)
                BreathCount = BreathCount + 1;
                Breath(BreathCount) = ix + windowsize/2;
            end
        end
    end
    BreathTotal = cat(2,BreathTotal,envelope_fDS(Breath));
    meanbreath = mean(BreathTotal);
    if isempty(Breath) && loopcount > 100 == 1
        for i = 1:10
            beep
            pause(.1)
        end
        EXIT = 0;
    end
    %% Keep Recording
    stop(y)
    signal_new = getaudiodata(y,'double');
    record(y)
    signal(1:end-length(signal_new)) =
signal(1+length(signal_new):end);
    signal(end-length(signal_new)+1:end) = signal_new;
    clear signal_new

    %% Plot
    figure(1)
    subplot(2,1,1)
    signalplot =  signal;
    time1 = (0:length(signalplot)-1) / (Fs/4);
```

```
    refresh
    plot(time1,signalplot)
    title('Raw Signal')
    xlabel('Time (seconds)')
    ylabel('Intensity')

    subplot(2,1,2)
    envelopeplot = envelope_fDS;
    time = (0:length(envelopeplot)-1) / (DownSamp/4);
    plot(time,envelopeplot)
    hold on

plot(Breath/(DownSamp/4),envelope_fDS(Breath),'rx','MarkerSize',16,'li
newidth',4)
    title('Envelope of Breath Signal w/ Breath Markers')
    xlabel('time (sec)')
    ylabel('Arbitrary Units')
    hold off
end
```

SAMPLE RESULTS-

The program took in audio data from a microphone and detected the peaks in the signal, as seen in Figure 1 below.





DISCUSSION-

This project is a breath detection system; the particular aim of the project is to be able to detect the breathing of an infant. By being able to detect breathing you can notice when it stops and for how long, this is important due sleep apnea. Sleep apnea is a condition where people pause their breathing while sleeping. This can potentially be hazardous, especially for infant and premature babies where it is called apnea of prematurity.

This system can be used to send early warnings to doctors and nurses so that they get to know about the problem and take necessary actions.

The project can be really helpful as by using this method we would be able to handle patients having sleep apnea in a safer and more advanced way without attaching any instrument physically to their body.

As this method is much more simpler than methods which involves attachment of instruments physically hence here the error percentage is very less and hence it gives accurate results. Various monitors already exist, some use attached electrical leads on the body to determine breathing and heart beats, while others are vibration sensors that detect movement of the baby.Monitors relying upon sensors attached to the body can be cumbersome and movement sensors are not always accurate.

CONCLUSION-

The project can be really helpful as by using this method we would be able to handle patients having sleep apnea in a safer and more advanced way without attaching any instrument physically to their body.

This system can be used to send early warnings to doctors and nurses so that they get to know about the problem and take necessary actions.

Thus by building this we can do something good to the society and we can also help the patients in the CMC(hospital).