FPGA implementation of ECG signal characterstics

1Dr B Khaleelu Rehman, 2Navya, 3Naveen, 4T.Rajani, 5Shivaranjani
1Associate Professor Dept of ECE, 2ECE,1Vth year student, 3ECE,1Vth year student, 4Associate Professor(HOD ECE), 5ECE,1Vth year student
Nalla Malla Reddy Engineering college

***Abstract* - The heart disease is dangerous and threat to human life. Most number of heart diseases are observed in the recent years .The diseases are diagnosed and cured completely if predicted in advance .The ECG signal, which contains the data, can be processed by different methods; there is a huge movement for the health care applications, which consists portable, less-cost monitoring applications like wearable watches, T-shirts. Electrocardiogram signal processing module is implemented in Verilog HDL and simulation on Xilinx Isim simulator. All the time domain parameters of ECG signal such as QRS complex, P wave, Q wave, R wave,S wave, T wave, PQ segment, QRS segment, ST segment, QT segments are implemented on high-end Zedboard Zynq-7020- series FPGA BOARD.**

***keywords* - Verilog HDL, FPGA board, Zed board**

I. INTRODUCTION

An electrocardiogram is an essential and fundamental diagnostic tool for recording the electrical activity of human heart. This activity is recorded by placing electrodes on the patient's skin.

The ECG signal is mainly a combination of P, QRS, and T waves. In a normal ECG wave, the major characteristic wave is R-peak and other waves P, Q, S, T are located by taking R-peak location as reference point. The most important part in ecg signal analysis is extracting and understanding of the QRS complex.

The ECG signal frequency range is 0.5Hz to 150Hz.This small frequency range makes ecg signal sensitive to noise. These noises effect the signal over the width frequency range, this makes the ECG denoising a difficult task.

STANDARD ECG VALUES:

Table 1.1 Standard ECG data [64]

Amplitude		***Description***	
P-wave	Voltage, 0.25 mV	P-R interval	Time (0.12 to 0.20) Sec
R-wave Q-wave	Voltage, 1.60mV Voltage, 25% of R wave	Q-T interval S-T segment	Time (0.35 to 0.44) Sec Time (0.05 to 0.15) Sec
T-wave	Voltage, 0.1 to 0.5mV	P wave Interval	Time (0.11) sec
		QRS complex	Time (0.09) Sec
		PR segment	Time (0.06 to 0.10) Sec
		ST segment T wave	Time (0.10 to 0.15) sec Depends on time variation

An ECG is a digital recording of the contractions in the heart. It is also called an electrocardiogram. For monitoring an electrocardiogram, electrodes are attached to the skin on the chest, arms, and legs.

3 Lead ECG: 3 lead ECGs are used for 24 reading

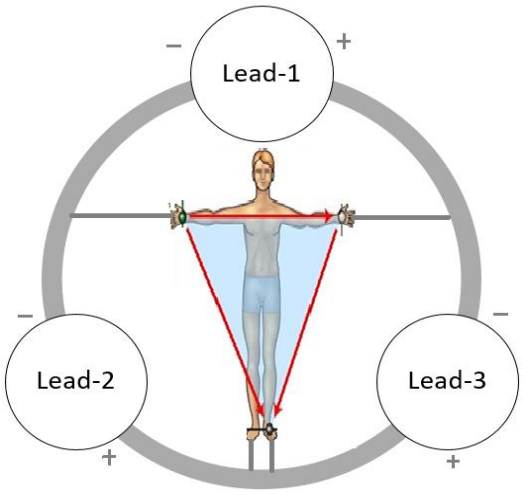

Fig 1.1

Fig 1.1 represents the 3 lead ECG system
The following equations supports the functionality of the system

Lead 1: $V_1 = \beta_L - \beta_R$

Where, β_L is the electric potential towards left arm

Lead 2: $V_{II} = \beta_F - \beta_R$

Where, β_R is the electric potential towards right arm

Lead 3: $V_{III} = \beta_F - \beta_L$

Where, β_F is the electric potential towards left foot

The analysis of the results shows

Lead 1 + Lead 2 = $\beta_L - \beta_R + \beta_F - \beta_L = \beta_F - \beta_R$ = Lead II

Similarly,
Lead II - Lead I= Lead III

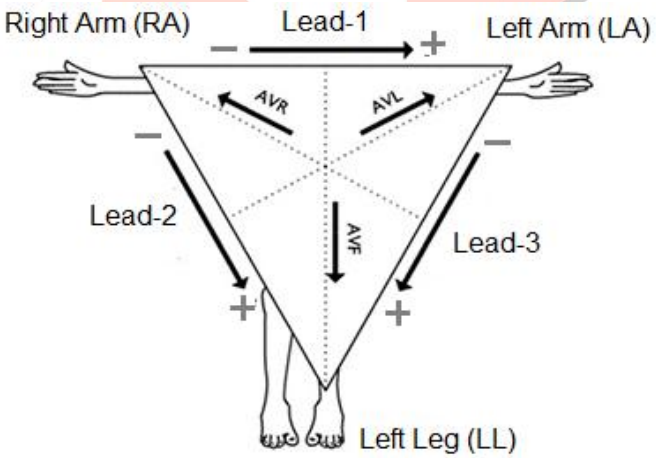

Fig 1.2

The ECG is a very safe test. The ECG leads are utilized to exchange a picture of the electrical action of the heart to trace on a paper. In the process, no electricity goes inside human's body from the machine, and there is no risk of getting an electrical shock. ECG signals are consequently vulnerable to several noises. The noise sources can be categorized into three different groups

- Originated noise from external sources to the patient
- Noise originated from the patient in case of moving condition.
- Unwanted electric voltages and interference created due to contacting the patient electrode.

At the point when an energized body is conveyed near an uncharged one, an equivalent and inverse charge is created over uncharged parts of body. For instance, if an ungrounded body is near any electronic machine, associated with 220V, 50 Hz mains supply, the body will build up surface electrons of equivalent and inverse potential despite the fact that minimum amount of current is flowing between the two bodies. This phenomenon is referred as Electrostatic Discharge (ESD). The process of electron exchange because of two objects approaching each other and after that separating by each is known as

'triboelectric charging'. The actuated potential will have the same frequency similar to main supply, as the frequency of main is 50 Hz.

Einthoven's law details that triangle points can be estimated along their values from one to another known points. It is very important and crucial for designing point of view. It can minimize the whole system design and reduces the complexity of hardware components used. The main important feature is that only two differential amplifiers are required. In the three lead ECG system, two lead are utilized for front-end hardware solutions and third lead is directly associated with software for simple subtraction or addition of values achieved from the two leads in the analog front end. Fig. 1.2 presents the position of leads as Einthoven's triangle corresponding to right arm and left arm.

II.LITERATURE REVIEW:

Many researchers has experimented ECG signal characteristics in MATLAB,LAB VIEW, Microcontroller based.

Rehman B et a1[1] proposed. A NOVEL APPROCH FOR R-PEAK DETECTION IN THE ELECTROCARDIOGRAM(ECG) SIGNAL. The R- Peak detection algorithm is implemented in MATLAB R 2012b.The R-wave in QRS complex play a vital role in the pathological diagnosis. ECG signal has variety of noises such as base line wander the 50HZ power line interface. These type of noises disrupts the original signal and detection of R-peaks. R-peak detection algorithm is executed using preprocessing and filtering techniques,windowing techniques and thresholding.

Rehman B et a1[2] proposed COMPARATIVE STUDY OF HIGH PERFORMANCE QRS COMPLEX DETECTION ON ELECTROCARDIOGRAM SIGNAL.A detailed comparison has been made between pan and Tompkins and derivative based algorithms for QRS detection of ECG signal.

Rehman B et a1[3] proposed HIGH PERFORMANCE ECG HEART BEAT MONITORING

In the research work, the chip design of the individual module and its integration as top-level chip and schematic is done successfully in Xilinx ISE14.2 software.The future research developed chip, design can be integrated and synthesis on recently launched virtex-7 highest performance and integration.

Rehman B et a1[4] proposed MODELING AND SIMULATION OF ECG SIGNAL FOR HEART BEAT APPLICATION.Electrocardiogram signal processing module is implemented in VHDL and simulation on mentor graphics modelsim simulator. An ECG signal which is a fuction of MATLAB is used as test input for modalism tool for simulator and functional verification. [5]-[10] Talked about ecg signal on FPGA

II. **PROPOSED SYSTEM**:

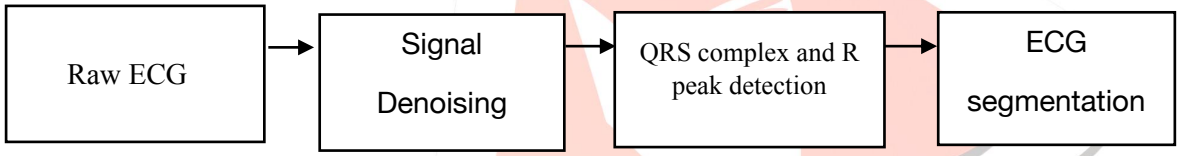

Fig 3.1 ECG system Block diagram

Raw ECG : An ECG raw signal is taken as an input which is from MIT-BIH database[11].The raw ECG signals are noisy signals which contain both low and high frequency components.

The MIT-BIH arrhythmia database is publicly available dataset which provides standard investigation material for the detection of heart arrhythmia. Since 1980, it is used for purpose of research on cardiac rhythm and related diseases.

Signal Denoising: In Signal processing, Denoising is eliminating noise from a given signal.The main objective of Signal Denoising is remove noise and preserve useful information.

In ECG signal, noise occur due to powerline interference, baseline wandering.By using bandpass filter noise is removed. And for the filtering process, ADTF (Adaptive dual threshold filter) [12], which is a more efficient than linear filters. The purpose of this filter is to calculate three elements for each window of the ECG signal. The mean of this window, the higher threshold and the lower threshold.

$Ht = g + [(Mx - g) * b]$,

$Lt = g - [(g - Mi) * b]$

Ht – High threshold, Lt-Lower threshold, g-mean, b- thresholding coefficient,

Mx – maxima of the window, Mi- minima of the window

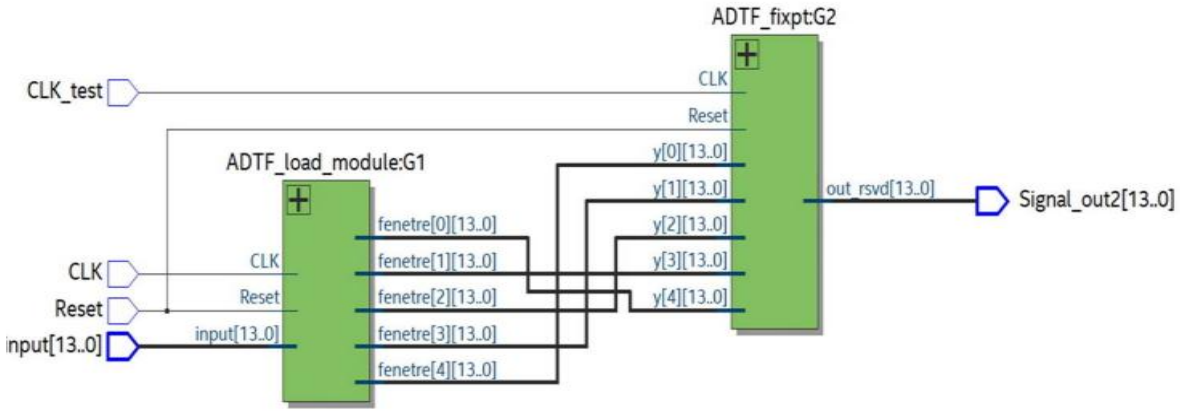

Fig 3.2 ADTF module RTL view

In ADTF, we have 3 steps:
1st step : it concerns about data loading by providing a real time process without occupying memory space.
2nd step: It makes possible to calculate elements necessary for ADTF processing
3rd step: Calculation of thresholding data.
In G1 load module, 4 sum and 1 division calculations are carried out.
In G2 fxpt module, Ht and Lt are calculate

QRS complex and R peak detection: QRS complex is major component in the ECG signal. The QRS duration represents time for ventricular depolarization. R peak is the highest peak in the ECG signal. It contains the major information about the heart.

ECG Segmentation:

ECG Segmentation locate the waves, segments, and intervals and carry out the comparision of these with known patterns, through their characteristics of time and morphology.

RTL:

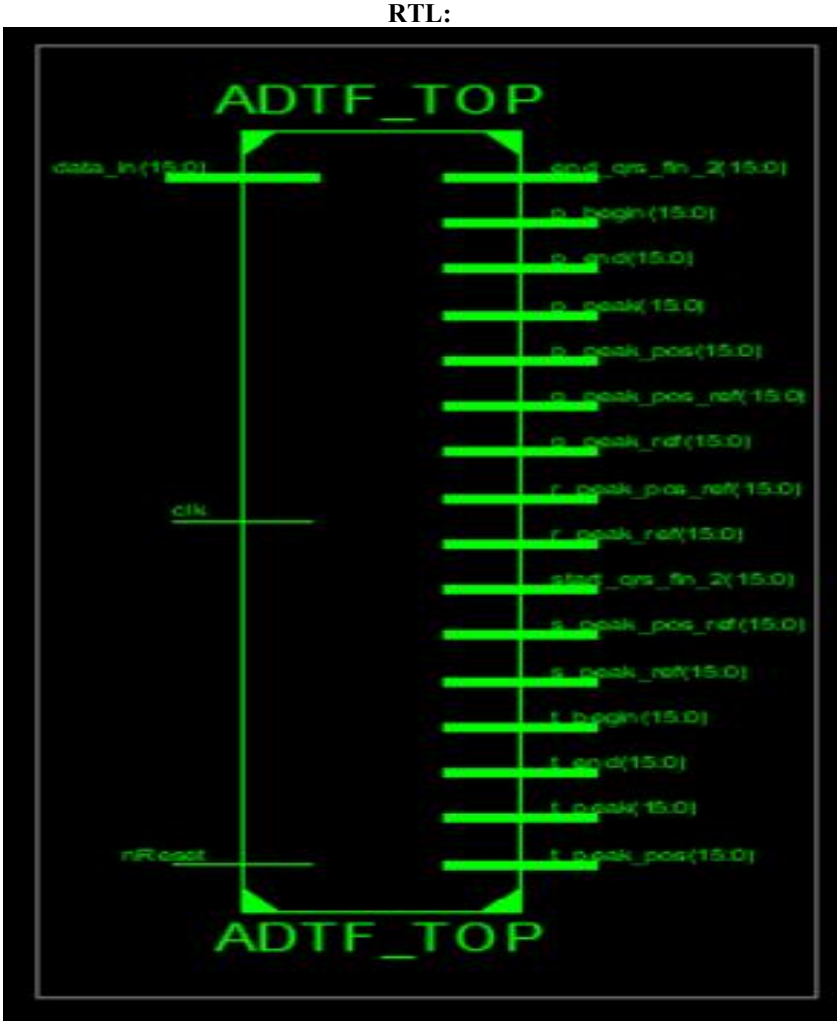

Fig 3.3 ECG top level RTL view

Inputs: RTL shows the top level module of th**e work from the figure it can be observed that the inputs are** data_in[15:0], clk, nR reset

Outputs: From the above RTL outputs are q_ peak_ref[15.0],q_peak_ pos_ref[15.0],r_peak_ref[15.0],r_peak _pos_ref[15.0],s_peak_ref[15.0],s_peak_pos_ref[15.0],start_qrs_fin_2[15.0],end_qrs_fin_2[15.0],p_begin[15.0],p_end[15.0],p _peak[15.0],p_peak_pos[15.0],t-begin[15.0],t-end[15.0],t_peak[15.0],t_peak_pos[15.0].It can be viewed that all the output data are of 16 bit lengths.

IV.Results and Discussion

Simulation results:

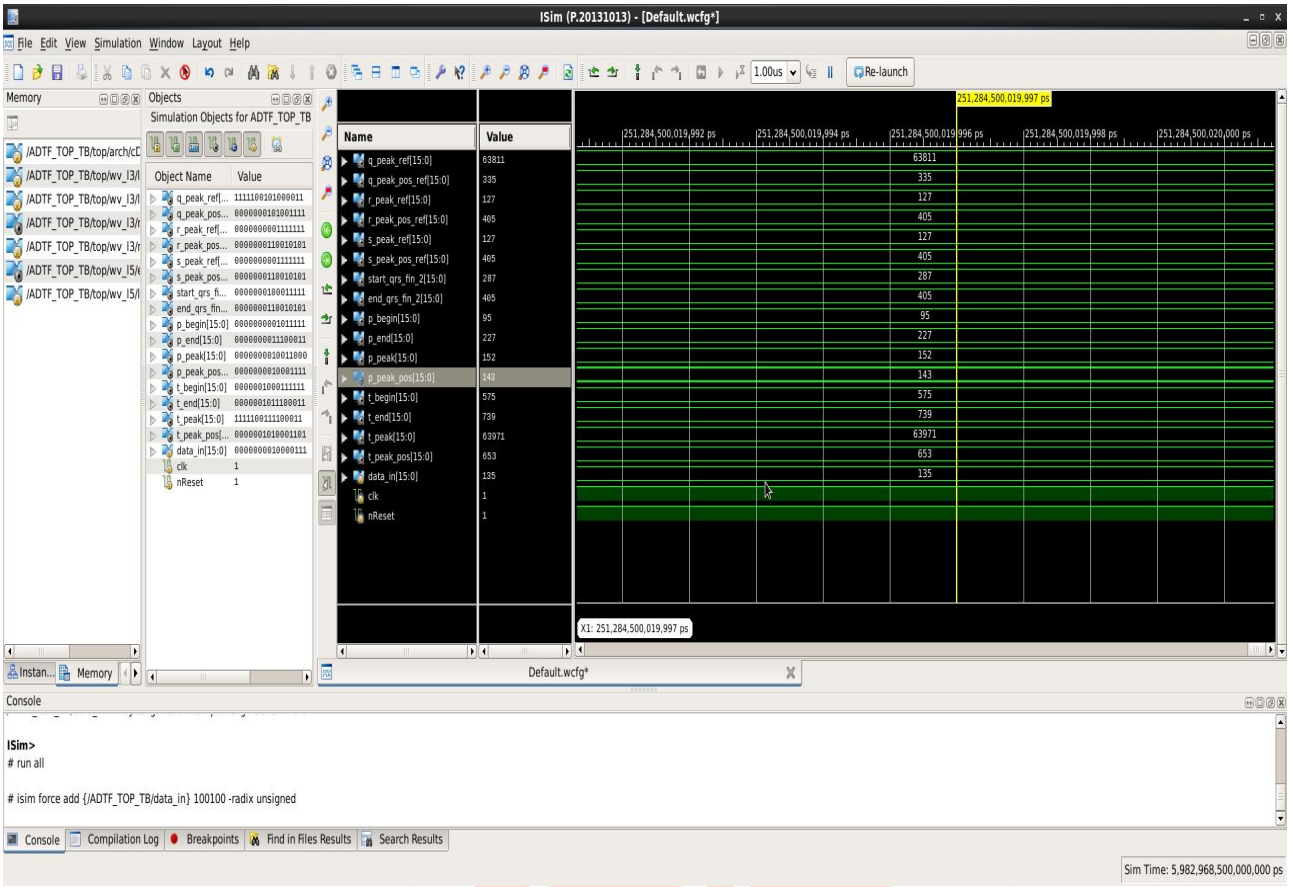

Fig 4.1 Simulation results

Fig shows the top level simulation by using ISIM simulator. The ECG signal can be given as a data. By applying the 16 bit data in the input data_in[15:0] and then run the simulation. All the inputs and outputs are assigned to the unsigned decimal format for better viewing the results. From the simulation analysis the p wave of the signal starts at 95 and ends at 227,qrs wave of the signal starts at 287 and ends at 405,and t wave of the signal starts at 575 and ends at 739.

Table 4.1: ECG signal parameters in time domain

ECG signal parameters	**Time in sec**	**Time in msec**
P	227-95=132	0.132
Qrs	405-287=164	0.164
T	739-575=118	0.118

Amplitude: The threshold value is 100.From simulation analysis for peak values, the p peak of the signal is 143.Q peak value is 112.R peak value is 405.

Table 4.2.ECG signal parameters in Amplitude

ECG signal parameters	***Amplitude(V)***	***Amplitude (mV)***
P	143	143-100=43mV
Q	112	112-100=12mV
R	405	405-100=305mV

In the ECG signal the threshold value is substracted from peak value.P peak value is 143v after subtracting threshold 100 value final value is 43mv.Similarly, we get Q,R peak values

Table 4.3. HARDWARE DEVICE UTILIZATION SUMMARY:

Device Utilization summary			
Logic Utilization	***Used***	***Available***	***Utilization***
Number of Slice Registers	17789	106,400	16%
Number of Slice LUTs	82874	53,200	80%
Number of fully used LUT-FF pairs	6076	94587	6%
Number of bonded IOBs	274	300	90%
Number of BUFG/BUFGCTRLs	2	32	6%

The number of Slice Registers available are 106,400 and used 17789 registers.The number of slice Look Up Tables available are 53200 and used 82874.The number of fully used Look Up Tables available are 94587 and used 6076.The number of bonded IOBs available are 300 and used 274.The number of BUFG/BUFGCTRLs available are 32 and used 2.

Table 4.4 The Timing Values for configured devices on xc7a100t-3csg324 on FPGA

Timing Parameter	*Utilization*
Max Frequency	88.940 Mhz
Minimum Period	11.24ns
Time before clk (minimum)	9.157 ns
Time after clock (maximum)	6.518 ns
Combinational Path delay	3.470 ns
Speed Grade	-3

The maximum frequency value is 88.940 Mhz and the time delay for output is 11.24ns
Table 4.3 shows the hardware utilization of the FPGA parameters: number of Slice Registers, number of Slice LUTs, number of fully used LUT-FF pairs, number of fully used LUT-FF pairs, Number of bonded IOBs, Number of BUFG/BUFGCTRLs

ACKNOWLEDGEMENT
The authors would like to thank the VLSI Lab, Head of the Department Mrs.T.Rajani, Department of Electronics and Communication Engineering, Nalla Malla Reddy Engineering College, Hyderabad for providing cooperation and laboratory facility to carry out our research work.

CONCLUSION
Electrocardiogram signal processing module is implemented in Verilog HDL and simulation on Xilinx Isim simulator. All the time domain parameters of ECG signal such as QRS complex, P wave, Q wave, R wave,S wave, T wave, PQ segment, QRS segment, ST segment, QT segments are implemented on high-end Zedboard Zynq-7020- series FPGA BOARD.Hardware device utilization summary and the timing values are tabulated.The time delay is also tabulated.Signal denoising by using wavlets is carried out.

REFERENCES
[1] Rehman, B. Khaleelu, Adesh Kumar, and Paawan Sharma. "A novel approach for R-Peak Detection in the Electrocardiogram (ECG) signal." *ARPN Journal of Engineering and Applied Sciences* 11.21 (2016): 13500-13503.
[2] Rehman, B. Khaleelu "COMPARATIVE STUDY OF HIGH PERFORMANCE QRS COMPLEX DETECTION ON ELECTROCARDIOGRAM SIGNAL".
[3] Rehman, B. Khaleelu. "High Performance ECG Heart Beat Monitoring." (2018).
[4] Khaleelu Rehman, B., Adesh Kumar, and Paawan Sharma. "Modeling and simulation of ECG signal for heartbeat application." *Intelligent Communication, Control and Devices*. Springer, Singapore, 2018. 503-511.
[5] Jenkal, Wissam, et al. "An efficient algorithm of ECG signal denoising using the adaptive dual threshold filter and the discrete wavelet transform." *Biocybernetics and Biomedical Engineering* 36.3 (2016): 499-508.
[6] ECG, ADAPTIVE DUAL THRESHOLD FILTER BASED. "Real-time hardware architecture of the adaptive dual threshold filter based ECG signal denoising." *Journal of Theoretical and Applied Information Technology* 96.14 (2018).
[7] Mali, Barbara, et al. "Matlab-based tool for ECG and HRV analysis." *Biomedical Signal Processing and Control* 10 (2014): 108-116.
[8] Talatov, Youkubjon, and Talat Mgrupov. "Algorithmic and software analysis and processing of ecg signals." *2019 International Multi-Conference on Engineering, Computer and Information Sciences (SIBIRCON)*. IEEE, 2019.
[9] Mayapur, Priyanka. "Classification of Arrhythmia from ECG Signals using MATLAB." *International Journal of Engineering and Management Research* 8.6 (2018): 115-129.
[10] Ojha DK, Subashini M. Analysis of electrocardiograph (ecg) signal for the detection of abnormalities using matlab. International Journal of Biomedical and Biological Engineering. 2014 Feb 6;8(2):120-3.
[11] https://physionet.org/content/mitdb/1.0.0/
[12] Jenkal, Wissam, et al. "FPGA Implementation of the Real-Time ADTF process using the Intel-Altera DE1 Board for ECG signal Denoising." *2019 4th World Conference on Complex Systems (WCCS)*. IEEE, 2019.

.