Design and Simulation Approach Introduced to ECG Peak Detection with Study on Different Cardiovascular Diseases

Sayanti Chattopadhyay[1], Susmita Das[2], Avishek Nag[3], Jayanta Kumar Ray[4], Soumyendu Bhattacharjee[5], Dr. Biswarup Neogi[6]

[1]Asst. Prof., EIE Dept., JISCE, WB, India, **chatterjeesayanti@gmail.com**
[2] Asst. Prof., EIE Dept., JISCE, WB, India,**susmitad2011@gmail.com**
[3] M-Tech Scholar, ECE, HIT, WB, India, **avisheknag89@gmail.com**
[4] Asst. Prof., ECE Dept., KIEM, Mankar, WB, India
[5] Asst. Prof.& HOD, ECE Dept., KIEM, Mankar, W.B, India, **s_vlsi@yahoo.com**
[6] Faculty member, ECE Dept., JISCE, Kalyani, WB, India, **biswarupneogi@gmail.com**

Abstract- Many research works has been done on ECG signal analysis. Present work is on ECG peak detection which are vital for different disease determination or heart malfunctioning is defined. Here simulation approach is attempted. For various diseases, different ECG signals' table representation is given in this paper. System prototype design is attempted. Including computational algorithmic approach it is visualized. In simulation approach ECG data analysis & peak detection is done.

Index Terms- EPD(ECG Peak Detector), ECG simulator, Cardiovascular disease, Regular ECG signal, Real life ECG H/W acquisition

I. Introduction

Bioinformatics is the application of computer technology to the management of biological information. An ECG (electrocardiogram) represents cardiac signals generated by cardiac muscles. A typical ECG cycle contains wave segments P, QRS and T which represents periodic depolarization and repolarization of atria and ventricles in a sequential manner. QRS, being the most striking segment of the waveform assumes special significance for cardiac interpretation of ECG signal. With the semiconductor technology advancement, embedded systems[1] are adopted to implement an ambulatory ECG monitor as a primary signal-processing device for detecting irregular heart conditions by evaluating ECG signals. Modern digital ECG equipment often includes some form of algorithm that performs a computer interpretation of the electrocardiogram. This paper illustrates a real time QRS detection algorithm using a microcontroller based embedded system. The algorithm[2] is tested on MATLAB platform. QRS complexes detection was based upon digital analyses of slope, amplitude, and width. A special digital band-pass filter was used to reduce false detections caused by the various types of interference present in ECG signals. The algorithm used here had the ability to adjust thresholds and parameters periodically.

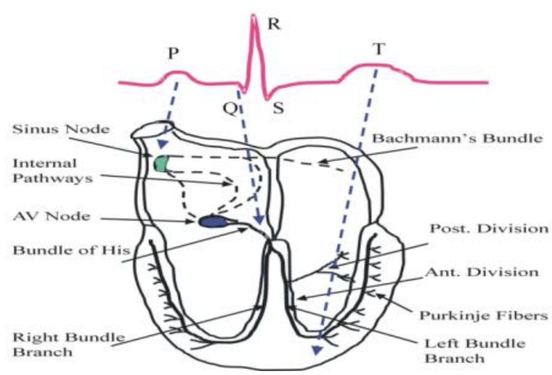

Fig 1: ECG generation in heart [1]

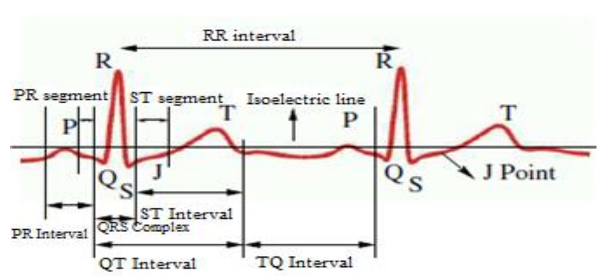

Fig 2: Normal Electrocardiogram [1]

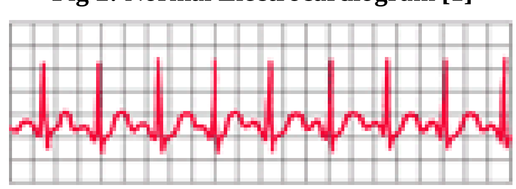

Fig 3: Fast Heartbeat [3]

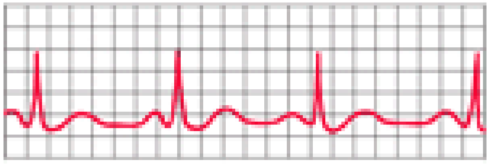

Fig 4: Slow Heartbeat [3]

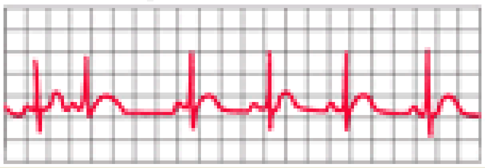

Fig 5: Irregular Heartbeat [3]

1.1 Characteristics of Normal ECG Signal [1]

Amplitude and duration of different wave, interval and segment as follows-

Amplitude:

- P wave: 0.25mV
- R wave: 1.60 mV
- Q wave: 25% of R wave
- T wave: 0.1 to .5mV

Duration:

- P-R interval: 0.12 to 0.20 sec
- Q- T interval: 0.35 to 0.44 sec
- S- T segment: 0.05 to 0.15 sec
- P wave interval: 0.11 sec
- QRS interval: 0.09 sec

Table-1: Regular ECG Signal

P Wave	Q Wave	R Wave	S Wave	T Wave
P wave is less than 2.5 mm. (0.25mv in amplitu-de & less than 2.5 mm, 0.12sec in width)	Q wave is less than 0.04 sec in duration and less than 25% of R waves	In limb lead, R wave is at least 5 mm in amplitu-de & in pericard ial lead, R wave is 10 mm in amplitu-de	S wave magnitu de is greater than R wave in amplitu de in lead v1 & smaller than R wave in amplitu-de in lead v6	In limb lead, T wave does not exceed 5mm. & in pericard ial lead it is 10 mm. in amplitu-de

1.2 Review for different diseases for P, R&T peak detection change

This paper gives an idea for real-time QRS detection [1] from ECG.

Jiapu Pan and Willis J. Tompkins have developed a real-time algorithm [2] for detection of the QRS complexes of ECG signals.

The diagnostic system for ECG rhythm monitoring [3] was based on syntactic approaches. A given frame of signal is first approximated piecewise linearly into a set of line segments which are completely specified in terms of their length and slope values.

In Paper [4] MIT-BIH Arrhythmia Database has been used for the detecting the performance of real-time QRS detection algorithms for the selection of QRS detectors.

In paper [5] ECG detection has been performed using continuous wavelet transform (CWT). Wavelet transforms are applied to decompose the signal into a set of coefficients that describe the signal frequency content at given times.

Paper [6] proposes an embedded real-time QRS detection algorithm system.

In paper [7] the QRS detection algorithm is based on the Empirical Mode Decomposition (EMD). Empirical mode decomposition can decompose the signal into a series of intrinsic mode function (IMFs).

The QRS detector [8] is based on the Hamilton- Tompkins algorithm. The preprocessor stage enhances the QRS complex by reducing the contribution of the non-correlated noise.

In paper [9] the algorithm is used for the characteristics of reconstructed phase portraits by delay coordinate mapping utilizing lag rotundity for a real-time detection of QRS complexes in ECG signals.

The method [10] consists of combining the differential threshold method and the amplitude detection method which is introduced for localization of R-waves.

Paper [11] presents a Hilbert transform method for extraction of the fetal heart rate. The method may be applied to signals derived from a single channel or an array of channels.

In this paper[12] an FPGA implementation of Real Time QRS Detection is presented.

Table-2: Essential tabular representations of parametric change ECG peaks (PQRST)

DISEASES	AMPLITUDE & WIDTH OF WAVES	CAUSES	SOLUTION
Mitral Valve Disease	In this condition, P wave is broad. P wave exceeds 2.5mm, 0.10sec in width. (P wave >2.5mm in width)	1.Rheumatic Fever (a childhood illness) 2.Endocarditis (an infection of endocardium of the heart) 3.Untreated high blood pressure	1.Heart muscle and blood vessel surgery is the best remedy 2.Mitral valve replacement or repairment can be done

		4.Leakage of blood into the left atrium into heart	
Myocardial Infarction	In this condition, Q waves are more than or equals to 0.04 sec in duration and more than 25% in depth of ensuring R waves. (Q waves => 0.04sec)	1.High blood pressure is the main cause which reduces blood supply to the heart muscle 2.When Thrombosis (blood clotting) occurs inside the coronary artery 3.Inflammatio-n of the coronary artery due to infection, injury or illness 4.Taking excessive cocaine	1.This disease can be significantly reduced if the symptoms are recognized early 2.Physical activities should be limited 3.Use of sedative, anxiolytic and hypnotic drugs at night may be helpful 4.Patients should avoid smoking and cocaine
Hypothyro -idism	In this condition, QRS complex is less than 5mm in limb leads and 10mm in pericardial leads. (QRS complex<5mm in limb leads, QRS complex<10mm in pericardial leads)	1.Grave's disease (abnormalities of body's immune system) 2.Excessive production of thyroxin from pituitary 3.Thyroiditis (inflammation of the thyroid gland) 4.Taking excessive iodine from diet	1.Should have primrose oil 2.Food that contains calcium, zinc, iron, copper, terbium are very useful 3.Spirulina is a good health booster and it can control the thyroid stimulation
Asthma	In this condition, QRS complex is wider. QRS complex exceeds 0.12sec in width. (QRS complex>1.2sec in width).	1.Excessive tobacco smoking 2.Long term inhalation of fume or any other chemical pollutants 3.CO2 deficiency in cholinergic	1.3-9 times reliever meditation 2.About 2 times less steroidal drugs 3.Sufficient

		nerve 4.Inflammation of airways due to any infection	physical activity.
Tricuspid valve regurtation	Heart muscle is stretcthed and chamber become enlarged, duration of P wave is 0.8-0.1 sec(max 0.11 sec)normal frontal plane of p wave axis in region +45 to 75degree.	Tricuspid regurgitation can cause vague symptoms, such as weakness and fatigue. They develop because the heart is pumping a smaller amount of blood	Usually, mild tricuspid regurgitation requires little or no treatment. However, the underlying disorder, such as emphysema, pulmonary hypertension, pulmonic stenosis, or abnormalities of the left side of the heart, is likely to require treatment.
Mytral stenosis	Normal P wave axis is between 0° and +75°.P waves should be upright in leads I and II, inverted in a VR. amplitude < 2.5 mm in the limb leads, Amplitude < 1.5 mm in the precordial lead	1.Complication of strep throat, rheumatic fever can damage the mitral valve, leading to mitral valve stenosis later in life. 2.In rare cases, babies are born with a narrowed mitral valve and develop mitral valve stenosis early in life. 3.Rarely, growths, blood clots or tumors can block the mitral valve, excessive calcium deposits can build up around the mitral valve, which	1. avoiding foods that are high in sodium (salt) 2. avoiding caffeine, which can exacerbate arrhythmias (irregular heartbeats). Children should limit their intake of caffeinated beverages, like soda. 3.Maintaining a healthy weight; being overweight causes the heart and lungs to work harder 4. surgical valve repair or replacement have excellent success rates for restoring normal heart function and blood flow.

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		sometimes causes significant mitral valve	

II. Prototype Block Diagram Representation of ECG Peak Detector (EPD)

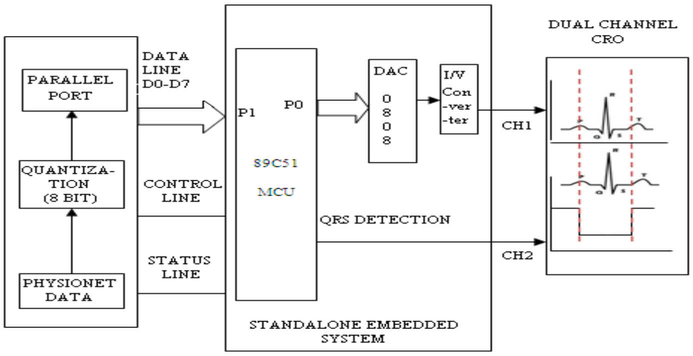


Fig 6: Block diagram of EPD [1]

Block diagram consists of two main modules.

I. **Block1** Synthetic ECG Signal Generator (PC) consists of

- Physionet Database
- 8-Bit Quantizer
- Parallel Port

In **block1** PC generates synthetic ECG data from a real ECG database (Physionet Database). Data of Physionet[8] Database are of 16 bit resolution which is converted into 8 bit data using Quantizer . This 8-Bit Quantized data has to be sent to SES (Standalone Embedded System) for R- peak detection. When a high to low transition is generated by PC, then Microcontroller will generate the square wave of 1 kHz frequency. The quantized[9] ECG samples are put on data lines D_0-D_7 by the MATLAB program on each rising edge of the pulse train. These samples are read at the microcontroller port at the next immediate falling edge of the square wave.

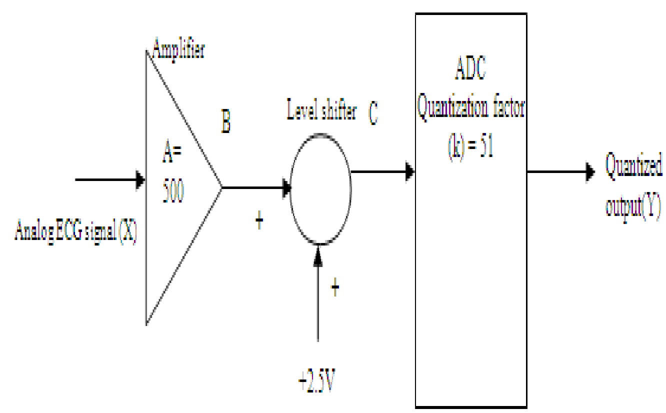
II. **Block 2** Standalone Embedded System consists of

- Microcontroller (89c51/ 89c52)
- DAC 0808
- I/V converter

In this block a DB-25 male type connector is used for data receiving from the PC-based platform.A DAC-0808 is connected to the P0 port of the microcontroller, through which the quantized ECG data samples, transferred from the PC, is again converted into an analog signal. A current-to-voltage converter is used along with the DAC-0808 for signal conversion. The voltage output is fed to one channel of an oscilloscope.P2.0 pin of microcontroller is toggled each time the microcontroller senses an R-peak and a rectangular wave shape is generated through that pin. These two signals, the synthetic ECG data signal and the QRS indication[10], are displayed at the two channels of a dual slope oscilloscope. By this arrangement, the QRS detection[7] can be verified.R-peaks will be detected in microcontroller. This detected R-peaks will be shown in the CRO by the alternating transaction of a line.

2.1 Simulation approach towards ECG peak detection

The algorithm for real-time QRS detection is implemented on digitized (8-bit)[4] synthetic ECG data generated from Physionet database using a PC-based system. To simulate the real time computing environment, a PC based system is developed where the digitized ECG samples will be delivered at 1 ms interval to the standalone embedded system, using parallel bus. ECG samples from a single lead data is quantized and delivered to the standalone embedded[5] system, which detects the R-peaks. The entire work consists into two parts. The generation of digitized ECG from ptbdb file, and development and testing of the algorithm using microcontroller. [6]



X= ECG sample
A= amplification factor=500;
B= amplified output= X*A;
C= amplified output with DC shift= B+2.5V
K= quantization factor= 51;
Y= final quantized output= C*51= [(X*A)+2.5]*51

Fig 7: Schematic diagram of Real-life ECG hardware acquisition [1]

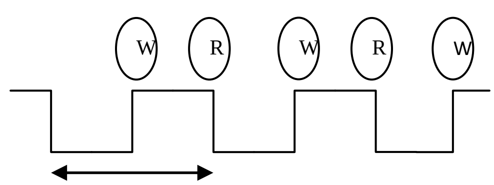


Fig 8: Data transfer scheme through parallel port [1]

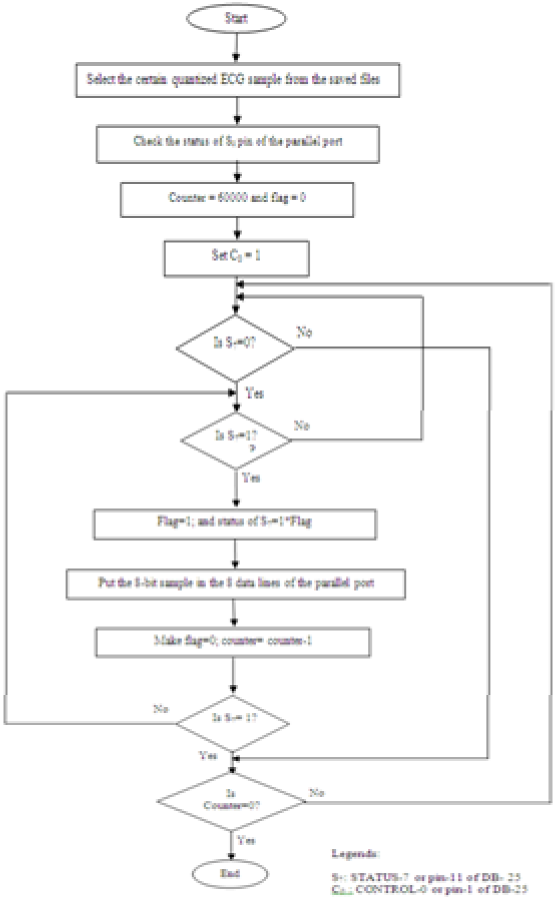


Fig 9: FLOWCHART OF AND DATA TRANSFER USING PARALLEL PORT IN MATLAB [1]

2.2 ECG QRS detection

In the training period using first 1500 samples the QRS signature, its nature of polarization by estimation of average slope [11] and its sign (positive or negative)is determined. The slope is computed by:

$$slp_j = \frac{S_{i+j} - S_i}{j-1}$$

where, slp_j = slope computed over a span of j-samples, ranging from i to i+j; S_j = *magnitude of* $j^{th.}$ *Sample*

Since the QRS peak[11] is having an upside and downside curvature, a 20-sample average slope w.r.t the midpoint of the FIFO stack will be continuously computed to capture the maximum value, with the objective of upside and downside slope of QRS peak. A probable QRS will be detected based on matching of a predefined threshold of slopes, and confirmed by comparing magnitudes of the samples[12] to their neighbors. Probably the most important complex in the electrocardiogram is the QRS. In QRS detection procedures, the evaluation criteria related to the performance of the algorithm are Sensitivity (Re) and Positive Predictivity (P+). They are defined as follows:

$$R_e = \frac{TP}{(TP+FN)}, \qquad P+ = \frac{TP}{(TP+FP)}$$

Where, TP = TRUE-POSITIVE detection of all QRS complexes. FN = False-Negative detection for all missed QRS complexes and FP = FALSE- POSITIVE detection for the number of misdetections.

2.3 Analysis and simulative approach towards ECG peak detection (<u>Results with in MATLAB)</u>

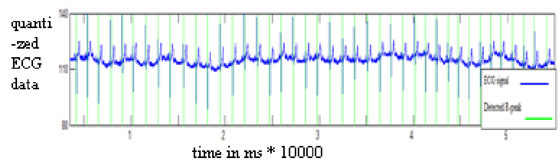


Fig 10: Detected R-peaks shown from mit-bih [3]

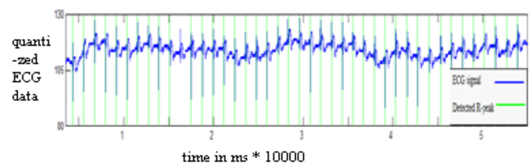


Fig 11: Detected R-peaks shown from mit-bih [3]

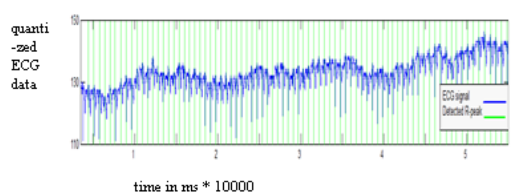


Fig 12: Detected R-peaks shown from ptb-db

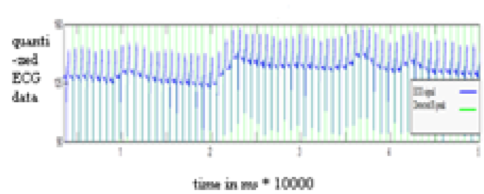


Fig 13: Detected R-peaks shown from ptb-db [3]

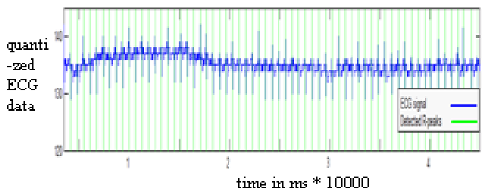


Fig 14: Detected R-peaks shown from ptb-db [3]

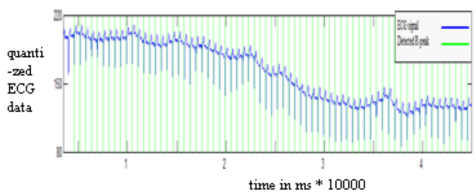


Fig 15: Detected R-peaks shown from ptb-db [3]

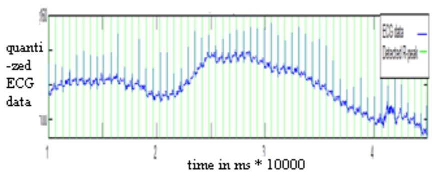


Fig 16: Detected R-peaks shown from ptb-db [3]

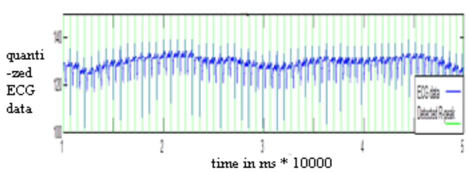


Fig 17: Detected R-peaks shown from ptb-db [3]

III. CONCLUSION

This work is done in a bridge with biomedical & signal systems. Here peak analysis is done and frequency domain analysis (Fourier Transform) will be done in future. Apparent change in wavelet domain will be analysed. An ECG signal defines heart characteristics. As disease changes ECG signal changes. If these two signals are compared then a good work can be done. Till now the analysis is done with R-peak but in future the work will go on with the other peaks too. A computational intelligence is created for different heart diseases. The PC-based ECG signal simulator designed for ECG data supply to the hardware can be used for any other research based processing procedures of ECG signal where parallel data transfer scheme in required.

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BIOGRAPHIES

Sayanti Chattopadhyay is awarded the degree of M.Tech in Instrumentation &

Control Engg. from Calcutta University (Rajabazar Science College) in 2012. Before that she received the B.Tech degree in Electronics and Instrumentation Engineering Dept. from AOT (WBUT) in 2009. Recently, she is engaged as an Assistant professor rank of EIE Dept. in JISCE, Kalyani. Her research interest includes Biomedical Engineering etc.

Susmita Das is awarded the degree of M.Tech in Instrumentation & Control Engg. from Calcutta University (Rajabazar Science College) in 2011. Before that she received the B.Tech degree in Electronics and Instrumentation Engineering Dept. from GNIT(WBUT) in 2008. Now she is engaged as an Assistant professor rank of EIE Dept. in JISCE, Kalyani. She has been engaged as a successful examiner of WBUT curriculum. She has initiated her PhD (engineering) under the supervision of Dr. B .Neogi. Her research interest includes Control Theory, Process control, Biomedical Engineering etc.

Avishek Nag is presently a teaching assistant and M-Tech Scholar in Heritage Institute of Technology, Kolkata. He received the B-Tech degree in Electronics and Communication Engineering from Durgapur Institute of Advanced Technology and Management in 2012. He has published a paper in an international conference (Elseviers). His research interest includes Control Theory, Biomedical Engineering, Simulation aspects, Communication etc.

Jayanta Kumar Ray received degree AMIETE from IETE Calcutta Centre. After that he awarded M.Tech in Electronics and Communication Engineering Dept. from MCKV College of Engineering. Recently, he is engaged as an Assistant professor rank of ECE Dept. in KIEM, Mankar. His research interest includes Control Theory, Biomedical Engineering, Microwave Engineering etc.

Sri. Soumyendu Bhattacharjee is designated as a Head of Electronics & Communication Engineering Dept. in KIEM, Mankar. Recently, he has initiated his PhD(engineering) under the supervision of Dr. B.Neogi. He received M.Tech degree in VLSI from B.E.S.U, Shibpur. Before that He obtained B.Tech in ECE from JIS College of Engineering, Kalyani. He is having a teaching experience of two and a half years in AIEMD Panagarh and three and a half years in KIEM, Mankar. He has been engaged as a successful examiner of WBUT curriculum. He was also awarded as for his innovative teaching idea from AIEMD Panagarh. His research interest includes Prosthetic heart Control, Biomedical Engineering, Digital Simulation, Microcontroller based Embedded System, VLSI, DSP etc.

Dr. Biswarup Neogi is awarded PhD (Engineering) from Jadavpur University, India. He received M.Tech degree in ECE from Kalyani Govt. Engg. College in 2007. Before that He obtained B.E in ECE from UIT, The University of Burdwan in 2005.He has a experience on various project of All India Radio attach with the Webel Mediatronics Ltd, Kolkata. He was a lecturer in ECE Dept, Haldia Institute of Technology. WB, India. He was working as a faculty in ECE Dept, Durgapur Institute of Advanced Technology & Management. Currently he is engaged with JIS College of Engineering, Kalyani as a Faculty member and flourished R&D related activity. Recent now he is also engaged as a consultant executive engineer of YECOES Ltd, Hooghly, and attached as an advising body of different Engineering College under WBUT. His research interest includes Prosthetic Control, Biomedical Engineering, Digital Simulation, Microcontroller based Embedded System. He is guiding five Ph.D theses in this area. He has published about fifty several papers in International and National Journal and Conference conducted both in India and abroad. Additionally, he attached as a reviewer of several journals and yearly conference.