International Journal of Computer Trends and Technology
ISSN: 2231-2803/ https://doi.org/10.14445/22312803/IJCTT-V70I2P107

Volume 68 Issue 7, 43-48, July, 2020

Original Article

Designing a Non-Contact Sensor for Capturing Pacemaker

Mohammad Almasi

Department of Mathematical Engineering, University Polytechnic of Catalonia, Barcelona, Spain

Received Date: 25 May 2020
Revised Date: 12 July 2020
Accepted Date: 17 July 2020

Abstract *- The obtained advances in heart surgery from the mid - 20th century has created the need for artificial means to stimulate the heart muscle. Initially, pacemakers were developed as machines outside the body and large, but technological advances led to the shrinking and miniaturization of electronic circuits and eventually the development of ICD devices. With recent advances, pacemakers have also been developed without lead, and these advances are to be continued. In this thesis, an FPGA based on PACEMAKER is proposed. The algorithm implemented in the Xilinx - type FPGA is programmed using VHDL and ISE software. Simulation results show the ability of the system to detect the absence of a heartbeat in the expected times and/ or to generate the required pulses or beats. In the following, an idea is presented at the end of the paper to continue the work, which has the ability to transform the device into a node and form a database of heart patients, which can contribute to improving the health situation of the community and reduce the high mortality rate caused by heart disease.*

Keywords *- Heart disease, Pacemaker, Heart rate. Electrocardiography, Signal processing, Arrhythmia, Micro Electronics,*

I. INTRODUCTION

A pacemaker is an implantable medical device that is commonly used to treat cardiac arrhythmia. Which Pathologies are related to depression or lack of heart rate? It is mainly composed of a measurement unit and a pulse generator: The former feels the electrical activity of the heart, and the latter creates electrical stimuli for the stimulation of the heart contraction if the diagnosis of depression exceeds the limit or, absence of the heart rate.
From 1993 to 2009 in the United States (the largest producer of Pacemakers worldwide), the overall use of pacemakers has increased by 55.6 %. This positive trend highlights the continuous expansion pathologies treated pacemakers and represents the potential increase in the future demand. Transplanted patients should undergo periodic examinations. The Pacemaker reschedules the machine for optimal treatment and prediction of replacement time with the objective of verifying the correct operation of its work. Many of the pathologies used by Pacemakers are evolving over time, and continuous regulation of the Pacemaker’s parameters can improve therapeutic effect and provide additional benefits to the patient. However, the patient's arrhythmic documentation can be limited due to the unreliability of the patient’s symptoms and the necessity of documenting the pathology by using short or long-term ECG recordings (A HOLTER device can be limited only with a few days of monitoring the need to wear the electrode). For this reason, many pacemakers have included some event recorders and counters. As an example, one can use statistics to measure the evolution of arrhythmias and finally regulate the electrical or drug procedure. However, not all parties are equipped with event recorders. The temporary Pacemaker system is used in an emergency or selectively situations (before the heart surgery) and generally for short-term periods (about two weeks) for people who need the Pacemaker. This type of Pacemaker is set through the chest and venous catheter, and it has two types: A) Chest: By means of the trocar, the pacemaker wire passes through the chest wall and is placed on the myocardium or inside the right ventricular myocardium. The Complications of this method is to damage the coronary artery, bleed and Cardiac tamponade arrest. B) venous: The most common method is the use of a temporary Pacemaker, which are guided by Jugular veins, Subclavian, brachial or Femoral catheter to the right atrium, and then passes through the tricuspid valve into the right ventricle. Catheter guidance is carried out by fluoroscopy. After performing this technique, the patient’s vital signs and ECG must be checked along with the location of operation in terms of inflation, bleeding and pain. Its Complications include fracture of the catheter due to lack of awareness and displacement. It is also an infection of the site of catheter entry, the bleeding site of the catheter entry, arrhythmias, myocardial rupture, and pneumothorax. Temporary Pacemaker can be carried out through intravenous, Epicardial, or skin. The stimulation of the right atrium or ventricle endocardium (or both) is carried out with the help of the temporary pacemaker electrode that is passed through a central vein. To apply the epicardial, the pacemaker leads should be placed directly on the surface or inside the epicardium (under direct vision). The Pacemaker through the skin, using the electrodes placed in the patient's chest, electrical currents are sent to the heart.

A pacemaker is a small device that controls the electrical impulses of the heart, or if the heart does not have an electrical impulse, the Pacemaker generates a pulse to cause pulse and pumping blood. Like other equipment, the Pacemaker has different types that are introduced below:

Temporary pacemaker system: it is used in emergencies or selectively (before the heart surgery) and generally for short-term periods (about two weeks) for people who need to be involved. A) Chest: By means of the trocar, the pacemaker lead (wire) passes through the chest wall and is placed on the myocardium or inside the right ventricular myocardium. The Complications of this method is to damage the coronary artery, bleed and Cardiac tamponade arrest. B) venous: The most common method is the use of a temporary Pacemaker, which are guided by Jugular veins, Subclavian, brachial or Femoral catheter to the right atrium, and then passes through the tricuspid valve into the right ventricle.

Permanent pacemaker system: Permanent pacemakers are needed when the patient has irreversible cardiac problems or if the conduction ways of the ventricular electrical waves are completely blocked. This type of Pacemaker is installed through the chest and intravenously. A) Through the chest: In this method, the patient's chest is opened in the space between the fifth ribs, and then the electrode is sutured to the left ventricular epicardium, then the pacemaker generator is placed in the lumbar abdominal area under the skin. B) intravenously: In this method, the pacemaker generator in a small chamber in the hypodermis is placed under the right or left clavicle bone.

External Pacemaker system: Applications for this type of Pacemaker include ventricular asystole or cardiac arrest until the preparation of permanent pacemakers, Prohibition of placing internal pacemakers (Artificial tricuspid valve, weakness of immune system, septicemia and hemorrhagic diseases), Prevention of arrhythmias and cardiac arrest during invasive procedures (E.g. Cardiac catheterization)and inhibition of ventricular tachycardia. The desired method of placing electrodes on the body surface is the Anterior-Posterior condition where the negative electrode is located to the left side of the chest between the Xiphoid process and the Midclavicular line and the positive electrode is deposited in the back of the patient under the left scapula.

Fixed-Rate (Asynchronous) Pacemaker: These types of pacemakers perform electrical stimulation regardless of the patient’s heart rhythm, based on a preset rate (70 - 80 beats per minute). The simplicity of the circuit that minimizes the risk of failure is a good property for this type of Pacemaker. But these pacemakers do not feel the patient's heart rhythm; hence, there is a possibility of competition between the patient's heart rhythm and the pacemaker rhythm. The result will be V.T or V.F if the Pacemaker its beats are on the T-wave of the patient's heart rate.

Demand (Synchronous non-competitive) Pacemaker: By receiving and strengthening the ECG signal from the right ventricle, it is determined whether the pulse is required to stimulate the ventricle. On the other hand, by sensing the R signal, this Pacemaker will not send a signal. The rate of these pulses by the Pacemaker is lower than the intrinsic rate of the beat produced by the heart itself. If the R signal is not received for more than a specified time, the Pacemaker generates a signal that shrinks the ventricle, and by receiving each R signal from the right ventricle, the Pacemaker starts timing from the beginning. Refractory Period is a period of time during which Pacemaker doesn’t generate any signal. This time is necessary because, after R-wave, we also have S and T signals that if a pulse is created at these times, it causes cardiac defibrillation. At this time, depending on the physiological issues, it is about 250 to 300 milliseconds in the ventricles and about 150 to 350 seconds in the atria. A demand-based pacemaker is only depleted when the patient's rate drops below the rate of the Pacemaker.

Single-chamber pacemakers: Single-lead (or single-chamber) pacemakers, as their name indicates, are used to stimulate only the right atrium or right ventricle. The stimulation of the atrium generates a spark on an ECG signal, which is followed by a P-wave. For most people, we use the single-chamber Pacemaker to control heartbeat pacing by connecting the lead to your right ventricle (lower heart chamber). Depending on your symptoms and the type of pacing you need, we connect the lead to your right atrium (upper heart chamber) to stimulate the pacing in that chamber.

Dual-chamber pacemaker: With two leads, this device connects to both chambers on the right side of your heart, the right atrium and the right ventricle. The doctor programs the dual-chamber Pacemaker to regulate the pace of contractions of both chambers.

This Pacemaker helps the two chambers work together, contracting and relaxing in the proper rhythm. The contractions allow blood to flow properly from the right atrium into the right ventricle.

In [1], an implantable cardiac pacemaker system is designed and manufactured. A Digital Electrocardiogram Tracker with low-power and high-efficiency (ECG) has become an essential requirement in modern implantable cardiac pacemakers. A digital ECG Tracker based on the fractional operator for modern pacemaker systems is also presented. That instead of normal thresholds, the adaptive slope prediction is used to distinguish the peak of the ECG. a random search algorithm, the cuckoo's search algorithm is being exploited to design an optimal fractional operator that is used for ECG abnormalities. It is shown that the threshold of adaptive slope prediction increases the performance of QRS complex detection performance. DER ranges from 0.01% to 0.56%, Positive predictive ranges (P +) varies from 99.32% to 99.98%, Sensitivity (Se) ranges from 99.45 % to 99.98 % and Access Detection (Acc) ranges from 99.43 % to 99.96 % is achieved for different databases for the proposed ECG tracker, which is better compared to existing ECG tracker. Lattice wave digital filter(LWDF) requires a minimum number of multiplications to achieve its structural realization.

In [2], a computer-based controlled pacemaker is designed and implemented. This article has been discussed the design and implementation of Computer-controlled external Pacemaker Software, which is guided by the P wave using the National Instrument SW development kit. Part of Pacemaker's performance software is based on the NI Elvis II hardware device and most of the NI LabVIEW software. The paper explains the step-by-step implementation of the Pacemaker's software and a description of the principles of the hardware device.

In [3], the implementation of a hardware double-chamber pacemaker has been proposed for different heart rate ranges with a minimum delay. The hardware is designed to perform demand-based double-chamber Pacemaker with a minimum delay. The minimum delay between measurement and stimulation is very important to maintain a sufficient heart rate. Therefore, the main motivation of this work is to reduce the delay in measurement and follow–up the Pacemaker. The demand-based Pacemaker is based on the patient's heart rate, which suffers from arrhythmia, and its range may vary for different patients. The range is from 30 beats per minute to 70 beats per minute. The Xilinx 14.7 is a tool that has been proposed for the construction of a double-chamber Pacemaker with low delay. The result shows that the proposed work is much better than previous work in terms of delay, computational complexity and cost.

Pacemaker design has evolved very rapidly over the past few years. A lot of work has been done to upgrade the Pacemaker's programming capability to work through programming and work with different selection parameters and actually work in different modes. In Taiwan, about 70% of patients with pacemakers pace from the ventricle alone. Of course, this is done with the help of some parameter planning capabilities. The purpose of this paper [4] is to design a cardiac pacemaker with different NBG modes. To achieve the desired goal, the state-machine approach has been followed. The pacemaker system is divided into three main parts, i.e. the control unit, the measurement unit and the pulse generator unit. In this paper, the focus is mainly on the control unit and pulse-generator unit. This software has been developed using VHDL programming and implemented in hardware using FPGA.

The paper [5] aims to design a double-chamber pacemaker that is simulated using VLSI architecture in Xilinx and modified by changing the clock cycle to provide better results than other pacemakers. To achieve the desired goal, the state-machine approach has been followed. the main part of the pulse generator system is pacing heart rate, which forms an important part of the project. This program is designed using VHDL and implemented in hardware using FPGA. The code for different states of stimulation is modified and optimized. The reasonable components are used to make the detection circuit and other accessories for the simulation. Monitoring devices with memory compression techniques and remote data have been used to improve overall performance.

In [6], a simple model of the winding response to pacemaker pulses is presented with suitable circuits for pulse detection. Laboratory tests are carried out using real pacemakers immersed in the saline solution. Experimental data were used to evaluate the accuracy of the model and evaluate the sensor performance. It was found that the amplitude of the winding signal decreases with increasing distance from the Pacemaker lead. This sensor was able to easily detect the pulses 12 cm apart from Pacemaker's lead. The degree of stimulation can be measured in real-time and with high precision. Because each electromagnetic pulse generates the same response as the winding, the EMI may distort the measurement performed by the sensor and should therefore be separated.

In this paper [7], pacemaker features such as core rate, pulse width, VOO resistance time period are achieved using a very low power MSP 430F1611 processor and IAR microcontroller. The instantaneous current corresponding to the instruction level is measured in the flow software, and the flow/energy performance and battery life have been tested [8], [9]. It has been confirmed that variation inflow/energy varies from 2.0 to 3.0%. This approach seems to be an innovative concept in estimating the energy associated with the software from such a critical real-time system.

II. METHODOLOGY

In this paper, a finite state machine is used to construct a demand-based pacemaker. Demand-based Pacemaker is one of the cases in which there is no difference between the intrinsic rate of the heart and the artificial pulse created by the machine. In othbe implemented using the hardware description language on the FPGA board. With the use of parallel architecture, the FPGA's chips provide significant computational power for high performance. The hardware FPGA chip is reconfigurable, so system designers allow it to optimize hardware architecture to implement algorithms that require high performance and low production costs. The main advantage of the FPGA is that it has high flexibility architecture. After the hardware implementation, a single-chamber pacemaker will be available. The board selected for hardware implementation is the ***Posedge One*** board with the SPARTAN6 chip. Field Programmable Gate Arrays (**FPGA**) are semiconductor devices that are based around a matrix of configurable logic blocks (CLBs) connected via programmable interconnects. Designers can configure and schedule these fragments to perform very diverse tasks. Depending on the FPGA's construction method, some of them are programmable only once, and others are programmable several times. These fragments are often used to model designs or provide an environment for reviewing the physical implementation of an algorithm. The most important feature of FPGAs is the low cost of development and the short supply time to the market. High-speed digital signal processing is usually done by a special microprocessor called the digital signal processor. However, today's FPGA may have multipliers embedded in built multipliers, very dedicated routing and lots of RAM on the chip, all of which facilitate the operation of digital signal processors. When these features are combined with FPGAs in parallel, its result is the fastest digital signal processor chips with a factor of 500 times or more.

Posted One is an FPGA development board based on the Xilinx SPARTAN 6 chip, and its design is inspired by the sPapilio project. **Posedge** is a design and development platform. This platform is designed so that the user can use the types of input/output to the desired system. as a result. The user will have a powerful kernel for its implementation, which can communicate with the outside world with the help of a variety of input/output interfaces. Considering the mentioned advantages and due to the relatively low cost of the board, the board is used to implement the project hardware implementation.

III. RESULTS AND DISCUSSION

As shown in Fig. 1. A and Fig. 1. B, the device operation is designed according to the state machine. However, this is for the ideal state, but In a real-time state, there is a delay between changing inputs and outputs.

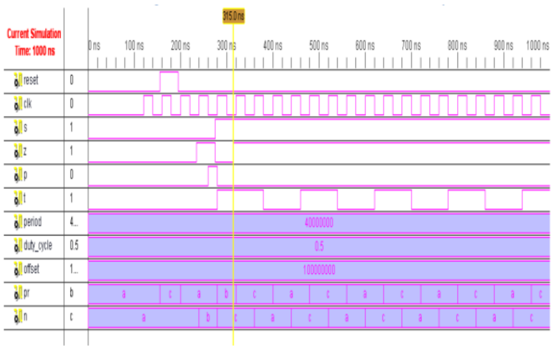

Fig. 1(a) Test signals for single-chamber pacemaker without delay.

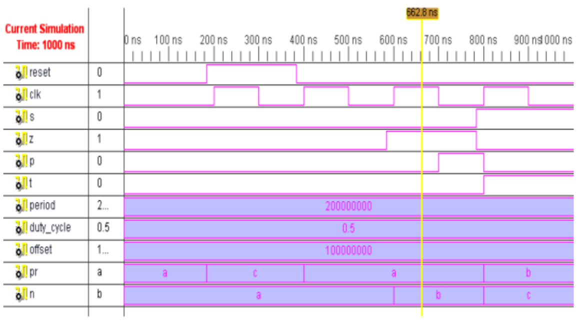

Fig. 1(b) Test signals for single-chamber pacemaker with delay.

The most important part of the pulse generator in the Pacemaker is the sensor circuit. The main task of this part is to capture the real-time signals of the heart due to sensor leads and the input to the pulse generator in a proper manner. The sensor circuit takes the signal from the patient and does the appropriate filtering on it, making the pulse generator input decision. The initial design involves the first sampling of the heart ECG signal, then the signal R wave recognition and pulse generation that can operate as input to the pulse generator corresponding to the R - wave to perform the necessary operation in the Pacemaker. The circuit is initially designed by producing an ECG signal from the heart attached to lead in Multisim. The R wave is then detected using the 555 timers, from which the signal is derived from the lead. After that, the pulse is produced with the required width to be fed to the digital circuit through the ADC. Further production of pulse continues through the pulse generator. The first block of the sensor circuit creates an electrocardiogram. The signals are taken from three ends. Right arm, left arm and left leg. These reflect signals from the heart and are considered as the reference level. It is assumed that the maximum distance is from the heart, assuming that the heart signals are weak enough to reach the feet. Fig. 2 shows the block diagram of the ECG circuit.

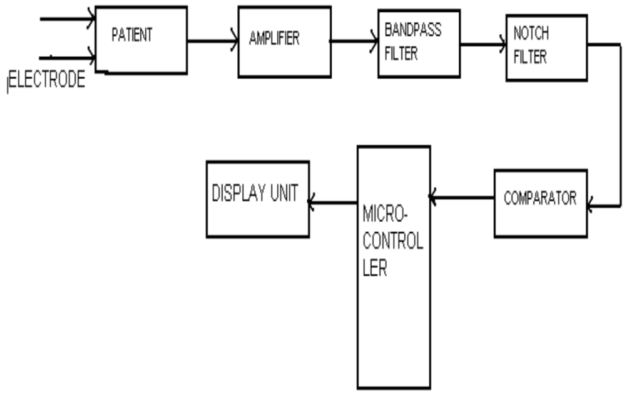

Fig. 2 ECG circuit diagram block.

The differential signals from two arms enter the input of a precision instrument amplifier. The strongest ECG signal has a magnitude of 0.5-10 mV. The most common amplifier used is the AD620 and is the first choice for most medical applications. The amplifier is used for the following reasons:
- High input impedance
- Low leakage current
- Flat and smooth frequency response from 0.05 to 150 Hz
- high CMRR

In the designed Pacemaker, the gain of this amplifier is set to 200. The amplified signal from AD620 is still polluted with much noise. Due to the movements of different parts of the human body, this noise is inevitable in every medical circuit. Therefore, to eliminate noise, a band-pass filter will be required. Typically, the filter ranges from 200 Hz to 2 kHz. This filter is obtained between two active filters, one low-pass filter with a cutoff frequency of 2 kHz and then the high-pass filter of 200 Hz. Negative feedback is used in filters to determine the back off frequency, while positive feedback is used to determine interest rates. In Fig. 5, the frequency selector circuit interrupts exactly 50 Hz frequency signals. An operating

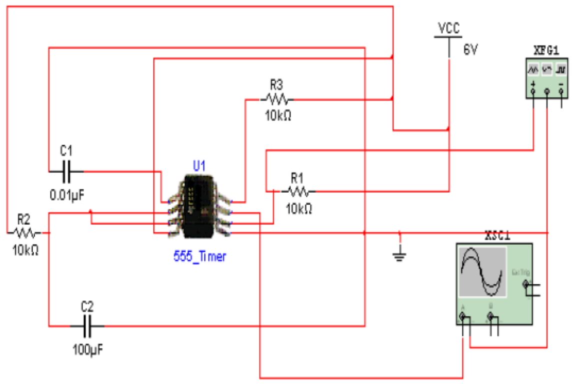

Fig. 5 Notch filter

amplifier acts as a voltage inverter and is approximately equal to the unit again and transfers its input signal that the 50 Hz frequency is removed, thus eliminating the urban power line noise.

In this section, the signal obtained by the ideal form is sent to a comparator and microcontroller to obtain the exact shape of the ECG wave or to display it on a monitor, or to print it on paper. But the goal here is only to identify the peak of the R wave. It is therefore prevented from adding circuitry because it adds cost and complexity to the system. This output can be used in the next section by the r wave detector and the input pulse generator. The output of the ECG circuit is transmitted as a trigger to the 555 adjustable chipsets in the adjustable state. This circuit works according to the following principle:

The operating period starts when the input signal value is less than one-third of Vs, this causes the output to increase to Vs + and the capacitor C1 to start charging through resistor R1. After this step, the trigger pulses are overlooked. The threshold input value reduces the voltage in C1, and when it reaches two-thirds of the Vs, the full time is reduced, and the output is reduced to a low value. The drain is always connected to the ground, drains the capacitor, and is ready to use the next pulse trigger. Since the reset function is not required, the reset pin must be connected to Vs +. Each time an R wave is detected, a pulse is generated to be constructed through the digital circuit to the pulse generator.

The input pulse generator circuit is represented by specifying all the values of the components. Finally, Fig. 6. A and Fig. 6(b) shows the actual wave obtained from the Pacemaker in an oscilloscope, indicating the actual performance of the device

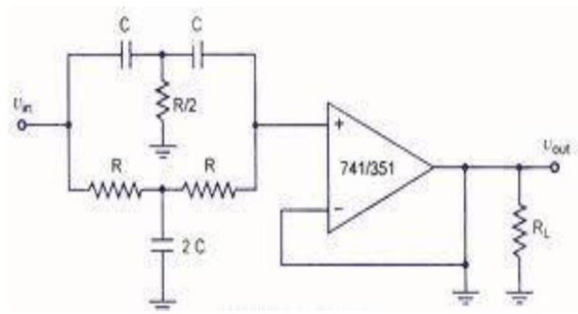

Fig. 6(a) Input pulse generator circuit.

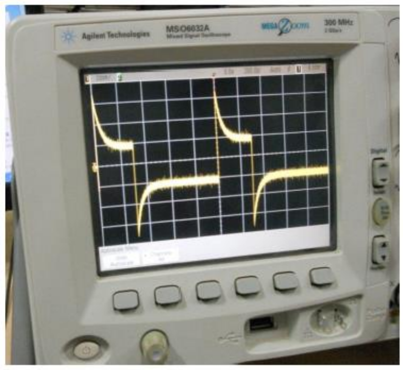

Fig. 6(b) The obtained actual waves shape from the pacemaker.

IV. CONCLUSION

Several different types of pacemakers were investigated in this paper. Their functional areas were investigated. The basic VHDL code was successfully completed, and the programs were loaded on the FPGA Spartan-3E screen. The programming was done accurately, so designed Pacemaker by delay and using the advanced computation algorithm, the best correlation between heart rate and metabolic needs implemented Pacing Rate Profile(PRPS) in hardware. A pulse generator is designed for different states of Pacemaker. The final code was optimized with respect to restrictions. The device has been implemented in VLSI systems. The sensor circuit is designed in the software. New pacemaker technology focuses more on the base of the software, and as hardware limitations become more limited, a new strategy for data storage is needed.

The implementation of this idea can be easily accomplished by the posedge board, which is presented in this article, and the patient's pacemaker information is permanently placed at the hands of the physician to be able to take pre-emptive measures before the onset of a heart attack. this idea, in case of appropriate financial support, can be invented at the lowest operational time and capture patients based on heart attack, which is one of the most important causes of mortality in the face of our country's progress. in fact, in the continuation of this superior idea, an online data network can form the patient's heart health and use its data for future research and development.

REFERENCES

[1] A. Kumar, R. Komaragiri, M. Kumar, Design of efficient fractional operator for ECG signal detection in implantable cardiac pacemaker systems, Int. J. Circ. Theory Applications, (2019)1–18.

[2] M. Penhaker, M. Heczko, Computer-Based Controlled Pacemaker Implementation, IFAC-PapersOnLine 48(4)(2015) 448-453.

[3] S. Ray, R. Srivastava, R.P. Tewari, B. Kumar, M. Sharma, N. Sahai, D. Bhatia, Implementation of Low Delay Dual Chamber Pacemaker Using Verilog, 6th International Conference on Signal Processing and Integrated Networks (SPIN), IEEE, 2019.

[4] O. Dwivedi, G. Srivastava, Design and Implementation of Programmable Cardiac Pacemaker Using VHDL, Int. Journal of Engineering Research and Applications, 5(5)(2015)155-158.

[5] A.Kaur, A. Kaur, Design and Analysis of A Dual Chamber Cardiac Pacemaker Using VHDL in Biomedical Application, International Journal on Recent and Innovation Trends in Computing and Communication, 2(7)(2014)2007-2009.

[6] E. Andreozzi, G. D. Gargiulo, A. Fratini, D. Esposito, P. Bifulco, A Contactless Sensor for Pacemaker Pulse Detection: Design Hints and Performance Assessment, Sensors, 8(2715)(2018) 1-19.

[7] S. Chede, K. Kulat, Design Overview of Processor-Based Implantable Pacemaker, Journal of Computers, 3(8)(2008)49-57.

[8] Naila Bano, Agha Zafarullah, Mohsin Ali,(2020). Analysis of Partial Discharge Model Under Various Stress Conditions. SSRG International Journal of Electrical and Electronics Engineering 7(2), 14-17.

[9] M. Alimardani and M. Almasi, Investigating the application of particle swarm optimization algorithm in the neural network to increase the accuracy of breast cancer prediction, International Journal of Computer Trends and Technology, 68(4)(2020)65–72. https://doi.org/10.14445/22312803/IJCTT-V68I4P112

[10] M. Almasi and M. Alimardani, Application of Self-Organizing map for Time-varying biological to predicting of complexity Systems, International Journal of Computer Trends and Technology,68(4)(2020)59–64. https://doi.org/10.14445/22312803/IJCTT-V68I4P111

[11] Dr Chandrakanth G Pujari. Supporting Structure For Prioritizing And Assigning Six Sigma Software Projects Using Fuzzy Logic Topsis And Fuzzy Logic Expert System International Journal of Computer Trends and Technology, 68(2)25-33.