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Design and Implementation of programmable Cardiac Pacemaker Using VHDL

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Abstract
Pacemaker design has evolved very rapidly over the last several years. There has been a great deal of work in enhancing the programmability of pacemakers, to enable them to be programmed to work with different selected operating parameters, and indeed to work in different modes. In Taiwan, about 70%of cardiac pacemakerpatients are paced only from the ventricle with some pacing parameter programmability. This paper goal is to design a cardiac pacemaker with various NBG modes. A state machine approach has been followed to achieve the desired purpose. The pacemaker system is divide into three main sections i.e. controlling unit, sensing unit and pulse generator. In this paper we mainly concentrate on controlling unit and pulse generator. It has been developed using VHDL coding and implemented in hardware using FPGA. In a simple pacemaker process i.e. single chamber or dual chamber pacemaker, first an input signal or an event is detected in heart through leads. When the input signal is detected a timer generates a delay for approximately 0.8 sec. It is the time between two consecutive heartbeats, thus giving us 72 heartbeats per minute. Once the generated delay expires, sensing unit again start detecting a new event. If any event is detected we repeat the process of detection and waiting. If no event is detected we need to provide an electrical pulse to the heart and then repeat the whole process of detection and waiting. The code has been optimized and modified for different pacemaker modes.
Keywords-Cardiac pacemaker, NBG codes, pacing mode, Refractory period.

I. Introduction

Heart disease or Cardio Vascular Disease is quiet normal in every age group now a days. According to a survey, in England(2007), CVD led to nearly 159,000 deaths (accounting for nearly 34% of all deaths in England). This includes 74,185 deaths from coronary heart disease (CHD) and 43,539 from stroke (British Heart Foundation 2009) [1]. CVD happens due to extreme pressure of working, imbalance between professional and personal life and due to some parameters of the surroundings. It is found that the premature CVD deaths i.e. deaths in the age group less than 75 years are preventable. Devices like Defibrillator and Pacemakers are used as a temporary and permanent cure to some kind of heart diseases.These devices are used to correct the heartbeat of the humans. The design and implementation of these kind of devices is a complex task as a many lifetime and efficiency are necessary and very difficult to generate corresponding to the requirement. Cost, Size and Efficiency are the important factor that act in the design of any device and in case of pacemaker besides these power and lifetime is also an important factor to be considered. Researchers are continuously trying to enhance the design of the pacemaker devices and their development considering the above factors and because of theenhancement of the development of the embedded systems they are capable of reducing some of the important constraints like cost and size to some extent. Simulation software are present for the designing these digital circuits by programming.

II. Programmable cardiac pacemaker

Generally cardiac pacemaker has three main sections i.e. pulses generator, sensing unit and controlling unit. Purpose of the pulse generator is to apply the electrical impulse to the chambers of theheart on the instruction received from the controlling unit. A controlling unit is consist of processor having a decision making capability. An algorithm or program is embedded into the processor according which its help in stimulation of heart. Whereas sensing units gathers the data through sensors placed at different location of heart. . There are one or more sensor are used in rate responsive pacemaker to sense the different body parameter. These parameter directly or indirectly increases the consumption of oxygen [2]. Whenever a change is detected in these parameter, the pacing rate is adjusted according the variation in parameter.

For example whenever we perform exercises our consumption of oxygen increases and in response to it pacemaker paces the heart at higher rate [3].Block diagram of cardiac pacemaker is shown in fig.1.

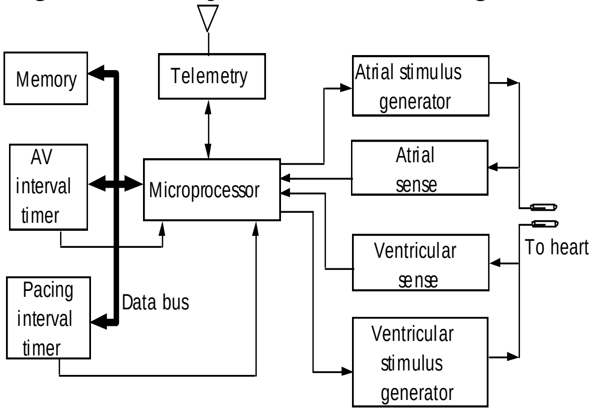

Figure1: Block diagram of cardiac pacemaker

The common types of sensors used in this class of pacemakers are:

A. *Activity sensor*

Activity sensor detect and respond to heart about various level of physical activity done by patient's body. These sensor are attached to metallic body of pacemaker to measure the response of muscle movement or body movement. These muscle produces vibration which is identified by the sensor placed on the pacemaker body [4]. Then these vibration are converted to the electrical signal which is guided to the controller of pacemaker. The two main activity sensors are accelerometers and vibration Sensors.

B. *Physiological sensor*

This type of sensors perceive and respond to heart about different body parameter such as body temperature, blood pH indications, blood pressure, respiration rate and concentration of oxygen. For example normal human body temperatures fluctuates between 36.8±0.5 °C (98.2±0.9 °F). The body temperature usually swings all the day, with the bottommost points around 03:30 a.m. and the uppermost [5] in the late afternoon, between 03:30 p.m. and 05:30 p.m. As body temperature varies heart rate changes. Similarly at high altitude the percentage of oxygen drops. Due to which concentration level of oxygen drops in blood and heart rate rise.

III. Timing Features

A. Refractory Periods

Pacemaker have two main functions sensing and pacing. Since heart is made of three types of muscles, each muscles have different depolarisation and repolarisation period. This period can be defined as interval during which these muscles does not respond to electrical triggering. So whenever an event is sensed or an electrical impulse is provided to heart, the pulse generator initiates a refractory period for that chamber or sensing channel. After the starting of refractory period, pulse generator unit ignores the internal cardiac signals. This process prevents the pacemaker from responding to the depolarization signal or the repolarization signal (T-wave) that may result in inappropriate inhibition or triggering.

If the pacemaker is programmed to dual chamber mode then the refractory periods are independently programmable for atria and ventricle.

B. AV Delay

The AV delay is the time interval between the two events i.e. An atrial paced or sensed event and the ventricular pacing pulse. AV delay must be selected wisely so that an intrinsic ventricular event occurring within the AV delay will inhibit the ventricular pacing pulse [6].AV delay must not be selected to short or to long so that ventricle event is inhibited. In our pacemaker we have used the Dynamic AV Delay feature. It provides independent selection of AV Delays from five different rate ranges as shown table 1.

Table 1: Dynamic AV delay settings

Rate Ranges	Time delay
below 70 bpm	180 ms
70—90 bpm	170 ms
91—110 bpm	160 ms
111—130 bpm	150 ms
above 130 bpm	140 ms

IV. Modes of pacemaker and features

A. VOO

VOO mode is used when ventricle chamber is unable to propagate the electrical signal to the purkinje fibres. This mode only pace the ventricles. Each letter in VOO indicates the function processed by heart as per NBG (NASPE/BPEG Generic) code. First letter V indicates that it pace only in ventricles, second letter O indicates that pacemaker does not sense any of the chambers and third letter O indicates that there is no mode of response is used. VOO mode algorithm is shown in the figure 3.

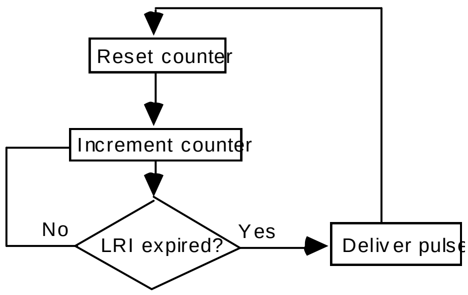

Figure 3: VOO mode algorithm

B. VVI

VVI mode is used for all symptomatic Brady arrhythmias, but particularly if the atrium does not significantly contribute to the hemo-dynamics (persistent or paroxysmal atrial flutter or fibrillation, dilated atria). Thismode only pace and sense the ventricles. Each letter in VVI indicates the function processed by heart as per NBG (NASPE/BPEG Generic) code. First letter V indicates that it pace only in ventricles, second letter v indicates that pacemaker sense the ventricle chamber and third letter I indicates that there is inhibition mode of response is used. VVI mode algorithm is shown in the figure 4.

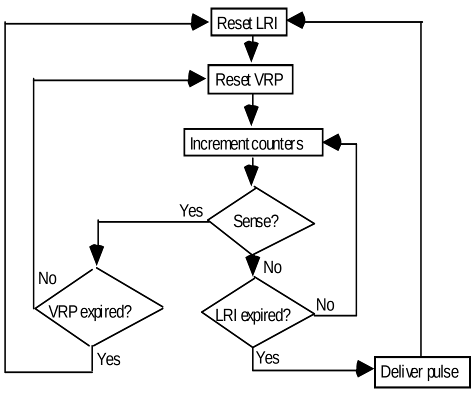

Figure 4: VVI mode algorithm

C. AAI

The AAI mode is usedforSymptomatic Sino-atrial node dysfunction (sick sinus syndrome. This mode only pace and sense the atrial chamber. Each letter in AAI indicates the function processed by heart as per NBG (NASPE/BPEG Generic) code. First letter A indicates that it pace only in atrial, second letter A indicates that pacemaker sense the atrial chamber and third letter I indicates that there is inhibition mode of response is used.

D. DDD

The DDD mode is used for AV synchrony is needed over a wide range of rates, suchas active or young patients with an adequate increase in atrial rate, and/or significant hemodynamic indication, and/or previous occurrence of pacemaker syndrome or of a reduction in systolic blood pressure of more than 20 mm Hg under ventricular pacing with pulse generator implantation (regardless of any evidence of retrograde VA conduction).

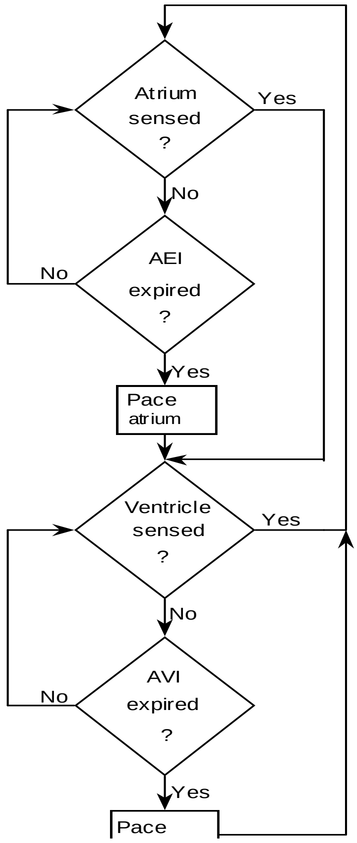

Figure 5: DDD mode algorithm

This mode pace and sense the both chamber. Each letter in DDD indicates the function processed by heart as per NBG (NASPE/BPEG Generic) code. First letter D indicates that it pace in both chamber, second letter D indicates that pacemaker sense the both chamber and third letter D indicates that there is both inhibition and triggered mode of response is used.

V. Problem

There are many equipment or devices which may affects the pacemaker such as electric arc welders, electric melting furnaces, radio, TV ,radar transmitters, high voltage transmissions line , electric ignition system, metaldetector and microwave transmitter .

VI. Result

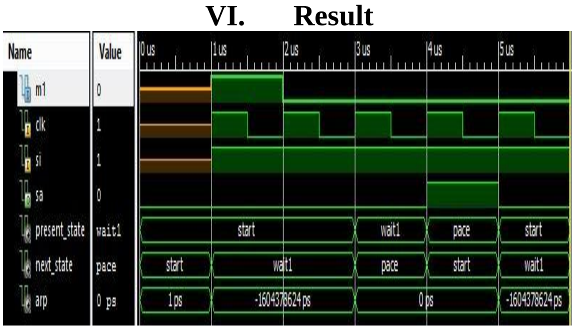

Figure 6: Simulation result of mode AOO.

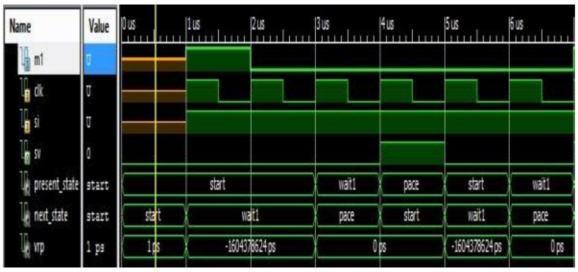

Figure 7: Simulation result of mode VOO.

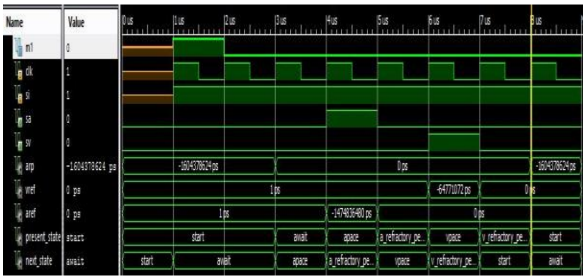

Figure 8: Simulation result of mode DOO.

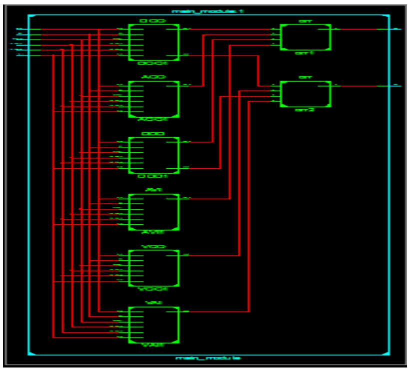

Figure 9: Schematic RTL symbol

VII. Conclusion

There are many problem which are discussed above that need to be improved such as it need to be made compatible to MRI. Many problem comes in notice during diagnostic process such as over sensing or under sensing. These problem may be solved by selecting correct sensitivity parameter. We need to understand basic pacing terminology and modes to treat patients effectively.

VIII. Future scope

Due to development in embedded system, clinicians can extract the patient diagnostic history from cardiac pacemaker system. An energy harvesting technique should be developed which can power itself from body i.e. no requirement of battery.

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