A Simple Laboratory Demonstrate Pacemaker

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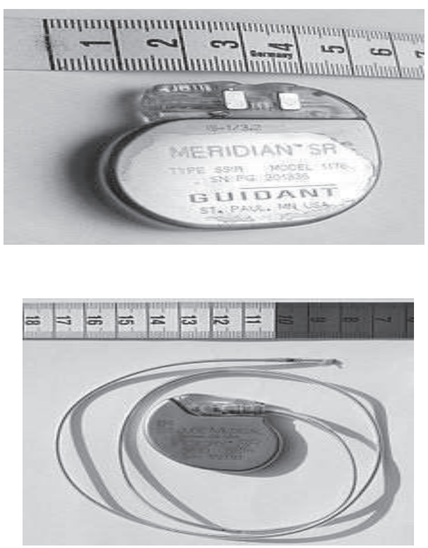
***Abstract*--A simple pacemaker circuit has been designed, fabricated and tested. The circuit consists of Signal Generator, Amplifier, Filters and Noise reduction circuits. The pulse signals generated from an operational amplifier circuit and fed to monostable 555 timer circuit. The pulses are acquired with Digital Storage Oscilloscope (DSO). The performance of the developed system is evaluated by recording the pulses of people having different heart beats, wave forms recorded are compared with standard pulse wave forms e.g. frequency, amplitude, pulse duration, shape etc. The accuracy of the diagnosis presently depends on the expertise of the physician.**

***Index Terms*-- Pacemaker, Monostable, Pulse duration.**

I. INTRODUCTION



Picture 1(a) 1(b) Pacemaker model.

A pacemaker is a device that placed in chest or abdomen to help abnormal heart rhythms. This device uses electronic pulse to promote the heart beat at a normal rate. In 1958, Arne Larsson became the first to receive an implantable pacemaker [1,2]. He had a total of 26 devices during his life and campaigned for other patients needing Pacemaker In 1899, J A McWilliams reported in the British Medical Journal of his experiments in which application of an electrical impulse to the human heart in a systole caused a ventricular contraction and that a heart rhythm of 60-70 beats per minute could be evoked by impulses applied at pacing equal to 60–70/minute. Picture-1a,1b shows the pace maker model.

A. Need of Pacemaker

Doctors recommend pacemaker for a number of reason. The most common reason is bradycardia and heart block. BRADYCARDIA is a slower than normal heart beat. HERT BLOCK is problem with hearts electrical system. The disorder occurs when an electrical signal is slowed or disrupted as it moves through the beat [3]. Heart block can happen as a result of aging damage to heart from heart attack or other condition that interface with heart electrical activity. Certain nerve and muscle disorder can also cause heart block, including muscular dystrophy. Aging or heart disease damages your sinus node's ability to set the correct pace for your heart beat. Such damage can cause slower than normal heart beat or long pause between heart beats. The damage also can cause your heart to alternate between slow and fast rhythms. This condition is called "sick sinus syndrome". You have had a medical procedure to treat an arrhythmia called atrial fibrillation. A pacemaker can help regulate your heart beat too much. You faint or have some other symptoms of a slow heartbeat. You have heart muscle problem that causes electrical signal to travel too slowly through your heart beat muscle. You have long QT syndrome which puts you at risk for dangerous arrhythmias.

B. Energy Requirement to Excite Heart Muscle

To overcome of these all some of the measures are taken like all muscles tissues. The heart can be simulated with an electric shock. The minimum energy required for excite the heart muscle is about 10 μj. For safety purpose, a pulse of energy 100 μj is applied on heart muscle. A pulse of 5V, 10mA and 2mS duration is used

DOI: 10.32377/cvrjst0413

[4]. Ventricular fibrillation is a dangerous condition. This occurs due to a too high pulse. A patient loses consciousness in 10 to 15 sec and the brain cell dead within a few minutes from oxygen deficiency in the brain. This is caused by pulse of 400 µj. These pulses should have the pulse to the ratio of 1:1000 and that should be negatively going pulse to avoid ionization of the muscle. Pulse voltage is allowed to adjust in such a way that the energy is delivered by the pacemaker to the heart during each pulse. The pulse rate is 70 pulse/min but many pacemakers are adjusted in the range of 50 to 150 pulse/min. The duration of each pulse is between 1 to 2 ms, shown in figure-1.

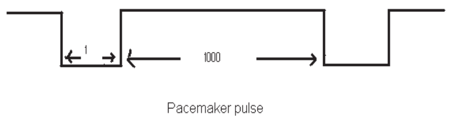


Figure 1. Duration of each pulse of Pacemaker.

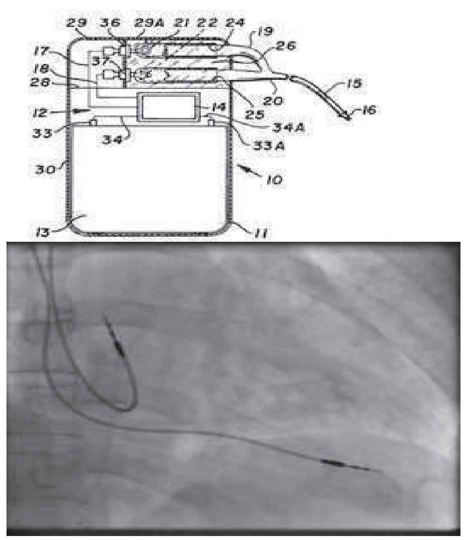
II. METHODS OF SIMULATION

There are two types of simulations or pacing [3]

- External simulation
- Internal simulation

A. External Simulation

This simulation is used to restart the normal rhythm of heart. In this case the cardiac stands still. This occur during open heart surgery or whenever there is sudden physical shocks or accidents. The paddle shaped electrode is applied on the surface of the chest and current of 20 to 150 mA are employed. Picture-2a, 2b shows the model of external simulation.



Pictures 2(a), 2(b). The model of external simulation of Pacemaker model.

B. Internal Simulation

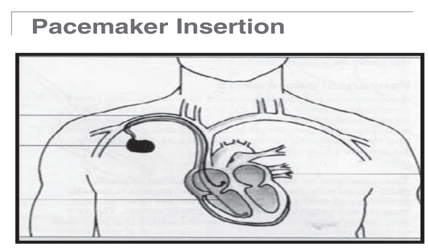
This simulation is employed in case where long term pacing is required because of permanent damage. The electrodes are in the form of fine wires coated with Teflon coated stainless steel. During restarting heart after open heart surgery a spoon like electrode is used with current range of 2 to 15 mA.

C. Different Types of Pacemakers

Based on modes of operation of pacemaker is divided into five types

- Ventricular Asynchronous Pacemaker (Fixed rate pacemaker)
- Ventricular synchronous pacemaker
- Ventricular Inhibited Pacemaker (Demand Pacemaker)
- Atrial synchronous Pacemaker
- Atrial Sequential ventricular inhibited Pacemaker

III. VENTRICULAR ASYNCHRONOUS PACEMAKER



Picture 3. Shows pacemaker insertion model

It is the first type of pacing can be used in atrium or ventricle. It has a simplest mechanism and longest battery life. It is so cheap and easy to check and least sensitive device to outside interference. This pacemaker is suitable for patient with a stable, total Atrioventricular (AV) block, a slow rate atrial rate or arterial arrhythmia. It is basically a simple astable multivibrator .this produces a stimulus at a fixed rate irrespective of behaviour of heart rhytms. It is possible that such an event can be dangerous because if pacemaker impulse reaches heart during a certain vulnerable period, the ventricular fibrillation may occur. Picture-3 shows pacemaker insertion model.

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A. Block Diagram of Pacemaker

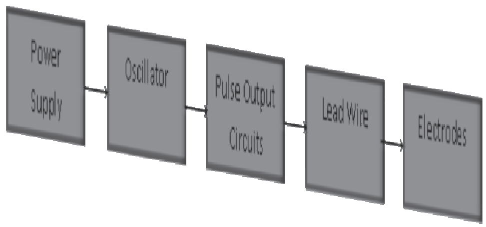

Figure 2. Block diagram of asynchronous pacemaker.

- Power supply – provides energy
- Oscillator – controls pulse rate
- Pulse output – produces stimuli
- Lead wires – conduct stimuli
- Electrodes – transmit stimuli to the tissue

Output circuit produces the electrical stimuli to be applied to the heart [4]. Stimulus generation is triggered by the timing circuit. Constant voltage pulses typically rated at 5.0 to 5.5V for 500 to 600µs Constant current pulses typically rated at 8 to 10mA for 1.0 to 1.2ms. Asynchronous pacing rates 70 to 90 beats per min. Figure-3 Realistic depiction of waveform appearing across heart emitted from capacitor discharge output circuit.

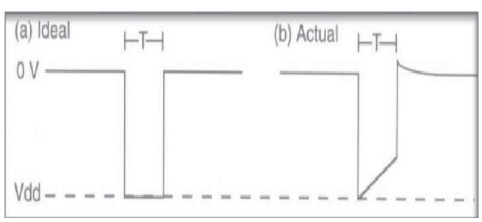

Figure 3. The Ideal and Realistic waveforms of O/P of pacemaker.

B. Schematic diagram

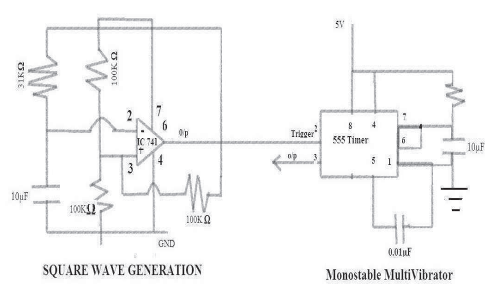

Figure 4. The schematic diagram of pacemaker

Figure-4 shows the schematic diagram of pacemaker. It consist of an integrated chip (IC) 741 and IC 555 timer. IC 741 acts as a square wave generator which generates square wave and its square wave o/p is fed to as trigger of 555 timer than IC 555 timer produce the required pulse width. IC 741, 555 timer, Resistors (100k-4, 10k, 31 k, 22k-1), Capacitors (10 µF-2, 0.01 µF-1), DSO A Square wave generator is obtained by connecting a capacitor of 10µ and resistors of 32kΩ to a voltage detector circuit [5]. The output of this combination will provide a positively and negatively going square waves with a equal duration of positive and negative pulses. The period of square wave generator is given by

$$T= -2RC \ln 1-\alpha / 1+\alpha \qquad (1)$$

Where α is feedback voltage fraction such that
$\alpha = R2/R1+R2$, T=0.8589 Sec.

The period of this oscillator can be changed by changing α or Time constant RC

The Square wave generator is nothing but astable multivibrator. Which periodically switches between | vsat | and -|vsat|. Now the output of the square wave generator is coupled to the positive edge triggered monostable multivibrater circuit. A positive Step at trigger circuit will pass through the capacitor CC . The capacitor CC is chosen so as to make 5time constant equal to the pulse duration TD. Otherwise trigger will still represent after TD has passed and a second would be wrongly generated

$$TD = 5C_C [R4\ R3/R3+R4] = -R5Cm\ Ln\ R3/R3+R4$$
$$= 5x0.16x10^{-6} [1200 / 2.2]$$
$$= -721(10^{-6}) Ln\ 1.2/2.2 = 0.437\ \mu sec$$

A pacemaker should deliver the pulse with period of T=0.8589 Sec and duration = 0.437 µsec

IV. ELECTRICAL CONDUCTION SYSTEM OF THE HEART

A. Principle of ECG formation

The normal intrinsic electrical conduction of the heart allows electrical propagation to be transmitted from the Sinoatrial Node through both atria and forward to the Atrioventricular Node. Normal/baseline physiology allows further propagation from the AV node to the ventricle or Purkinje Fibers and respective bundle branches and subdivisions/fascicles. Both the Sinoatrial node (SA) and AV nodes stimulate the Myocardium. Time ordered stimulation of the myocardium allows efficient contraction of all

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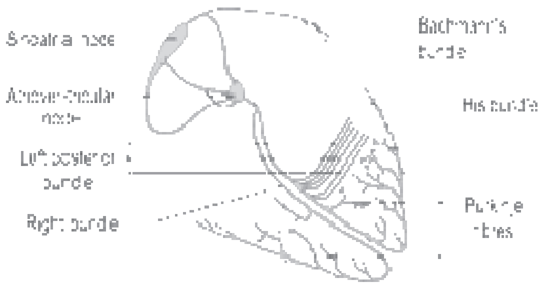
four chambers of the heart, thereby allowing selective blood perfusion through both the lungs and systemic circulation [6]. Picture-4 shows the Electrical conduction system of the heart



Picture 4. Electrical conduction system of the heart

B. Conduction Pathway

Action potentials arising in the SA node (and propagating to the left atrium via Bachmann's bundle) cause the atria to contract. Simultaneously, action potentials travel to the AV node via three internodal pathways. After a delay, the stimulus is conducted through the bundle of His branches and then to the purkinje fibers and the endocardium at the apex of the heart, then finally to the ventricular myocardium. The pathway can be summarized as: SA node → anterior, middle, and posterior internodal tracts → transitional fibers → AV node → penetrating fibers → distal fibers → Bundle of His (AV bundle) → right and left bundle branches → Purkinje fibers → myocardium [7]. The total time taken by the nerve impulse to travel from the SA node to the ventricular myocardium is 0.19 seconds. Microscopically, the wave of depolarization propagates to adjacent cells via gap junctions located on the intercalated disk. The heart is a functional syncytium. In a functional syncytium, electrical impulses propagate freely between communicating cells via gap junctions, so that the myocardium functions as a single contractile unit. This property allows rapid, synchronous depolarization of the myocardium. While normally advantageous, this property can be detrimental as it potentially allows the propagation of incorrect electrical signals (e.g., via an ectopic pacemaker). Gap junctions can close, e.g., after a cardiac ischemic event such as myocardial infarction, thus isolating damaged or dying tissue in the myocardium, which then no longer participate in synchronous myocardial contractility.

V. RESULTS AND CONCLUSION

A Brief overview of the history and development of the circuit design applied in pacemakers has been presented and successfully developed and demonstrated in our lab with Tektronix DSO model TDS 1012B. And we found that the designed system performance is satisfactory. The advances in integrated circuit designs have resulted in increasingly sophisticated pacing circuitry, providing, for instance, for diagnostic analysis, adaptive rate response and programmability Using fixed rate pacemaker, the heart rate cannot be increased to generate physical effort. Simulation with fixed impulse frequency results in ventricles area beating at different rates. This varies the stroke volume of the Heart Causes some loss in Cardiac Output Possibility for ventricular fibrillation will be more, when we use it for the patient with unstable block, due to interference between the ventricular contracts evoked by the pacemaker and the Atria. The present developed system is only for students practice to analyse and understanding of working conditions of pacemaker in their laboratory.

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DOI: 10.32377/cvrjst0413