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Using Electrical Stimulus to Drive Healthy Hearts

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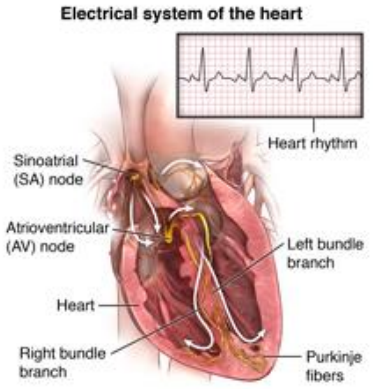
An Investigation of The Heart's Electrical System & The Importance of Pacemaker Innovation

Introduction

Nearly half (48%) of all adults in the United States have some type of cardiovascular disease, according to the American Heart Association's Heart and Stroke Statistics 2019 update. This statistic drives an interest in heart healthy diets, but what about the unlucky portion of the 48% who inherit cardiovascular disease genetically. Over the last 100 years, engineers and physicians have studied the heart's electrical system extensively and have grown an impressive set of technological tools. Tools such as defibrillators, electrocardiograms, and pacemakers prove that innovation in this field can be extraordinarily beneficial. This article is not designed to convince the reader into purchasing one of these devices, but this article will drive an interest towards the innovation of implantable electronics.



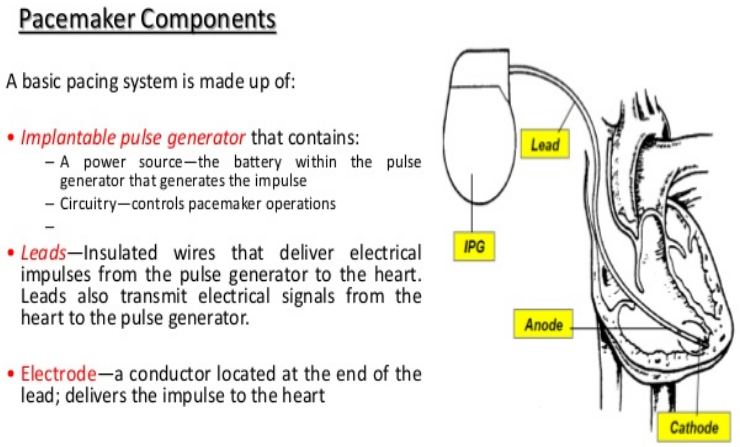


Figure 1 & 2: Electrical System of the Heart and Pacemaker Components. Credit source [2 & 5].

History of Pacemaker Development & Technical Components

The first successful pacemaker was designed in 1960 which extended a patient's life for ten months. A relatively unsuccessful endeavor compared to the success of today's devices. Today more than three million people have implanted pacemakers with success rates as high as 99%. A statistic of this magnitude demonstrates the importance of innovation in this field. A basic pacing system is made up of a pulse generator, leads, and an electrode. The pulse generator, leads, and an electrode are the main components we will discuss.

Details of technical components

The pulse generator is the component that relates the manufactured device to the heart's electrical system. The heart naturally produces electrical impulse to sustain rhythmic blood pumping. The pulse generator of the pacemaker produces the same functionality, but only as a backup system. When the heart's natural rhythm is defective the impulse generator of the pacemaker will send an electrical signal to help the heart pump properly. The impulse generator can do this by accepting an input from a microcontroller. Figure 3 shows the control flow from the heart back to the pulse generator. The next main component is the leads and electrodes. The leads deliver the electrical signal from the heart back to the controller. The electrodes act as the signal connector at the end of the leads. These components together seen in figure 3 result in a modern pacemaker. The result of these innovations provides the capability to save lives.

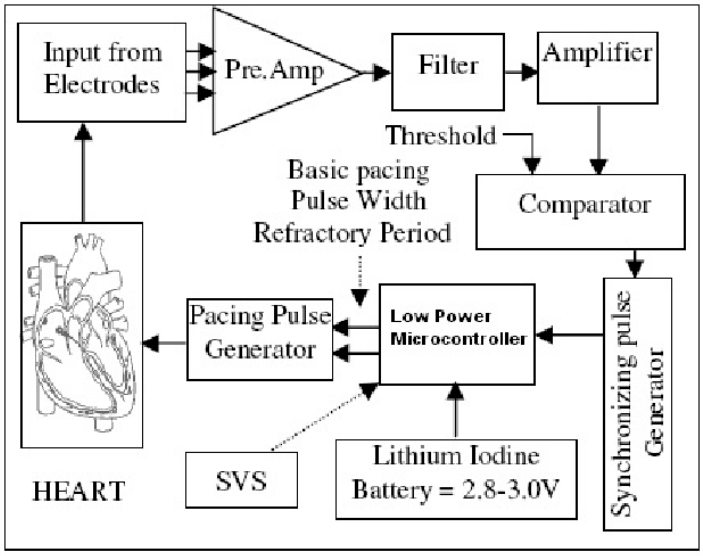


Figure 3: Schematic Overview of Pulse Generator System. Credit source [1]

A Look Inside the Pulse Generator

The pulse generator is where the rubber meets the road and produces the desired pacemaker functionality. To understand the importance and innovation behind these devices it is necessary to look inside and see what is under the hood. Figure 4 shows a pulse generator schematic from The Art of Electronics [3]. The circuit in figure 4 produces a pulse output from a step input. The 2 Bipolar Junction Transistors (BJTs) in the schematic are critical in producing the pulse generation functionality. BJT Q_2 is usually in saturation mode because of resistor R_3, and BJT Q_1 is usually in cutoff mode because the circuit input is 0 Volts (V). The capacitor C_1 is charged with 5V typically until the circuit receives the step input. When the circuit receives the 5V step input Q_1 is brought into saturation mode. Q_2 is then brought into cutoff mode because of the charge across C_1. Since Q_2 is cutoff momentarily the circuit outputs 5V which begins the output pulse. Since the capacitor is now discharging, the time constant Tau (τ) determines the length of the

output pulse. Once the capacitor is finished discharging Q_2 will be brought back to saturation mode and the circuit will stop outputting 5V. This pulse mimics the natural functionality of heartbeats.

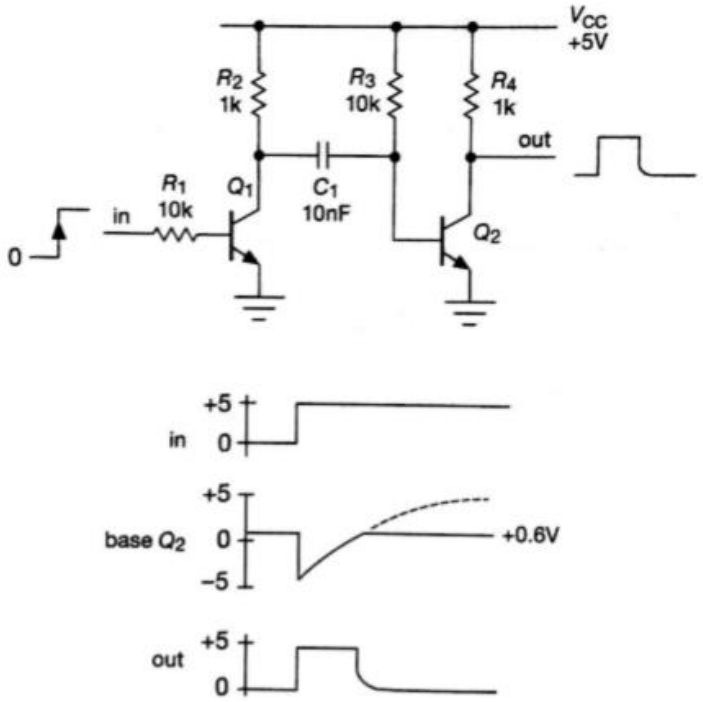


Figure 4: Example pulse generator schematic. Credit source [3]

Conclusion

The invention of implantable electronics has already proved to be a groundbreaking evolution in medicine. Tools such as defibrillators, electrocardiograms, and pacemakers prove that innovation in this field can be extraordinarily beneficial. This article will hopefully drive an interest towards the innovation of implantable electronics. Through further research and education, pacemakers and other implantable electronics can be solutions for many ailing patients. By pursuing innovative solutions to the limitations of these devices, engineers and physicians have potential to save lives.

References

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