PACEMAKER FOR HUMAN HEART

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Overview

DESIGNED A IRREGULAR BEATING HUMAN HEART AND THEN DESIGNED A PACEMAKER TO CORRECT THE HEART BEAT USING LT SPICE WITH THE HELP OF ELECTRICAL CIRCUITS .

Goals

1. At first Design the SA(sinoatrial) Node using Transistor Circuit
2. Then Design a Ventricular Cell with fast Depolarization Plateau and Repolarization
3. Then we combine the SA node and Ventricular cell to design a circuital Human Heart.
4. Then we Design a Pacemaker for the Human Heart we have Designed using 555 Timer.

Operations :

In our research, we will delve into the intricate world of RC circuits and transistor circuits, employing them to replicate the intricate channel structures found in biological systems responsible for regulating the flow of ions, thus controlling the electrical current in heart, muscle, and nerve cells. These electrically active cells within the human body are equipped with a variety of ion-passing channels that are exquisitely sensitive to changes in the cell membrane's voltage. These channels serve as gatekeepers, allowing the passage of specific ions, such as sodium ions (Na+), which facilitate rapid depolarization, or potassium ions (K+), which play a slower yet crucial role in the repolarization process. In some instances, a combination of ions is permitted to pass through, resulting in a gradual and partial repolarization.

Our approach involves the utilization of RC circuits to precisely control the timing of channel activation, thereby emulating the temporal dynamics of cellular membrane

responses. Specifically, during depolarization, sodium ions (Na+) enter the nerve membrane, while during repolarization, potassium ions (K+) exit the membrane. Through the integration of RC circuits and transistor circuits, we aim to gain a deeper understanding of these biological processes and mimic their intricate behaviors for further study and potential applications.

SA_ Node Model :

Our investigation involves the measurement of current-versus-voltage (I-V) curves for various circuits, particularly those designed to mimic the behavior of ion channels in response to changes in voltage. When dealing with a simple resistive circuit, the I-V relationship follows a linear pattern with a slope represented by 1/R, as described by Ohm's law (I = V/R). However, our exploration goes beyond conventional resistors, as we employ transistors to create circuits with highly nonlinear I-V curves, akin to the intricate behavior exhibited by biological ion channels.

These ion channels, essential protein molecules spanning the cell membrane, play a pivotal role in regulating ion passage from one side of the membrane to the other. Their behavior is contingent upon a conformational change in the protein structure, leading to the opening of an aqueous pore, allowing ions to pass through. This dynamic property is what we seek to replicate in our circuits.

It's important to note that in the absence of voltage-dependent amplifier channels, voltage pulses would attenuate rapidly, rendering both nerve and muscle function ineffective. Therefore, we commence our investigation by examining passive RC circuits, which provide valuable insights into the initial stages of our endeavor to model the intricate dynamics of ion channels and their vital contributions to cellular function.

Transistor characteristics:

Collector current, Ic, is an exponential function of the voltage between the base and emitter, Vbe. Vt is a constant which depends on the absolute temperature and at 300K (room temp) Vt=0.026 volts. Ies is a constant which depends on transistor construction but is commonly around 10^{-12} amps. We can write the collector current as:

$$Ic = Ies\ (e^{(Vbe/Vt)} - 1)$$

which basically says that for every increase of Vbe by 0.026 volts (26 millivolts), the current increases 2.71 times. Note that the real transistor will burn or explode if the current becomes greater than about 0.1 amp.

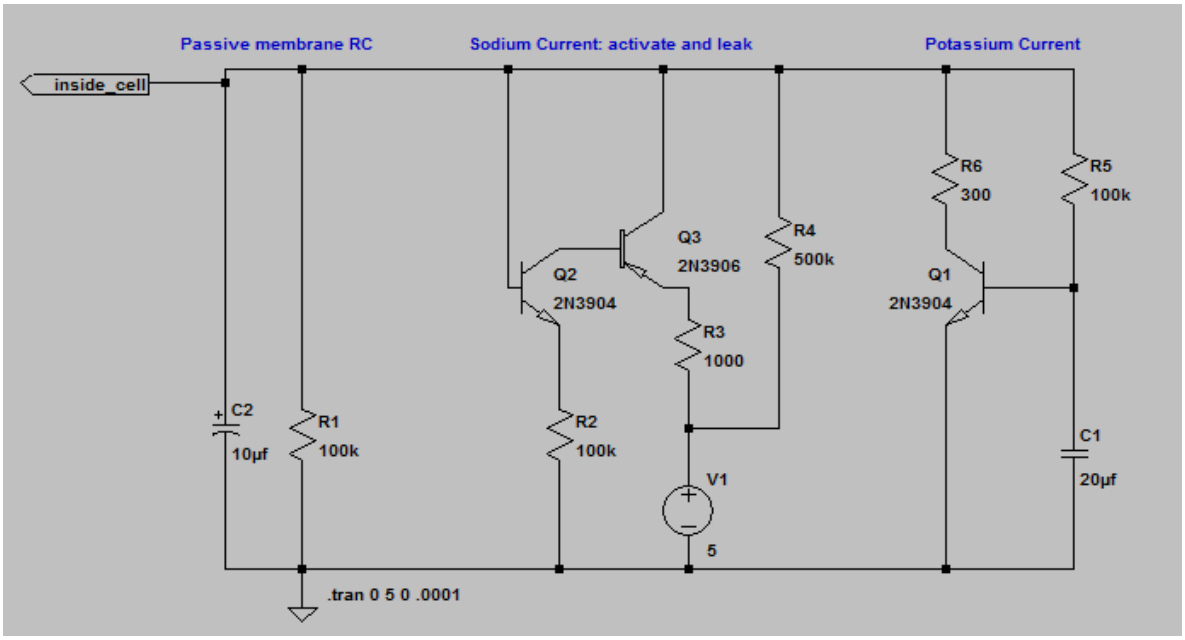
Axon Characteristics:

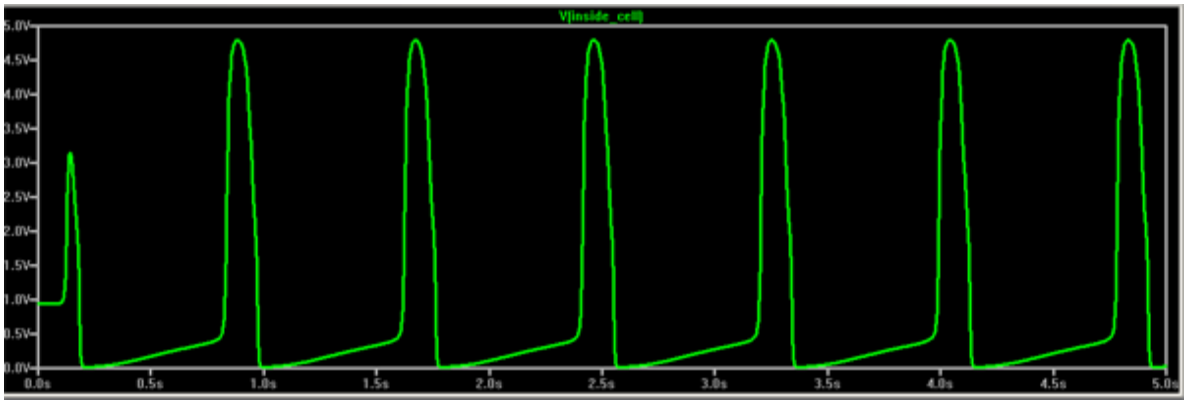
The current through the sodium channel increases exponentially 2.71 times (e) for every 7 millivolts of voltage increase, or about 4 times faster than a transistor.

$$Ichannel = Ileak\ (e^{(4*Vchannel/Vt)} - 1)$$

A transistor is a good model in that the current is exponenential, but a weaker model for channel sensitivity.

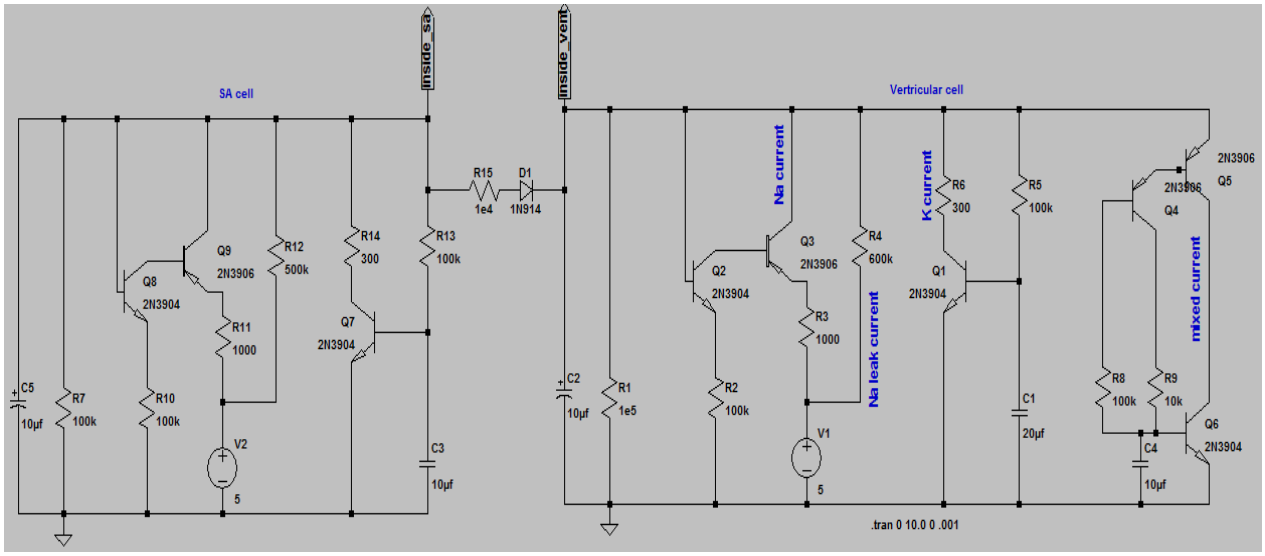
Circuit Diagram And Output :

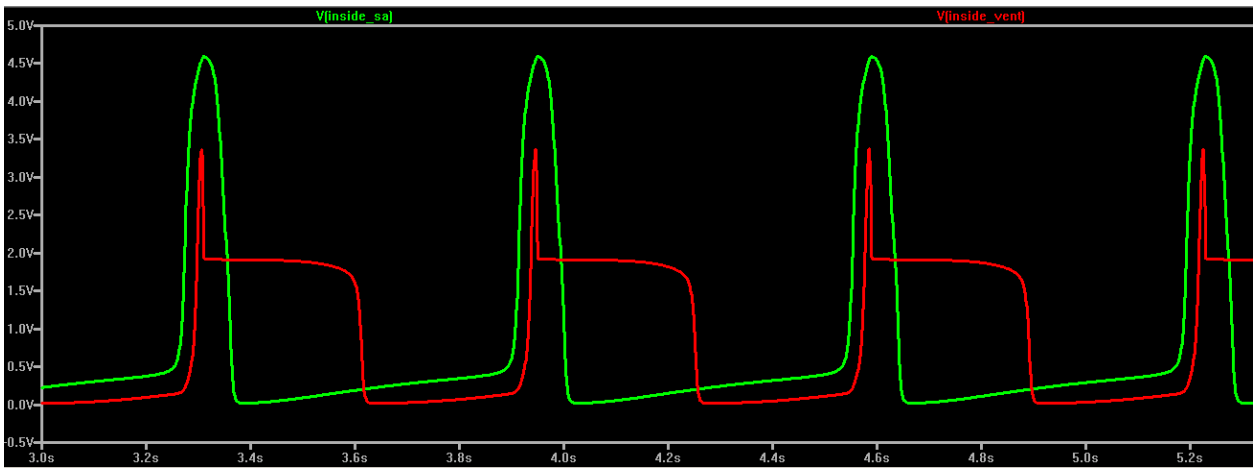




SinoAtrial_Node and Ventricular Cell Model :

Design Ventricular Cell Same as SA_Node and the rate of the SA cell by changing R12 and the ventricular cell (spontaneous rate) by changing R4. The ability of the SA cell to drive (and synchronize) the ventricle depends on SA rate, ventricular spontaneous rate, and coupling resistance R15. We will vary R4 to show the changes in the rate.





Pacemaker Model :

We will use a pulse generator to build a pacemaker to drive a *damaged* version of the heart model you have built.

Procedure :

1. We will Disable spontaneous heart beat by setting both Na leak resistors (sa and ventricle) to 1e8 ohms. In real life, this would be equivalent to a heart attack.
2. Vary pacemaker rate, pulse length, and coupling resistor. We Demonstrate phase lock between the pacemaker, SA node and ventricle models for some combinations of parameters.
3. Build the pacemaker circuit using a 555 timer. We will Connect our pacemaker to our SA-ventricle circuit. We may need to play with the pulse width and or coupling resistor to get phase-locking.

Circuit Diagram and Result :