Rate-Responsive Pacemaker

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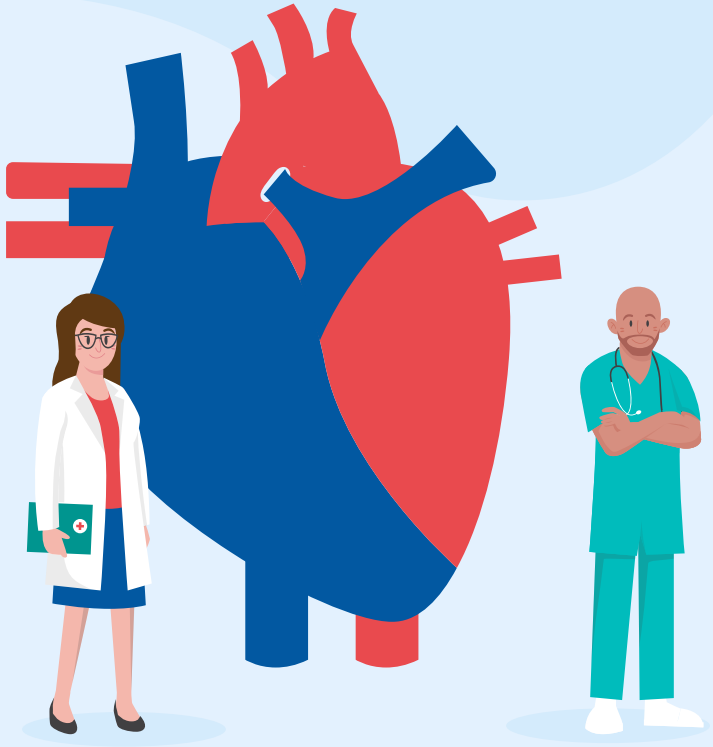
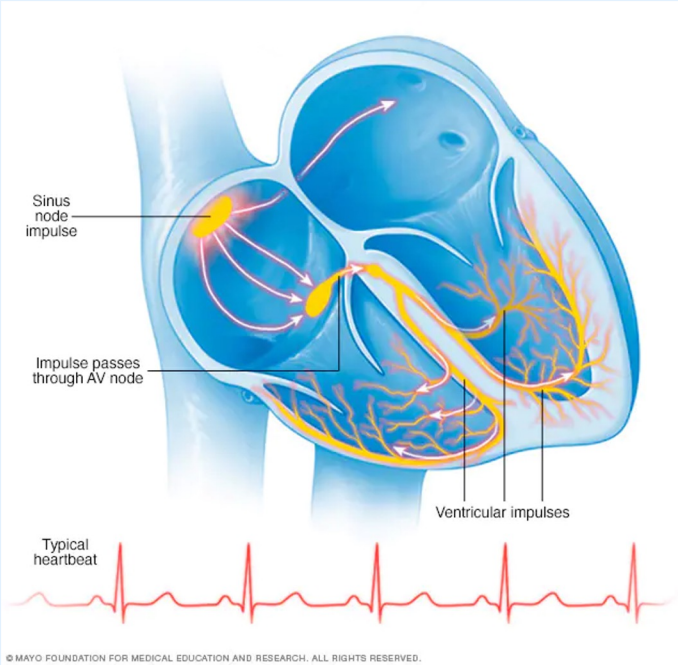


01

Introduction

Physiology

- **Cardiac Arrhythmia:** An irregular heartbeat which occurs when there is faulty electrical signaling in the heart [1]
- Types of Arrhythmia
  - **Tachycardia**
    - Faster heart rate
    - > 100 BPM [2]
  - **Bradycardia**
    - Slower heart rate
    - <60 BPM [2]



Epidemiology

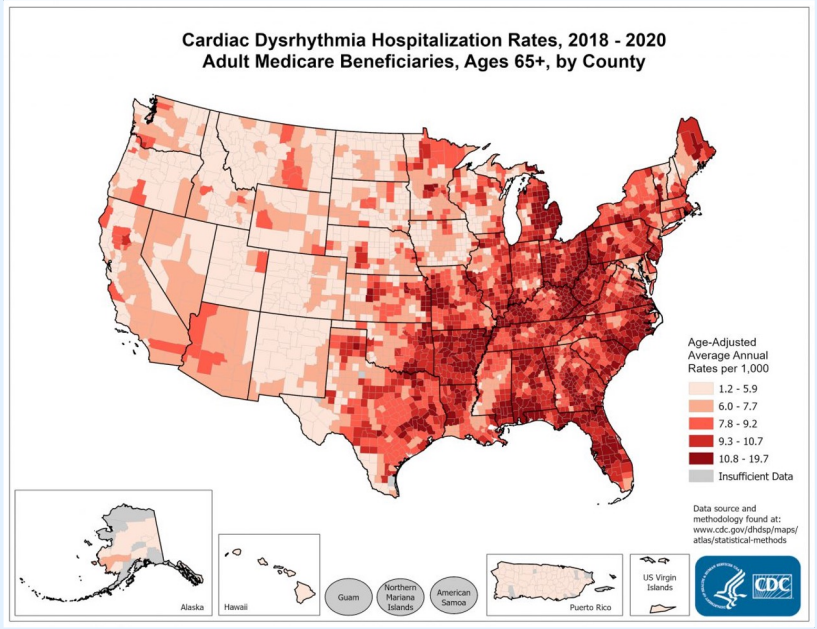
Heart disease is the leading cause of death in the United States [3]

1.5% to 5% of the population have an cardiac arrhythmia [3]

More women than men experience cardiac arrhythmia [6]

Importance of Cardiac Pacing

- **Pacemaker**: Medical device that senses and processes electrical signals from the heart to send corrective impulses [7]
- Some arrhythmias can cause bothersome, and even life-threatening, symptoms [6]
- Electrically stimulating the heart reestablishes hemodynamics altered by irregular heart rates [4]
- Helps prevent and detect more serious cardiovascular disorders (e.g. coronary artery disease) [5]
- Most **serious arrhythmias are ventricular in nature** [2]



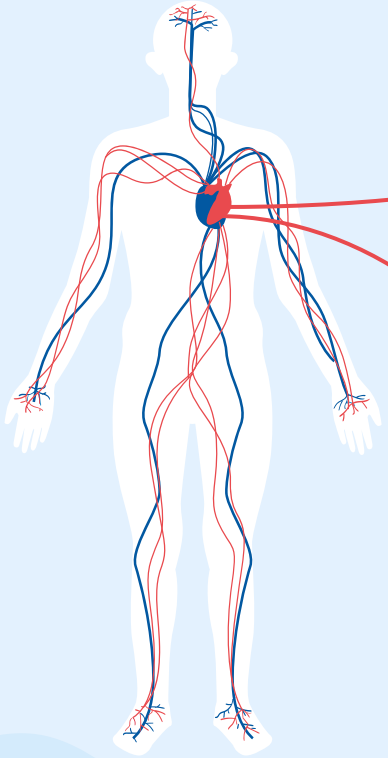
Patients with serious cases of **cardiac arrhythmia** need their heart rates to be constantly **monitored and regulated** to prevent more detrimental cardiovascular complications. When **non-disorder stimuli** impacts pacing, how does one design a device to **detect and correct an abnormal heart rate?**

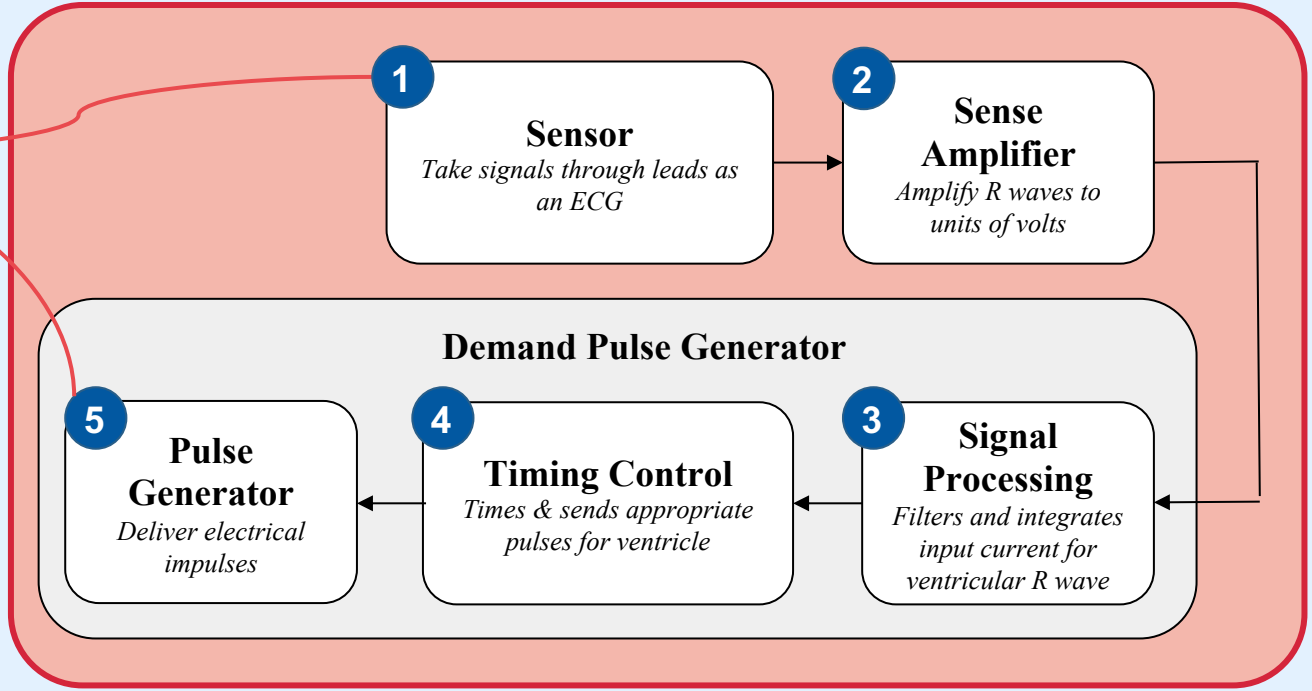
Create a single lead, **rate-responsive pacemaker** to improve effectiveness in detecting and correcting abnormal heart rates

02

Methods

Pacemaker Circuit Schematic



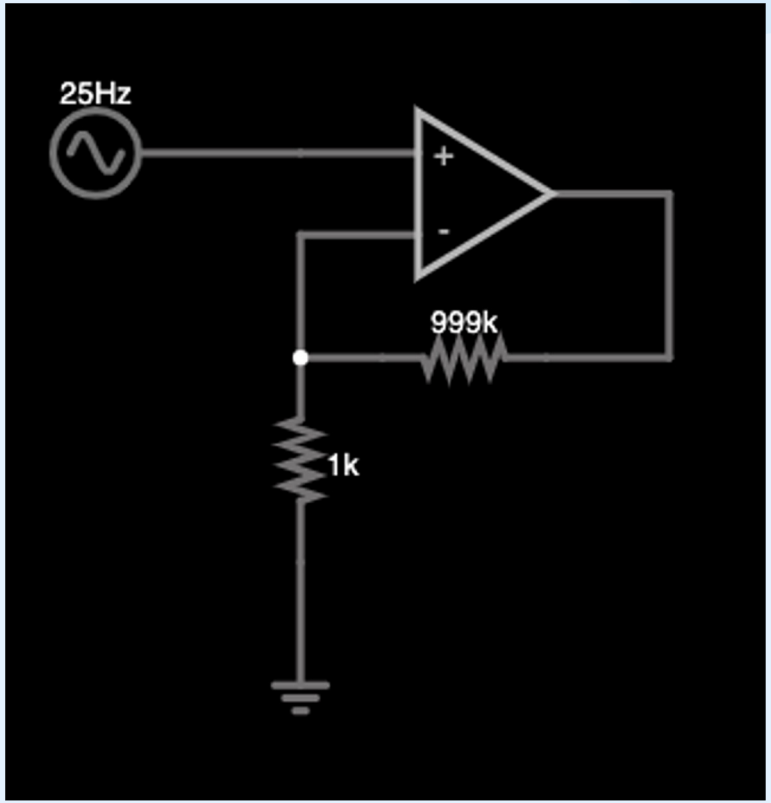


Signal Amplifier Design

- An amplifier receives the signal from the pacing lead.
- Signal Amplifier Objective:

  Amplify R-wave signals to units of volts

- Makes input to comparator reasonable so normal resistance values can be used.

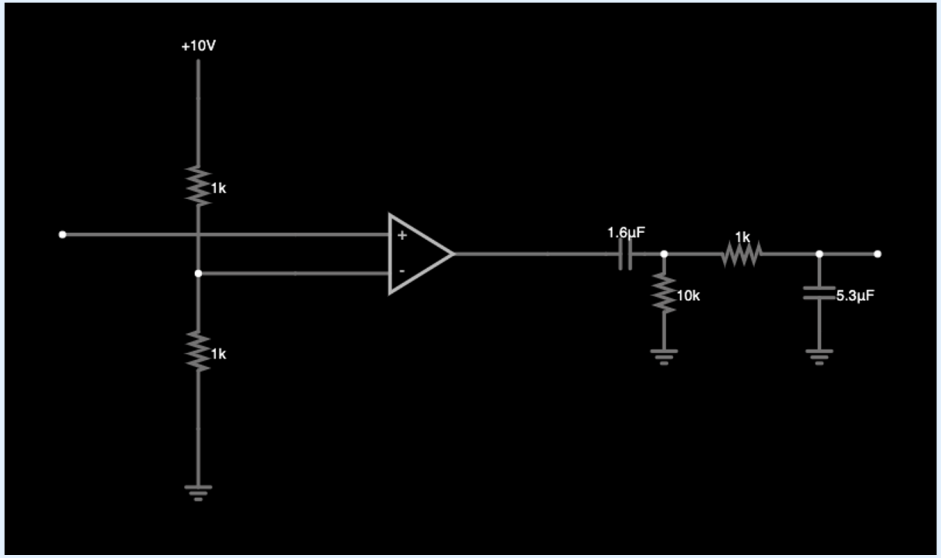


R-Wave Processor Design

- Most cardiovascular disorders are ventricular by nature
- ECG: R-wave represents ventricular pulse
- Signal Processing Objective:

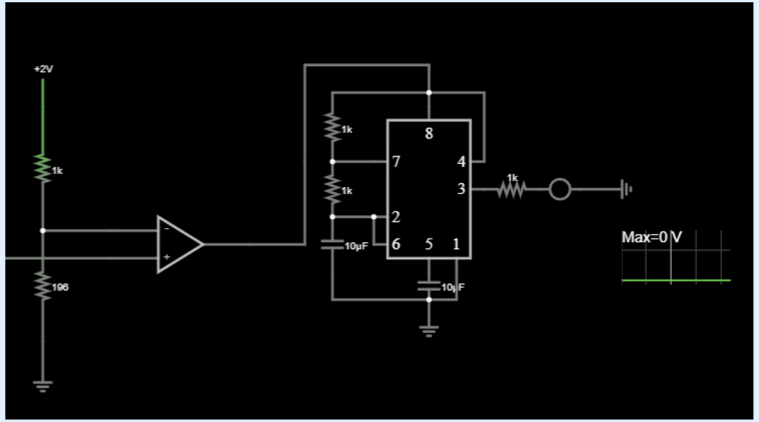
  Create an R-wave processor to filter R-wave signals

- Primary components:
  - Comparator
  - Bandpass filter



Timer Circuit Design

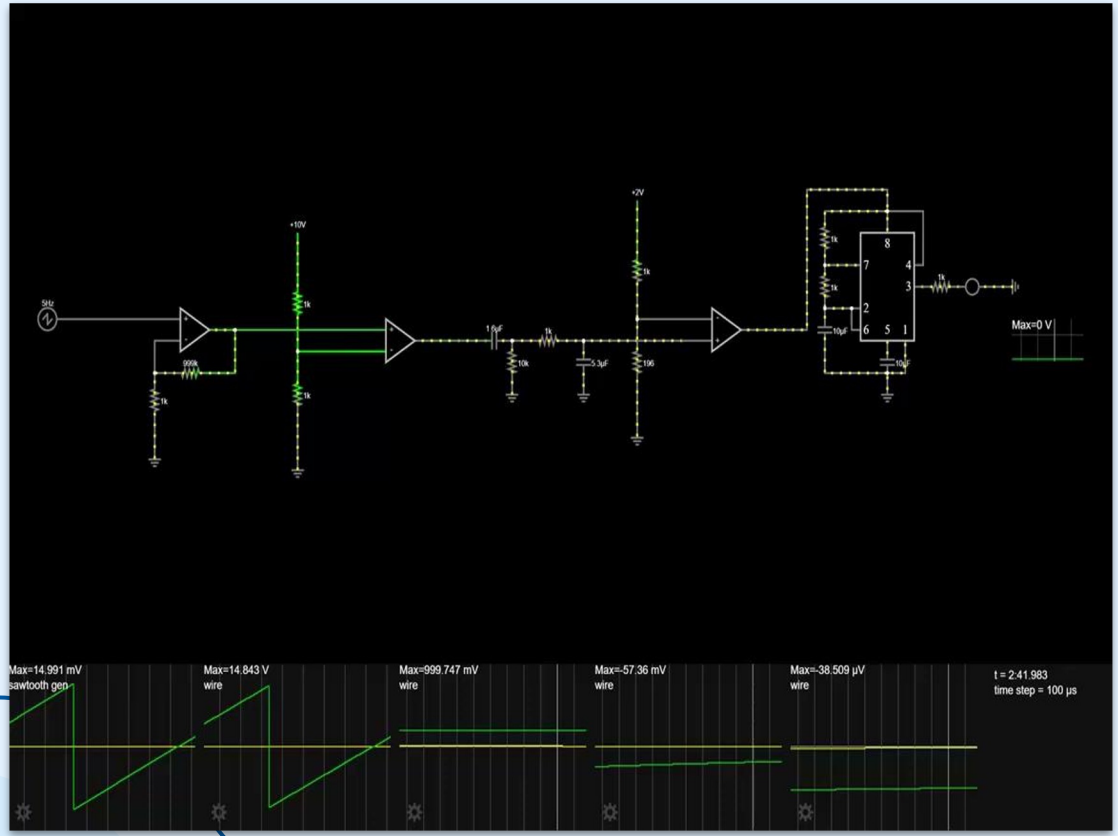
- A comparator sends voltage to the source pin of the timer.
- The timer will turn on during stop band frequencies.
- Timer Design Objective:
  - **Design a timer component which sends electrical impulses to the heart at unstable frequencies.**
- Primary components:
  - Comparator
  - Timer
  - LED



03 Results

Rate Responsive Pacemaker Circuit Simulation

Rate Responsive Pacemaker Circuit Simulation



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Conclusion

Discussion

Advantages

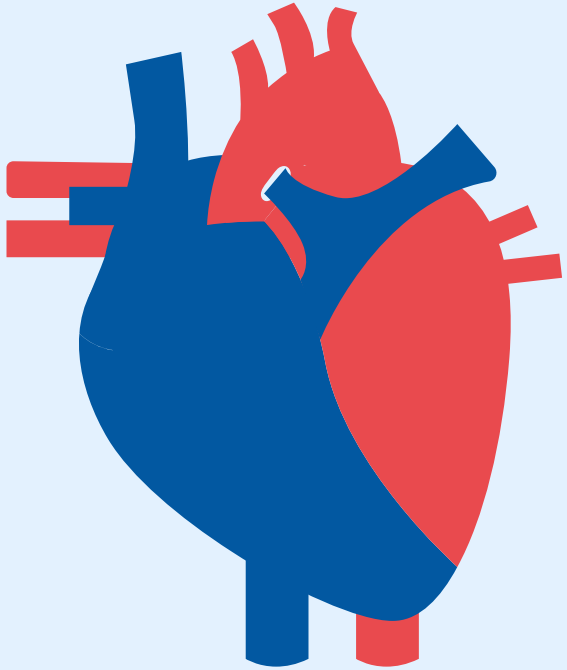
- Adjusting pacing ranges accordingly can improve cardiac output
- Patients can utilize it in a non-resting or passive state

Limitations

- Cannot track patient or device historical data
- Has to be calibrated based on individual's normal pacing range
- Pacemakers applicable on a case-by-case basis
- Not as accurate as two leads - lead only goes to the ventricle

Future Steps

- Potentially incorporating less components
  - Increase in cost effectiveness
  - Decreased probability in design malfunction with less components
- Develop an exercise modality for the pacemaker



Special Thanks

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References

[1] *Analysis of arrhythmic events is useful to ... - Wiley Online Library*. (n.d.). Retrieved March 16, 2023, from https://onlinelibrary.wiley.com/doi/10.1111/jce.13399

[2] *Categories of arrhythmias*. The Texas Heart Institute. (2020, September 30). Retrieved March 16, 2023, from https://www.texasheart.org/heart-health/heart-information-center/topics/categories-of-arrhythmias/#:~:text=Your%20heartbeat%20quickens%2C%20and%20you,%2C%20or%20fainting%20(syncope).&text=The%20most%20serious%20arrhythmia%20is,is%20an%20uncontrolled%2C%20irregular%20beat.

[3] Centers for Disease Control and Prevention. (2022, October 14). *Atrial fibrillation*. Centers for Disease Control and Prevention. Retrieved March 16, 2023, from https://www.cdc.gov/heartdisease/atrial_fibrillation.htm

[4] Dell'Orto, S., Valli, P., & Greco, E. M. (2004, July 1). *Sensors for rate responsive pacing*. Indian pacing and electrophysiology journal. Retrieved March 16, 2023, from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC1501080/

[5] M;, S. J. E. M. C. D. T. B. K. (n.d.). *Physiologic benefits of rate responsiveness*. Pacing and clinical electrophysiology : PACE. Retrieved March 16, 2023, from https://pubmed.ncbi.nlm.nih.gov/6189075/#:~:text=A%20pacemaker%20that%20increases%20pacing,cardiac%20output%20and%20work%20capacity.

[6] Mayo Foundation for Medical Education and Research. (2022, April 30). *Heart arrhythmia*. Mayo Clinic. Retrieved March 16, 2023, from https://www.mayoclinic.org/diseases-conditions/heart-arrhythmia/symptoms-causes/syc-20350668#:~:text=A%20heart%20arrhythmia%20(uh%2DRITH,slow%20(bradycardia)%20or%20irregularly.

[7] UpToDate. (n.d.). Retrieved March 16, 2023, from https://www.uptodate.com/contents/temporary-cardiac-pacing#:~:text=Temporary%20cardiac%20pacing%20involves%20electrical,slow%20or%20fast%20heart%20rate.