Cardiac Rhythm Generator and Temporary Pacemaker Training Simulator

ZACH BOWER, MAKAYLA KIERSTEN, DHYUTI RAMADAS
CLIENTS: DR. SCOTT HAGEN and DR. JOSHUA MEDOW
ADVISOR: DR. JOHN PUCCINELLI

ABSTRACT

Medical simulators aid in training and maintenance of a physician's skills. Currently, medical students learn to adjust pacemakers mainly from observation. Present training tools are prohibitively costly and have limited functionality. To improve the training that medical students receive, we designed a low-cost, interactive pacemaker simulator with a user interface to change parameters to generate a customizable ECG waveform. This device simulates a patient's arrhythmia, sending both to the pacemaker and a standard hospital monitor, such that students can practice adjusting the pacemaker under a variety of clinical conditions.

BACKGROUND

- Electrocardiogram (ECG) is a reading of the electrical activity of the cardiac muscles in a patient
- A pacemaker provides electrical pacing to correct abnormal arrhythmias by delivering timed electrical stimuli that cause cardiac depolarization of the different chambers and induce beating as shown in *Figure 1*.

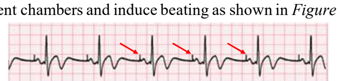


Figure 1. ECG with displayed pacemaker spikes [3]

- Pacemaker parameters such as rate, atrial current, and ventricular current are set via a trial-and-error method [4].

Competing Designs

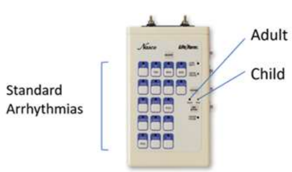


Figure 2. Life/form Interactive ECG Simulator that outputs limited number of arrhythmias to a hospital monitor [5]

Figure 3. PacerMan, a costly competitor that also only outputs a limited number of arrhythmias[6]

MOTIVATION

Current methods for teaching the use of temporary pacemakers are insufficient because they are limited. Use of a simulator allows students to practice setting the pacemaker output to correct the arrhythmias and receive visual feedback from the hospital monitor for their settings. Implementation of this product would help our client and other healthcare professionals in hospitals and universities nationwide to improve student learning.

DESIGN CRITERIA

- Read current and pulses per minute (ppm) from the pacemaker
- Bluetooth communication between components of the simulator
- Voltage output to the pacemaker to simulate heart rhythm inputs and cause the predicted reaction from the pacemaker
- Customizable ECG waveform with corresponding pacemaker spikes on display
- Real-time communication of ECG signal via Bluetooth

SIMULATOR DESIGN

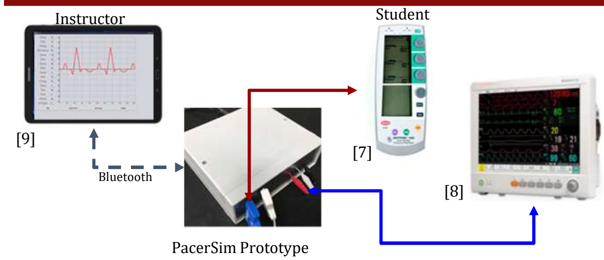


Figure 4. Cardiac Rhythm Generator and Temporary Pacemaker Training Simulator overview

Simulator Block Diagram

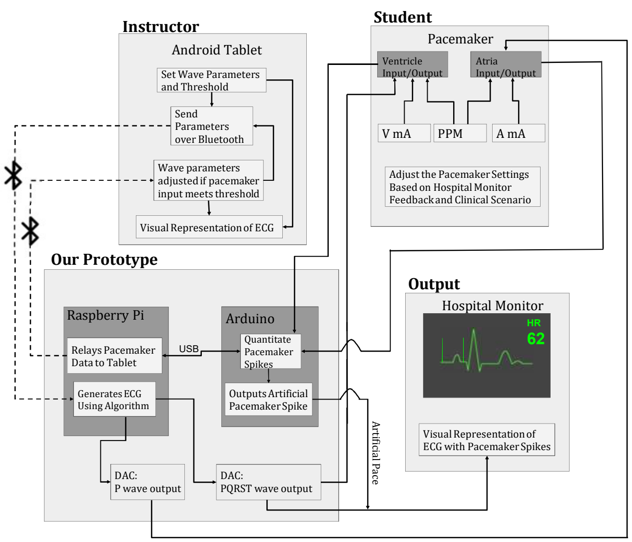


Figure 5. Block diagram for using the simulator in training

Electrical Schematics

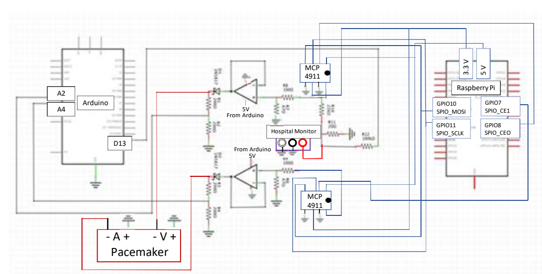
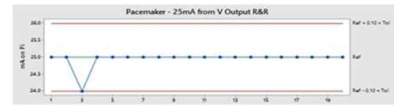


Figure 6. Circuitry for PacerSim Prototype including an Arduino for quantitating the pacemaker spikes, DAC(MCP 4911) components for outputting a voltage to simulate the ECG, a Raspberry Pi for processing and Bluetooth communication and the integration of the pacemaker and hospital monitor leads.

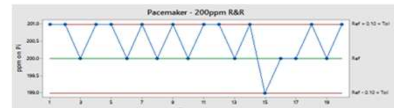
TESTING

Gage Repeatability and Reproducibility Test for Pacemaker to Pi Data:



Mean: 24.95
St. Dev: 0.224
P_Value: 0.330
Bias: -0.05

Figure 7. Results for 25 mA from the ventricle output of the pacemaker



Mean: 200.50
St. Dev: 0.607
P_Value: 0.002
Bias: 0.50

Figure 8. Results for 200 ppm frequency output of the pacemaker

V mA	A	PPM mA	AV Pacing Interval
12	13	80	-29304
12	13	80	-680
12	13	80	-29296
12	13	80	-29296
12	13	80	-656
12	13	80	27872

Figure 9. Pacemaker Data Output Sent to Tablet.

The circuitry and software is able to successfully quantitate and relay the pacemaker amplitude (mA) and frequency (ppm) to the Pi as shown by the low standard deviation and limited bias. The two extreme cases of measurements are shown above in *Figure 7* and *Figure 8*.

Prototype ECG Sample Outputs:

Figure 10. Simulated Healthy ECG Signal

Setting: Pacemaker ppm set below HR
Parameters: Normal
Result: No pacing, only sensing

Figure 11. Simulated Paced ECG Signal

Setting: Pacemaker ppm set above HR
Parameters: Normal
Result: Pacing and sensing

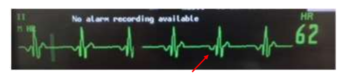


Figure 12. Simulated ECG Signal With Inverted P-wave

Setting: Pacemaker ppm set below HR
Parameters: P-wave amplitude changed to -1
Results: Inverted P-wave

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0,0.5,1,1,1,1
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vs.

```
0,0.5,1,-1,1,1
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FUTURE WORK

- Establish automatic Bluetooth communication between the Raspberry Pi and the Android tablet
- Program conditional statements for ECG to react to pacemaker input
- Order PCB of finalized circuit
- Implement hospital monitor snaps instead of alligator clips
- Use of tablet as control over Raspberry Pi instead of computer monitor

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