

The Design of A Rectenna Energy Harvesting Photoplethysmography (PPG) Monitor with Bluetooth Connectivity

Author: Joshua Port (2114468)
Supervisor: Stephen Mosey

Introduction

This project has been established to design a functioning photoplethysmography monitor which uses energy captures at 2.4 GHz to power its functionalities. This monitors function is to analyse the users heart rate and send a signal over Bluetooth to their phone should the heart rate measurement fall outside of the safe heart rate limits. The prototype utilises a rectenna design which combines the use of a receive antenna and a rectifier circuit to obtain Alternating Current (AC) from free space Radio Frequency (RF) and convert it into Direct Current (DC) for circuitry operations.



[1]

Previous Design Models / Background Research

There are multiple models of heart rate monitors currently on the market including Apple Watches, Fitbits and whoop bands. In order to assess what aspects of the models are needed within this design, a comparison chart was drawn highlighting details such as price, connectivity, subscriptions and their overall capabilities. The aspects focused on this design were:

- Communication Protocols** – UART and I2C protocols initialised to communicate between the PPG chip and the PIC as well as, the Bluetooth chip and the PIC.
- Rectenna Designs** – The design of an antenna to harvest / scavenge frequency from free space and rectify the AC to DC for battery charging.
- Liquid Crystal Display** – Used as an easy way to display the heart rate reading for easy analysis by the user.



Design and Implementation

The design uses a combination of chipsets including a PPG sensor module, a Bluetooth 5.0 chip [2] and for this prototype an Arduino R3 Uno board. The code is written and then transferred to the main chip to carry out its designated instructions. The Arduino can and will be interchanged for a PIC18F45K50 for the final model to reduce its size and capabilities. Previously devised methods (Bus Pirate) of checking the communication protocols show the pins and code are also interchangeable.

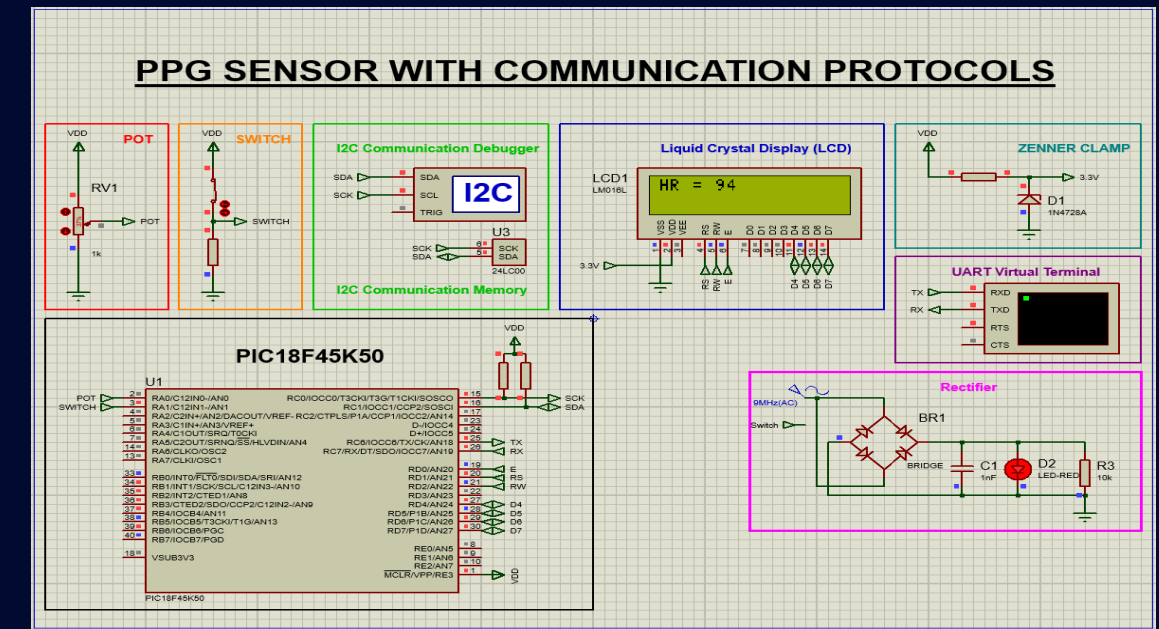
Project Aims and Objectives

Main Aim

- Create a functioning prototype of a photoplethysmography monitor which could be powered by rectenna charging and communicate via Bluetooth.

Objectives

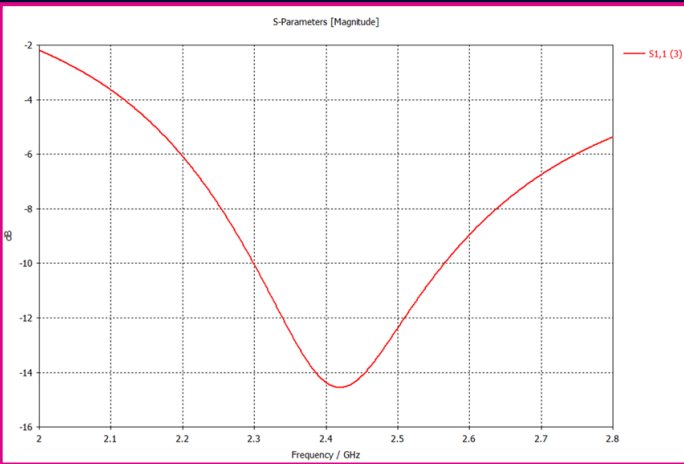
- Use both UART and I2C communication protocols to transmit between the on-board chipsets (Bluetooth and PPG).
- Create a 2.4 GHz antenna for energy scavenging capabilities.
- Display the users heart rate in an easily readable manner on an LCD.
- Create the design to be as cost effective as possible and comfortable.



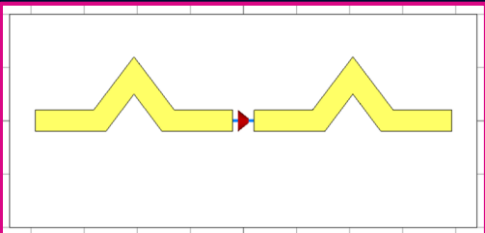
Full PPG Circuit Design

Conclusion

The prototype designed here is effective and at built at a low cost for the user. The model has the capability to, read the users heart rate, display the values onto an LCD, as well as connect to the users' phone. With more time the designed PCB could be printed and the rectenna inserted to provide a charging capability. This project is a great start to the fundamentals of energy scavenging for future green energy.



Antenna S1,1 Reflections



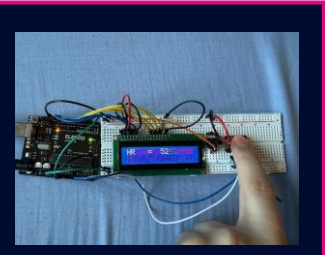
Antenna Design

$$\text{Wavelength } (\lambda) = \frac{\text{Speed of Light } (c)}{\text{Frequency } (F)}$$

Antenna Calculation

Results and Testing

The antenna was designed and tested using the CST simulation software where it was determined that the operational frequency was 2.4 GHz as expected at -15 dBs. -10 dBs means 90% power is transmitted showing this antenna was optimal for the project. Multiple designs were tested however, due to sizing a bent dipole was the optimal choice. For the prototype, the original testing was conducted with predesigned Arduino IDE code files to establish the baseline coding functions. This was a success with the code from IDE being almost directly transferred into C. This performance in proteus simulations showed the operations could be carried out using either the Arduino board or the PIC. Upon testing power consumption, it was found that a secondary charging capability may need to be added to ensure the device is able to get enough power for operation.



References

- [1] Macys, "What Is A Fitbit and How do you use it?," 2025. [Online]. Available: <https://www.macys.com/ce/watches-buying-guide/what-is-a-fitbit>. [Accessed 31 March 2025].
- [2] A. Nguyen, "Bluetooth 1.0 vs 2.0 vs 3.0 vs 4.0 vs 5.0 - How They Compare | Symmetry Blog," Symmetry Electronics, 18 April 2018. [Online]. Available: <https://www.symmetryelectronics.com/blog/bluetooth-1-0-vs-2-0-vs-3-0-vs-4-0-vs-5-0-how-they-compare-symmetry-blog/?srsltid=AfmBOorcu7bD7vyq0orsVtyYz94j-tWf7gTL-k9ESDqzTqQtz9-j0LO>.
- [3] J. S. P. P. M. G. A. C. F. X. P. K. P. J. B. M. P. R. D. J. R. a. N. M. A. E. Donchev, "The Rectenna Device - from theory to practice (A review)," Materials Research Society, London, 2014.