Characterizing Charge Time of Wearable Devices using Qi Wireless Charging System

Kiriaki Rajotte[1], Benjamin McDonald[2], Anson Wooding[2], Todd Farrell[2], Edward A. Clancy[1].
[1]Worcester Polytechnic Institute (WPI), Worcester, MA, USA. [2]Liberating Technologies, Inc., Holliston, MA, USA.

Introduction: When developing wireless, wearable biomedical sensors, some considerations that the designer(s) must make include the device's form factor, source of power, and usability. Wireless charging can be implemented to simplify the user experience and may easily integrate with existing chargers depending on the charging protocol selected. One challenge associated with the use of wireless charging in small form factor wearables is ensuring that the smaller receive (Rx) coil can reliably pair with the larger transmit (Tx) coils used in charging pads designed for devices such as smartphones.

In this work, the Qi wireless protocol was used to characterize the time required to charge a 105 mAh, lithium polymer battery for a small form factor (1–3 cm diameter and 1 cm thickness) wearable biomedical signal acquisition system. Two Rx coils of different shape and size were tested, and the material (representative of distinct device packaging options) placed between the Tx coil and Rx coil was varied to study its influence on battery charge time. For each measurement, the Rx and Tx coils were centered to ensure proper alignment.

Methods: As shown in Fig. 1, an Amazon Basics 15W Qi certified wireless charging pad was used to transmit power to the Texas Instruments (TI) wireless power receiver evaluation kit (BQ51050EVM-764). The kit features the BQ51050 Qi receiver with an integrated LiPoly battery charger; the output charge current was limited to 100 mA (set by the output circuit of the BQ51050EVM) to achieve a charge rate of 1C. To monitor the battery's charge, Adafruit's MAX17048 fuel gauge was selected. An Arduino Uno was used to read and log data from the fuel gauge. To discharge the battery, the HRTC C150 Balance (Dis)Charger was used.

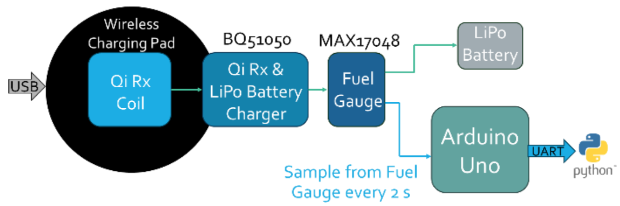

Figure 1. Block diagram of the experimental set-up

Two Rx coils from Würth Elektronik were tested: a large, rectangular coil (part number: 760308103215) measuring 48x32 mm and a smaller, round, 17 mm diameter coil (part number: 760308101220). Four different potential packaging materials were tested: 1) Rx coil directly placed on Tx pad separated by air, 2) Rx coil placed inside of the TI Rx evaluation kit's 2 mm thick enclosure, 3) Rx coil placed on 2 mm thick 3D printed ABS sample, and 4) Rx coil placed on 2 mm thick 3D printed PLA sample.

For each trial, the battery was initially discharged to under 10%. Then, the battery was connected to the output of the BQ51050EVM-764 and to the fuel gauge. The initial battery charge read by the fuel gauge was recorded. The Qi receiver set-up was placed on the Amazon Basics Qi transmitter pad, using the selected potential packaging options. The battery was left to charge until the percentage charge reached 95% or (due to transitioning to trickle charging) did not change for 15 minutes (whichever end condition was reached first).

Results: For each combination of coil and package option, five trials were completed. Table I shows the mean and standard deviation charging time for each combination. On average, 2.5–3 hrs. were required to charge the battery and the 17 mm diameter coil charged the battery faster than the larger antenna for each condition tested. When looking at the influence of the packaging options, placing the coil inside of the evaluation kit's enclosure led to the longest average charging times, while the 2 mm thick ABS material had the shortest average charge time for the two coils.

Table I: Summary of Results. Time, in hours to charge.

Coil Placement	48x32 mm Antenna	Ø 17 mm Antenna
Direct on TX pad	2.84 ± 0.10	2.68 ± 0.04
Inside of evaluation kit	2.95 ± 0.10	2.68 ± 0.22
On PLA	2.87 ± 0.12	2.53 ± 0.06
On ABS	2.71 ± 0.21	2.48 ± 0.36

Conclusions: This investigation determined Qi to be a feasible option for developing a wirelessly charged, biomedical sensor. The 105 mAh battery was found to charge from its initial charge point until it reached the stop criteria typically in under 3 hours for all trials with a minimum final charge of 88% achieved. Future work could look at the impact of smaller Rx coils or other Qi Rx circuits from different manufacturers. Additionally, there are other wireless charging protocols, such as NFC, that could be considered.

References:

1. Mirbozorgi SA. IET Power Elect. 2021;13(18):4183-4193.
2. Lyu H. IEEE Sensors Letters. 2019;3(3).
3. Kim J. Nature Reviews Bioengineering. 2023;1:631-647.

Acknowledgements: This work is supported by DoD STTR Contract W81XWH-22-C-0049. Any opinions, findings and conclusions or recommendations are those of the author(s) and do not necessarily reflect the views of the U.S. Army Medical Research and Development Command (USAMRDC).

DEI: Electrical engineering remains a male dominated field. To broaden participation for underrepresented groups in this field, early engagement with middle and high school students of different backgrounds through programs such as FIRST Robotics may help introduce and foster interest in this field while building student connections with practicing engineers. Building these connections prior to higher education may create future electrical engineers.