RFRD Phase II

TO DESIGN A RADIO FREQUENCY READOUT DEVICE TO USE IN A BOLT ANCHOR SURVEYING APPLICATION.

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1 Introduction

1.1 PROJECT STATEMENT

In this project a Radio Frequency Readout device (RFRD) is designed to send and receive data from an RF tag.

Our goal is to be able to wirelessly sense the tightness of a nut by measuring the capacitance of a sensing washer that is secured between the anchor bolt and nut.

1.2 PURPOSE

The purpose of this project is to address the time-consuming act of checking each nut for secured tightness on bolts of large lamp posts. Currently, each nut must be manually checked on each post for tightness to prevent a failure in the structure. This process takes a lot of time and cost to check each nut.

To address this problem, this project will use a Radio Frequency Readout Device (RFRD) to read if each nut is tight or needs to be torqued properly. This RFRD will be usable in a vehicle driving next to each structure to reduce the time needed to check each nut. The RFRD will be reading a capacitance value from a passive RF tag. The capacitance value will then allow the user to know if the nut is tight or loose.

1.3 GOALS

The RFRD and RF tag is intended to be used by civil engineers and construction workers on lamp posts and other large structures that require constant inspections to the structures integrity. The main goal is to provide a less time-consuming and cost-efficient way to check for tightness of nuts on structures.

2 DELIVERABLES

To meet these goals, a Radio Frequency Readout Device prototype must be designed to send and receive a signal from an RF tag prototype tag that can measure the capacitance of a bolt and nut.

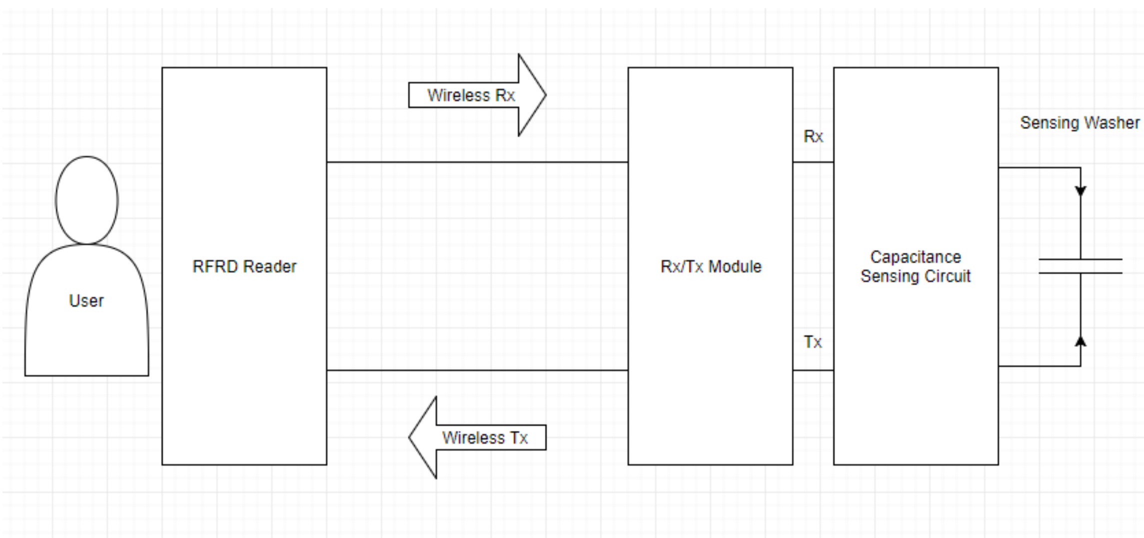
3 Design

Describe any possible methods and/or solutions for approaching the project at hand. You may want to include diagrams such as flowcharts to, block diagrams, or other types to visualize these concepts.

3.1 PREVIOUS WORK/LITERATURE

We will not be using many of the resources from Phase I. We will aim to use the frequencies that were recommended and simulated by the prior group.

3.2 PROPOSED SYSTEM FLOWCHART



The above flowchart describes the closed loop functionality of which the tag receives power from the reader and transmits data back to the reader.

The RFRD reader will be activated by the user. Once data is received by the reader, the user will be responsible to make a decision on whether to torque the anchor bolt or to do nothing based on the feedback from the tag.

3.3 ASSESSMENT OF PROPOSED METHODS

Capacitive Sensor:

We have decided to use a relaxation oscillator to measure capacitance across the washers.

This non-linear relaxation oscillator is a comparator with a capacitor connected to the inverting input. This oscillator will create a PWM output that changes the period of the waveform linearly with the value of capacitance. We decided to pursue this circuit due to the low power, high gain bandwidth, and accuracy of measurement for this design.

We will need to measure capacitances in the ranges of 20 pF to 50 pF. This will be an optimal range for a relaxation oscillator per IEEE paper "Limitations of a Relaxation Oscillator in Capacitance" by Yili Liu, Song Chen, Masakatsu Nakayama, and Kenzo Watanabe.

We have decided for our design, we will be using STMicroelectronics op amps. Our antenna team proposed an estimated received power of ~ 0.45 mW at 1 meter distance from the RFRD reader. This means we will be able to use op amps up to this power consumption limit.

Our biggest constraint for our relaxation oscillator design is the amount of power we can harvest from our Power Harvesting circuitry.

Power Harvesting:

We plan on using an inverted-F antenna in our design due to a high efficiency rating at the area restrictions for our RF tag. We will need a rectifier circuit to follow the antenna.

We determined from papers such as "A Compact Fractal Loop Rectenna for RF Energy Harvesting" by Miaowang Zeng, Andrey S. Andrenko, Senior Member, IEEE, Xianluo Liu, Zihong Li, and Hong-Zhou Tan, Senior Member, the estimated received power that we will obtain is ~0.45 mW at 1 meter distance from the reader to the tag.

TX/RX Module:

We plan in using a very low power microcontroller that will be housed on the tag for communications.

RFRD Reader:

We plan to use a software defined radio combined with GNU Radio to implement a reader that will receive and decode the signal from the tag. This will allow us to do incremental testing of our design and make revisions if necessary.

3.4 VALIDATION

Capacitive Sensor:

We will confirm our capacitive sensor design using the following procedure:

1) Confirm design with professor.

2) Simulate design using SPICE.

3) Spec out components for our design and generate a BOM (Bill of Materials).

4) Fabricate design on a breadboard.

5) Demo breadboard.

6) Fabricate design on a PCB with surface mount parts.

7) Demo PCB.

4 Project Requirements/Specifications

4.1 FUNCTIONAL

The reader should be able to read the tag from a meter away. The capacitance measuring should be able to read capacitances from 20 pF to 50 pF with an accuracy of +/- 1 pF. The tag will be powered wirelessly from the reader and will need to be a low power circuit.

4.2 NON-FUNCTIONAL

The tag will need to be able to withstand the weather and temperature fluctuations from being outside, although this is an aspect of the project we don't intent to be involved with.

4.3 STANDARDS

The main standards that we will have to be concerned with while working on this project are the standards from the FCC regarding frequencies that are used to send power and data.

5 Challenges

The most challenging aspect of this project will be finding the parameters that will allow us to power the tag using the reader from about a meter and using a very small amount of power to measure the capacitance. We will have to extensive research to understand these aspects of the project.

6 Timeline

6.1 FIRST SEMESTER

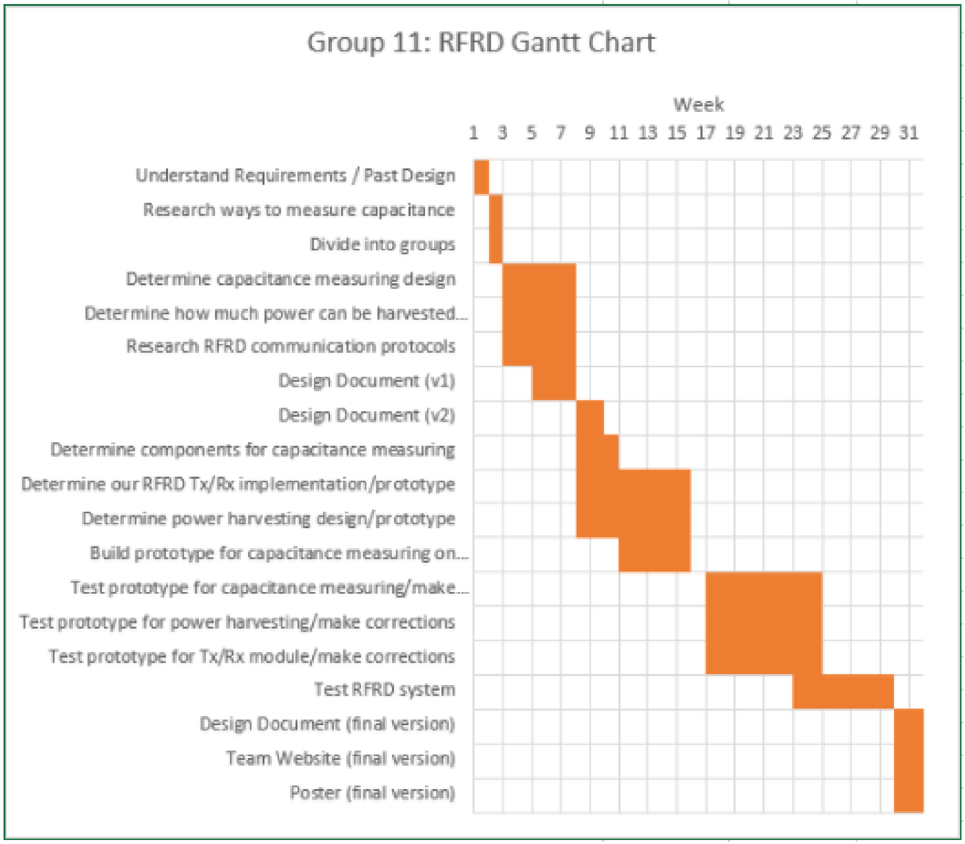
Our goal for the first semester of this project is to have designed a circuit that can be used to measure the capacitance across the sensing washer, have a proof of concept for the power harvesting and antenna aspect of the project, and have an understanding of how we want to communicate between the reader and the tag. Bailey Akers and Colin Sunderman will be working on creating the capacitance measuring circuit. Lyle Bishop and Pengyu Qu will be working on the power harvesting and antenna. Nathan Mulbrook will work on the communication between the reader and the tag.

6.2 SECOND SEMESTER

In the second semester of this project we will take our designs from the first semester and prototype them. We will test to see if the capacitance measuring circuit can measure capacitance correctly and with the proper accuracy. We will test if we can power the tag with the reader and if we can use the reader to receive a signal from the tag. If the designs don't work or can't reach our given parameters we will research, design, and create a new prototype.

Once these aspects of the lab are complete we will work on making the reader work from a greater distance and allowing it to send data to the cloud.

RFRD Gantt Chart:



Above is our schedule for our project.

7 Conclusions

Above all, the main goal for this project is to use a RFRD(Radio Frequency Reader Device) to check if every bolt of the large lamp is tight. We will enable an easier way to check these bolts. To achieve this goal, we need to design a RFRD device that could send and receive the signal from a tag and we need a reader to read the signal.

This is a two-semester project; in the first semester we are designing the circuit and in the second semester we will build a prototype and test it.

8 References

List all the sources you used in understanding your project statement, defining your goals and your system design. This report will help you collect all the useful sources together so you can go back and use them when you need them.

Capacitance Measuring Resources:

Liu, Yili, et al. "Limitations of a relaxation oscillator in capacitance measurements." *IEEE Transactions on Instrumentation and Measurement*, vol. 49, no. 5, 2000, pp. 980–983., doi:10.1109/19.872917.

Tuttle, Dr. Gary. "Non Linear Oscillators." *EE 230 Website*, Dr. Gary Tuttle, tuttle.merc.iastate.edu/ee230/topics/op_amps/non_linear_oscillators.pdf.

"TS881 Rail-To-Rail 0.9 V nanopower comparator." www.st.com/content/ccc/resource/technical/document/datasheet/a2/60/3e/5d/b2/c1/4a/e9/DM00057901.pdf/files/DM00057901.pdf/jcr:content/translations/en.DM00057901.pdf.

Antenna Resources:

Zeng, Miaowang, et al. "A Compact Fractal Loop Rectenna for RF Energy Harvesting." IEEE Antennas and Wireless Propagation Letters, vol. 16, 2017, pp. 2424–2427., doi:10.1109/lawp.2017.2722460.

Kervel, Fredirk. "868 MHz, 915 MHz and 955 MHz Inverted F Antenna." www.ti.com/lit/an/swra228c/swra228c.pdf.