MEMS Wireless Transceiver for Use of Non-Invasive System Diagnostics

Senior Design 1

Initial Project Document and Group Identification

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Group 9

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Project Narrative

The subjects of non-invasive testing and predictive failure of structural integrity has been a growing interest in recent years. This is primarily due to the large amount of cost avoidance that can be gained by sensing a problem and correcting it before the issue has to opportunity to reach a point of a catastrophic failure. Additionally, non-invasive testing also allows for reduced troubleshooting time. By reducing troubleshooting time, companies are able to reduce the amount of manpower allocated to troubleshooting and save on labor costs.

Non-invasive testing is typically accomplished by means of small sensors that are positioned within the structure or system and remain there throughout the life of the unit in question. One of the primary difficulties of implementation lies in the communication of the sensor to a processor and the utilization of the data obtained from the sensor. The data gathered from the sensor is used to analyze the general health of a system. The most common metrics for this analysis are the frequency and amplitude of the system's or structure's vibration. These measurements are especially important in systems which involve motors. The sensors allow companies to monitor the health of the motor by monitoring the number of rotations over a certain time period. If the frequency suddenly increases or decreases, it signals that something may be wrong with the systems and that it requires attention or maintenance.

Devices like this have been been designed and are available on the market. One such design, a high frequency variation, was designed by Mark Looney, an applications engineer at Analog Devices. This MEMS wireless vibration system operates at a frequency range of 862-928 MHz. One of the biggest issues with devices operating at this frequency is interference. In the design, the transmitter and receiver have different frequencies to avoid interference as such modulation is required. Shifting the already high frequency to even higher frequencies could result in encroachment on commercial or government bands.

In an attempt to avoid issues caused by operation at higher frequencies, our project aims to communicate with a MEMs sensor (which will be provided by the sponsor) via radio frequencies for the purpose of non-invasive testing. This goal is to be accomplished by means of sending high power radio signals to the sensor for excitation, then switching to a receiving mode to gather data from the sensor. Although this process sounds like an RFID unit, it differs from RFID units in that the response of the sensor is frequency variant within the ISM band of 27 MHz. This variance in frequency will allow us to determine the overall health of the system. This will be accomplished by taking the received frequency response of the system and applying a Fast Fourier Transform (FFT) to the signal and looking for frequencies that are outside of the standard value. Once the FFT has been performed on the systems microcontroller, the microcontroller will relay the data to a computer where a graph will be plotted to display the characteristics of the systems status.

We will design and provide a fully integrated system consisting of a PCB with embedded microcontroller that provides bidirectional communication to the sensor through the 27 MHz antenna. The PCB will also be capable of interfacing with the PC via serial USB communication. The system will have a launchable application on the Windows platform to provide the user with system diagnostics. The end goal of this project is to create a fully functional and reliable piece of test equipment that will allow our sponsor to easily monitor the health of their systems.

Requirement Specifications

- Ability to transmit data at relatively low FCC approved ISM frequency band
- Transmission range of ~1 m.
- Power Consumption ~10 W.
- Organized Display of Collected Data.
- Simple Graphic User Interface for customer ease.
- Fast setup and response time.
- Must store the latest result in data analytics software.
- Provide list of improvement needed in the future
- Reliable communication protocol.

The Federal Communications Commission (FCC) has strict requirements for transmitters and receivers. Some of the relevant standards are listed below:

- Non-licensed transmitters are prohibited from causing interference to licensed transmitters and must accept any interference that they receive.
- Operators do not need a license to operate “non-licensed” transmitters.
- Low-power, non-licensed transmitters must have permanently attached antennas or detachable antennas with unique connectors
    - We will use a permanently attached antenna
- Depending on the 27.X MHz we will be using, the emission limit is either 30 µV/m (at 30 m) or 10,000 µV/m (at 3 m).
- The design should be tested for compliance with FCC standards.

House of Quality Diagram:
The diagram shown in Figure 1 provides the tradeoff matrix for the MEMs wireless transceiver project. This matrix shows the tradeoff between various aspects of the design specifications and requirements.

			Engineering Requirements							
			Power Output	Signal Quality (SNR)	Cost	Response Time	Low Frequency	Transmission Range	g-Range	[redacted]
			-	-	-	-	+	+	-	
Marketing Requirements	1) Citizens Band Frequency	+	↑	↑	↑	↓↓	↑↑	↑↑	↑↑	
	2) Measurement Accuracy	+	↑↑	↑↑	↑↑	↓↓	↓↓	↓	↑	
	3) Cost	-	↓	↓↓	↑↑	↑↑	↓↓	↑	↓↓	
	4) Moderate Power Consumption	-	↑↑	↑↑	↑↑	↑	↓	↑	↓↓	
	5) Transmission Range	+	↑↑	↑↑	↑↑	↓↓	↓↓	↑↑	↑	
	6) Simple GUI	+	o	o	↑↑	↑	o	o	o	
	Target		~10 W	10-15 dB	$1,093.50	5 secs	27 MHz	~1 m	25 g	

Figure 1: House of Quality Diagram

Legend:

- ↑↑ Strong Positive Correlation
- ↑ Positive Correlation
- o No Correlation.
- ↓ Negative Correlation
- ↓↓ Strong Negative Correlation
- \+ Positive Polarity
- \- Negative Polarity

Block Diagrams

The block diagram, shown in Figure 2, provides a large amount of information in a single image. In addition to showing how components will interact with one another, the color- and shape-schemes identify who is responsible for the component where the component is in the design process.

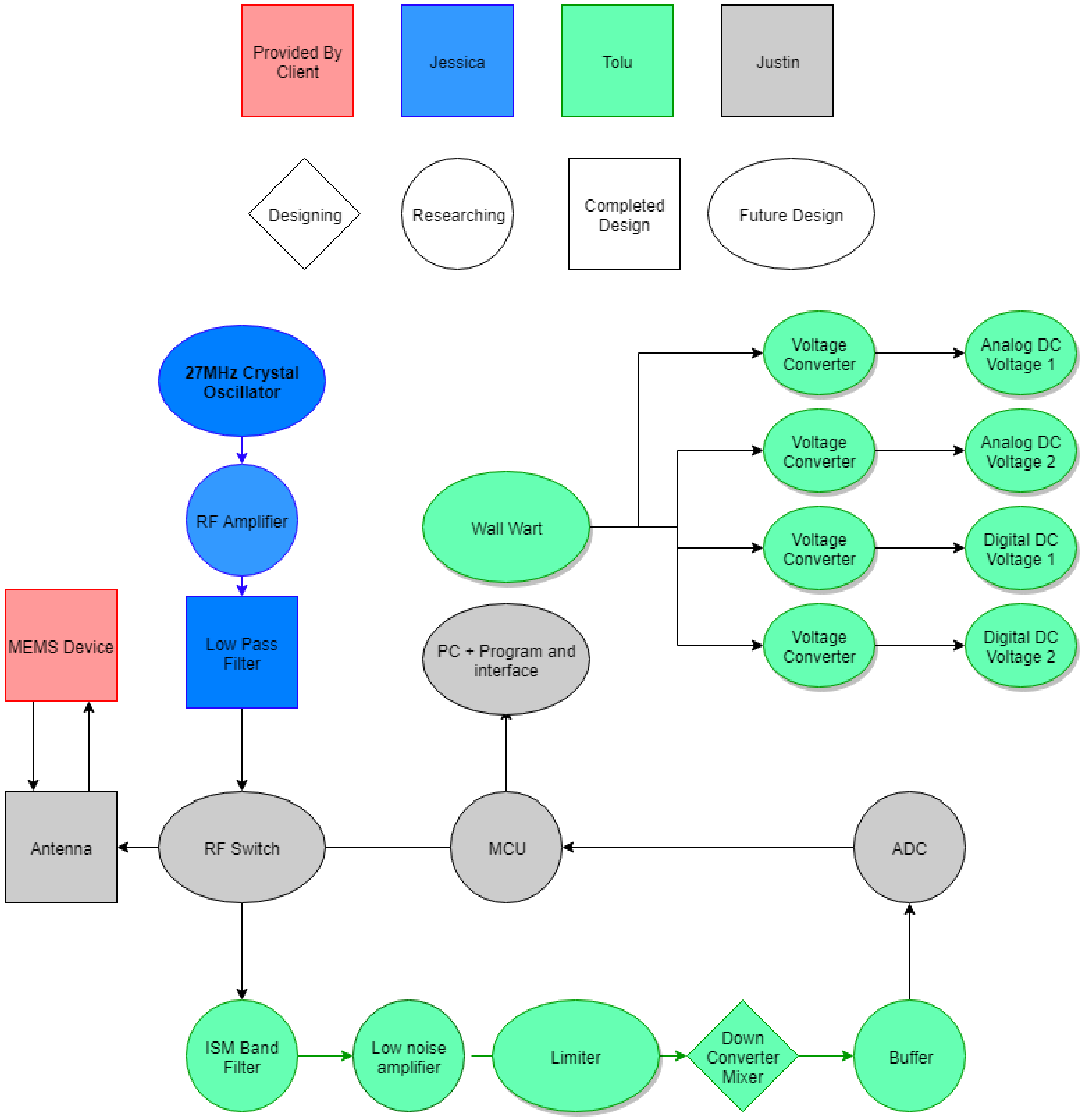

Figure 2: Block Diagram

Financial Considerations

Table 1: Parts List and Project Cost Approximation

Product Description	Quantity	Price Estimate
RF Switch	1	$100.00
RF Amplifier	2	$101.50
LN RF Amplifier	1	$250.00
ISM Band Filter	5	$6.00
Programmable Oscillator	2	$200
Voltage Supplies Board	1	$250
Mixer	4	$10
Downcoverter Mixer	1	$7
Antenna	2	$30
50 Ohm Terminator	2	$6
ADC Buffer PCB	2	$10
ADC Buffer	4	$9
ISM Band Transceiver	1	$100
UART Communication ADC Module	1	$14
PCB	TBD	TBD
PCB Prototyping Software	TBD	TBD
Total Cost		**$1,093.50**

The parts list listed in Table 1 gives a basic idea of the components that will need to be required for this project. Some of the most important components of this design are the frequency dependant parts. The mixers, downconverting mixer, antenna, and transceiver will all have to be carefully chosen so that they are capable of supporting the required frequency bands.

The total price is only a rough estimate, as it is likely that essential parts were overlooked and the design will change as the semester progresses. The parts listed will be purchased by the sponsor with the request that we minimize the cost of the components as much as possible while keeping quality, power, and footprint considerations in mind. Although the cost of the components could be decreased by requesting sample parts from suppliers, the sponsor has requested that we avoid doing this in order to provide them with a more accurate production cost for future device reproduction.

An additional cost consideration is the software required to prototype the PCB. We are considering using a software from Altium if it is reasonably priced and capable of prototyping and simulating the PCB. If the software's cost is within reason, the price may be split by the group members or a single member may pay for it if they wish to retain the rights to the product license. If Altium's software is too expensive, Eagle or another free prototyping software will be used.

Project Milestones

The major project milestones have been divided into two tables - Table 2 summarizes the important tasks for Senior Design I and Table 3 lists the expected tasks for Senior Design II.

Table 2: Project Milestones for Senior Design I

SENIOR DESIGN I	Tasked to:	Start Date:	End Date:	Status:
Familiarize ourselves with the project	Group 9	1/7/2019	1/12/2019	Completed
Role assignments	Group 9	1/7/2019	1/7/2019	Completed
Identify parts	Group 9	1/14/2019	1/31/2019	Completed
Project Report				
Initial Document	Group 9	1/26/2019	1/31/2019	Completed
Updated initial document	Group 9	2/1/2019	2/15/2019	Completed
First draft	Group 9	2/16/2019	3/29/2019	In Progress
Final draft	Group 9	3/30/2019	4/12/2019	In Progress
Final document	Group 9	4/12/2019	4/22/2019	In Progress
Research, Documentation, and Design				
Low pass filter design	Justin	1/14/2019	4/1/2019	Completed
RF switch	Tolu	1/14/2019	4/1/2019	Researching
Power amplifier	Justin	1/14/2019	4/1/2019	Researching
Low noise amplifier	Justin	1/14/2019	4/1/2019	Researching
Downconverter mixer	Jessica	1/14/2019	4/1/2019	Researching
ADC buffer	Tolu	1/14/2019	4/1/2019	Researching

Transmitting and mixing frequency	Jessica	1/14/2019	4/1/2019	Researching
Antenna	Tolu	1/14/2019	4/1/2019	Designed
MCU	Tolu	1/14/2019	4/1/2019	Researching
Schematics	Justin	2/1/2019	4/12/2019	Researching
PCB	Jessica	2/1/2019	4/12/2019	Researching
Order and Test Parts	Group 9	4/12	5/5/18	Researching

Table 3: Project Milestones for Senior Design II

SENIOR DESIGN II	Tasked to:	Start Date:	End Date:	Status:
Build Prototype	Group 9	5/6/2019	6/6/2019	
Testing and Redesign	Group 9	TBD	TBD	
Finalize Prototype	Group 9	TBD	TBD	
Peer Presentation	Group 9	TBD	TBD	
Final Report	Group 9	TBD	TBD	
Final Presentation	Group 9	TBD	TBD	

Resources:

MEMs Devices:
[1] H. Fatemi, M. J. Modarres-Zadeh and R. Abdolvand, "Passive wireless temperature sensing with piezoelectric MEMS resonators," *2015 28th IEEE International Conference on Micro Electro Mechanical Systems (MEMS)*, Estoril, 2015, pp. 909-912.
doi: 10.1109/MEMSYS.2015.7051107

[2] K. Liang, "Transistor Circuits For A MEMS Based Transceiver", *Www2.eecs.berkeley.edu*, 2019. [Online]. Available: https://www2.eecs.berkeley.edu/Pubs/TechRpts/2015/EECS-2015-48.pdf. [Accessed: 22- Jan- 2019].

FCC Regulations:
[3]
http://transition.fcc.gov/Bureaus/Engineering_Technology/Documents/bulletins/oet63/oet63rev.pdf

[4] https://transition.fcc.gov/bureaus/oet/receiver-workshop1/Session5/SESSION-5-3-Drocella-NTIA.pdf