Portable Wireless Interrogation System for Magnetoelastic Biosensors

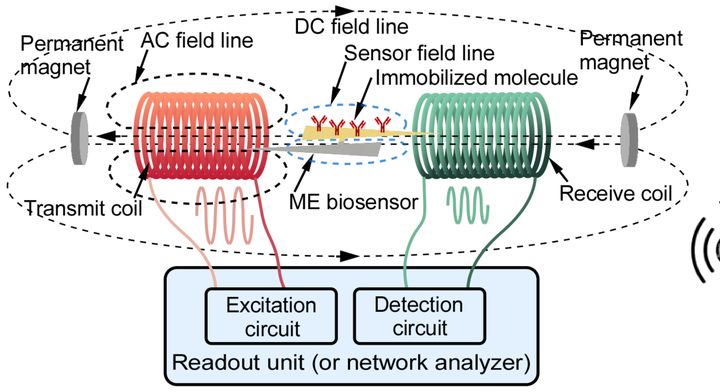
University of CINCINNATI CEAS

CEAS EXPO

Abstract

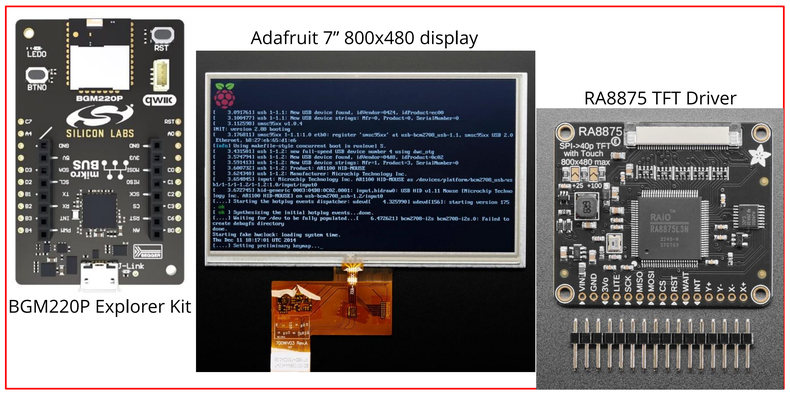
Magnetoelastic (ME) materials have been universally used as anti-theft security tags in shops. These materials exhibit the magnetostriction behavior in which the magnetic property of the material changes under mechanical deformation (strain). The application of such materials as implantable microsensors for biomedical applications, is of high interest due to its inherent passive wireless nature, which eliminates the needs for battery or antenna, leading to implanted devices with reduced complexity, size and cost. Functionalization of sensor surfaces with selected antibodies allows the sensor to target specific types of bacteria of interest. This portable wireless interrogation system allows for the real-time detection and monitoring of Magnetoelastic sensors and uses the "Ringdown" method of detection using a Transmit side and a Receive side. The Ringdown Analysis method characterizes an ME sensor by looking at its vibration duration vs frequency of a time-varying magnetic field. The objectives of this Senior Design Project was to send BLE packets of the generated data over to a Bluetooth capable device to be viewed using a HTML webapp, graph the results obtained from the sensor readout system on a Touch Screen that has an interactive GUI to set/change system control parameters, as well as characterize and optimize the existing readout system.

System Concept and Design



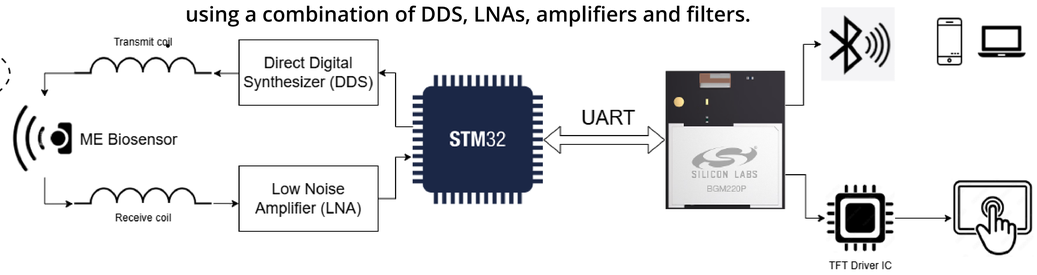
- The Ringdown Analysis method characterizes an ME sensor by looking at its vibration duration vs frequency of a time-varying magnetic field.
- Magnetoelastic materials are ferromagnetic alloys.
  - When a sinusoidal magnetic field is applied to a ME sensor, it will begin to vibrate.
  - As it vibrates, it generates magnetic flux of its own.
  - The resonant frequency is the frequency at which the ME sensor will vibrate the most.
- If antibodies attach to the sensor, resonant frequency shifts downwards.

- The objectives of this Senior Design Project were:
  - To send BLE packets of the data to be viewed using a HTML webapp
  - Graph the results obtained from the readout system on a Touch Screen that has a GUI to set/change system control parameters
  - Characterize and optimize the existing system.
- These goals were achieved by using a Silicon Labs BGM220P module which supports Bluetooth Low Energy and has a 2.4 GHz radio built-in.
- The RA8875 TFT driver IC along with a 7" 800x480 touch-capable display was used as well.

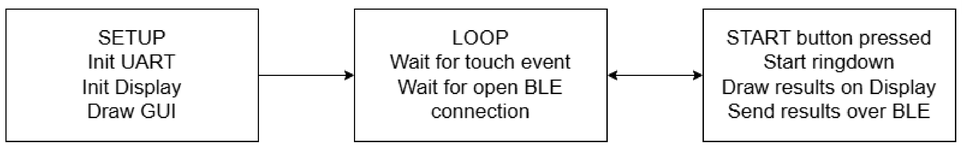


Pictures of parts used in this project

- The system is split into two parts, the STM32 and the BGM220P microcontroller side. They communicate over UART to send two different kinds of packets, ringdown data and ringdown parameters.
- The STM32 handles obtaining the ringdown data from the biosensor by using a combination of DDS, LNAs, amplifiers and filters.

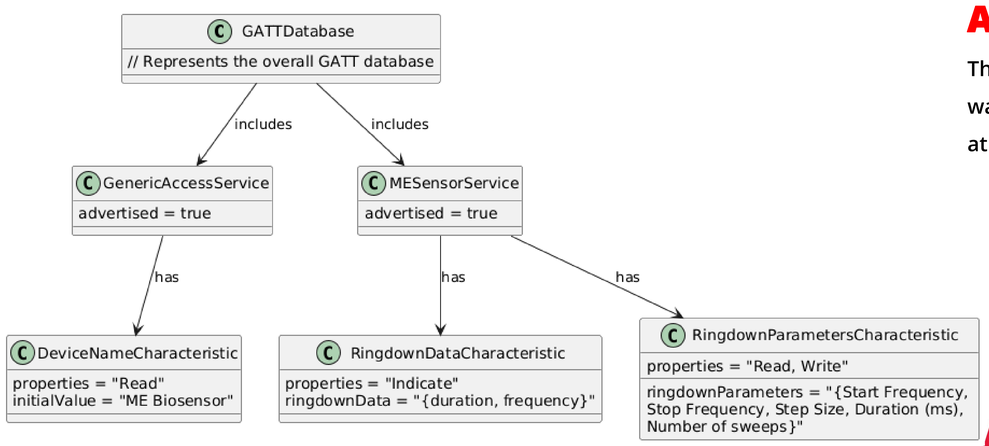


- The BGM220P microcontroller handles obtaining the specific control parameters from the user such as
  - Start Frequency
  - Stop Frequency
  - Step Size
  - Forced Response Duration (ms)
  - Number of sweeps
- It obtains these parameters from either the touchscreen or through BLE.



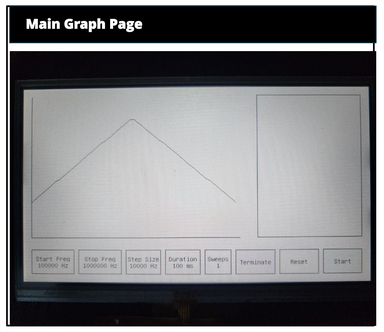
BLE GATT Profile

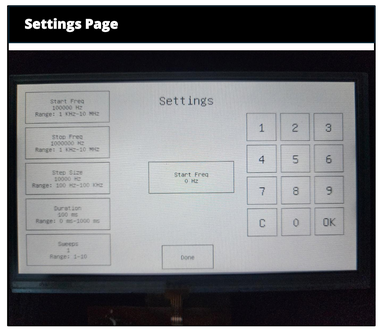
- When the BGM220P boots, the BLE stack initializes a GATT database that includes a custom ME sensor service with data characteristics for sending sensor readings via indications and receiving the parameters to/from a cell phone or laptop using a HTML based app.
- When client connects and enables indications, the system sends sensor data encapsulated in a structured payload containing the ringdown data.



Touch Screen Display

- The BGM220P module also displays the results on a 7" 800x480 Touch-capable display controlled using a TFT driver IC over SPI, which the user can interact with to see the results obtained from the ringdown method in real-time.
- The touchscreen also has a GUI to start/terminate the ringdown process and settings to tweak the Start/Stop frequency, step size of frequency, forced response duration and the number of sweeps.





Characterization Results

- Transmit Side
  - Range: For a valid response, 0.1 – 3.8 MHz and 5 – 9.8 MHz
  - Signal to Noise Ratio: 20.53 ± 0.75σ
- Receive Side
  - Accuracy: Resonant Frequency is detectable with an accuracy down to 1 kHz
  - Precision: Standard Deviation of ringdown frequency was 1.56 us
  - Resolution: Step Size of 200 Hz produces a measurable and detectable change in Ringdown Frequency
  - Minimum Detectable Ringdown Duration: 49 us

Acknowledgements

The Magnetoelastic sensor readout system using the ringdown method was developed by Sarvesh Deshmukh, a graduate student at the AIM lab at UC.

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