UNIVERSITY OF ILLINOIS URBANA-CHAMPAIGN

Mason Bee House

Electrical & Computer Engineering

Team 27

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The Problem

Currently, farmers that require pollination for their crops import honeybees. With the presence of Colony Collapse Disorder, as well as increasing transportation costs, this is becoming more difficult.

Fostering native bee populations is a compelling support in modern agriculture and gardening, as they are more efficient pollinators of native plants.

Current Mason Bee Houses

Beekeepers keep mason bees in artificial tunnel nests [Fig 1], but these nests are prone to **fungal problems** and **parasite issues** because of the artificially dense nests.

Fig. 1: current mason bee houses: opaque

Fig. 2: Illinois native Blue Orchard Mason Bee

photo credit to Anthony Altorenna on Feltmagnet and the US Forest Service

High Level Requirements

- Capacitor sensor setup shall differentiate between entering and exiting simulated bees (6mm ball) in each tunnel
- Sensor setup shall differentiate between simulated bee and simulated parasite (3mm ball to approximate the size of the Houdini fruit fly, a parasite that eats mason bee larvae)
- An integrated SD card shall store data about behavior of bees in the tunnel, which can be read and displayed by plugging it into a separate computer.

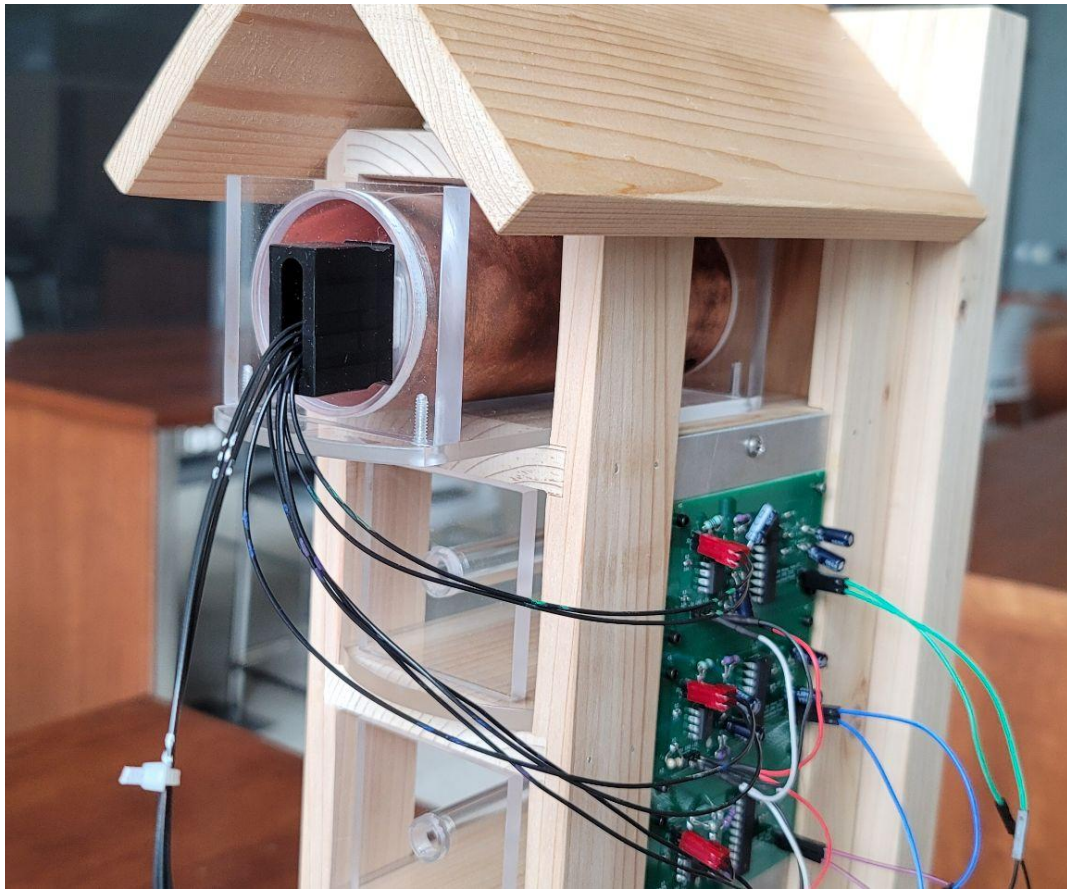


Fig 3. Our Mason Bee House

Sensor Equipped Mason Bee House

We integrated sensors into a mason bee house so that beekeepers can monitor bee activity. This data can be used to tell whether bees' activity is normal and used to monitor for the presence of parasites.

If a disturbance has been observed, the tunnel can be retrieved and the bee larvae can be removed to be stored for the winter.

Prompt removal greatly reduces the fungal and parasite risk.

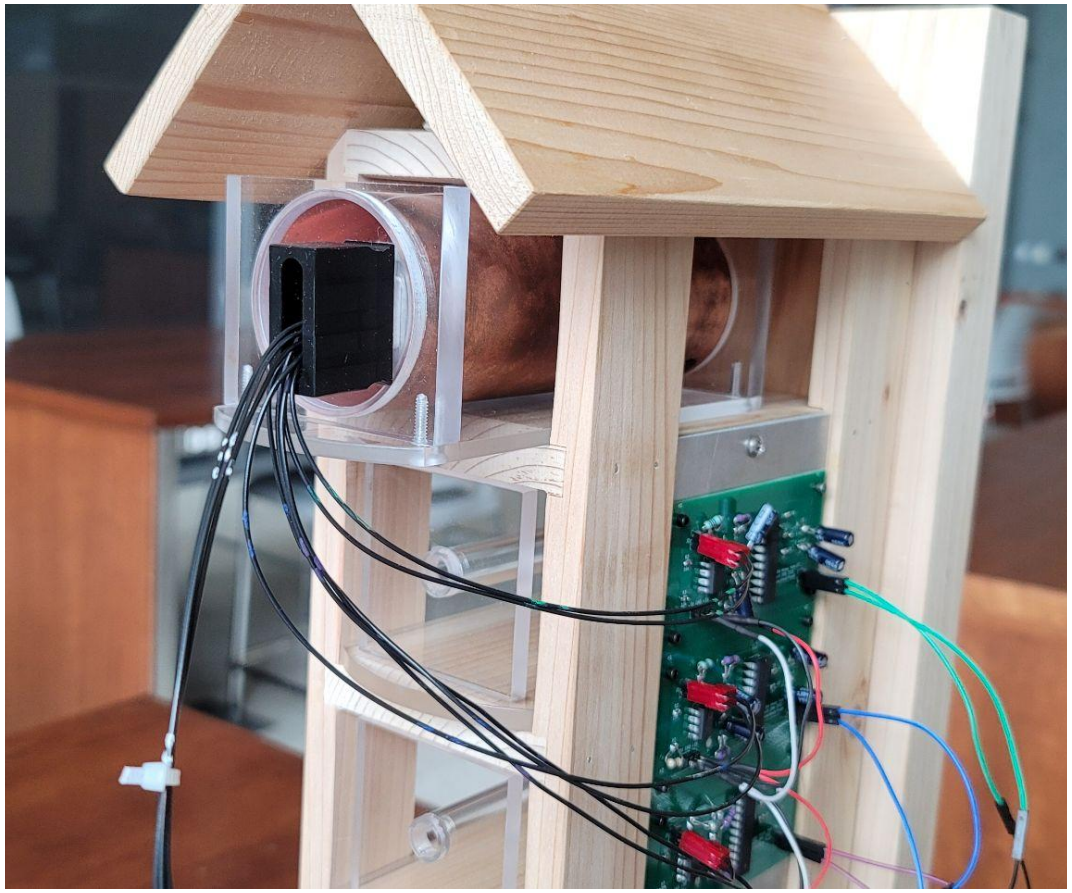


Fig 3. Our Mason Bee House

Noninvasive Observation

- Sensors mounted outside of the bee's tunnel
- Mason bees are not affected by the changing electrical field
- Sensors at different depths to understand movement within the tube

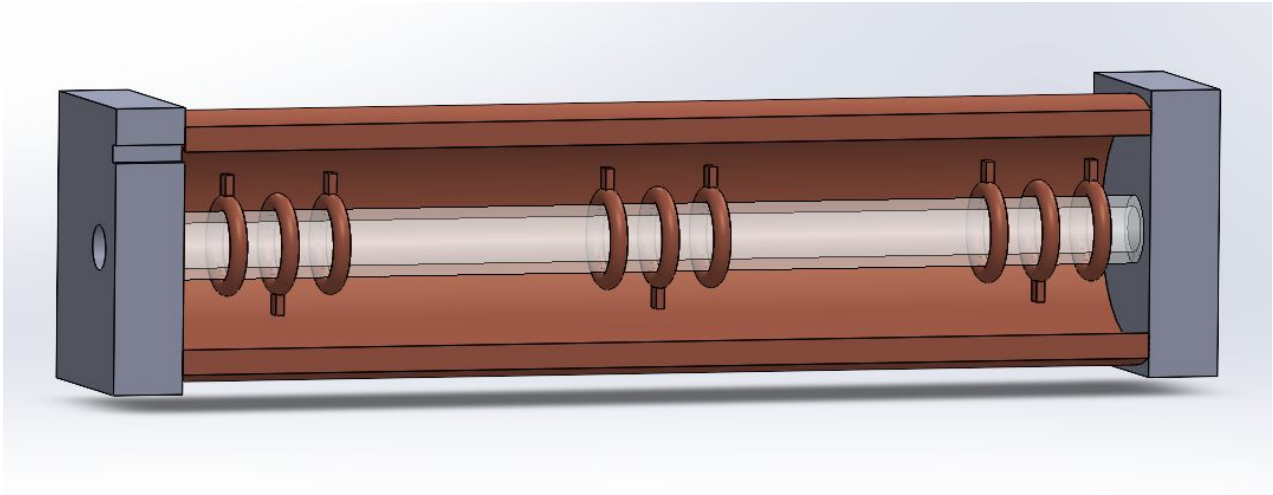
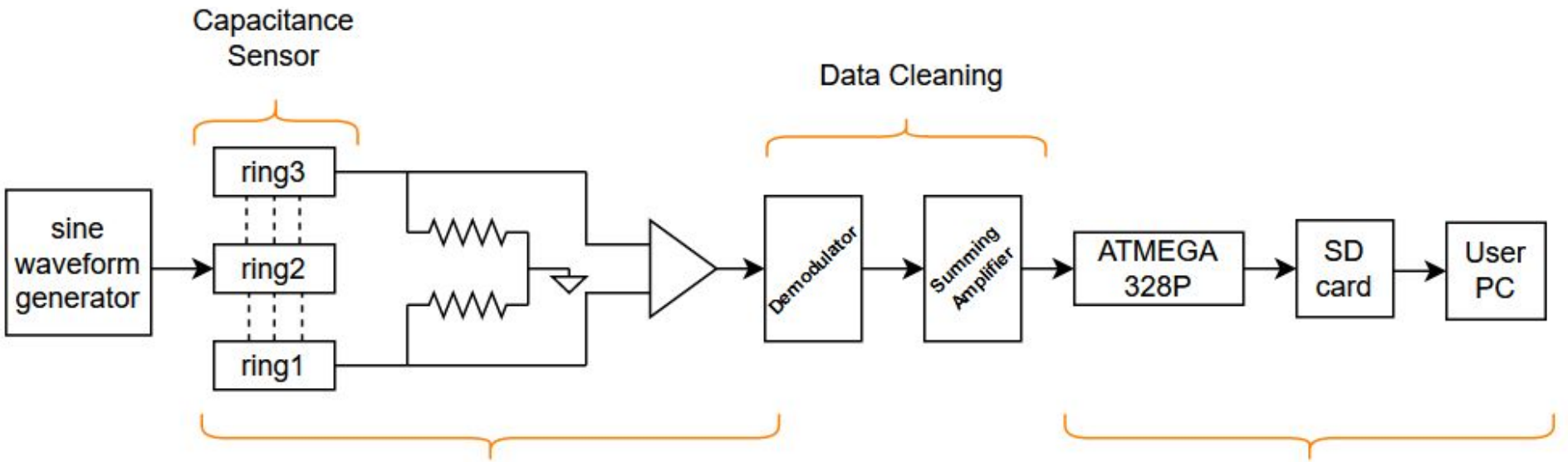


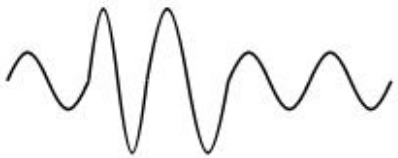
Fig. 4: cutaway of capacitance sensor tube

Design: Data Pipeline



Data

Bee



Varying Amplitude

Positive or negative voltage

Positive voltage

100,328
110,329
120,570
130,578
140,437
150,320

Digital timestamped Data

Some changes we made throughout the design and testing process:

- used waveform generator chips rather than generating the signal from ATMEGA and using filters and amplifiers
- used hi-frequency op amps for 2x gain on the waveform generators
- Added another power supply to create positive and negative voltage
- Added summing amplifier to prevent negative analog input to microcontroller
- Decided to use desktop script for analysis rather than on microcontroller

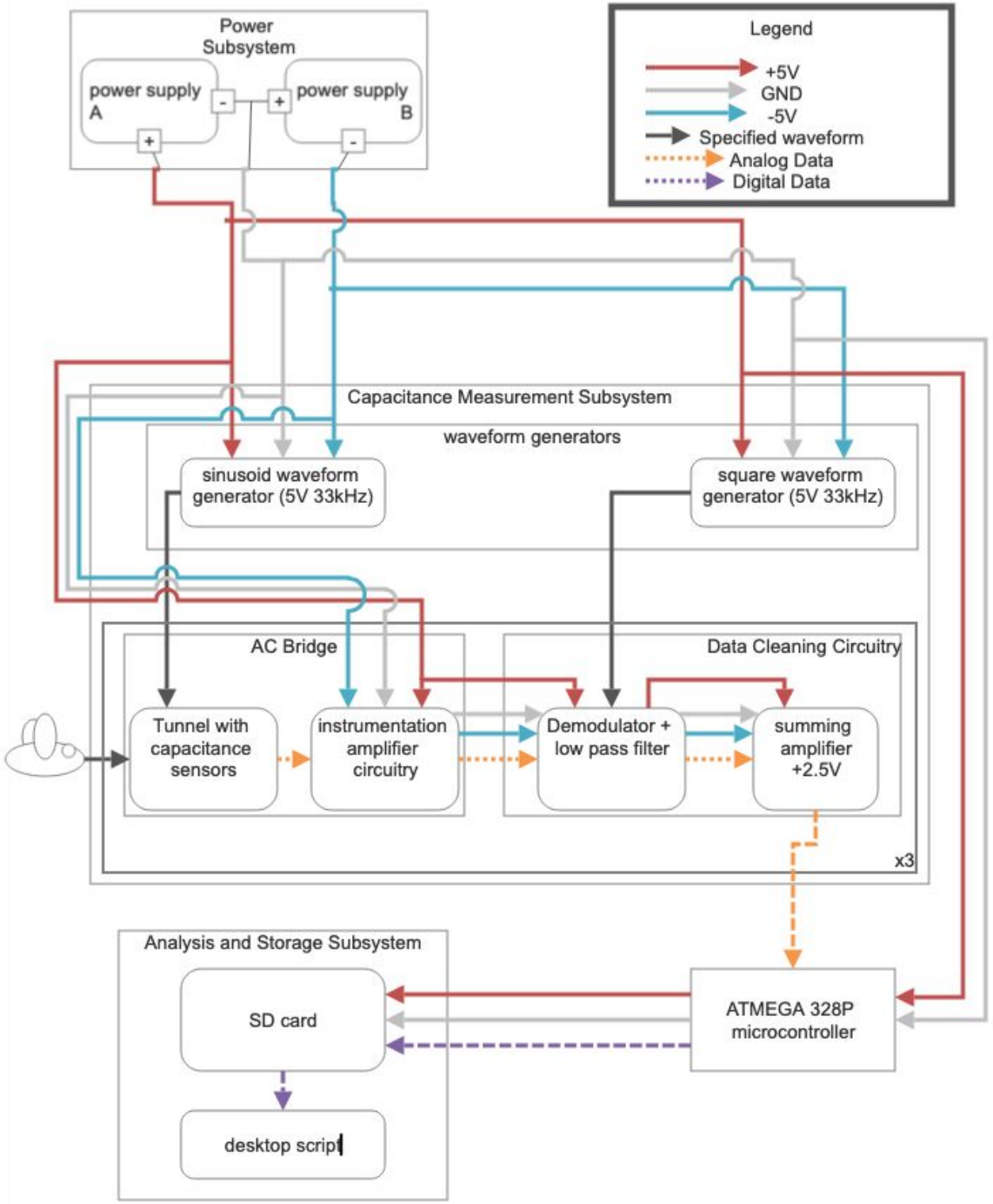


Fig. 5: Mason bee house CAD

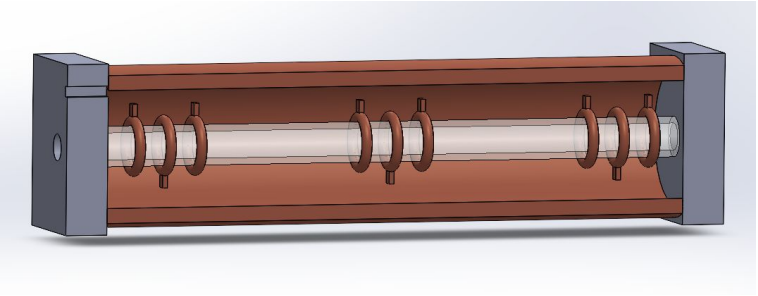


Fig. 6:
cutaway of capacitance sensor tube

Mechanical Design

The house consists of 4 removable tunnels, each made of acrylic and surrounded by copper shielding to remove any unwanted electrical noise.

The tunnels are surrounded by 3 sets of 3-ring capacitors, with each ring in a sensor being separated by 8 mm. The tunnels have an inner diameter of 9 mm.

The house and stand are both made of wood, and the printed circuit boards are mounted on the side of the house.

We used a standard VGA connector to connect the 9 pins (3 sets of 3 pins each) of the capacitor pairs to the rest of the circuitry. This allows the tunnel to be removed and replaced.

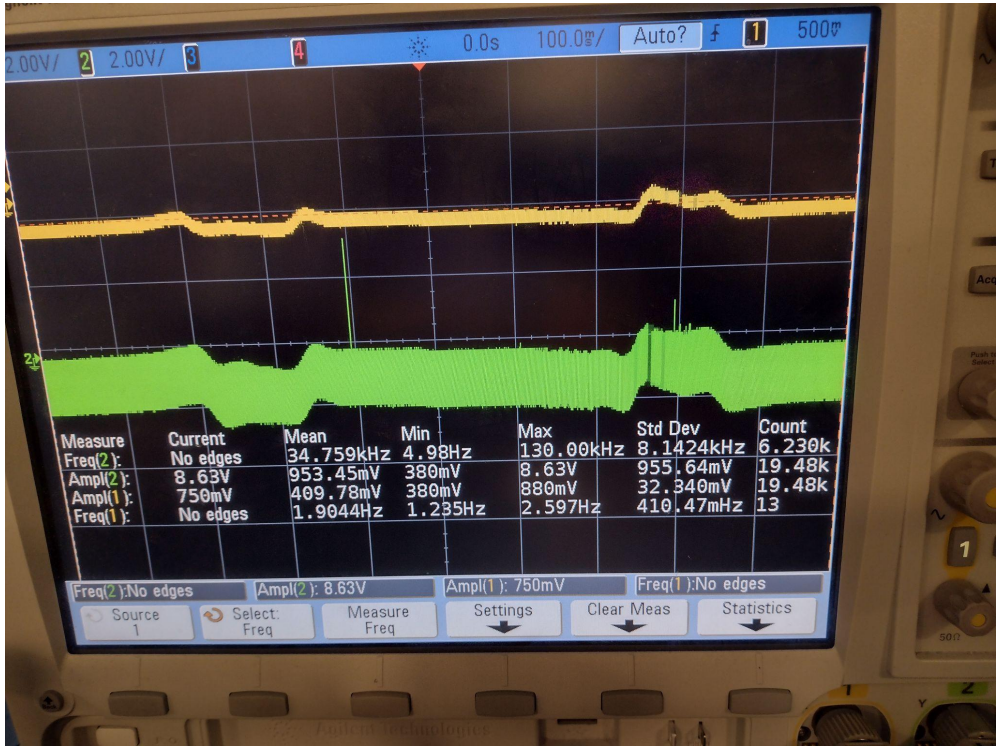


Fig 7: Prototyping setup and results

Electrical Prototyping

- Confirmed that output of sensor board tracked the envelope of the instrumentation amplifier output, even with slightly mismatched frequency of square and sin wave
  - instrumentation amplifier decision
- Confirmed that the output of the waveform generator chips is correctly shaped, and of the expected frequency and voltage
- Tested sensor with different distances and voltages to see the effect
  - sensitivity
- Determined need for summing amplifier to avoid negative inputs

Project Build: Electrical Design Microcontroller Board

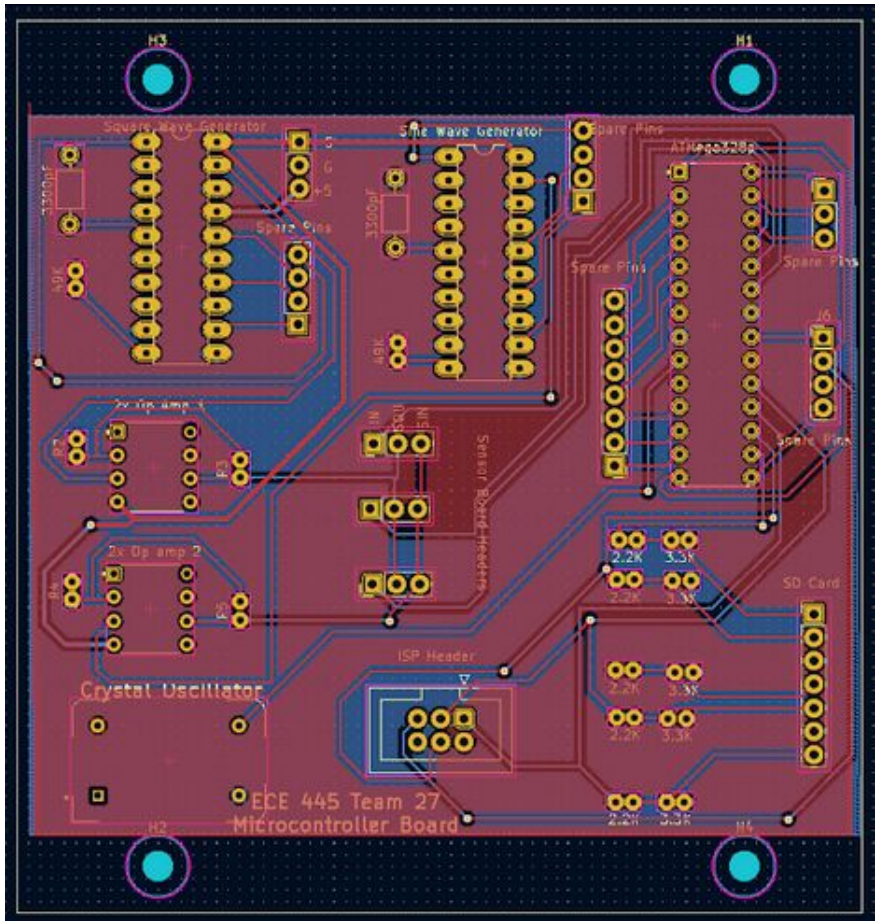


Fig. 8: Microcontroller Board PCB

Electrical Design

- 2 board designs: sensor board for per sensor circuitry, microcontroller board for common components

- Microcontroller Board
  - ATMEGA 328P
  - 16MHz external oscillator
  - programming header
  - MAX 038 waveform generator w/ frequency setting circuitry
  - x2 gain op amps (x2)
  - SD card connection circuitry
  - inputs and outputs for sensor board

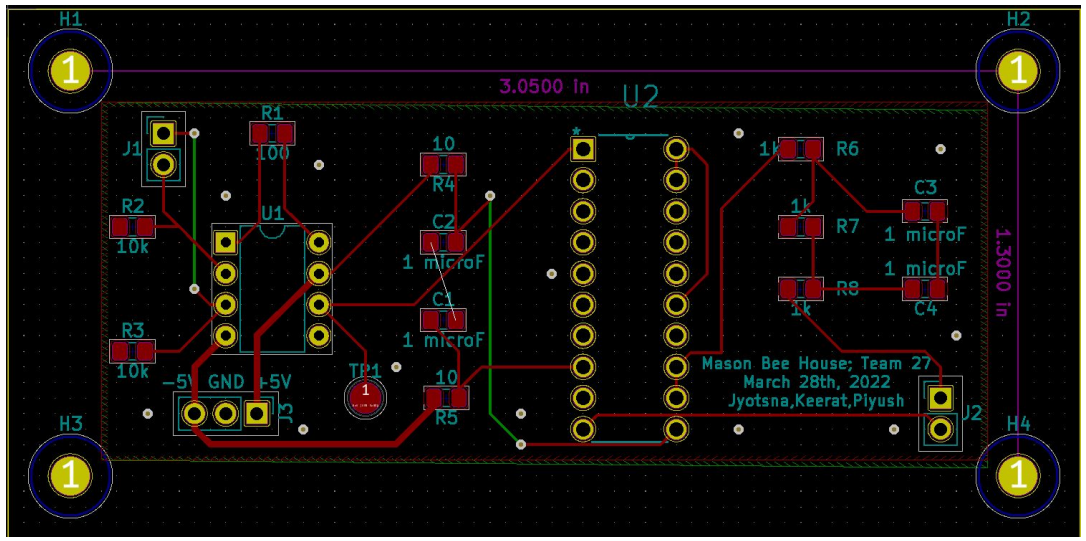


Fig. 9: Sensor Board Layout

Electrical Design

- 2 board designs: sensor board for per sensor circuitry, microcontroller board for common components

- Sensor Board
  - inputs for capacitor sensor
  - instrumentation amplifier
  - test point for instrumentation amplifier output
  - demodulator
  - low pass filter after demodulator
  - output for microcontroller board

Visuals + Processing of Bee Movement Data

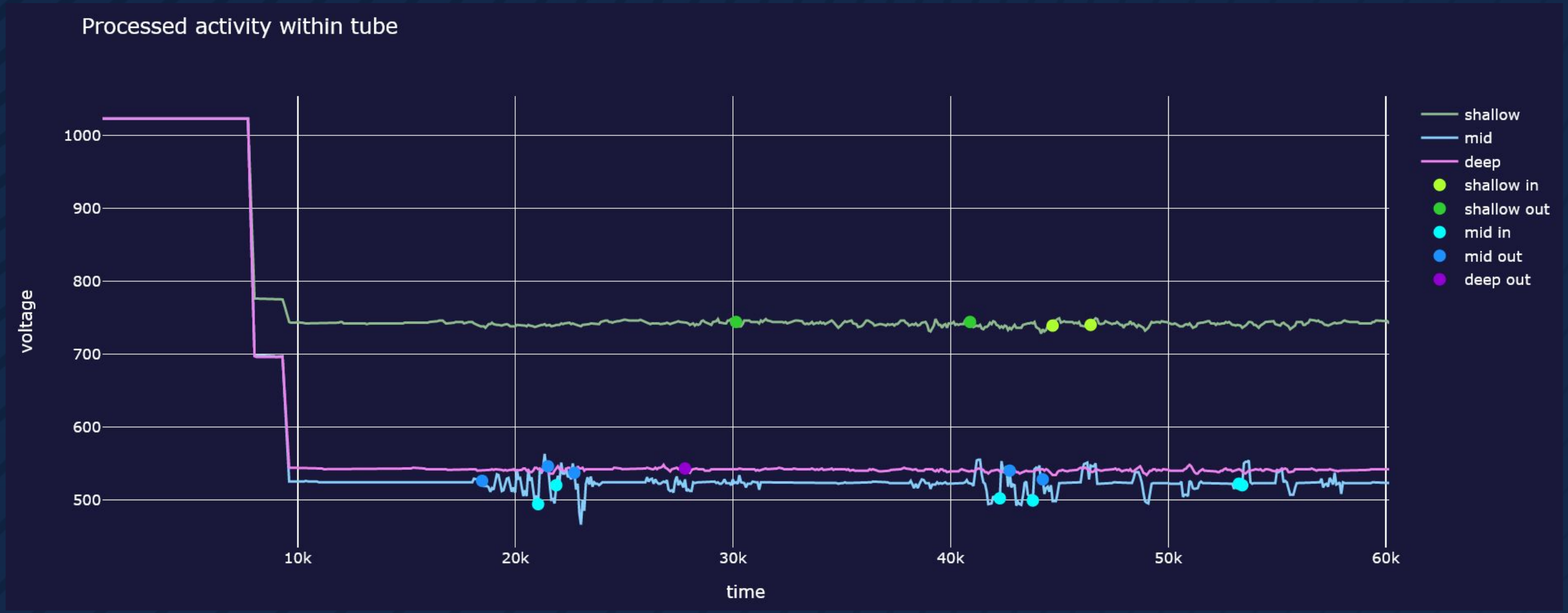
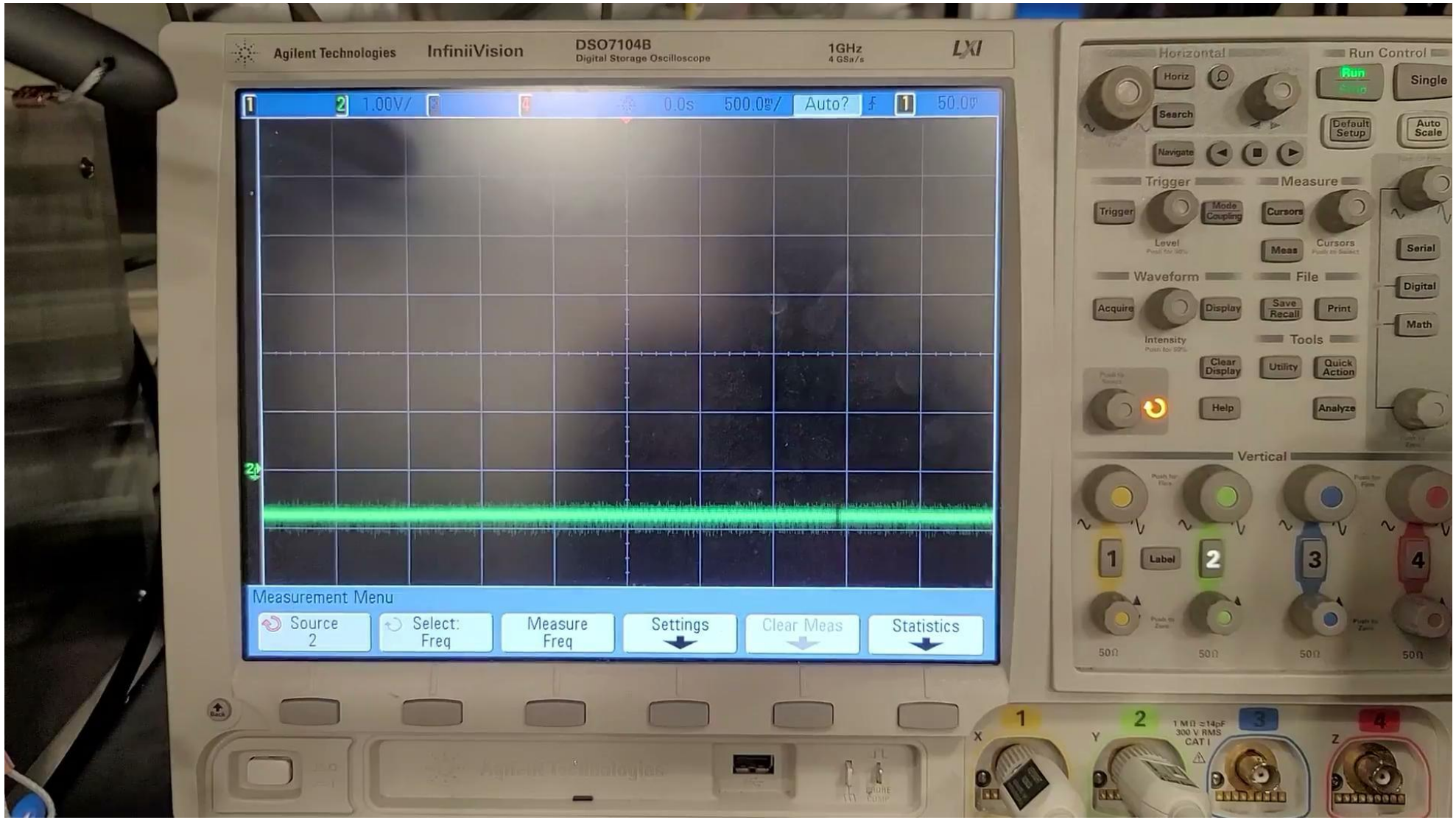


Fig 10. graph generated with python script based on data from SD card

Demo Video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InfiniiVision
DSO7104B
Digital Storage Oscilloscope
1GHz
4 GSa/s
LXI
1.00V/
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Auto?
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Measurement Menu
Source 2
Select: Freq
Measure Freq
Settings
Clear Meas
Statistics
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Run Control
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Stop
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Default Setup
Auto Scale
Trigger
Trigger
Mode Coupling
Level
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Math
Waveform
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Save Recall
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Utility
Quick Action
Help
Analyze
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1
Label
2
3
4
50Ω
50Ω
50Ω
50Ω
X
Y
Z
1 MΩ ≈14pF
300 V RMS
CAT I

Challenges

- Hardware Concepts
  - Hollow capacitor (UPEI research)
  - AC Bridge
  - Phase Sensitive Detection

- SD library provided by the Arduino IDE.
  - There was a mismatch between the required implementation and the recommended implementations; took a week of digging through forums to enable SD card writing.
  - Writing to the SD card lowered the quality of the signal

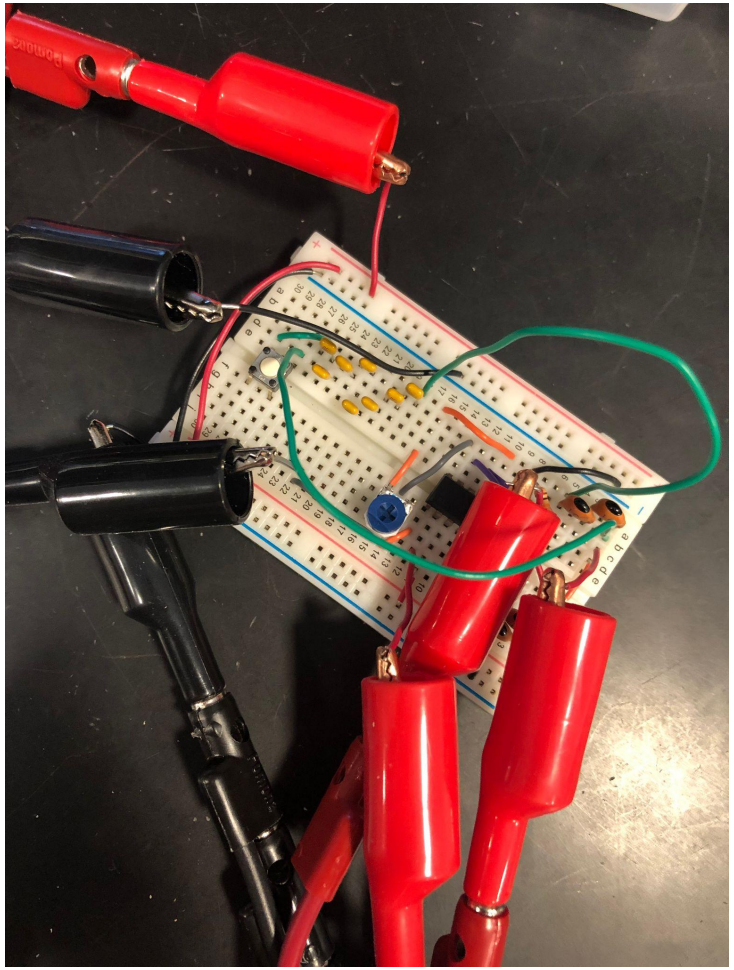

Fig. 11: Our first AC Bridge Prototype

Challenges

- We were unable to successfully verify that
  - System was weather and shock-proof
  - Secure housing for all circuitry

- Generating the right frequency from waveform generator chips
  - Calculating the correct resistor and capacitor values
  - Hi-frequency opamps

- Parts sourcing
  - ATMEGA
  - Through-hole PCB components

Fig 12. Waveform Generation Testing Results

Conclusion

Our bee house provides a proof-of-concept for a commercial bee house that can be used be beekeepers.

Our bee house is a basis for future research, and provides a platform for beekeepers to study the behavior of mason bees.

We hope that in the future, sensor-equipped mason bee houses will reduce dependency on imported European honey bees by improving native bee populations.

Fig. 13: A female mason bee.

Recommendations for future work

In the future, we would like to:

- whether or not there is a bee in a tunnel
- if there are eggs in a tunnel
- indicate if there is a parasite in the tunnel using LEDs
- seal off tunnel with mechanical door in case fungus or parasite is detected
- reduce the cost of our system currently
  - demodulator and instrumentation amplifier are the most expensive components

Overall, the Mason Bee House is a solid foundation for all sorts of development; can be taken in many different directions !

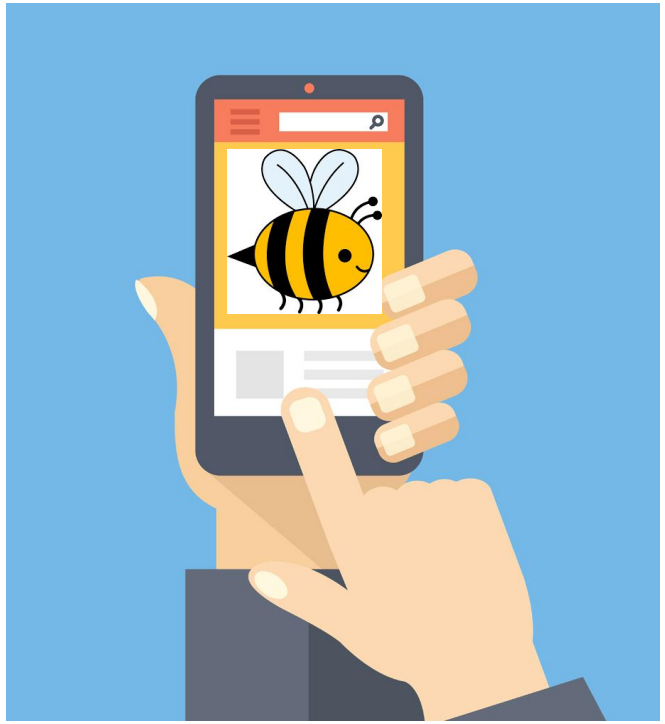

Fig 14. Visualization of potential further work

picture credits to mni.com and clipart-library.com

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Questions?

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Piyush Sud - psud2@illinois.edu

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- Gregg, Glen Hedin from the Machine Shop
- Wally and Margie in the Electronic Services Shop
- Amr Ghoname for such a great TA

Thank You !

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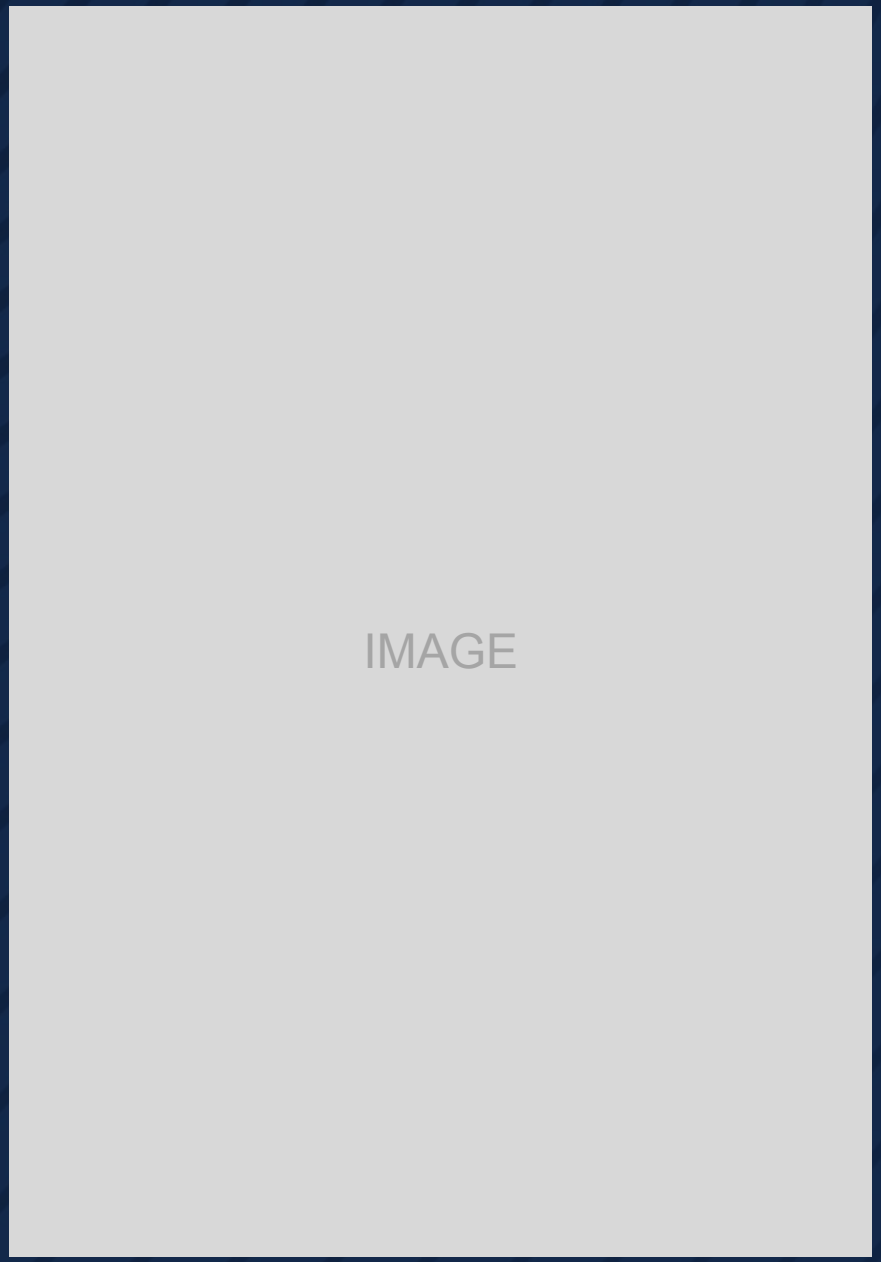

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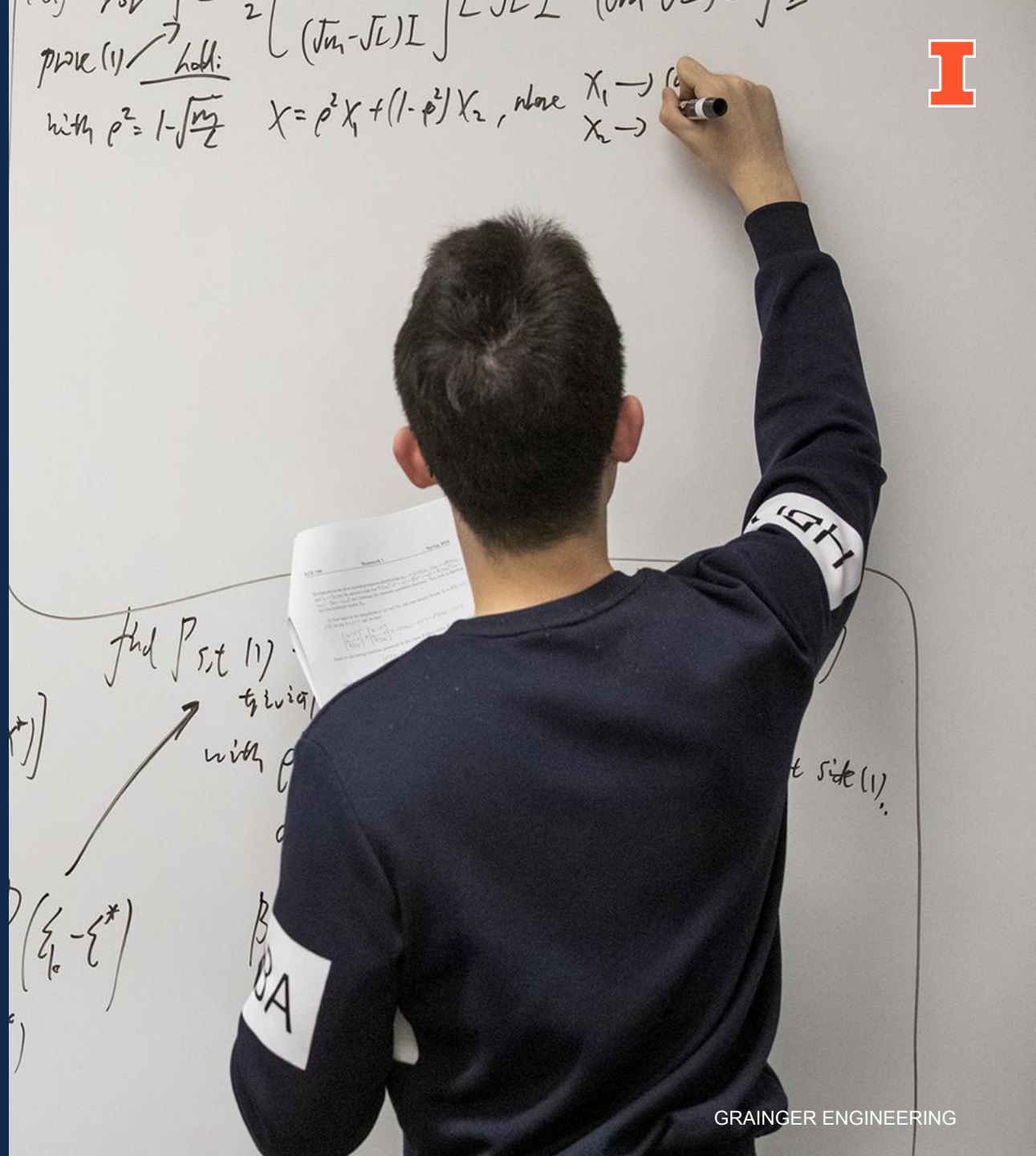

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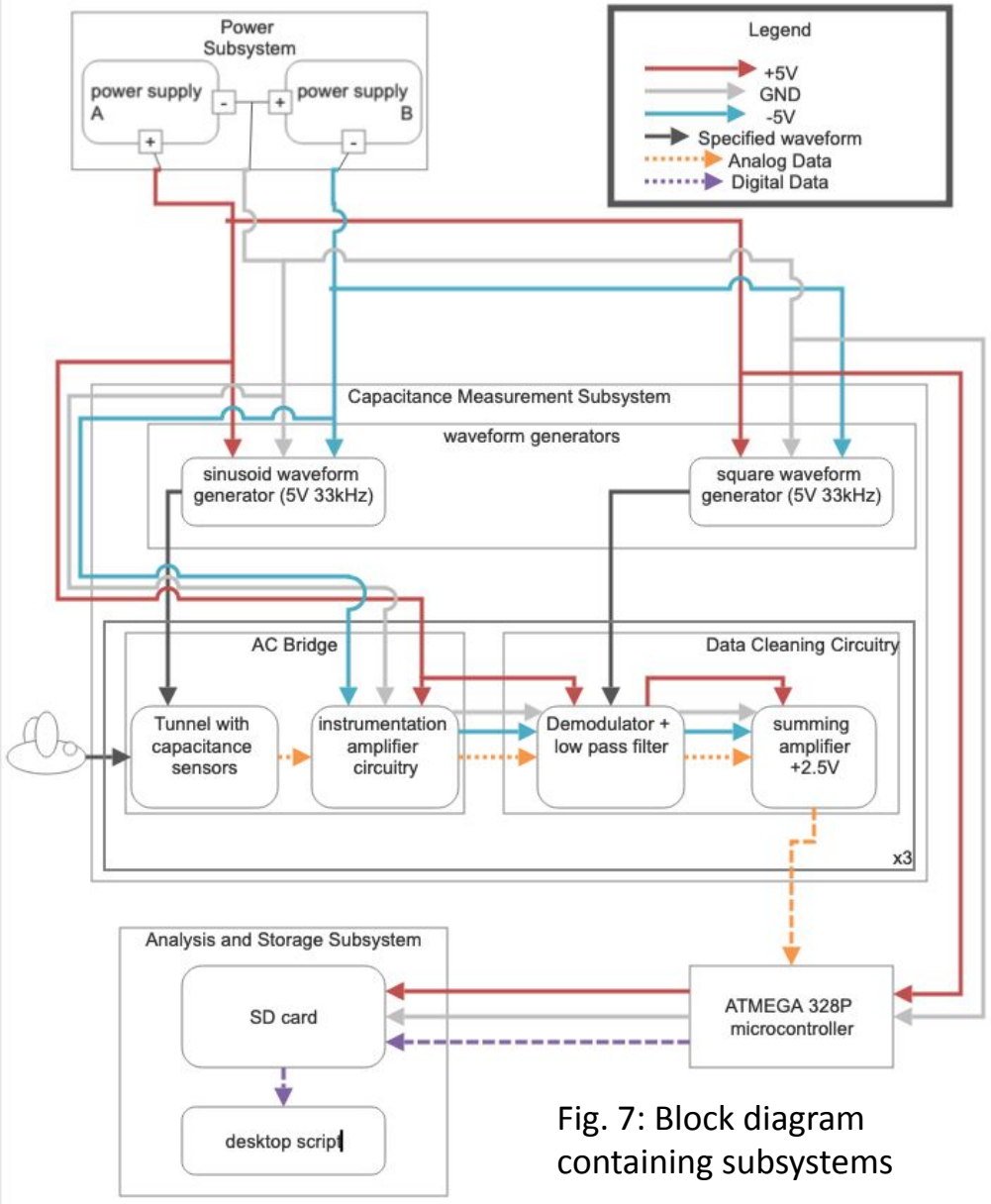

Fig. 7: Block diagram containing subsystems

Some changes we made throughout the design and testing process:

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