Noise-Reducing Electromagnetic Latch System for NICU Isolettes

Jillian Carter, Austin Goncz, Sara Merlock, Samuel Mircoff, Blair Smith

Advisors: Dr. Yu Chen, Fischell Department of Bioengineering, UMD and Dr. Rose Viscardi, UMMC

Special Thanks to: Allen (Yalun) Wu, Michael Restaino, Gary Seibel, Dr. Yang Tau

Motivation

Background: The Neonatal Intensive Care Unit (NICU) is a section of the hospital where high-risk infants are sent to be continuously monitored. Many of these high-risk infants are born prematurely, or before 37 weeks[1]. Premature infants are more vulnerable to hearing loss due to underdevelopment. Current noise reduction solutions focus on total sound and not solely sound from the doors.

Problem Statement: The current opening and closing mechanism on isolette doors reaches noise levels of up to 90 dB, while the recommended level for the NICU is 45 dB[2].

Objectives
1. Redesign the port-latch mechanism of the isolette such that noise output upon opening or closing is 45 dB maximum
2. Keep the opening of the doors as hands free and quick
3. Design the new mechanism such that it can be easily integrated to current models and is low cost

Figure 1. Original latch mechanism

Methods

Define the problem → Design concept → Design circuit & code → Design housing unit → Material selection → Testing

The Problem: The current plastic latch mechanism emitted a loud clicking noise.

Design Concept: Remove the latch and add an electromagnet and sensor.
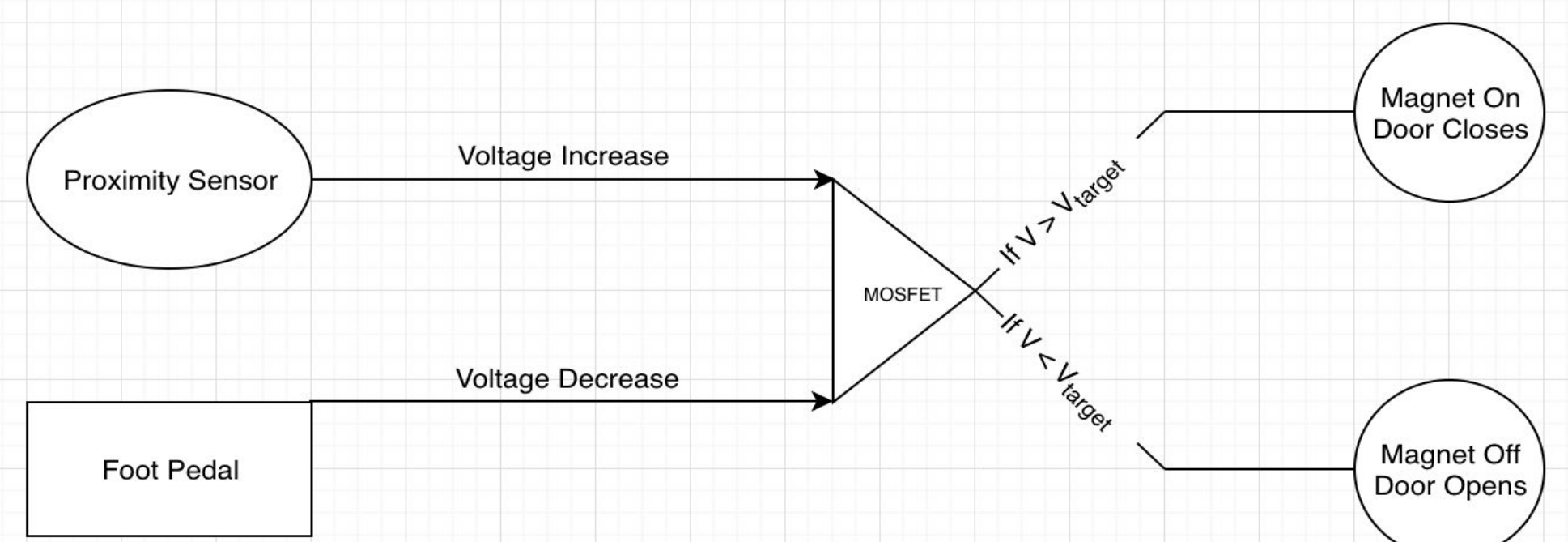

Figure 2. Logic diagram depicting how each component will control the magnet.

Circuit Design & Code: Figure 2 was adapted into a circuit and used to develop the Arduino code (See Fig. 4). Specifications for the circuit components:
- Electromagnet: At least 5 kg holding force to hold ~1 kg door
- Proximity sensor: Sense at least 20 cm

Design Housing Unit: Housing unit for the magnet and sensor was designed to be easily integrated onto the current isolette. Polycarbonate was used to house a piece of metal to the porthole door.
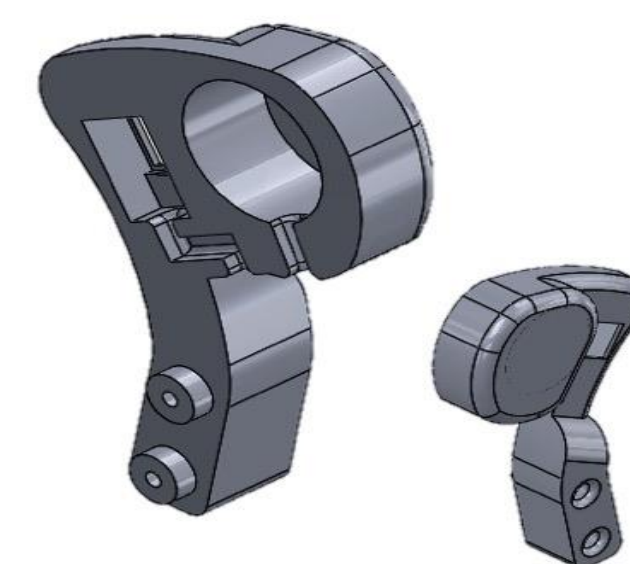

Figure 3. CAD design of the housing unit

Material Selection: (1) The material around the porthole needed to be cheap, noise resistant, and compatible with sanitation methods. (2) To ensure that the electromagnet did not heat up, a material was needed with low specific heat that was also safe. Cork was chosen due to its specific heat of 1.9 kJ/ (kg-K).

Testing: The noise output levels of the opening and closing of the door were measured using the app DecibelX in a room with noise level similar to the NICU.

Final Design

Primary Materials

Arduino Uno	Adrafruit 5V Electromagnet	Adrafruit VCNL4010 Proximity Sensor	EPDM Rubber Foam Lining	3D Printed Housing Unit

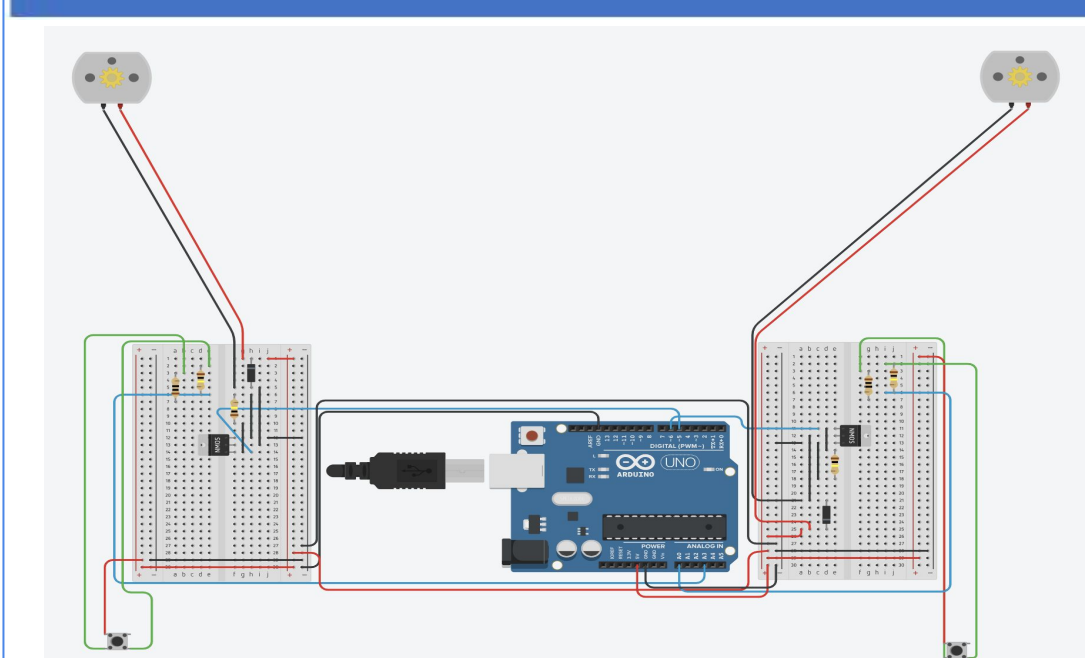| Circuit Schematic	Final Prototype

Figure 4. Finalized circuit model that controls the electromagnet that will hold the porthole closed. Sensor not included, no representative model available in the software used.

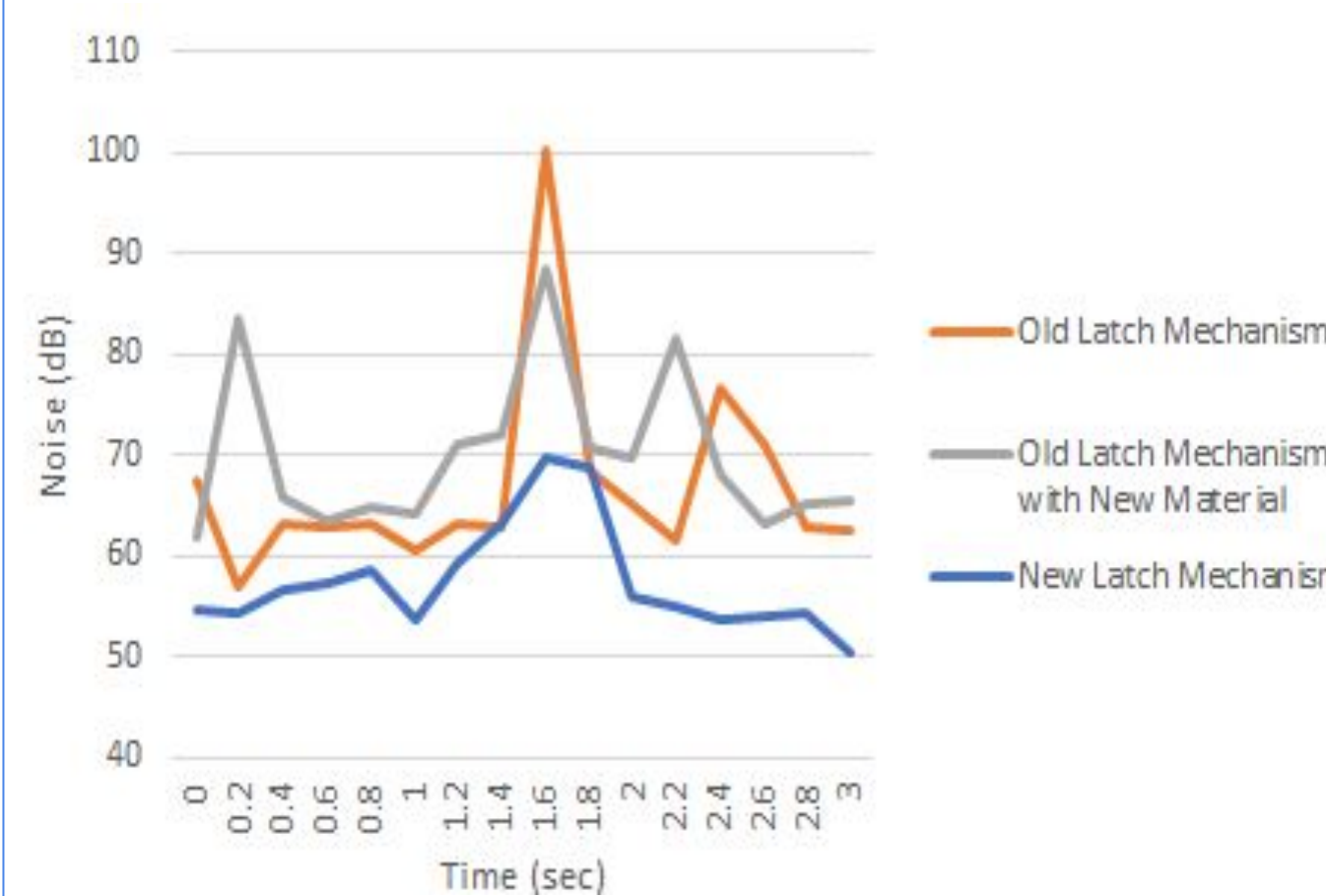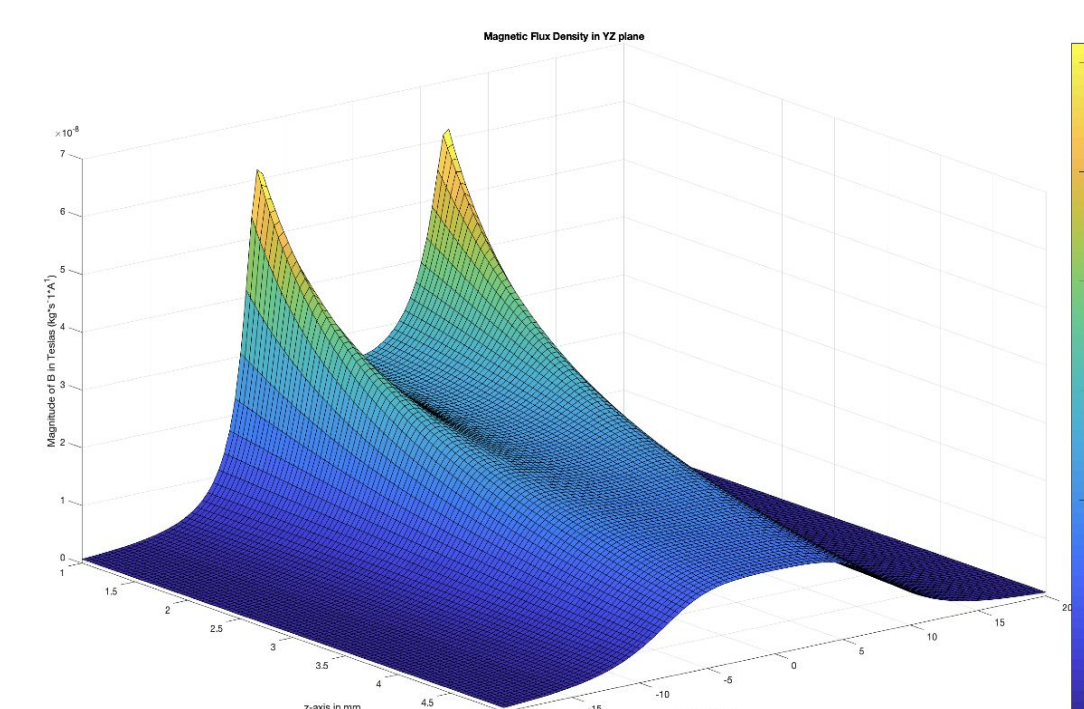**Figure 5**. Prototype design mounted on isolette next to original latch.

Results

Figure 6. Max noise output for each mechanism tested.

Table 1. Max noise output for each mechanism tested.

	Max Noise Output (dB)	Average Max Output (dB)
Old Latch Mechanism	100.3	98.3
Old Latch Mechanism with New Material	88.3	84.5
New Latch Mechanism	69.9	68.4

The results show that the noise is reduced by replacing the latch mechanism. They also show that the new material reduces the noise output.
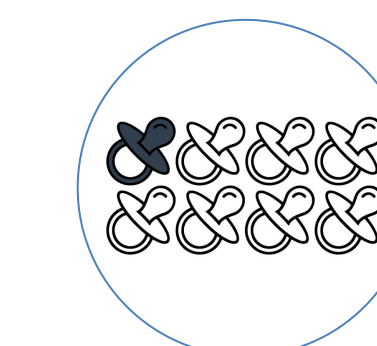
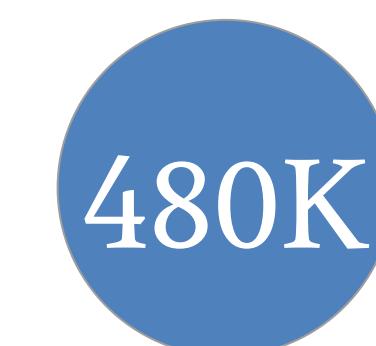Once the code was finalized the electromagnetic field of the magnet was modeled using MATLAB.

The flux density, which is proportional to the force generated by the field, is greatest within a few millimeters of the face of the magnet and decreases rapidly.

Figure 7. Adapted from a third party MATLAB function, the figure above represents the magnetic flux density in Teslas, where the face of the magnet sits in the XY plane, and the field is therefore in the Z plane.
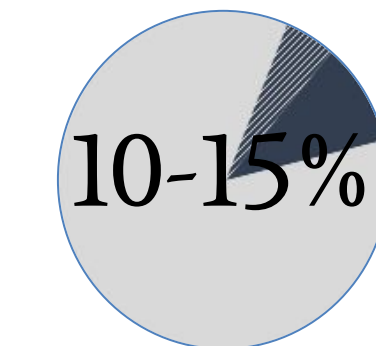
Ethical Implication

~12% of babies are born premature[1]

480K — ~4 million births a year means ~480K premature

10-15% — ~10-15% of babies go to the NICU[3]

600K — ~400K-600K babies go to the NICU a year

Conclusions

- The new latch design did reduce the maximum noise output compared to the current latch mechanism and had a hands free and quick open. The device was easily integrated, but was not as low cost as intended.
- Many other factors contribute to the ambient decibel range in the NICU. This latch system eliminates any major rise from the baseline, but ambient noise remains around 50-60dB. Thus reducing this to under 50 dB likely requires redesign of the environment itself.
- The team learned that working with devices for infants allows a lot of room for creativity; but it also lends many limitations to design possibilities due to the fragility of these patients.

Future Work

- Enhance mechanism for two door operation
- Updated build with more robust parts and finish to allow for autoclaving
  - IP69K rated parts and housing material
  - Encase sensitive components in potting compounds
- Six Sigma Analysis
- Implement fail safe/fail secure circuitry
  - In the event of power loss, magnet should remain on but be operable with a light pull so doors are not hanging open
- Revisit circuit design with smaller or more efficient hardware to reduce potential heat damage and provide maximum visibility into the isolette

Significant References

1. Lucile Packard Children's Hospital. (n.d.). Prematurity. *Stanford Children's Health*. Retrieved from https://www.stanfordchildrens.org/en/topic/default?id=prematurity-90-P02401.
2. Zacarias, F. F., Jimenez, J. L., Velazquez-Gaztelu, P. J., Molina, R. H., & Lopez, S. L. (2018). Noise level in neonatal incubators: A comparative study of three models. *International Journal of Pediatric Otorhinolaryngology 107*, 150-153.
3. Knispel, S. (n.d.) What Parents Should Know About NICU Care. *Meredith Corporation*. Retrieved from https://www.parenting.com/article/nicu-care.