Proposed Wearable Fetal Heart Rate and Fetal Movement Sensor that Eliminates Maternal Heart Rate Artefact

A. Kyu

***Abstract*— Signal artefacts are a major issue in current fetal heart rate sensors, leading to misdiagnoses that can lead to fetal mortality. Both Fetal Heart Rate and Fetal Movement are essential indicators for fetal health, providing information on cardiovascular and nervous system development, respectively. The device proposed here aims to limit these artefacts.**

***Clinical Relevance*— The design presented establishes an alternative device that would eliminate Maternal Heart Rate Artefact in Fetal Heart Rate measurements while providing additional movement information, reducing misinterpretation of signal output and misdiagnosis of abnormal fetal heart rates.**

I. Introduction

In the perinatal period of pregnancy, both Fetal Heart Rate and Fetal Movement are major health indicators. Fetal movement has been shown to identify an infants' neuro-motor development and brain dysfunction while Fetal Heart Rate indicative to fetal conditions that could lead to pre-existing fetal death [1, 2].

Currently, fetal heart rate is captured through cardiotocography, a method that uses ultrasound waves. When an abnormal heart rate is detected, a physician may decide to deliver the fetus early by performing a cesarean section. However, two artefacts may appear in these which could lead to a misdiagnosis. The first is the Maternal Heart Rate Artefact (MHRA) when the mother's heart rate is misinterpreted by the CTG machine as the fetus's and the second is the Fetal Heart Rate Artefact (FHRA) when a fetal heart rate is processed or outputted incorrectly—this can occur in the case of twins where one fetus's heart rate can be interpreted as the others. A preliminary study identified these artefacts as part of 40% of perinatal fatalities examined in a sample report from 2009 to 2019 [1]. The device here provides a proposed way to measure fetal heart rate more accurately by eliminating these artefacts to decrease rates of perinatal mortality while also providing other fetal movement characteristics.

II. Methods

The proposed sensor presented here is a dual microphone transducer to capture fetal heart rate with an IMU sensor to capture fetal movement. One microphone would be used to capture the heart rate of the fetus while the other microphone would be used to filter out ambient sounds and the maternal heart rate, using a differential operational amplifier topology. This would eliminate or reduce MHRA. This signal was then converted into a digital signal using a non-inverting level shifter. The IMU would be used to capture fetal movements, like other accelerometer-based fetal movement sensor systems. This system also includes a touchscreen for user interaction and to display relevant information related to the sensor readings.

III. Results

The dual microphone schematic is shown below.

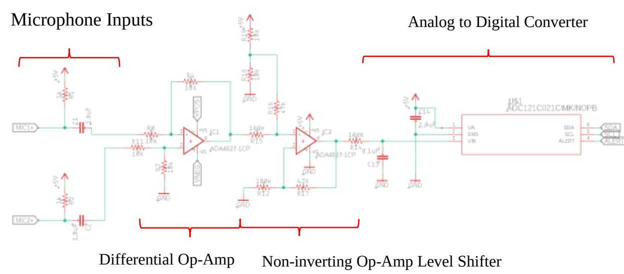

***Figure 1:** Dual-Microphone Schematic. Note that the voltage sources for the operational amplifier are not shown to keep the schematic readable. See Appendix for the full schematic.*

A two-layered PCB was designed for this device, powered by two AA batteries. All circuit components are on the top layer, except the ports that connect to the touchscreen which are on the bottom side. This eliminates the problem of the touchscreen inadvertently interacting with other components on the PCB. See Appendix for a figure of the PCB.

IV. Discussion & Conclusion

It is worth noting that this is more of a proof of concept for a potential solution to some common problems that can occur with currently used cardiotocography devices while also providing additional fetal health informatics. However, additional filters, and methods should be investigated to improve measurements. For example, reinvestigating ultrasound transducers, additional microphones, and additional filtering methods may help further eliminate noise for fetal heart rate monitoring. And for fetal movement monitoring, other vibration-based sensors should be investigated like piezoelectric diaphragms and other acoustic sensors. These other sensors have been shown to be able to detect weaker movements, but also tend to generate higher power signal artefacts [2, 3].

Furthermore, board design should be analyzed to make sure that it is optimized for both noise reduction and for overall product design. Port placement, touchscreen placement, and battery placement should be reconsidered from a product perspective. Finally, other components should be analyzed to ensure that analog and digital signals are in their respective sections.

REFERENCES

[1] D. J. Kiely, L. W. Oppenheimer, and J. C. Dornan, “Unrecognized maternal heart rate artefact in cases of perinatal mortality reported to the United States Food and Drug Administration from 2009 to 2019: a critical patient safety issue,” *BMC Pregnancy and Childbirth*, vol. 19, no. 1, Dec. 2019, doi: 10.1186/s12884-019-2660-5.

[2] J. Lai *et al.*, “Performance of a wearable acoustic system for fetal movement discrimination,” *PLOS ONE*, vol. 13, no. 5, p. e0195728, May 2018, doi: 10.1371/journal.pone.0195728.

[3] A. K. Ghosh *et al.*, “A Novel Fetal Movement Simulator for the Performance Evaluation of Vibration Sensors for Wearable Fetal Movement Monitors,” *Sensors*, vol 20, no. 21, p. 6020, Oct 2020, doi:10.3390/s20216020

Appendix

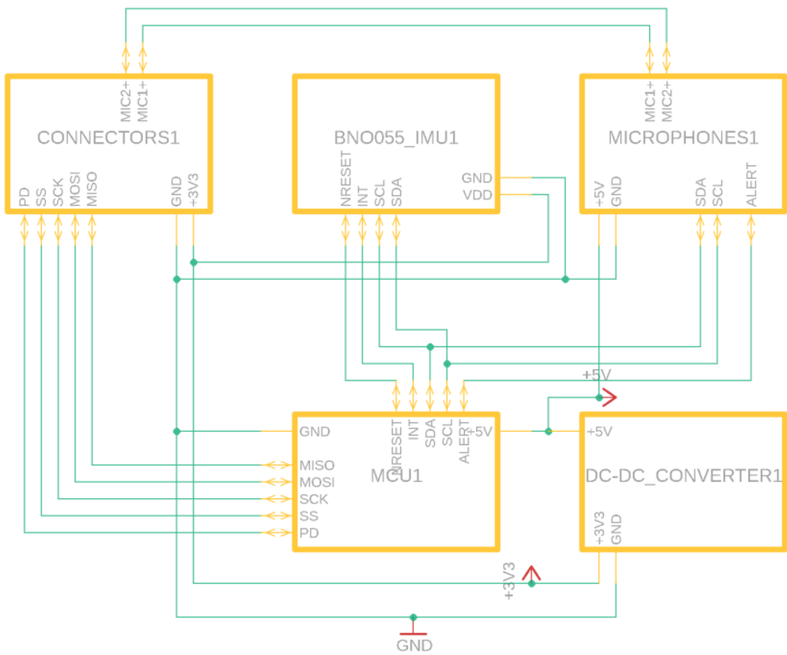

Figure 2*: Schematic of the Various Modules for this device.*

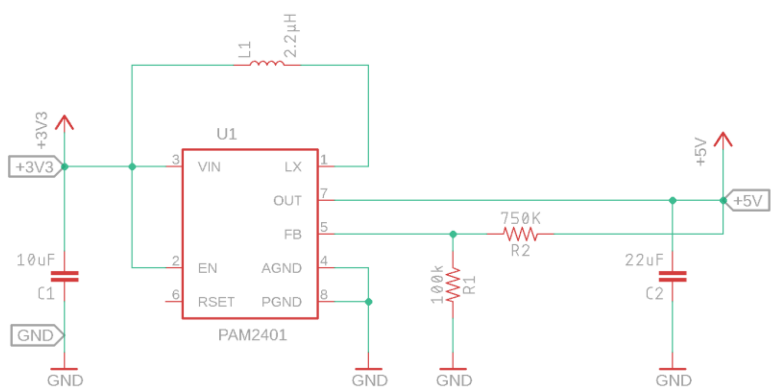

Figure 3: *DC-DC Converter (3V3 to 5V) used to power the microphones and the microcontroller.*

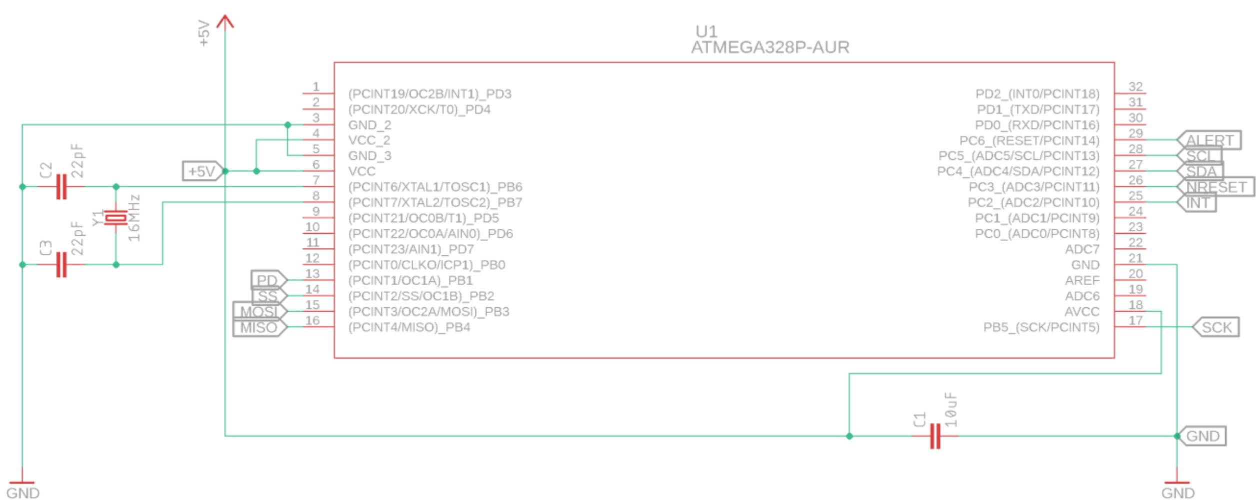

Figure 4: *Schematic of the chosen microcontroller (Atmega328P-AUR). This schematic features an external clock for faster speeds.*

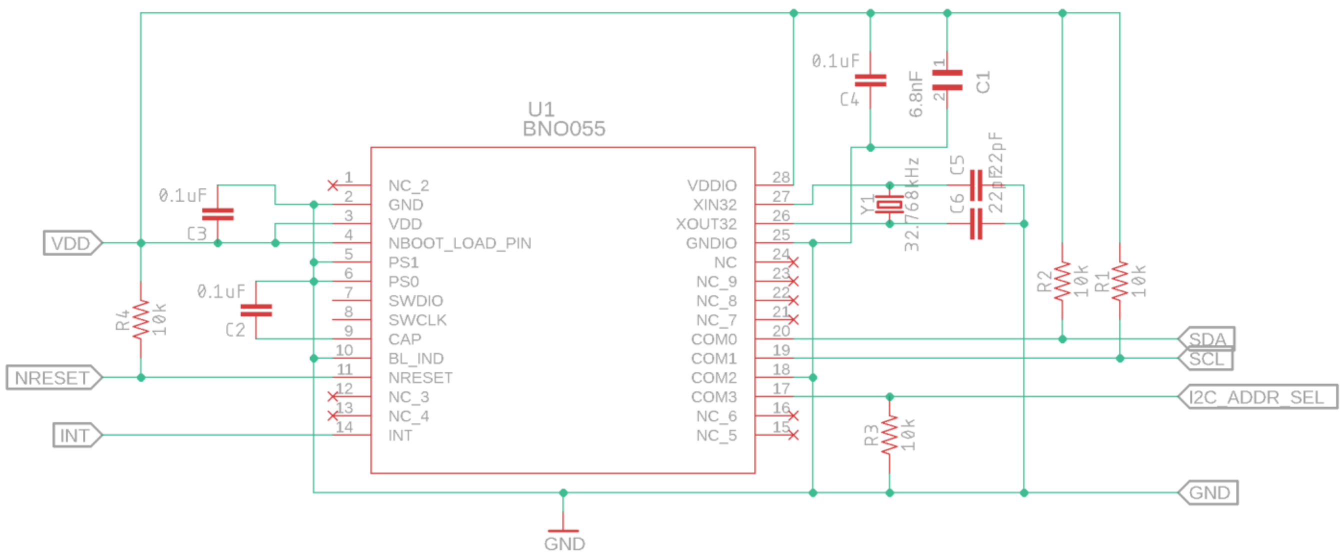

Figure 5: *Schematic for the IMU (BNO055). The layout is an I2C configuration as specified on the datasheet for the BNO055.*

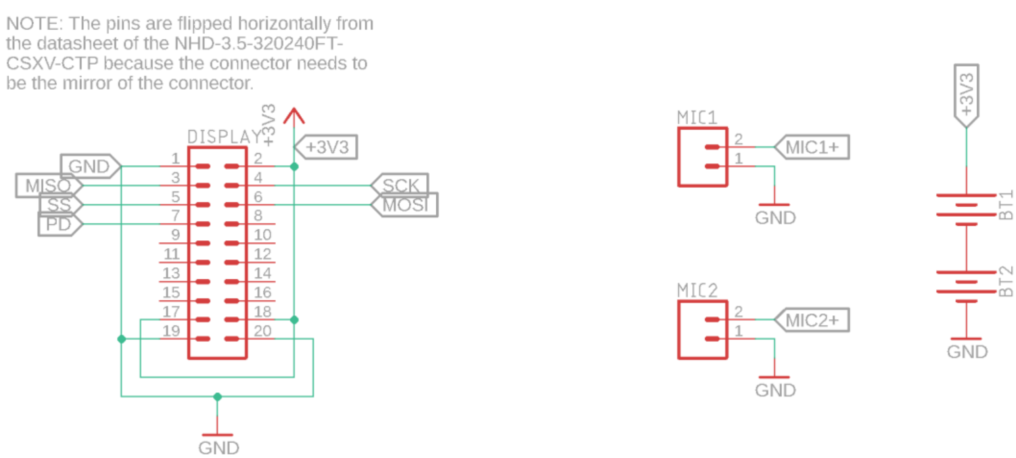

Figure 6: *Schematic for the connectors to the board. This is composed of a 2x10 connector for the touchscreen, two 2x1 connectors for the two microphones, and two AA batteries.*

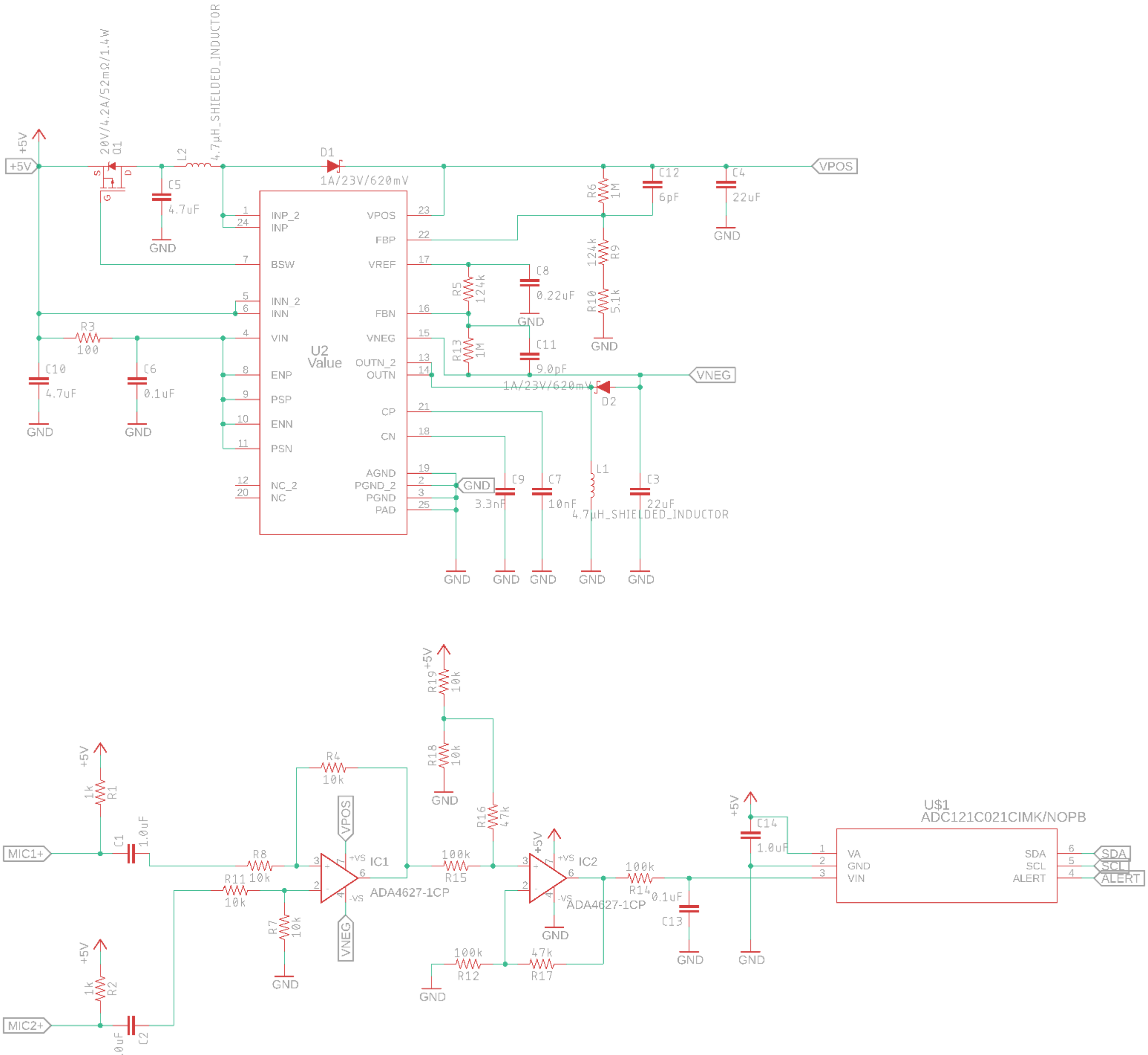

Figure 7: *Schematic of the overall dual microphones system. The top half is to convert a 5V input to ~ +/-10V output that is then provided as the VPOS and VNEG to the differential operation amplifier topology. The bottom half is the one shown in the abstract above, which contains the inputs to the microphone, a differential op-amp topology, a non-inverting op-amp level shifter (to shift the negative voltage to 0V), and an analog-to-digital converter.*

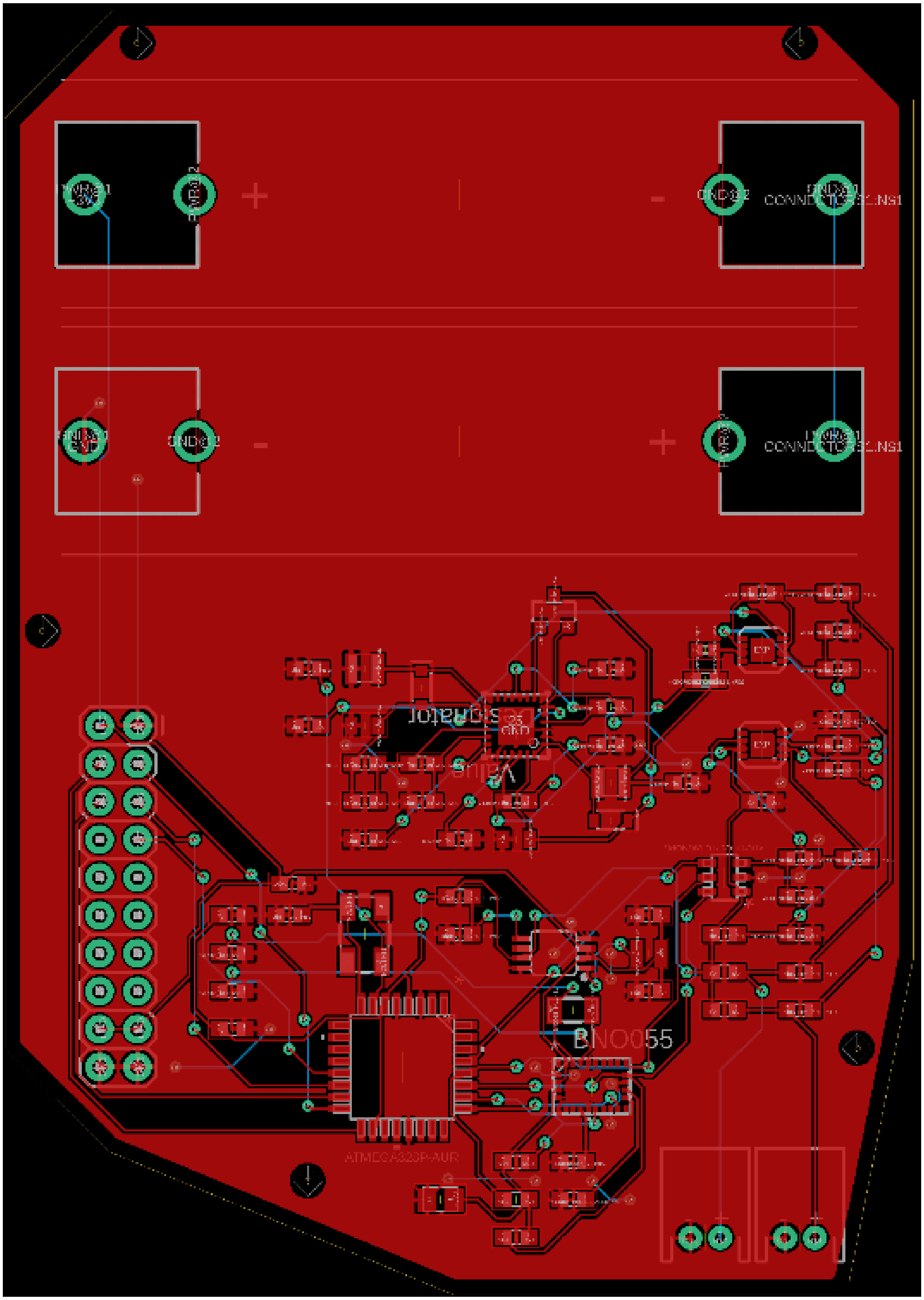

Figure 8: *Board design for the proposed device. This is a 2-layer PCB with all components are on the top layer except the connectors for the touchscreen.*