Embedded Wireless Sensor Design for Long Term Structural Health Monitoring

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[1]Finite Element Modelling
[2]Instrumentation Development

May 1, 2014

I have read this paper in its entirety and approve it for submission.

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6.1 Instrumentation

6.1.1 Integration of Strain Gauge

Integration of Strain Gauge

Figure 6.1 is one of the 3-element rosette strain gauges with pre-soldered ribbon leads. Purchased from omega engineering with model number SGD-6/120RYT23. These strain gauges were necessary after realizing the difficulty of soldering leads to the original set of strain gauges. The pre-soldered ribbon leads on the second set of strain gauges also proved to be unsuccessful during experimentation. This was because the leads would not stay secured to the attaching clips while tests were being run. Even with the persistent attempts to get the strain gauges connected and working correctly, the data received was still very inaccurate. One possible contributing factor to this may have be the lack of precision when applying the strain gauge to the exact location on the beam. However, one definite factor that contributed to the inaccurate data from the strain gauges was the type of strain gauge that was used. A strain gauge with a different gauge factor and a higher resistance would have been more favorable. The higher the resistance of a strain gauge, the higher the sensitivity. The original sets of strain gauges had a resistance of 120 Ω, but to precisely measure strain on a beam the resistance must be much higher, 350 Ω or more. The costs for a pack of 6 similar strain gauges with a resistance of 350 Ω from omega engineering is one hundred dollars. Another factor that haulted the efforts to apply the strain gauge was that they required another ADC output. It is possible to make more outputs, however this also demands that the time synchronization is even more accurate. Nevertheless, higher resistant strain gauges would be better for sensor packages for future developments.

Package Assembly

Package Location Figure 6.2 is an abaqus visualization of the Newport Bridge with the proposed location for the sensor package to be mounted. As shown in the figure, the center of the bridge is the best location for the sensor package. This is because the greatest amplitude of displacement will occur during the first mode of vibration at the middle of the bridge.

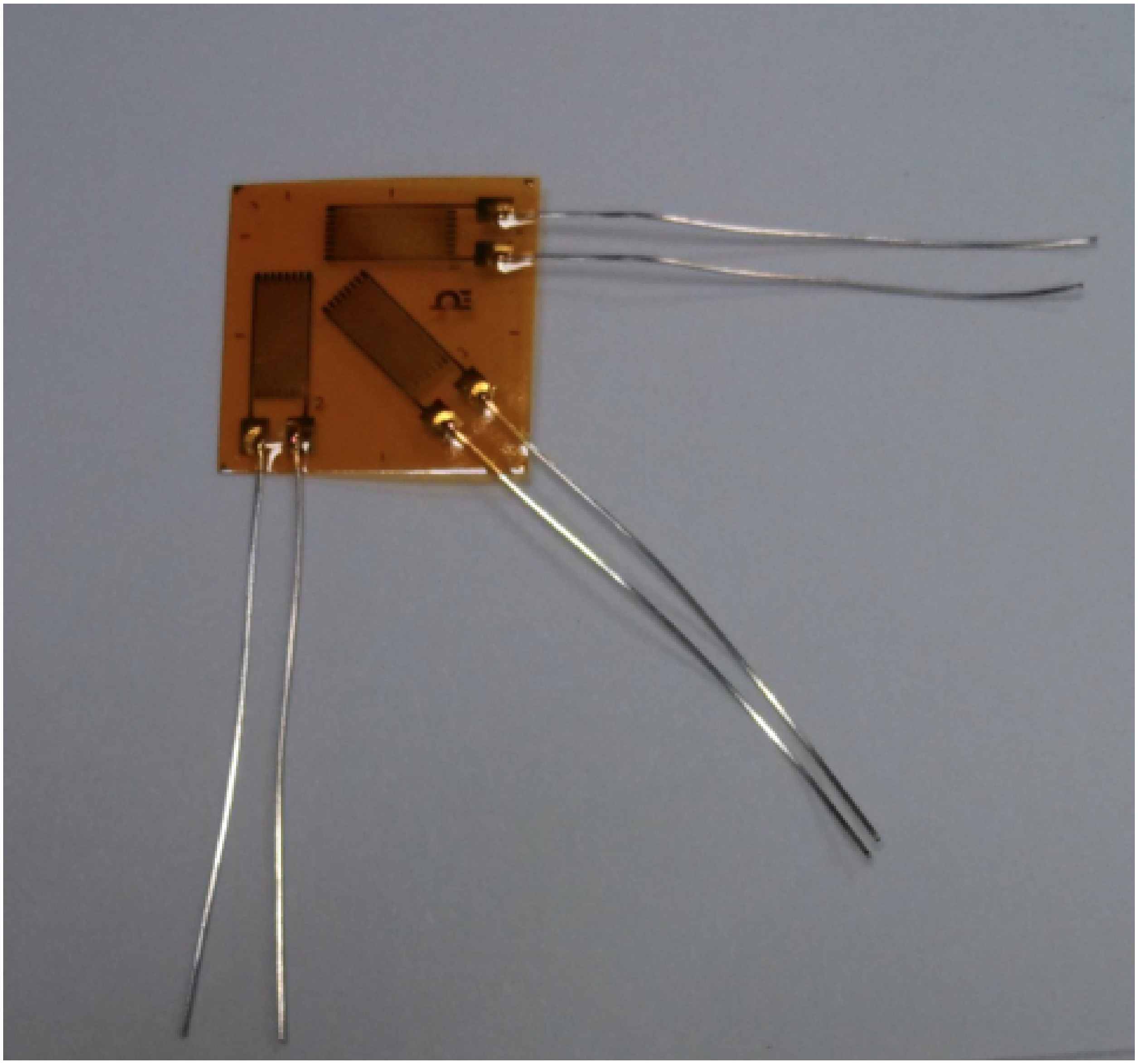

Figure 6.1: Omega 3-Element Rosette with pre-soldered leads.

Mounting the sensor package to the bridge must be done without damaging the structure in any way. The sensor package must also be capable of being moved easily. Most importantly, the package must be secured without any of its own motion, this is so that the sensors can recognize the movement of the bridge and not the package itself. The most economical way of securing the sensor package to the bridge is to use powerful magnets. Neodymium Magnets are strong magnets that work well in all environments and resist demagnetization. One negative aspect of the magnets is that it can be prone to corrosion if not protected with a coating properly. There is also a concern that the magnetic field can disrupt the electronics within the case. However, these issues can be prevented if the correct precautions are taken. The magnets come in many shapes and sizes, shown in Figure 6.2 one can see that the magnets can be bought with pre made holes for screws for mounting to the package.

The magnets in figure 6.2 are model MMR-A-XC from KJMagnetics.com. This magnet is hardly larger than a penny, yet it can easily be screwed into the sensor package and pull a force of 54.14 pounds. With two of these magnets screwed into the sensor package the package would be secured to the bridge. If calculations are run to prove the wind speed on the surface of the package to be too much for this pull force, stronger magnets are available. KJMagnetics.com also has similar magnets but with different pull forces ranging from 26.8 pounds to 260 pounds. These magnets can be used for securing the solar panels and wind turbine as well. Figure 6.4 shows a practicable location for the sensor package along with the solar panels above and the wind turbine hanging just below. The sensor package should be mounted on the outside of one of the major vertical beams at midspan of the bridge. The solar panels and wind turbine must be mounted close within a reasonable distance to keep the cable length to a minimum. The best place to mount the solar panels is on top of the upper horizontal beam on the southern side of the bridge. This will allow for the most amount of sun light and the shortest amount of cable necessary. The best place to mount the wind turbine is on the bottom of the lower horizontal beam on the southern side of the bridge. This location has plenty of wind because it is above the middle of the Narragansett Bay. By mounting the sensor package, solar panels and wind turbine below the deck on the southern side of the bridge the package will be capable of producing its own power and accurately measuring the vibrations of the bridge.

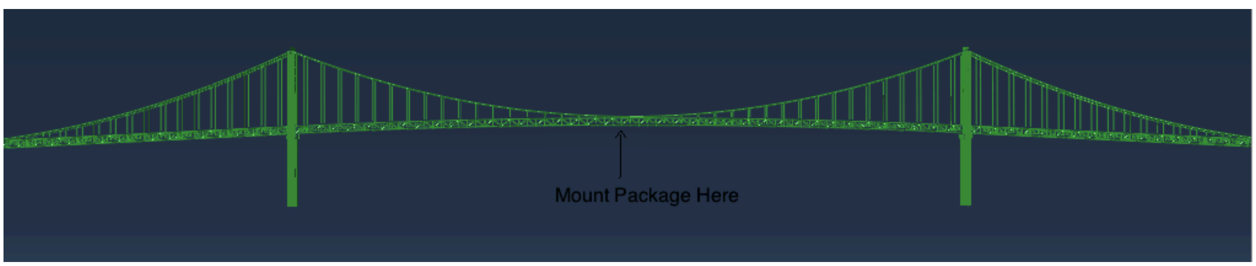

Figure 6.2: Proposed Package Mounting Location.

6.1.2 Wireless Transmission

6.1.3 GPS Time Synchronization

6.1.4 Package Assembly

Fabrication of Circuit Board

Battery Integration

Package Enclosure

Power Management

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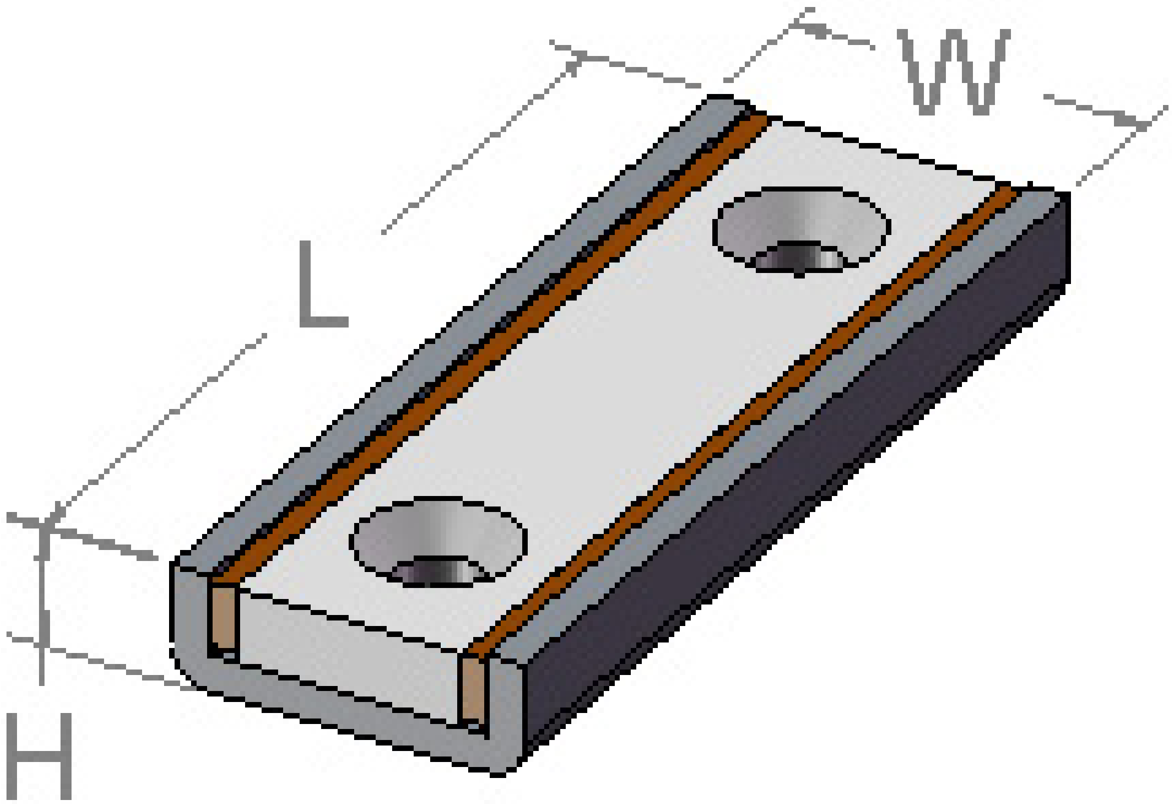
6.2.1 Model Improvements

6.2.2 Dynamic Loading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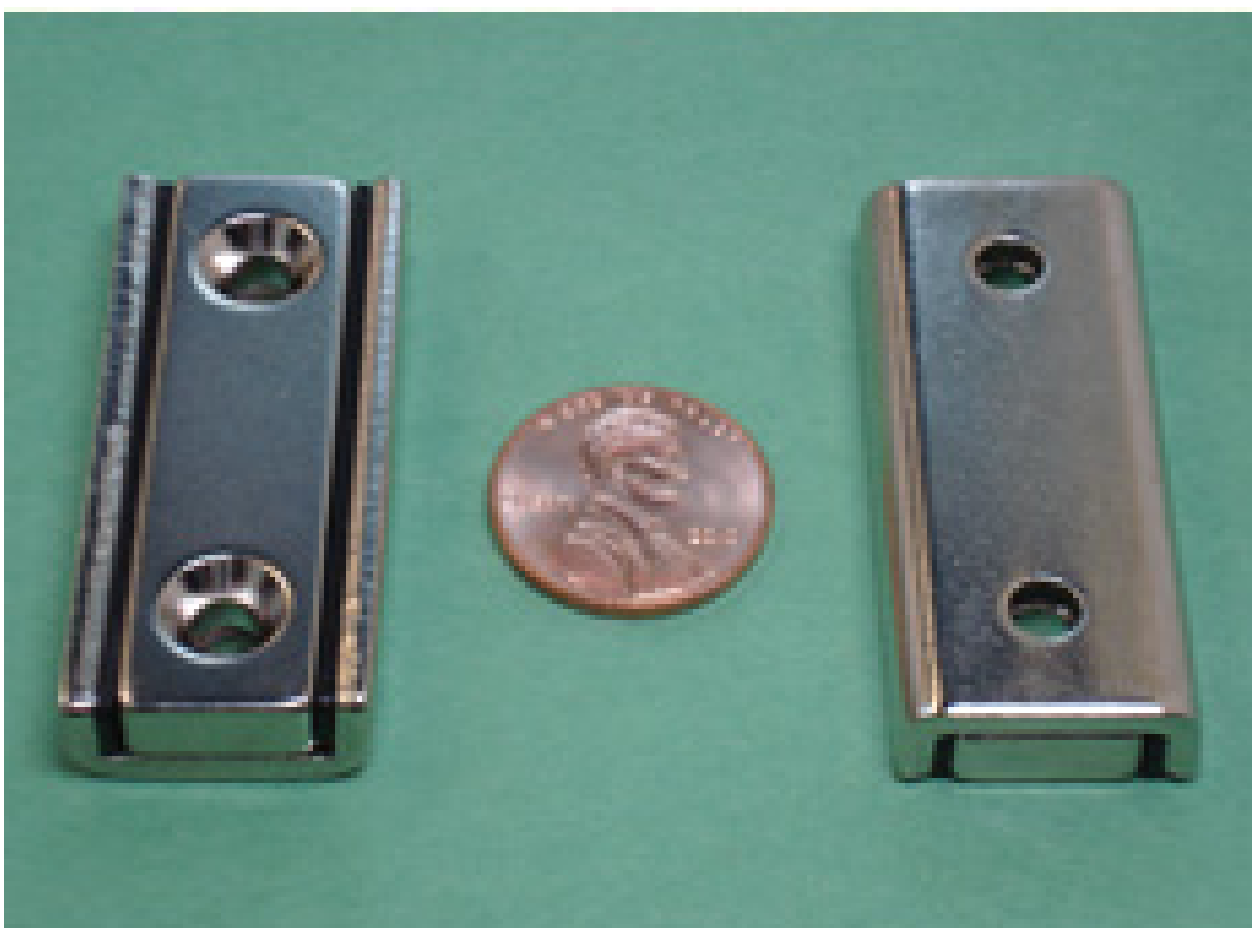

Figure 6.4: Proposed Location for Sensor Package, Wind Turbine and Solar Panels.

Chapter 7

Conclusion

Appendix A

Sensor Package Schematics

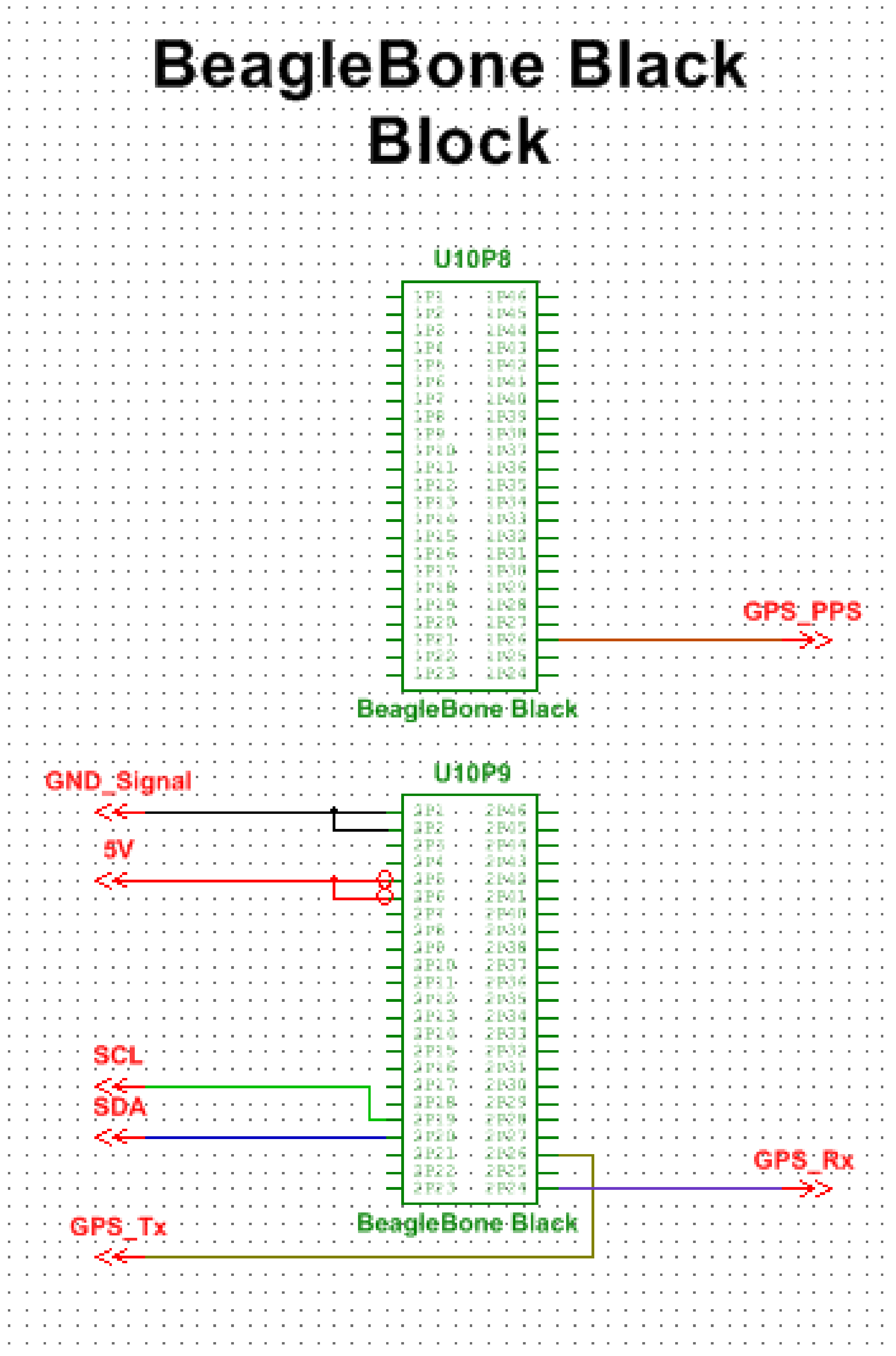

Figure A.1: Schematic of BeagleBone Black

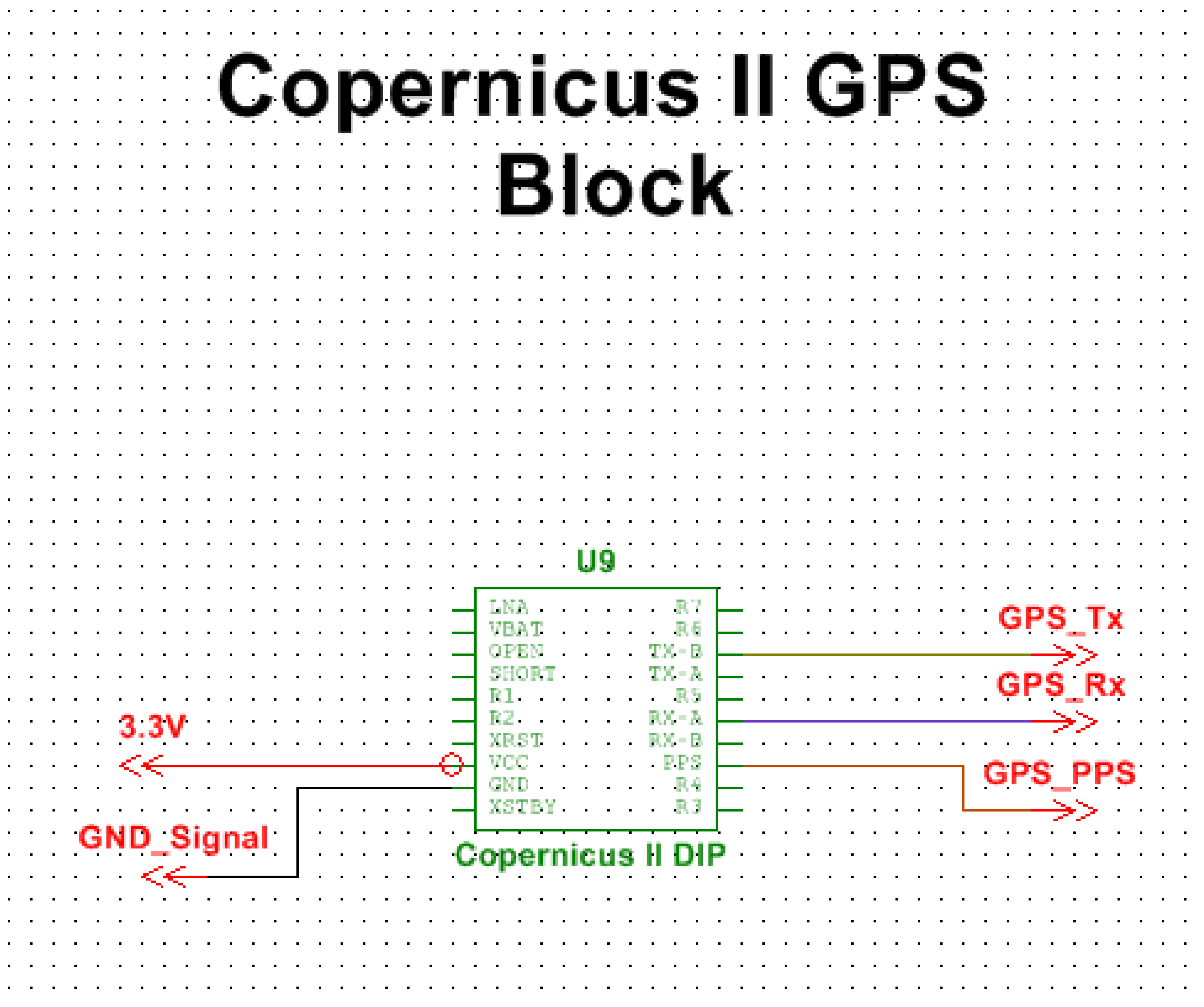

Figure A.2: Schematic of Copernicus II GPS Receiver

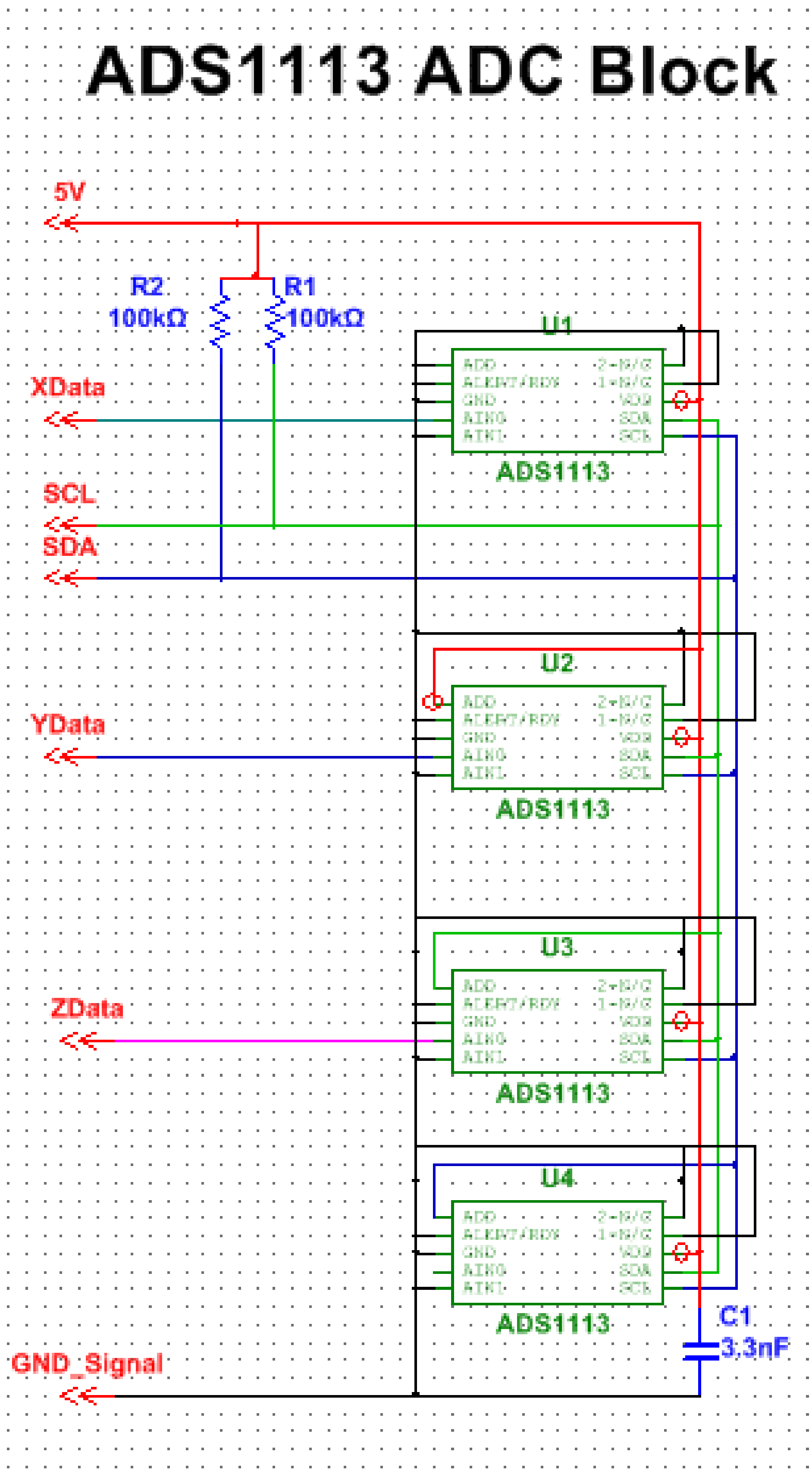

Figure A.3: Schematic of four ADS1113 ADC units in parallel

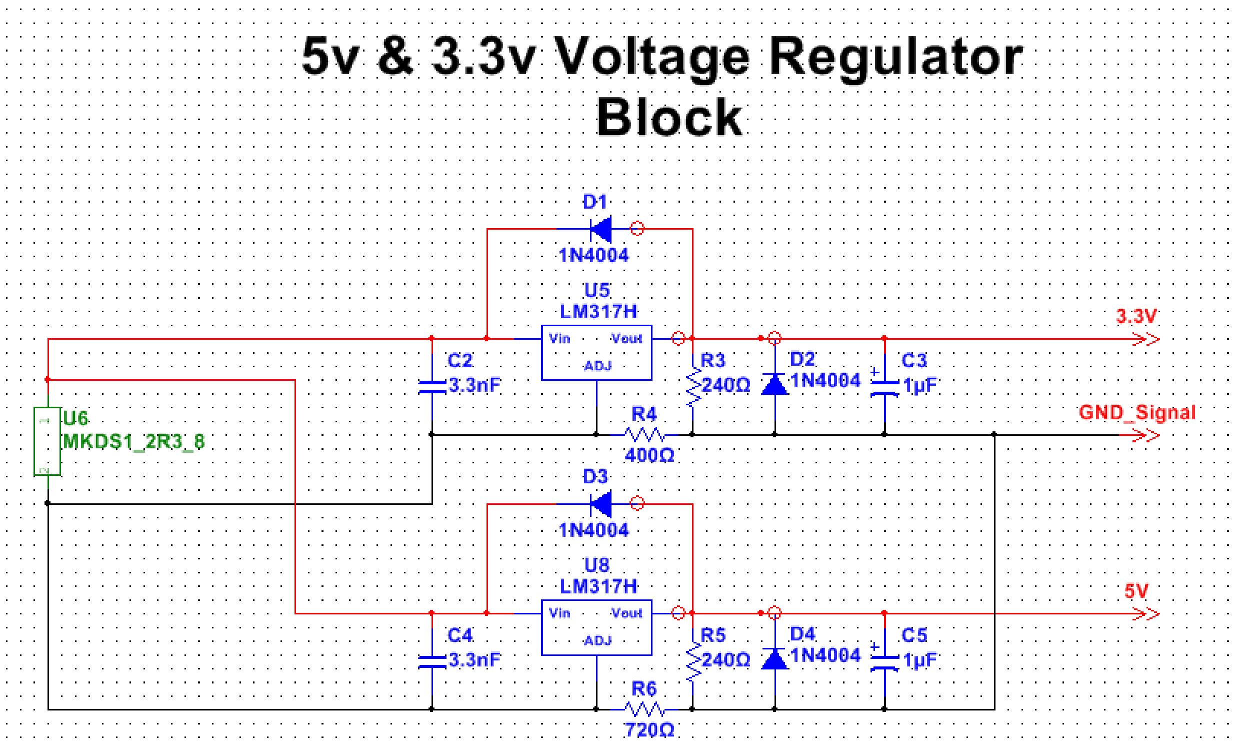

Figure A.4: Schematic of 5V and 3.3V voltage regulator circuit

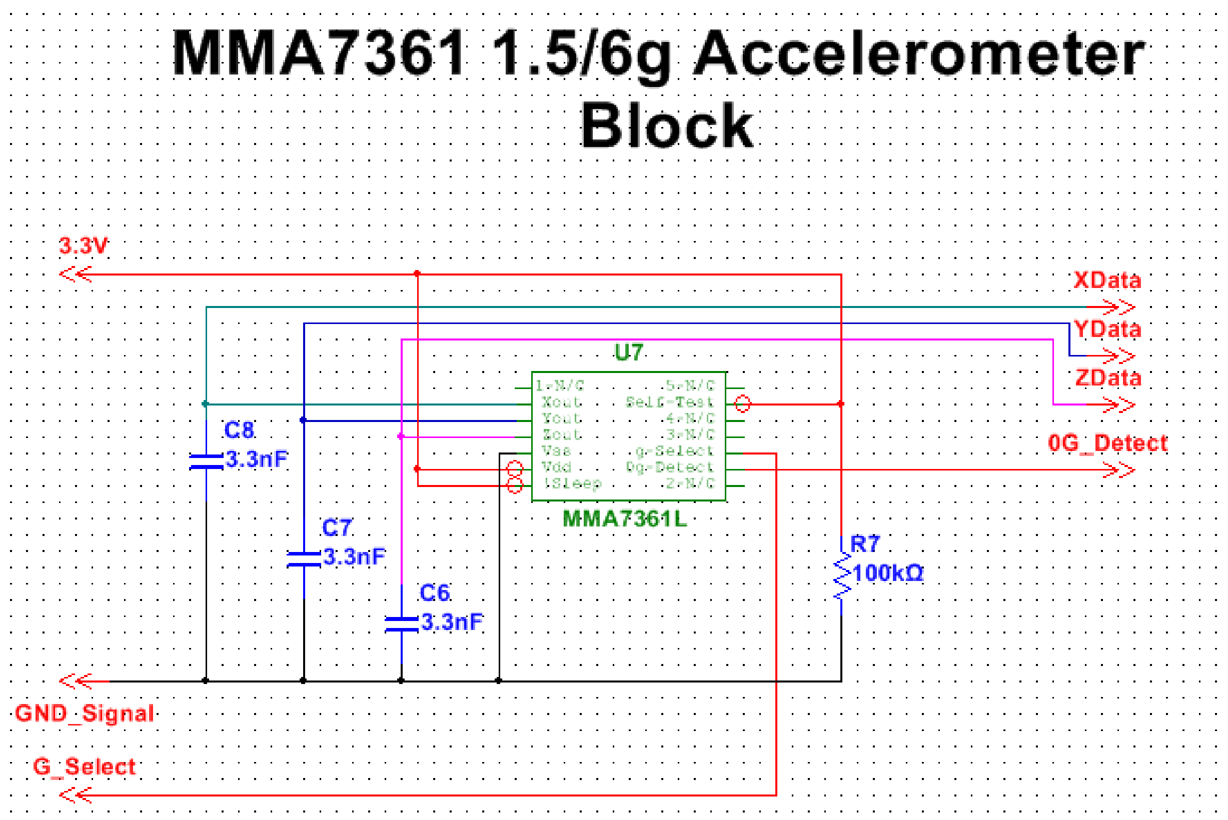

Figure A.5: Schematic of MMA7361 $\pm 1.5g/\pm 6g$ Tri-Axial Accelerometer