SMART SOLE INSERT

THE GLOBAL CHIP SHORTAGE: AN ANALYSIS OF SEMICONDUCTOR SUPPLY

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On my honor as a University student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments.

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Introduction

In 2018, for the first time ever, more than 1 trillion semiconductors were sold in a year (Yinug, 2019). The sheer enormity of this figure alone shows a lot about the impact semiconductor chips have on our daily lives. They can be found just about everywhere; if something has a plug or a battery, it almost certainly contains a semiconductor. However, the globe is currently facing a shortage of chips, as a result of many factors to be explored. This shortage has impacted production of goods, research, and more around the world. In fact, this shortage has even reached the technical side of this project. Instructions were given by the technical advisors to ensure that any parts we choose to use in the project design have a large quantity in stock. This is especially the case when choosing microcontrollers, which are extremely complex semiconductor chips. This instruction is a result of the current volatility of chip supply; if a product goes out of stock, there's no guarantee that the product will be available by the time it is needed. The technical project utilized several forms of semiconductor technology, including microcontrollers, diodes, and passive components like resistors and capacitors. Our project is the Smart Shoe Insole. Essentially, this is a device that uses sensors and bluetooth to send a real time signal to a display application that maps the pressure points on your feet. This project is being worked on concurrently with this writing. The STS project will be focused on the global chip shortage, including its cause, effects on industry, and potential solutions. Specifically, the project will take a dive deep into the effects of the shortage on the automobile industry.

Technical Topic

Foot pressure distribution (FPD) is a useful metric for diagnosing potential issues with a person's balance or gait. It can be used to identify foot deformities, provide a diagnosis for gait disorders, and can provide strategies for preventing foot ulcers in diabetics (Hessert et al., 2005). Additionally, the technology can be utilized by athletes. Golf players can use this technology to assess the form and stability of their swing (Odabas, Bulgan, Bingul, & Sarpyener, 2019). In snowboarding, a crucial aspect of control is shifting the weight distribution between your heels and the balls of your feet. FPD measurements can be used to assess snowboarders' weight shifting techniques (Holleczek, Rüegg, Harms, & Tröster, 2010). The technical group aims to design a low-cost and accessible device to provide accurate FPD measurements for a broad range of use cases.

Devices to provide FPD measurements can be found in a variety of forms. The most culturally relevant one is the "Dr. Scholl's" kiosk. This device is essentially a platform with a grid of sensors to take pressure measurements and calculate biometrical data (Xia, Howlett, & Lundy, 2006). More recently, a robotic shoe was developed to measure ground reaction forces and the foot center of pressure (Wolf, 2020). This device also includes motors that can exert force on and manipulate the foot and lower limb. There are also devices similar to our Smart Sole, which focus on balance or gain evaluation (Malawey et al., 2021) (Grenez, Villarejo, Zapirain, & Zorilla, 2021). The project aims to provide novelty by creating a device that could be purchased by all, can be used in a variety of use cases, and is very convenient and user-friendly.

The project deliverables can be divided into 3 main parts: the physical shoe sole with sensors attached, the hardware paired with the sole, and the software application to visualize the data. For the physical design of the shoe, sensors will be attached to the underside of a removable shoe sole. A set of wires will then lead to the hardware, contained within a 3D printed casing. This casing will be strapped around the ankle of the user, and the wires can be detached from this module. The hardware contains several main components: a charging circuit, a voltage regulator, sensor processing, and bluetooth transmission. Lastly, the data will be transmitted to a computer, and a Java program will be written to create a heatmap of the pressure readings. The block diagram below shows the flow of the system:

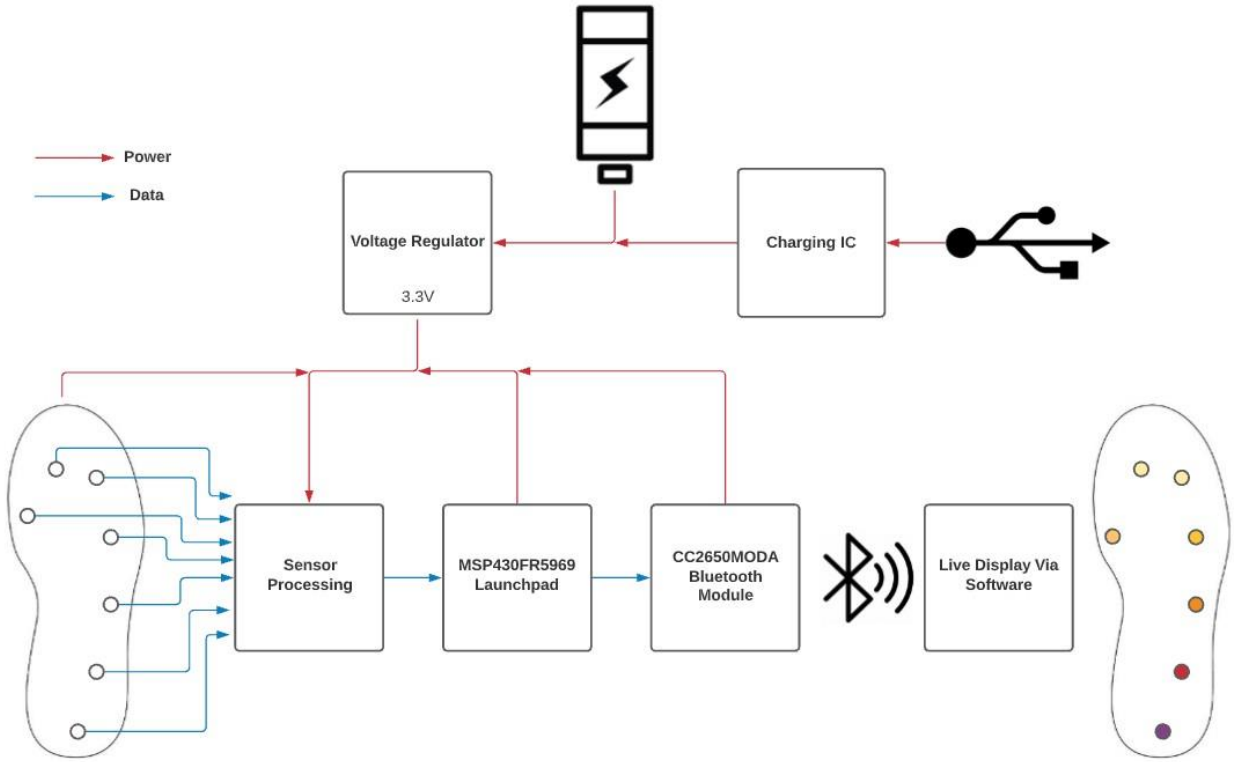

Figure 1: Project Block Diagram

The sole will consist of 7 sensors; this is limited by the number of analog input pins on the selected microcontroller. According to studies, the heel carries around 60% of the load in the average gait, the "midfoot" carries around 8%, and the front carries around 28% (Cavanaugh, Rodgers, & Iiboshi, 1987). The preliminary design has two sensors at the heel, one at the midfoot, and four at the ball of the foot. Based on research and estimations, the product should be usable by people up to 280 lbs. This estimate comes from a study that found that the maximum pressure exerted at the heel was approximately 65 PSI (Orendurff et al., 2007).

STS Topic

When the world shut down as a result of the COVID-19 pandemic, factories shut down as well, causing the materials required for the production of semiconductors to be unavailable for months. While supply had shut down, demand for consumer electronics only increased as a result of quarantines and social distancing (Feder, 2021). With the shift to online life, electronics have become even more integral to everyday life. As a result, manufacturers have backlogs that continue to grow. Another cause of the shortage of chips is the rise of 5G. Considering its promise as a future technology, companies are looking to fund its research and development. While this research and development will certainly benefit society once the shortage is resolved, it has caused an increase in demand for semiconductor technology at a time where the demand can't be met (Baraniuk, 2021). Additionally, for the misinformed, it is popular to quickly attribute the shortage to political failure, specifically that of the US government. There are a couple reasons why this would be an inaccurate assumption. First, the issue is primarily one that must be addressed by the private sector, as they ultimately have control over the majority of supply and demand for semiconductors. Second, the majority of semiconductor manufacturing occurs overseas (Newman, 2021). Currently, margins for supplying chips are just not competitive enough in the United States to justify the investment. The US government is attempting to remedy this by passing the CHIPS Act. This bill would provide $52 billion in federal subsidies to support domestic semiconductor manufacturing (Kelly, 2021).

The automotive industry got hit particularly hard by the semiconductor shortage. One estimation for the losses experienced by the industry sits at $210 billion (Tung, 2021). If the monetary value isn't enough to describe the impacts of the shortage, contextual evidence may create a clearer picture: it was hit so severely that some people were able to sell their used cars for more than they purchased them for. This was due to the shortage; companies wanted to sell new cars, but weren't receiving the chips necessary to complete the vehicles. As a result, they bought back used vehicles in order to repurpose the chips (Radcliffe, 2021). Additionally, this industry was very adversely affected by poor planning. During the second quarter of 2020, automotive manufacturers "shut down, as did most of the world, but as they did that they canceled orders from a lot of the supply chain." This caused suppliers to find new customers for their remaining chips (Shein, 2021). Lastly, there is some misalignment between the target market of semiconductor manufacturers and the chips desired for automobile manufacturing. Chip foundries are interested in creating cutting-edge technology for the latest smartphones and computers, as this will create the most profit for them. On the other hand, automobile manufacturers are interested in utilizing older, cheaper chips, as this will save costs.

There are three main alternatives that could replace the now-mainstream silicon semiconductor technology. The first is germanium. This was the first material used for semiconductor devices, and it is technically still viable. However, it would be a massive undertaking to shift production methods from silicon back to germanium. The next are metal oxides. The problem with this technology is that it becomes unreliable when made the size of modern-day chips. Lastly, we could use so-called III-V compound semiconductors. These contain indium, and can have electron mobility up to 50 times higher than silicon, which is a very desirable quality. However, there isn't a reliable supply of these compounds, which is a serious issue to consider (Hopkinson, 2015).

Research Methods

For the technical side of the capstone project, one of the primary methods of research has been looking at similar projects that have been done in the past. For example, projects that utilize the same components. Additionally, one of the methodologies is simply experimentation. There are several opportunities to redesign the project, allowing us room for experimentation. The project will also be guided by the capstone instructors, Professor Harry Powell, Professor Todd DeLong, and Professor Avik Ghosh.

For the STS topic, I have been using a question-driven research methodology. The primary questions that have been used to drive research are: “What factors are contributing the most to the chip shortage?”, “What have been the effects of the shortage on the global chip market?”, “How has the automobile industry specifically been affected by the shortage?”, “Will there be long-term effects as a result of this shortage?”, “Is it possible to renew supply using current semiconductor production methods?”, and “What new technologies may be used to replace silicon semiconductors?”.

Conclusion

The deliverable for the technical project will be a fully functional system that maps the pressure distribution throughout your foot. It is a bluetooth enabled device that will provide a heat map with color gradients to indicate pressure levels. This will allow doctors to diagnose gait disorders and predict the formation of diabetic ulcers, as well as allow athletes to fine tune their performance. The STS deliverable will be a roadmap of the way out of the semiconductor shortage. By analyzing the causes, effects, and potential solutions of the shortage, a way to alleviate the shortage will be made apparent.

References

Yinug, F. (2019, February 14). *More Than 1 Trillion Semiconductors Sold Annually for the First Time Ever in 2018.* Semiconductor Industry Association. https://www.semiconductors.org/more-than-1-trillion-semiconductors-sold-annually-for-the-first-time-ever-in-2018/.

Hessert, M., Vyas, M. Leach, J., Hu, K., Lipsitz, L. & Novak, V. (2005). *Foot pressure distribution during walking in young and adults*. BMC. https://doi.org/10.1186/1471-2318-5-8.

Odabas, H., Bulgan, C., Bungul, B. & Sarpyener, B. (2020, February 6). *The evaluation of foot pressure and postural structure of national golfers*. AOTT, vol. 53, no. 2, p150-153. https://doi.org/10.1016/j.aott.2019.02.005.

Holleczek, T., Ruegg, A., Harms, H. & Troster, G. (2010, November 1). *Textile pressure sensors for sports applications*. IEEE. https://ieeexplore-ieee-org.proxy01.its.virginia.edu/document/5690041.

Xia B., Howlett H., & Lundy, C. (2006). Footcare product dispensing kiosk. *US Patent # 8,117,922.* Memphis, TN. U.S. Patent & Trademark Office.

Wolf, A. (2020). Robotic Shoe for Diagnosis and Rehabilitation of Gait Anomalies. *US Patent #62562454.* Haifa, IL. U.S. Patent & Trademark Office.

Malawey, M., Lupfer, T., Steusloff, P., Liguori, T., Kurtz, M., Thilenius, M. (2021). Passive multiple foot sensor insole real-time feedback device. *US Patent # 11,076,803.* San Diego, CA. U.S. Patent & Trademark Office.

Grenez, F., Villarejo, M., Zapirain, B. & Zorrilla, A. (2013). *Wireless Prototype Based on Pressure and Bending Sensors for Measuring Gate Quality*. MPDI. https://ieeexplore-ieee-org.proxy01.its.virginia.edu/document/5690041.

Cavanaugh, P., Rodgers, M., Iiboshi, A. (1987, April 7). *Pressure Distribution under symptom-free feet during barefoot standing.* NCBI. https://pubmed.ncbi.nlm.nih.gov/3583160/.

Orendurff, M., Rohr, E., Segal, A., Medley, J., Green, J., & Kadel, N. (2007). *Regional Foot Pressure during Running, Current, Jumping, and Landing.* SAGE Journals. https://journals.sagepub.com/doi/10.1177/0363546507309315?url_ver=Z39.88-2003&rfr_id=ori:rid:crossref.org&rfr_dat=cr_pub%20%200pubmed.

Feder, S. (2021, October 12). *Understanding the global chip shortage, a big crisis involving tiny components*. Popular Science. https://www.popsci.com/technology/global-chip-shortage/

Baraniuk, C. (2021, August 27). *Why is there a chip shortage?* BBC News. https://www.bbc.com/news/business-58230388

Newman, R. (2021, September 9). *Why Biden can't fix the semiconductor shortage.* Yahoo!news. https://news.yahoo.com/why-biden-cant-fix-the-semiconductor-shortage-201713716.html?guccounter=1&guce_referrer=aHR0cHM6Ly93d3cuZ29vZ2xlLmNvbS8&guce_referrer_sig=AQAAAN0QttK68Y25WGpRG84v_Yu7zFoBz5a-ajeXP06ubQ10pQhZ9jngkWRXap-ZxsK3LQER718FLm8S6HaXkP0wHHUzDXRRhCFe-3WESiujFMrd8gMfv5F4Fiy7yfXYeS3BYdv22FcTuEbxm6PQZLiUP07WMYARuE6wc02NQDYID_Pb

Kelly, M. (2021, June 8). *Senate approves billions for US semiconductor manufacturing.* The Verge.

https://www.theverge.com/2021/6/8/22457293/semiconductor-chip-shortage-funding-frontier-china-competition-act

Tung, L. (2021, September 24). *The global chip shortage is still causing big problems for car makers*. ZDNet. https://www.zdnet.com/article/the-global-chip-shortage-is-still-causing-big-problems-for-car-makers/

Radcliffe, K. (2021, September 23). *Is now a good time to buy or sell your car?* KCEN TV. https://www.kcentv.com/article/money/money-talks/buying-selling-cars-in-2021-money-talks/500-637834bd-a7d2-4062-8e31-9b301bf4a860

Shein, E. (2021, May 28). *The global chip shortage: What caused it, how long will it last?* Tech Republic. https://www.techrepublic.com/article/the-global-chip-shortage-what-caused-it-how-long-will-it-last/

Hopkinson, M. (2015, August 27) *WIth silicon pushed to its limits, what will power the next electronics revolution?* The Conversation. https://theconversation.com/with-silicon-pushed-to-its-limits-what-will-power-the-next-electronics-revolution-46287