Autonomous Chess Robot

The Semiconductor Industry

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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

The semiconductor industry has grown exponentially over the past 50 – 70 years, and it is a force that continues to grow. (*Mission - The Voice of the US Semiconductor Industry*, n.d.) With the rise of transistors, there has been transformation in electronics technology and hence a shift in the computing power of said technology. One of the main ways transistors and other semiconductive materials changed history is through the continuous development of computers. The very first computers used vacuum tubes to do their processing and logic. (*Vacuum-Tube Computer*, n.d.) The flow of electrons was controlled inside a vacuum and acted like a switch, similar to today's semiconductors. (Kopyto, 2019) The next generation of computers were defined by transistors, then the integrated circuit, and then the microprocessor. (Bellis, 2019) With the rise of importance of semiconductors, these developments would not have been possible without the seemingly ever-improving transistors. The pressure to keep innovating is high in the semiconductor industry, but sometimes outside forces can take that constant desire and need to improve and produce can slow it down or halt. My STS project will aim to tackle the semiconductor industry and how the chip shortage has affected it.

When designing our capstone project, we knew that the supply chain will be an issue this year, maybe even more of an issue than last year, and this is just one example of how the effects of the COVID 19 pandemic are being felt. From global reports, it seems like this chip shortage will not end soon, as different social and geopolitical issues are still affecting the production of semiconductor chips. (*Top 3 Reasons Why There Is a Chip Shortage Right Now*, n.d.) One of the world's largest suppliers of semiconductor integrated circuit, IC, chips is the automobile industry, and when the pandemic hit, a lot of manufacturers paused production in that they expected a decrease in demand for cars. (*Top 3 Reasons Why There Is a Chip Shortage Right*

Now, n.d.) This snowballed into not having enough chips and boards to meet demand when demand rose again towards the end of the pandemic. The pandemic also caused a rise in demand for personal electronics as the world moved to an online norm and people were working from their homes. It became imperative to have a laptop for students to continue to learn in k-12. (*Top 3 Reasons Why There Is a Chip Shortage Right Now*, n.d.) Peoples' at home setup might have been inadequate for their workload, and hence needed to purchase more or better electronics. The pandemic also caused many factories to cease production, as continuing production was no longer economically feasible. (*Top 3 Reasons Why There Is a Chip Shortage Right Now*, n.d.) That combined with the increased demand for electronics resulted in a scarcity that we are still feeling today.

In addition to the factory production halts, transportation of goods across the globe faced issues. There are many products that rely on semiconductor chips, and hence when those are scarce, the products further up the line also become less frequently made or obtainable. In my research, I plan to gather sources as to how the chip shortage came to be, what is being done to fix it, and how best can the United States use the money from the recently passed chip act to pivot production of chips from overseas to domestic. I am planning on gathering information from different academic articles about the history of the semiconductor industry and specific technological innovations and their research papers that pressed the development of transistors and ICs forward. I would also like to speak with people and companies in the industry about their thoughts on the chip act, and how they as a company are planning on using that money to better the US's production of ICs as a whole. I am curious to learn about different companies' approaches and to see if the industry as a whole has a specific plan in mind.

Technical Project

For my technical project, I am designing an autonomous chess playing robot with my team that will have the capability to play a full game of chess against a human opponent. Figure 1 shows the design of the robot in computer aided design, CAD, and Figure 2 shows the robot fully assembled. This project has a few main components to it which need to work together for it to function properly. The mechanical design, the electrical design, and the software design all need to be in sync with each other to be a successful project. My main work on the project is the printed circuit board design, PCB, and the senor network integration. We will be using skills gained throughout our coursework on this capstone project which includes embedded design and coding, and circuit design.

The PCB design is completely up to us as a team. The circuitry needed for the robot to function first needed to be designed at the schematic level and then transferred over into a PCB design. We were lucky to find parts from previous projects that we could salvage to save on production costs and get a head start on the mechanical design and the motor control. The components for the PCB all need to be ordered and customized according to the specific needs of our project, like the maximum current our microprocessor can handle, and the current needed by the motors. The robot has a sensor network under the chess board to tell it where the pieces are, then that data is sent to the microcontroller via the PCB and then sent to a raspberry pi which will have an open-source chess engine running on it.

The sensor network is made up of a cross point array of reed switches. Reed switches operate in that they are open until closed by a magnetic field nearby. Stockfish is the open source chess engine that is running on the Raspberry Pi. Stockfish takes care of all the “thinking” that the robot needs to do. It can take in a board state and output the best move. After stockfish outputs a move, it will be sent back to the motors via the PCB and the MSP432, our microcontroller.

Some of the goals for this project include having the robot have a deterministic response, being fully autonomous, and being able to do special moves like castling, en passant, and pawn-queen promotions. The schematic having all the needed circuity was a main concern during production, as there are a lot of connections that need to be made with the MSP, other ICs, and outputs. The MSP also needs protection, as we do not want to fry any chips, or even worse, our microcontroller. This is a real valid concern, as in if we fry a critical chip and there is not enough time to get a replacement, our project might not work as intended. This is another place where the supply chain issues come in to play. Ideally, we will not fry any of our chips, and we need to design our circuity in such a way that we are prepared for abnormal events like a large current spike. We also need to design for test in that we need to ensure our PCB has enough test points and shunts where we can cut off different subsystems to test them individually. One challenge of this semester in particular is the process of finding and buying components for our project. The supply chain has been having issues since the onset of the COVID19 pandemic and that is still being felt today in the ordering of parts.

Figure 1: Final Robot CAD - Image courtesy of Eli Jelesko

Figure 2: Final Robot Assembly - Image courtesy of Eli Jelesko

STS Project

Engineering education often emphasizes the technical knowledge of a career, but the social and political impact of technology cannot be underestimated during the design process. I want to explore these sociopolitical avenues of how the semiconductor industry flows and where money comes from. Even if there is a desire to produce certain items domestically, there is a reason why so much production has shifted overseas. It is more economically beneficial to companies to manufacture cheap chips and then ship them back to the US. One of the main questions that I want to answer is what the main US-based chip manufacturing companies are planning on doing or what they have already been doing to take advantage of this influx of government money due to the recent chip act of 2022. The act is known as the Chips and Science Act by the public (Breuninger, 2022) and in congress is officially called H.R.4346 - Supreme Court Security Funding Act of 2022 (The Chips and Science Act of 2022, n.d.) (P.L 117 – 167) (*The CHIPS And Science Act Of 2022*, 2022) I would also like to explore how different sides of the same industry are approaching the chip act.

Some companies that used to be big in the semiconductor manufacturing scene like IBM have now pivoted to a more software driven company model than a hardware one. BAE Systems in Manassas also had to close one of their transistor manufacturing plants due to decreased demand. There are two main sides when it comes to companies who are developing these technologies. They can do mainly government contracting or they can do private sector projects, though some companies do both. Some of the main producers of semiconductor chips in the US right now are Intel, Texas Instruments, and Micron. (Reiff, 2022) I want to dive deeper into the processes that they use and how they are different from their overseas competitors like Taiwan Semiconductor Manufacturing (TSMC) and Qualcomm (QCOM). (Reiff, 2022) One of the questions that comes up when discussing the increase in semiconductor production in the United States in the is the quality of ICs. This is due to one of the main reasons that overseas chips can be manufactured at such a cheap price relative to their counterparts is that the quality of the chip goes down. The US currently is very good at producing high end chips, but if the US wants to stop importing such a high quantity of chips, the quality of said chips will need to decrease to maintain consumer price point expectations.

There are many different social groups at play here in this analysis, such as the government, the manufacturing companies, their suppliers, the transportation companies, and the consumer. What happens further up the supply chain has a direct impact on resources and products further down the supply chain. Therefore, the framework of actor-network theory would be best for my STS project. I would like to see how each of these different actors interact with each other to form a common goal, what issues they have with each other, and specific weak points in the industry that could be changed. I would also like to see the different effects of the chip shortage on different economic/social classes of people in the United States, especially at the beginning of the pandemic when we all suddenly had to start working and studying from home. The impact of race also on the employees makes a huge difference in workplace experience (Appelhans, 2021).

Another aspect of this analysis is the environmental impact that the semiconductor industry has. The neon shortage also has had an impact on the semiconductor shortage since neon is a critical natural resource that is used in the manufacturing of silicon wafers which are used abundantly in ICs. (Asianometry, n.d.) One on the main producers of neon is Ukraine, which has been fighting a war with Russia for since March of 2022. Ukraine was the world's largest supplier of neon, and when Russia invaded, production was halted. Neon is a key component for the semiconductor manufacturing process, in that it is used for photolithography, a process of etching designs onto silicon using light. Overall, I hope to research how the chip shortage came to be, and what is being done about it.

Key Texts

Since I have chosen to use Actor-Network theory, one of the key texts I will be using is Latour's *Aramis, or the Love of Technology.* (Latour, 2002) The book is the birth of Actor-Network theory and a key STS text. Latour writes about Aramis, a proposed ideal transportation system in that there are individual pods but one major network. He aims to answer the question of "Who killed Aramis?" and with that brings into the discussion a framework of Actor-Network theory which aims to pinpoint different "actors" in a technological setting. This piece is important to my project because it is a good intro to Actor-Network theory.

Another key text I will be using is the H.R.4346 – Supreme Court Security Funding Act of 2022. (The Chips and Science Act of 2022, n.d.) This is the bill from congress which is known colloquially as the Chip Act. This is the actual bill that congress signed and different versions of that bill through its time in congress. It became public law on 08/09/2022. The latest date they have for a summary of it is 07/28/2022 which includes "funding for wireless supply chain innovation, establishes an advanced manufacturing investment tax credit, ..., and required the coordination of federal science and technology efforts to ensure secure, reliable, and environmentally sustainable supplies of critical materials to the United States..." (The Chips and Science Act of 2022, n.d.) In the summary of the bill, they do not mention any specific companies or organizations, and also does not mention the word chip. The bill text does have specificities about specific sciences, like biological and environmental research, nuclear physics, isotope research and other sections on manufacturing and promoting domestic production. This is relevant to my project because I am using this bill to base my research from.

I also plan to use Sara E. Appelhans's dissertation (Appelhans, 2021). She does a case study on the work environments of workers in the semiconductor industry in the northeast united states. She describes how different the environment is in the northeast compared to the west, Silicon Valley, or Texas. Her fieldwork was from May 2018 to August 2019 in the Northeast. She brings an anthropological perspective on the highly technical field of integrated circuit design which is a heavily male dominated field. She aims to talk about the "bleeding edge" which is a step above "cutting edge" in the R&D world, in that companies may take huge investments in these very risky "bleeding edge" technologies with very serious consequences of backfire. She aims to describe the experience of women and migrants in this analysis. This source is important for my project in that this is a deeper dive into the design side of chip manufacturing and what really goes on behind closed doors.

One last impactful source I plan to use is a paper titled "An Analysis on the Crisis of 'Chips shortage' in Automobile Industry ——Based on the Double Influence of COVID-19 and Trade Friction" (Wu et al., 2021). They do "empirical analysis on the structure of global integrated cicuit market and study supply and demand in the market" (Wu et al., 2021). They state that strain that the chip shortage in the consumer electronic industry was feeling had already been felt in the automobile industry as early as mid-2020, leading to closing of automobile production lines and other effects. This piece is important to my project in that they do a very similar analysis of the situation as what I would like to do for my project.

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