FSAE CAN Sensor Board

Integrated Circuitry's Impact on Domestic Automotive Manufacturing

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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 automotive industry is one of the most omnipresent industries in the entire country. Unless you happen to live in a major metropolitan area, it's nearly guaranteed that you need a car to survive. That is simply the way our society is built. These technical marvels have undergone over a century's worth of innovations, yet one stands above all else. The introduction of the integrated circuit into the automobile industry revolutionized what could be possible within the limited power and confined space of cars. Digital components can do things that would've been unimaginable with the limited and finicky potential of analog circuitry. Now, nearly every new car driving off the lot is a glorified computer on wheels (Marshall, 2024).

Integrated circuitry is also used by such groups as the Virginia Motorsports Club. This club builds an electric formula car (as seen in Figure 1) for Formula SAE competitions, where they then race against other motorsports clubs from other universities (Virginia Motorsports Education, 2024).

Figure 1: Virginia Motorsports 2024 Formula Car

One main limitation put in place by FSAE is that a new car must be built every season (which corresponds to the school year), which allows for the best systems of the previous vehicle to be fixed up and re-added while the worst systems get replaced entirely (FSAE, 2024). For this season, the new lead of the electrical team had his eyes set on the most glaring flaw of the previous car: the data acquisition harness. This rat's nest was a jumbled bundle of wires that snaked its way from the central data collection computer, through the frame, into each of the four wheels of the car. Each wheel had numerous sensors, gathering everything from wheel speed to brake temperature. Given that all of these sensors output their data in analog signals, it was decided that each sensor simply be wired directly into the central computer. When you factored in the number of sensors per wheel, this resulted in a bundle of roughly 20 wires connected to every wheel. Not only did this result in a harness that was incredibly failure-prone, but it weighed down the car itself as well, which defeats the point of a race car. My Capstone group stepped in to update this antiquated harness. This project focuses on replacing the current analog data acquisition system with an integrated circuit on each wheel that sends all the data on one line via the CAN protocol. This knowledge on integrated circuits can be effectively used for my STS topic on how the circuits need to be viewed as an actor with its own desires, which falls in line with Actor Network Theory.

Technical Topic

The project consists of designing and building a corner board, which will go on each of the four wheels of the car. This corner board will take in a variety of different signals from 4 sets of sensors on each wheel, that being brake temperature, wheel speed, tire temperature, and suspension compression. There is a program flashed onto the corner board that first takes in these signals via an Analog-to-Digital Converter and packs them into a message that follows the CAN protocol, specifically CAN FD. The CAN protocol, short for Controller Area Network, is a method of compacting several unrelated signals into a single condensed data signal. One way to conceptualize CAN would be, when you have several letters to send to someone, choosing to send them all as a single parcel, instead of sending each letter individually, resulting in all the letters arriving together. This CAN signal is then sent out to the central data acquisition computer in a single pair of twisted wires, down from the original 20+ of the old analog harness. CAN is the current automotive standard for data transfer (NI, 2024), on account of its high data rate, reliability, and flexibility in connecting a variety of electronic control units to a single data line (Corrigan, 2016). CAN FD is the newest iteration of CAN, with it having 8 times more data storage per message than its predecessor CAN 2.0 (Smith, 2024). Note the 64 byte data frame versus the 8 byte data frame in the structs shown in Figure 2. This new harness will greatly improve the reliability and the throughput of the data acquisition system, as well as reduce the weight of the car itself.

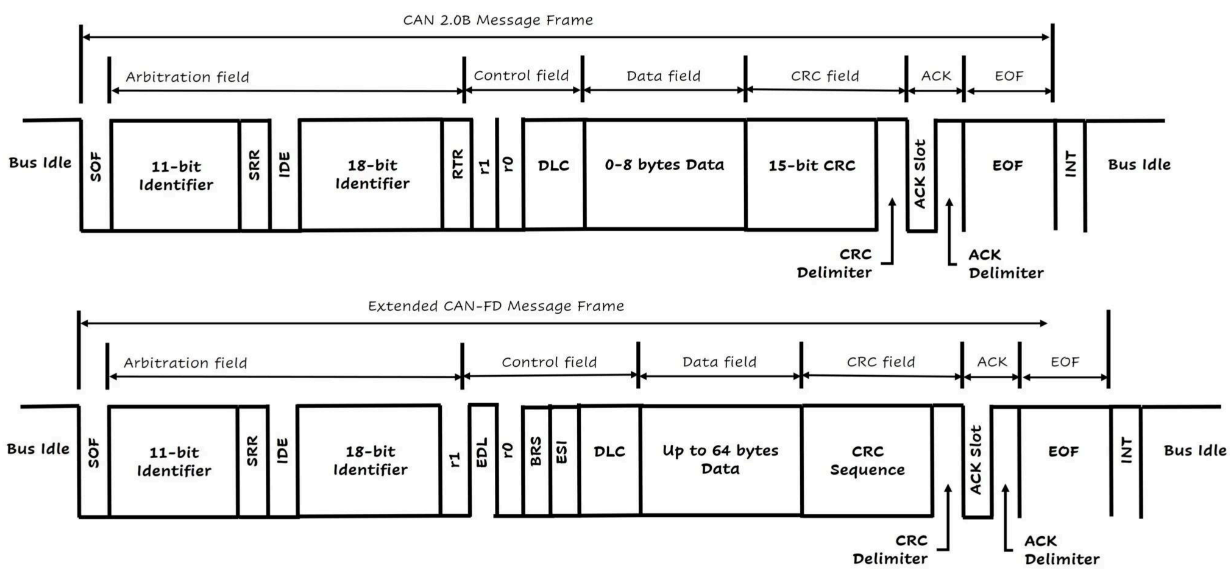

Figure 2: CAN 2.0 vs CAN FD Message Struct (Embedded Flakes, 2022)

Most of the hurdles for this project are the strict requirements that arise from the fact that this board will be strapped to an electric vehicle. For one, we needed to make sure that we used connectors that were vibration resistant, which resulted in us deciding on automotive spec connectors that were specifically designed for that use case. This vibration resistance also required that we only use surface mount components on the board. These are far more secure than traditional through-hole soldering, which causes them to be standard in basically every industry that uses printed circuit boards. Given that the car is an electric vehicle, we also had to make sure that everything was resistant to electromagnetic interference. The car's batteries store a total of 404 volts of electricity, which can result in the wires producing electromagnetic waves that can mess with the other components. This could theoretically lead to data loss in our CAN line or on the board itself. Therefore, we will use properly shielded wire to prevent interference on the actual transmission, and we are going to completely encase each board in a material that reflects EMF waves. This case serves a dual purpose, as it also makes the board water resistant, which is a requirement from FSAE as a safety precaution.

STS Topic

While adding integrated circuits and other digital devices to vehicles has clear monetary and function value, it comes at the cost of the employment of everyday workers in the United States. The US automotive industry, which was once booming, has been left a hollow shell of its former self as all of the unskilled labor positions have been exported to overseas countries with more lax labor laws, leaving all of the remaining jobs in the industry requiring higher education in circuit design and programming. Utilizing Bruno Latour's framework of Actor Network Theory found in the 1992 paper "Where Are the Missing Masses? The Sociology of a Few Mundane Artifacts", one can begin to piece together how these different groups impact and are impacted by the technology.

Latour (1992) states that Actor Network Theory (ANT) is used to "[resolve] the technological determinism/social constructivism dichotomy in technology studies", which take opposing positions on whether technology influences society or society influences technology, respectively. ANT posits instead that, while "sociotechnical systems are developed through negotiations between people, institutions, and organizations", it misses out on the fact "that [the] artifacts are part of these negotiations as well." That means that one must consider the interaction between technology and society a two-way street, with each being molded to the other's benefit.

Looking at what the actors do and what they need to be done by the other actors gives an insight into how the industry has been shaped and where it will continue from here. First, there are the automotive companies, which desire to create quality vehicles that can be sold for the most profit. To do this, they increase features to improve quality and price tags, and decrease costs. This impacts all the other major actors, with the consumers getting more features at a higher price tag (Dery, 2006), the workers being replaced with cheaper (Crossa, 2020) or more efficient (Adler et al, 1997) options, and the artifact of focus (integrated circuitry), gaining demand due to its capability of more robust feature sets at lower costs. Consumers have similar desires as the corporations, with the notable exception of increasing price tags (Hardigree, 2023). This results in a further push for corporations to cut costs while increasing features, which then propagates to the other actors (Sugiman, 1992). This furthers the need for better integrated circuits and cheaper workers. Ultimately, it is the workers that suffer as a result of these needs. The main manufacturing workforce is exported to cheaper overseas sweatshops (Goh and Tang, 2024), leaving behind only the integrated circuit design. Ultimately, integrated circuitry forms the perfect example for ANT, in that both the societal actors impact how technology is molded and utilized, and the technological actor in turn has its own desires that affect the human actors. While they are designed to create more robust features to satisfy the companies and the consumers, they also impart their needs for a more skilled workforce (Ngcwangu, 2023).

On the other hand, there are concepts like prescriptions, in which the nonhuman actors impose back on the human actors (sometimes rigidly, in the case of discrimination). The integrated circuit has its own needs and desires. It prescribes its mechanical and technical needs on those who build and design them, and it prescribes its monetary needs on those who purchase them. These delicate pieces of technology require the utmost care and delicacy, which discriminates upon the laborers the need to be incredibly careful with the circuitry, or risk losing their jobs.

Research Topic

Introducing integrated circuitry has widespread effects throughout automotive manufacturing. The actors that have the least agency in influencing these results are undoubtedly the laborers, who are at the mercy of their employers. This leads to the main question: How has the continued adoption of integrated circuits in the automotive industry impacted the quantity and type of employment within it?

To further research this question, I am planning on combining three different avenues. First, I'll comb through labor statistics in the automotive industry at large in order to discern the overall trends. To do this, I'll utilize the US Bureau of Labor Statistics database and the US Census Annual Survey of Manufacturers, focusing on the automotive industry's stats to create a timeline of these trends. Next, I'll create another timeline, this time for the adoption of integrated circuitry, which will then be combined in order to determine the possible correlation between these two datasets. This second timeline will be generated from two books. The first book is *Understanding Automotive Electronics: An Engineering Perspective*, which outlines the technology utilized and how it was assimilated into the industry. The second one is the *Handbook of Automotive Power Electronics and Motor Drives*, which covers every single possible section of electronics found in cars. The main focus will be chapter 6, titled "Automotive Power Semiconductor Devices", which will be most in line with my research topic.

In order to bring this closer to my Capstone project, I'll also look into the creation and updating of CAN, utilizing the CAN in Automation group's technical documentation that chronicles the various versions of CAN. All of these different timelines can be viewed as different actors in the ANT, showing how they interacted with each other over time.

Conclusion

The use of integrated circuitry has vastly improved the reliability and efficiency of nearly every automotive system that it has been implemented in, and the Virginia Motorsports' Formula car will be no exception. The addition of the corner board compacting the data acquisition down to a single CAN bus per wheel will result in a car that is faster, more dependable, and safer. The knowledge acquired while building this corner board will facilitate the ability to understand how integrated circuitry is utilized in the automotive industry, as well as how it has grown from its conception. This will assist in giving insight into how and when the industry has changed over time as a result of this technology. As a result, it might allow for ideas on how and where to simplify the knowledge base that is required to develop and build the circuitry. If that were to happen, perhaps it could lead to more reasonable and affordable methods of meeting the requirements to work in the current domestic automotive manufacturing sector.

References

Virginia Motorsports Education. (n.d.). About Us. Retrieved October 20, 2024, from https://www.virginiamotorsportseducation.org/

Adler, P. S., Goldoftas, B., & Levine, D. I. (1997). ERGONOMICS, EMPLOYEE INVOLVEMENT, AND THE TOYOTA PRODUCTION SYSTEM: A CASE STUDY OF

NUMMI'S 1993 MODEL INTRODUCTION. *ILR Review*, *50*(3), 416–437. Business Source Alumni Edition. https://doi.org/10.1177/001979399705000303

Bureau of Labor Statistics. (2024). *Automotive Industry: Employment, Earnings, and Hours : U.S. Bureau of Labor Statistics*. Bureau of Labor Statistics. https://www.bls.gov/iag/tgs/iagauto.htm

CAN in Automotive. (2024). *Technical documents*. https://www.can-cia.org/cia-groups/technical-documents

Corrigan, S. (2016, May). *Https://www.ti.com/lit/an/sloa101b/sloa101b.pdf?ts=1727622488768*. https://www.ti.com/lit/an/sloa101b/sloa101b.pdf?ts=1727622488768

Crossa, M., & Ebner, N. (2020). Automotive global value chains in Mexico: A mirage of development? *Third World Quarterly*, *41*(7), 1218–1239. Political Science Complete. https://doi.org/10.1080/01436597.2020.1761252

Dery, M. (2006). "Always crashing in the same car": A head-on collision with the technosphere1. *Sociological Review*, *54*(1), 223–239. https://doi.org/10.1111/j.1467-954X.2006.00646.x

Embedded Flakes. (2022, December 11). *CANFD: The Next Big Thing in Automotive Communication - Embedded Flakes*. https://embeddedflakes.com/next-big-thing-in-automotive-canfd/

FSAE. (2024). *FSAEOnline.com*. https://www.fsaeonline.com/

Goh, M., & Tang, L. (2024, April 22). *More foreign companies moving manufacturing facilities from China to Malaysia amid trade tensions—CNA*. https://www.channelnewsasia.com/asia/malaysia-china-companies-move-manufacturing-facilities-semiconductors-trade-war-4282471

Hardigree, M. (2023, October 20). *Automakers Are Starting To Realize Their Cars Are Too Expensive*. The Autopian. https://www.theautopian.com/automakers-are-starting-to-realize-their-cars-are-too-expensive/

Kazmierkowski, M. (2008). Handbook of Automotive Power Electronics and Motor Drives (Emadi, A.; 2006) [Book News]. *IEEE Industrial Electronics Magazine*, *2*(2), 46–47. https://doi.org/10.1109/MIE.2008.926483

Latour, B. (1992). *'"Where Are the Missing Masses? The Sociology of a Few Mundane Artifacts."'*

Marshall, A. (n.d.). Cars Are Rolling Computers Now. So What Happens When They Stop Getting Updates? *Wired*. Retrieved November 8, 2024, from https://www.wired.com/story/cars-are-now-rolling-computers-so-how-long-will-they-get-updates-automakers-cant-say/

Ngcwangu, S. (2023). Skill and Deskilling in Two Automotive Assembly Plants in South Africa. *Qualitative Sociology Review*, *19*(1), 102–121. https://doi.org/10.18778/1733-8077.19.1.05

NI. (2024, July 2). *Controller Area Network (CAN) Overview & Specifications*. https://www.ni.com/en/shop/seamlessly-connect-to-third-party-devices-and-supervisory-system/controller-area-network--can--overview.html

R, Niranjana. (2024, August 8). *Ultimate Guide to Controller Area Network (CAN) in 2024*. https://www.logic-fruit.com/blog/can/controller-area-network-can-guide/

Ribbens, W. B. (2017). *Understanding automotive electronics: An engineering perspective* (8th ed). Butterworth-Heinemann.

Smith, G. M. (2024, February 13). *What Is Can Bus (Controller Area Network)*. Data Acquisition | Test and Measurement Solutions. https://dewesoft.com/blog/what-is-can-bus

Sugiman, P. (1992). "That wall's comin" down': Gendered strategies of worker resistance in the UAW Canadian region (1963-1970). *Canadian Journal of Sociology*, *17*(1), 1. https://doi.org/10.2307/3340587