Impedance-based BMS Lowering Carbon-emissions and Increasing Safety Associated with Lithium-Ion Cells

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***Abstract*— This article considers the environmental and societal impacts of an impedance-based battery management system on the production and usage of Lithium-Ion cells. The environmental impact considered is the large amount of greenhouse gases produced in the production of greenhouse gases [1]. Specifically, the greenhouse gases produced from mining and transportation vehicles used to gather the raw materials. The societal impact considered is safety. The largest issue with Lithium-Ion cells is in battery packs where different cells have significantly different voltage values. This issue is known as cell mismatch. Using the impedance-based battery management system (BMS) that was developed, it has the potential to reduce the demand and therefore reduce the need for vehicles producing greenhouse gases. As the usage of this BMS increases, the affect it has on the issues stated also increases.**

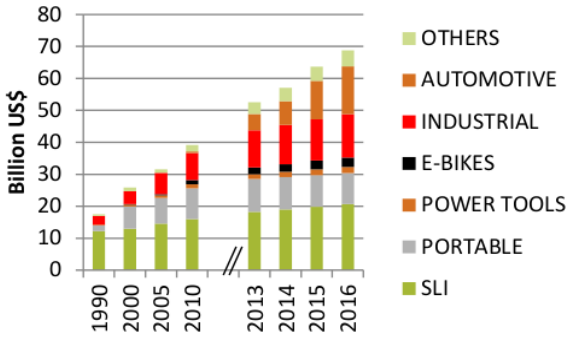
***Keywords*— Lithium-Ion Batteries, Battery Management System, UCR, Battery Health, Environmental effects of Lithium-Ion battery production, Battery Safety**

I. INTRODUCTION

Since 1990 when they were first introduced, Lithium-Ion batteries have gained more widespread use in everyday technologies and industries [3]. Based on trends in figures 1 and 2, Lithium-Ion is expected to be the majority of battery type sold on the market in transportation and portable electronics [4]. However, these batteries come with several concerns. The production of Lithium-Ion produces a large carbon-footprint and if cell mismatch occurs are dangerous to human and device safety. Cell mismatch being when cells in a pack have different voltage values. The impedance-based battery management system can help minimize the environmental issues associated with the production by reducing demand and improve the overall safety by continually monitoring cells for mismatch by calculating impedance.

II. LOWERING CARBON-EMISSIONS

Figure 1. shows the increasing magnitude of money spent on Lithium-Ion batteries in different industries since their introduction in 1990. Over the years the types of industries using these batteries have become more numerous and the overall usage, based on dollars spent in specific products, has increased.



INDUSTRIAL
- MOTIVE: Forklift (95%), others
- STATIONARY: Telecom, UPS, Energy Storage System, Medical, Others (Emergency Lighting, Security, Railroad Signaling,, Diesel Generator Starting, Control & Switchgear,

AUTOMOTIVE: HEV, P-HEV, EV
OTHERS: Medical: wheelchairs, medical carts, medical devices (surgical power tools, mobile instrumentation (x-ray, ultrasound, EKG/ECG, large oxygen concentrators

Fig. 1 Lithium-Ion Battery Usage from 1990 to 2016 [3]

Figure 2. shows the projected market share of several battery types in the transportation industry until 2035. Lithium-Ion batteries currently makes up 100% of the market until 2017 when other battery types become available. But some variation of Lithium-Ion batteries will maintain market majority for the foreseeable future in transportation.

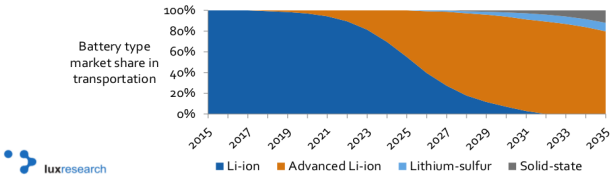


Fig. 2 Battery type market share in transportation [4]

While Lithium-Ion batteries are finding their use in more devices and industries, the production of these batteries is a major environmental issue. Currently, getting the metals used for production (e.g., steel, aluminum, copper) and their subsequent processing is provided energy by non-renewable energy sources that produce a large carbon footprint [1]. What the study "Contribution of Li-Ion Batteries to the Environmental Impact of Electric Vehicles," found was that the largest contributor to pollution from Lithium-Ion batteries came from the gathering and transportation of the required materials. The materials are still gathered and transported by machines like diggers and trucks powered by oil and gasoline. Unless the entire supply chain and production of Lithium-Ion batteries is powered by cleaner, renewable sources then this environmental cost associated will persist. In Figure 4. is an image of an electric powered semi-truck produced by Tesla, this and other companies have begun to introduce these vehicles into transport fleets. If electric semis become more widespread they could be used to address the issue of pollution from transporting raw materials for Lithium-Ion battery production.


Fig. 4 A Tesla electric semi truck [6]

While the battery management system (BMS) cannot directly address the issue of pollution in Lithium-Ion battery production but it can indirectly lower it. The BMS can be used to maximize the use time of batteries. As the lifespans are extended this helps to lessen the demand for batteries and their production, which in turns reduces the pollution produced from gathering more raw materials. While the BMS can also extend the lifespan of batteries, the device also increases the safety when using Lithium-Ion batteries.

III. INCREASING SAFETY

The impedance-based BMS created can increase safety when using devices powered by Lithium-Ion batteries. A big problem associated with battery packs made of multiple Lithium-Ion batteries is cell mismatch [7]. Cell mismatch is when one or more cells in a battery pack is at a significantly different voltage level than the majority of cells. According to research done at Johns Hopkins, cell mismatch is one of the biggest problems and if left untreated can lead to more problems in the future [7]. Cell mismatch can cause overcharging and over discharging in neighboring cells, making the problem worse over time. The overall lifespan of cells will decrease and shorts will occur more often. The BMS that was created addresses when cells are mismatched as they happen, and hopefully the mismatch can be fixed or replaced. It should be noted that the BMS does not directly fix the issue but can identify and notify someone to address the issue.

IV. CONCLUSION

In this report the environmental and societal impact of Lithium-Ion batteries and how the impedance-based battery management system addresses these issues was discussed. The largest environmental issue associated with Lithium-Ion battery production is the sourcing and transportation of raw materials. The impedance-based BMS attempts to limit environmental impact by reducing demand and production for more batteries. Lithium-Ion batteries affects the safety of the societies that use them in emerging industries and devices. Without continued maintenance they can injure those who use them. The impedance-based BMS is designed to lower the big issue of cell mismatch that affects batteries and causes safety issues. As Lithium-Ion batteries see their use grow further concerns will rise with it but the impedance-based BMS can also grow and address issues as they occur.

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How Small Form Trends Dictated the Size of the Impedance-based BMS and How Life Long Learning is Required to Stay Relevant with Emerging Trends

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***Abstract*— This article shows how trends in making electronics smaller informed the desire for a small battery management system. Beginning in the 1970s as transistors became smaller, electronics followed the same trend. This is because industry demanded the same functionality of electronics in a smaller form [1]. The impedance-based BMS is the response to these trends in the electronics industry and marketplace. But, it takes understanding and learning of industry to know these trends and exists and that there is a desire for a small BMS. By learning the trends, engineers can always stay ahead in what problem needs a solution. This is the duty of engineers to solve problems when and before they arrive.**

***Keywords*— Low Power, Small form factor, Lithium-Ion Batteries, Lifelong learning**

I. INTRODUCTION

Since the 1970s, electronics have become smaller because people are able to make transistors smaller. Figure 1 shows how transistors have scaled down over time. This is because industry has demanded greater speed, efficiency, power, and decreased weight [1] for their devices (e.g., phones, laptops, computers). For example, the electronic calculator went down in size by several magnitudes within a decade [5]. Battery health management systems (BMS) are also beginning to follow this smaller form trend. Engineers need to continuously inform themselves on the latest trends. Figure 2 shows a commercially available BMS, it is a large cabinet-sized machine. This instrument was determined to be the average size for BMS. With this knowledge and experience, the impedance-based was developed for this specific market to address the issue of size.

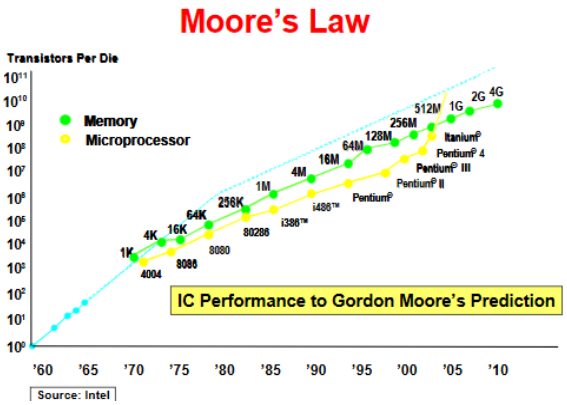

Figure 1. Moore's Law [4]

Figure 2. shows an average, cabinet-sized battery tester. The device also typically takes several hours to fully drain and recharge the battery. The processing of charging and draining is used to create a voltage curve of the battery. Through comparison with other batteries, the health and mismatch of batteries can be determined.

Figure 2. Bio-Logic Science Instruments Battery Cycler

II. SMALL FORM ELECTRONICS TRENDS

In order to answer the increasing demands of industry, mainly the demand for decreased weight, devices have become smaller and more portable over time. Figure 3. shows the downward trend of size in electronics beginning in 1970. The impedance-based BMS is under similar demands, Lithium-Ion batteries are gaining widespread use in the automotive and computer industries [2]. With the increased use, faster and more lightweight BMS are required to properly manage the batteries after production. Without the BMS, the lifespan of the batteries could be significantly shorter and possibly damage the devices they are used in. The reason being cell mismatch damaging the cells within a pack. If one battery is damaged, inefficiency and shorts may occur. The impedance-based BMS is the answer to current issues with BMS. The impedance-based method is faster and the overall system to calculate it is lightweight; the device is only 16 cm long and 10 cm wide. However, the need for this type of system would have gone unknown if engineers did not monitor the trends in the automotive sector. It is the duty of engineers to answer the problems society faces, but engineers must be able to know what problems need solutions.

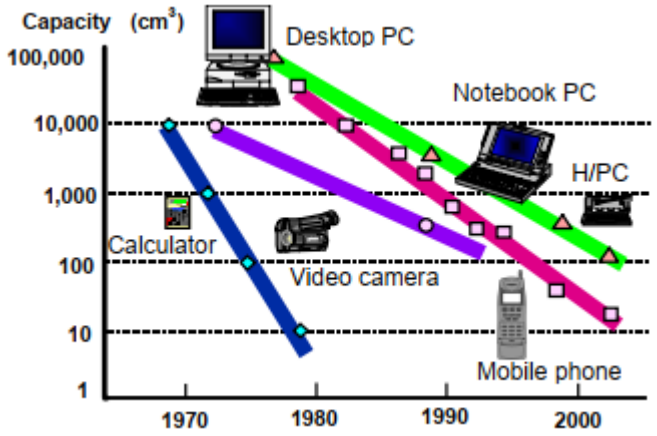

Figure 3. Size trends of electronic equipment [3]

III. LIFE LONG LEARNING IN ORDER TO STAY UPDATED WITH THE LATEST TRENDS

Through this project, being able to identify the trends in the electronics industry is very important. The problem of size in the BMS sector is what the impedance-based BMS was designed for. But, in order to design and create this product it was important to know there was a problem at all. An engineer needs to continuously update themselves with the latest info and trends in engineering if they want to stay relevant. This project not only helped recognize the need but also the ability to continuously learn. At certain points of the project, no one in the group knew what to do next but we learned what possible solutions could be taken. Just taking apart and rebuilding a circuit will not always help. It takes knowledge and new eyes to see the problems.

IV. CONCLUSION

In this report the downward size trend found in industry and how it created the need for a small BMS and how life long learning is important was discussed. The downtrend size trend found in the electronics industry created the need for a small BMS. The impedance-based BMS is the answer to this desire, producing a device that is only 16 by 10 cm. However, with continuously updating on trends in industry, the desire for this type of product would never have been known. A problem needs to be acknowledged before it can be fixed. The impedance-based BMS is the product of understanding the growing trend of Lithium-Ion in industries, especially the automotive industry. As trends come, engineers must be able to see, understand, and react to them.

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How Project Management and Teamwork Helped the Impedance-Based BMS Reach Completion

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***Abstract*— This article considers how project management and teamwork played a role in helping the impedance-based BMS project reach completion. Project management helps to assigns duties and tasks to appropriate and relevant individuals. This ensures efficient use of time and resources. Teamwork is also a key topic, teamwork helps to bring distributed knowledge together to solve problems. As engineers, team projects will become normal operation and it is important to know how to manage a project and working with others.**

***Keywords*— Project management, team work, impedance, battery management system**

I. INTRODUCTION

Throughout an engineer's career, they are going to be put on a team to complete a goal. This goal could be to fix a problem or make a new device. Especially on this project, it was necessary to properly management the scheduling meetings and assign testing and design tasks. Throughout this project, while learning to manage time and others, I began to understand the importance of teamwork to complete those tasks. The impedance-based BMS project helped realized how good project management and teamwork gets goals done**.**

II. PROJECT MANAGEMENT

Project management is important for any group effort. It helps to define each tasks and responsibilities for everyone involved. In our group, any and every choice was made by a democratic decision based on individual skill and familiarity with a topic. Among the things that a group must decide, and specifically, the impedance-based BMS group is task distribution, scheduling, and design methodology. For this group, tasks were distributed on each individual's aptitude. For especially difficult tasks, additional members were designated as needed. But things like testing, or checking simulations could be down by one member. Moving on to the schedule, it was decided that along with the regularly scheduled lab times that the group would meet up at least once a week to update members and talk about plans for the upcoming week. We would also meet as needed to complete modules for the design, such as testing and integrating smaller modules into the overall system. None of what the group did was based on any particular management software or strict methodology. Again, the group looked at each individual's aptitude for a particular task and asked them if they complete the task. That, or someone else would volunteer for the task. Throughout this whole project and trying to manage it, a good lesson was learned; teamwork. Having a good group of people that work well and worked well together made every poor situation easy to handle. Teamwork played an important role in helping this project continue to move forward.

III. THE IMPORTANCE OF TEAMWORK

Teamwork really was the motivational force that help the project continue. Without teamwork, some of the difficulties that we faced would have been much harder on an individual. Especially since everyone did work well and with each other. There often times that a set back would come but because we were working together we were able to find a solution. A few times, it seemed some of the circuits that we created were not working or completely broken and would set us back financially. But because we were able to come together, we found the problem or could make quick fixes. This shows that it helps to have others with different views and experience, when one person knowledge fails one of could be there to fill in the gap in knowledge. Filling in gaps in knowledge is especially important on a multidisciplinary teams, while our group was entirely electrical engineers, we still required help. While the group as a whole as familiarity with computer programming, but there is a lot that we do not know about. Several computer science friends of our helped data structures and how they could help make our program more efficient. Knowing when to ask is just as important, an engineer can not be expected to know everything, and that is why they work on teams.

IV. CONCLUSION

In this report, project management and how properly assigning and scheduling duties and tasks kept the project on schedule to complete. The importance of teamwork and the ability to help complete normally difficult task is discussed. Any group project must be managed somehow, whether is be democratically or dictorially. It is important to assign responsibilities to members so that tasks do not overlap.

Project management also helps to ensure that resources are properly given, in our case aptitude in certain design areas like hardware versus software knowledge. Teamwork is also discussed, teamwork allows a greater pool of knowledge to access in order to solve problems. As engineers, we will continuously be put on team projects where it is important to have a method for project management and be able to work well with others.