

Battery Monitoring for Electric Vehicle Battery Packs

Analysis of Senior Project Design

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Functional Requirements

1. The system must be capable of measuring the individual voltages of eighteen 12V batteries in series.
2. The system must be capable of measuring all batteries at least once per minute.
3. The system must be capable of measuring the voltage of the battery to within 2% of the true voltage (within 240mV).
4. The system must electrically isolate batteries from each other in order to prevent short circuits.
5. The system must never draw more than 1mA of current from the battery pack.
6. The system must be able to function at 50°C with no airflow, and survive temperatures of up to 100°C while not in use.

Primary Constraints

The primary challenge with designing this system was choosing a mechanism by which to measure the voltage of a relatively high voltage (216V) battery pack using a low voltage (3.3V or 5V) system (microcontroller and peripherals). The two aspects of this challenge were designing a mechanism to measure the voltage of the battery pack, and designing a mechanism to power the system. There are existing SOC's designed to measure battery voltages, but few of them can withstand such high voltages, and the ones that do exist are prohibitively costly. Another option (the option that was used) is to use a voltage divider to produce a smaller, measureable voltage (0-5V). In this system, however, resistances must be chosen carefully to ensure that a minimal amount of power is drawn (and wasted) from the battery pack in the process of measuring, but also that the equivalent resistance of the voltage divider is much, much lower than that of the measuring circuit (so that the measurement circuit does not significantly affect the current flowing through the voltage divider. It is also possible to use a DC/DC converter to power the system from the main battery pack, but the availability of such devices is limited, and costs can be prohibitively high. Another solution (the solution that was used) is to power the system

from its own battery, while connecting the grounds from the system and the battery pack in order to take accurate measurements. Other challenges included designing a mechanism to electronically isolate batteries from one another, as well as developing a system to select which battery is being tested at any given time.

Economic

Planned cost at project inception	\$70.00			
Final cost of completed system	\$42.97			
Bill of materials	See Table 1: Bill of Materials			
Additional equipment cost	Item	Quantity	Unit Cost	Total Cost
	Solderless Breadboard	3	\$16.59	\$49.77
	Power supply	1	\$50.00	\$50.00
	Multimeter	1	\$25.00	\$25.00
	Battery Pack	1	\$1,500.00	\$1,500.00
	Total			\$1,624.77
Planned development time at project inception	10 Weeks			
Actual development time	7 Weeks			

Table 1: Bill of Materials

Part Description	Reference Designator(s)	Distributor	Distributor Part Number	Quantity Required	Unit Price	Total Price
Atmega32u4 Breakout Board	X4	adafruit	296	1	\$19.90	\$19.90
249kΩ Resistor (CMF55249K00BEEB)	R19	Digi-Key	CMF249KHB CT-ND	1	\$0.93	\$0.93
4.7kΩ Resistor (MFP-25BRD52-4K7)	R20	Digi-Key	4.7KADCT-ND	1	\$0.46	\$0.46
Optocoupler (TLP222G(F))	U1-U18	Digi-Key	TLP222GF-ND	18	\$1.013 (quantities of 10 or more)	\$18.24
Analog to Digital Converter (MCP3301-CI/P)	X6	Digi-Key	MCP3301-CI/P-ND	1	\$2.27	\$2.27
3:8 Decoder (SN74AHCT138N)	X1-X3	Digi-Key	296-4666-5-ND	3	\$0.39	\$1.17
Total						\$42.97

Manufacturing

Estimated units sold per year	25,000
Estimated manufacturing cost per unit	\$40.00
Estimated purchase price	\$50.00
Estimated profit per year	\$250,000
Estimated cost of operation per year	\$10.00

Environmental

Manufacturing of this system would have many of the same environmental factors as most other electronic systems. The use of integrated circuits and printed circuit boards means that some heavy metals and uncommon elements would be used. Like all electronics, improper disposal of this system could release toxins into ecosystems or the water tables. Also like other electronics, however, the majority of this system could be recycled and made into other electronics at a future time.

Use of the system would also have a minor negative effect on the environment, as the system uses a battery, which would need to be disposed of. This effect would be minor because the battery only needs to be replaced occasionally.

Use of the system could also have an indirect positive effect on the environment. This system could enable greater adoption of electric vehicles, as well as better management of those vehicles' batteries. Greater adoption of electric vehicles reduces greenhouse gas emissions from vehicles, and would allow some of the energy used to power those vehicles to come from renewable resources. Furthermore, this system can help prolong the life of the batteries electric vehicles use, reducing how frequently they must be replaced. Because the batteries are by far the most toxic component in electric vehicles, reducing the frequency with which they must be replaced could have a very positive outcome on the environmental effects of the vehicles as a whole.

Manufacturing

While the manufacturing of the system itself would be relatively simple, the integration of it into commercially available battery packs would pose challenges. Adapting the system to work with each different battery pack would pose some challenges, and actually connecting each battery to the system would pose other challenges.

In order for this device to become a commercial success, there would need to be variations of it that worked with a wide variety of different battery packs. As of now, there is no standard for electric vehicle batteries. They vary widely in voltage as well as chemistry. Because different battery chemistries have different characteristics, the 2% accuracy requirement for this system may not be sufficient for some battery packs. In order to adapt the system to work with these systems, significant changes would need to be made to the design, which would lead to significant engineering costs. Furthermore, many electric vehicle batteries are now 300V or more, which is outside the range of acceptable voltages for this system. While the system could be relatively easily adapted to work with higher voltage systems, an increase in acceptable voltage would lead to a proportional decrease in measurement accuracy, which may not be acceptable. Finally, some battery packs may have more than eighteen batteries. As many as 6 more batteries could be relatively easily added to the current system, but if the battery pack has more batteries than that, a significant redesign would be necessary.

Another difficulty with manufacturing is actually wiring each battery to the system to be monitored. In a commercial battery pack, space constraints will be very tight, and it may not be acceptable to have extra wires coming to and from each battery. Integrating the system into a commercial battery pack would require significant collaboration with the maker of the battery pack.

Sustainability

This system could have a very positive overall effect on the use of resources in our society. The battery monitoring system can help keep electric vehicle batteries in good working order for longer, reducing how frequently they must be replaced. Because the batteries are the most toxic component in electric vehicles, keeping them working longer could have a major positive effect on the sustainability of electric vehicles and personal transportation as a whole.

The system does have one minor downfall in terms of sustainability, which is the auxiliary battery that supplies power to the system itself. This battery must be replaced periodically, creating waste. While these batteries are extremely small compared to the entire battery pack, and the overall effects of the system are therefore positive, it would be preferable to not have this limitation at all.

In order to remove the need for an auxiliary battery, the system could be run on power from the battery pack being monitored itself. This could be accomplished by using a DC to DC converter to step down from the 216V battery pack to the 5V power required for the system. Unfortunately, such DC to DC converters are quite expensive, and not widely available, so this could add significant cost and complexity to the system.

Ethics

As with most automation systems, this battery monitoring system has the potential to destroy the jobs of some individuals. Currently, people must be employed to periodically check battery packs. While this does not seem like a major job for a single vehicle, it could potentially be a full time job at certain institutions with large fleets of electric vehicles. By automating this system, the need for that employee is greatly reduced.

From a broader view, this system could potentially also destroy jobs in the oil industry. If this system were a factor in popularizing electric vehicles and replacing fossil fuels, the oil industry would shrink significantly, and the number of available jobs in that industry would decline.

Health and Safety

The development and deployment of this system involves significant risk of electric shock. In order to connect the battery monitoring system to the battery pack, it is necessary to interact with the terminals of the batteries within the pack. If the person performing the installation accidentally connected the terminals of the battery through their body, they would receive a shock that could easily be deadly. This risk is compounded by the fact that the person performing the installation must interact with the battery terminals themselves, without any type of fuse or circuit breaker to help protect them.

During development, a contactor was used in the battery to disconnect one array of 9 batteries from the other array of 9. While this does not entirely prevent the possibility of shock, it does reduce the maximum voltage that could be received to 108V rather than 216V. While 108V is still hazardous, and could even be deadly, it is significantly less so than the full 216V.

Social and Political

There is currently great pressure on corporations, politicians, and individuals to move towards a more “green” society. Because this system helps enable electric vehicles to become more common, it could make a big difference to this goal. Furthermore, a significant reservation that many people have about purchasing an electric vehicle is the prospect of having to replace the battery pack. This system could help alleviate that concern, which could help make electric vehicles more common.

One of the most important ways in which our society is moving towards a more “green” future is the requirement for car manufacturers to improve their average fuel economy. Because it helps make

electric vehicles more practical, this system could make a major difference in helping auto manufacturers meet the new requirements.

Development

The development of this system was the first time that I had personally interacted in any significant way with high voltage systems. As a computer engineering student (rather than electrical engineering), I did not take the power courses, and therefore did not have exposure to high voltage systems. Because of this, I had to learn best practices for working on these systems in order to not hurt myself or others.

This was also the first time that I had used many of the features of Arduino, such as SPI. While I've written basic Arduino programs in the past, such as turning on and off general purpose in/out pins, I had not used most of the more advanced features. This will likely be useful experience in my future career, as many companies use Arduino as a rapid prototyping platform.