Rapid Battery Interchange System

Presented to Dr. Art MacCarley

ELECTRICAL ENGINEERING DEPARTMENT
CALIFORNIA POLYTECHNIC STATE UNIVERSITY
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Acknowledgements

I would like to thank Dr.MacCarley for his dedication and support towards the completion of this project. Also, to the entire EVEC team for helping out, in Winter 2011 when we began construction on this project we were significantly short-handed. The newer members that joined in Fall 2011had a huge impact on the completion of the project. Newer members supporting the electrical team were Justin Fang who was responsible for actuator and circuitry mounting, Michael Desando who provided support for board manufacturing and cable management, David Hoyt who provided support for our AC motor rewiring, and Anthony Cisneros for providing final manufacturing support. Newer members that provided significant support on the mechanical side were Stephanos and Scotty who provided support in getting the receptacle to fit in to the van, something that wouldn't have happened without them. Furthermore none of this would have been possible without our existing members as well; Adam Rizkalla proved to a reliable and knowledgeable asset providing us with software support of our control systems. Alex Kravecas was the heart of our team with his project management skills, pushing us hard to complete the project (even when we had finals to study for); and last but not least, Michael Machado. Simply put, from my perspective Michael is a genius. Whenever we hit a roadblock in our mechanical design, Michael was always there with an idea and a solution not too long after. Also I would like to thank my Mom for telling me to study in high school.

Abstract

As our nation strives towards a departure from widespread use of fossil fuels, we must focus on a plan for what is to be the substitute for Internal Combustion Engine vehicles as well as the infrastructure to support this. The most popular alternative to the internal combustion engine is the electrically propelled vehicle, one that can provide us with many benefits including simplified construction, lower operational costs, and for the driving enthusiasts more torque. The prevailing issue in the widespread acceptance and use of the electric vehicle thus far is "range anxiety". Range anxiety is defined as "The fear of being stranded by an electric car because of insufficient battery performance or charge.[1]" The main source of this anxiety lies with the limited energy density of the battery pack, as shown in Table 1 few models are able to maintain a range near what an internal combustion engine can handle, about 400 miles[2].

Table 1: Production EVs with corresponding Battery Energy and Range

Vehicle Model	Battery	Range (using EPA estimates)
Tesla Model S	85 kWh	300 mi
Tesla Roadster	53 kWh	244 mi
Audi A3 e-tron	26.5 kWh	90 mi
Nissan Leaf	24 kWh	73 mi
Coda	31 kWh	88 mi
Ford Focus BEV	23 kWh	76 mi

The closest to the 400 mile range is the luxury auto maker Tesla, whose vehicles remain out of reach for most drivers. There are two paths to a solution for range anxiety, increased energy density in the battery pack is one obvious solution. The remaining is one that is similar to what a gas station is to an ICE vehicle; a Rapid Battery Interchange System, in other words is a system which can provide automated battery swapping for an electric vehicle in a reasonably convenient amount of time. If a widespread adoption of such a system can be realized, electric vehicles can be put in place of every ICE vehicle being used today. This will lead to a new future in which we do not have to harm our environment in order to get to work every day, it will lead us to a future where we can transport ourselves sustainably for years to come.

[1] (Range Anxiety)
[2] (Department of Energy, 2012)

I. Introduction

I had initially joined the Electric Vehicle Engineering club in the Winter quarter of 2008 as I was fascinated by the electric vehicles that were starting to be reintroduced into the mainstream. I have always had a strong belief that electric vehicles would be the future of transportation if we wanted to maintain our current habits of transporting ourselves. In modern times there are two significant concerns that surface with the widespread adoptions of electric vehicle. The first being that electric vehicles in their current state cannot complete a charge cycle at the same rate it takes to fill up your gas tank, this is a significant inconvenience for most people. The second being range anxiety, the idea that people do not want to be concerned with when their battery is going run dry, this issue is primarily concerned with the energy density of modern batteries. While hybrid vehicles like the Toyota Prius have been a welcome solution for many green minded individuals, we must continue to pursue our vision of a green transportation system.

II. Background

This Rapid Battery Interchange system will consist of an electric van which can accept as well as deliver a battery pack and a ramp which can provide the "swapping" of the used battery pack for a fresh one. The result being a system which can provide a replenished energy source for the vehicle securely, safely, and with no inconvenience to the user further than the push of a button. The ramp will behave as outlined in the following paragraph:

With the acceptance of the electric van onto the ramp, the ramp will sense through two sensors (front right wheel, rear left wheel) that the van is properly positioned on the system. The system will then prompt the driver to provide feedback confirming participation. After the driver does so, the lift will raise itself to make contact with the discharged pack in the van. This lift will be an off-the-shelf motorcycle lift specified to maintain the 1200lb weight of the battery pack. Upon sensing that the lift is in a position to accept the weight of the pack, the four actuators which are suspending the battery pack in the van will detract and release the battery pack to the guidance of the lift. The lift will then lower itself into an empty cart which is in position to accept the aforementioned pack.

The two carts containing the battery packs will be conjoined and the lateral movement of the battery packs across their track will be controlled by an AC induction motor. The operation of which will be controlled by the microcontroller pending the discretion of the sensors which will determine whether the pack is in the correct position. These movements will be controlled by an Atmel AVR microcontroller which is to follow the steps outlined by the state diagram which is shown in the appendix.

Due to the nature of the Rapid Battery Interchange System, there will need to be two separate circuits, one in the system and one in the van. These two circuits will need to communicate in order for the state of the ramp to be known at all times. They will provide bidirectional telemetry to the microcontroller in order to insure that the steps are followed sequentially.

III. Requirements

Create a system that can:

1. A circuit which can provide output control signals to the AC motor, the motorcycle lift, the battery chargers, and the actuators from the Atmel AVR output pins.
2. All circuits will be self-contained, securely mounted, aesthetically pleasing, and will be capable of withstanding the test of time.

IV. Design

There are three primary components that are to be taken into consideration when creating the circuitry for the Rapid Battery Interchange System. One is the linear actuators which are to be located on the receptacle that will be holding the battery packs in the van. The second would be the AC motor controls which will be faced with the task of converting a 5 volt signal into an AC signal which will power the motor to operate CW or CCW. The third would be the lift controls which would be converting a 5 volt signal into a connection between two of the wires.

The behavior of these components will be investigated prior to the design of their respective circuits as every active device maintains a differing behavior.

Actuator Controls

There will be four actuators used in our system according to the mechanical teams' design, these actuators will be faced with the responsibility of retaining the battery pack within the receptacle of the van thus they will be maintaining a significant amount of pressure. The design of the circuitry to control these four actuators began with an investigation of their internal circuitry design.

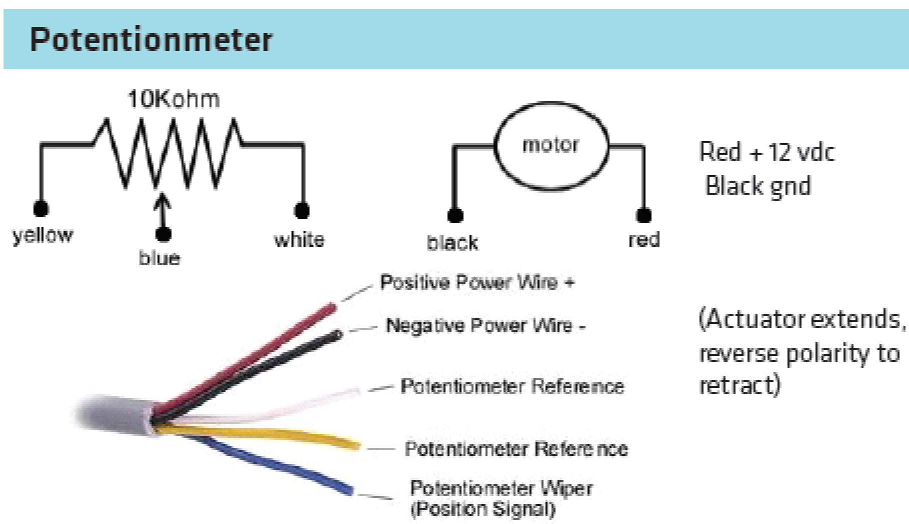

Figure 1: Actuator Datasheet Schematic

Figure 1 shows that there are a total of 5 leads protruding from the main cable on the actuator. The red and black wires are clearly the power leads requiring a 12 volt difference across them. A side note on Figure 1 notes that in order to change the direction of the actuator extension, the red and black leads are to be interchanged. Internal to the linear actuator, there also is a 10kohm resistor whose leads are shown to be yellow and white. A potential difference will be created across these two in order to get and accurate reading from the blue wire which will send a feedback signal that is no greater than or less than the potential difference across the white and yellow reference points. The two reference points will be within 0 -5 volts which is the operating range of the microcontroller. The blue feedback lead will

share a node with the A/D converters on the microcontroller so the feedback can be accepted and interpreted. This information has been synthesized in the table 1 shown below.

Table 2: Actuator Interfacing Breakdown

Lead Color	Lead Function	RBX Function
Red	Positive Power Wire	12v (out) / 0v (in)
Black	Negative Power Wire	0v (out) / 12v(in)
White	Potentiometer Reference	5v
Blue	Potentiometer Reference Feedback	Feedback to Micro Controller
Yellow	Potentiometer Reference	0v (Ground)

The primary obstacle in creating a control circuit for the actuators is finding a way to provide a 12 volt difference across the red and black leads in order to extend the linear actuator and interchanging the red and black lead to retract the linear actuator. The solution is a simple H-Bridge shown in figure 2 below.

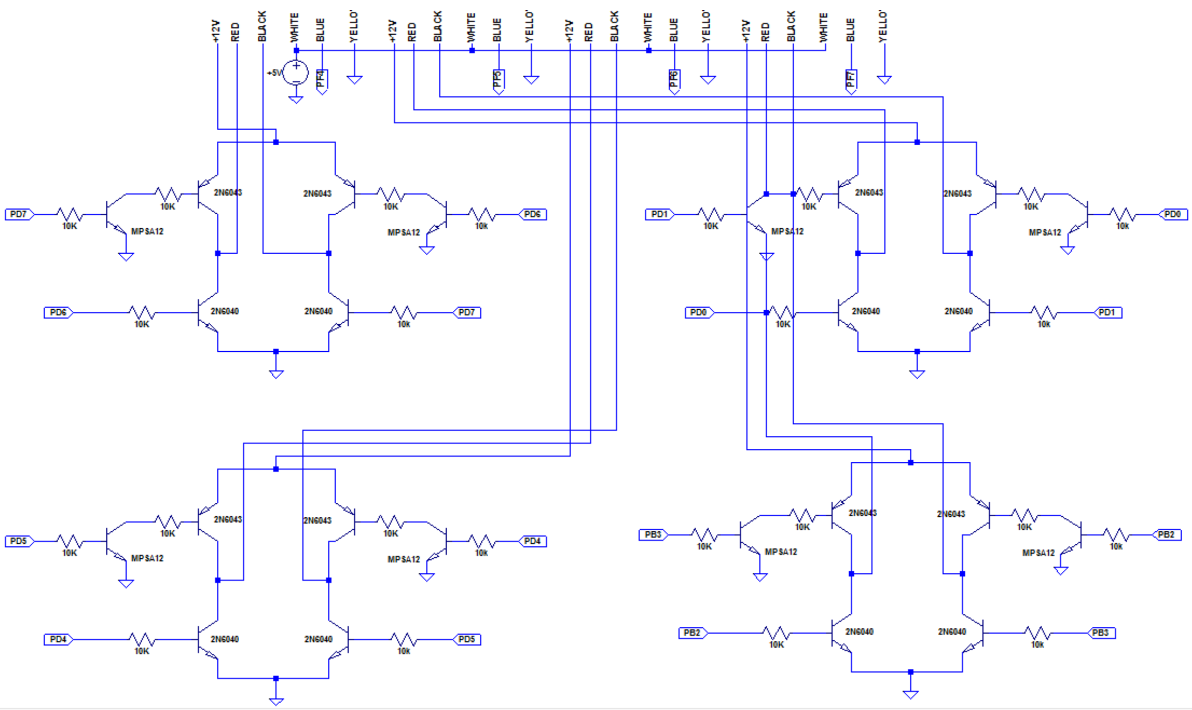

Figure 2: Actuator Control Circuit

Figure 2 contains four identical H-Bridge circuits which are used to provide the microcontroller with individual control of each actuator. This H-bridge is to be controlled by a 5 volt input which is to be received from the microcontroller. Upon first glance we can see an additional two NPN transistors incorporated into the H-Bridge, the reason for this is to provide a ground signal to the PNP to activate it as the microcontroller cannot provide this function. We can see that the MPSH12 NPN acts as a switch to provide a ground signal to the 2N6043 PNP transistors whenever a 5 volt signal is applied to its base. A 5 volt signal is taken from the main 5 volt rail

of the board and directed to the white lead of the actuator whereas the yellow actuator leads are sent to ground. The blue leads were sent directly to the microcontroller.

AC Motor Controls

Ideally we would have this entire system using a 220 VAC source, however due to our lack of such a source in our clubroom, we will be running the system entirely using a 110VAC source. Since we will be using a 110VAC source our circuit will be usin gthe low volt setting shown in Figure 3. My test results have shown that line 1 and line 2 will be receiving the two hot leads from the 120 VAC source. Upon closer inspection of Figure 3 we can see that in order to go from CW to CCW rotation on the lines the red and black leads on lines 1 and 2 must be interchanged. Thus a circuit to swap the red and black leads becomes necessary.

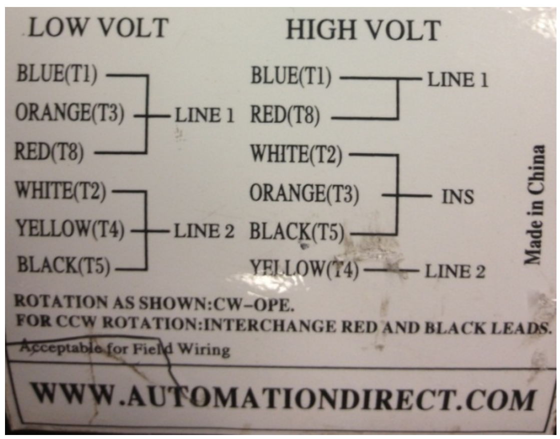

Figure 3: AC Motor Wiring Diagram

The design for the control circuitry for the AC motor involved a Metasol MC-50a. This is a 3-pole, 50 AMP contactor with a 120VAC coil, 2 N.O., and 2 N.C. base-mounted contacts. The 2N.O. and 2N.C. contacts were integral to our design as shown in Figure 4 as they were the heart of the switching action, additionally two SPST 12VDC coil relays were integrated providing two functions, one that provided power to the AC motor and the other than provided CW as well as CCW function to the motor. Those relays were provided microcontroller support by means of a NPN switch which closed the 12v circuit across the relay coil.

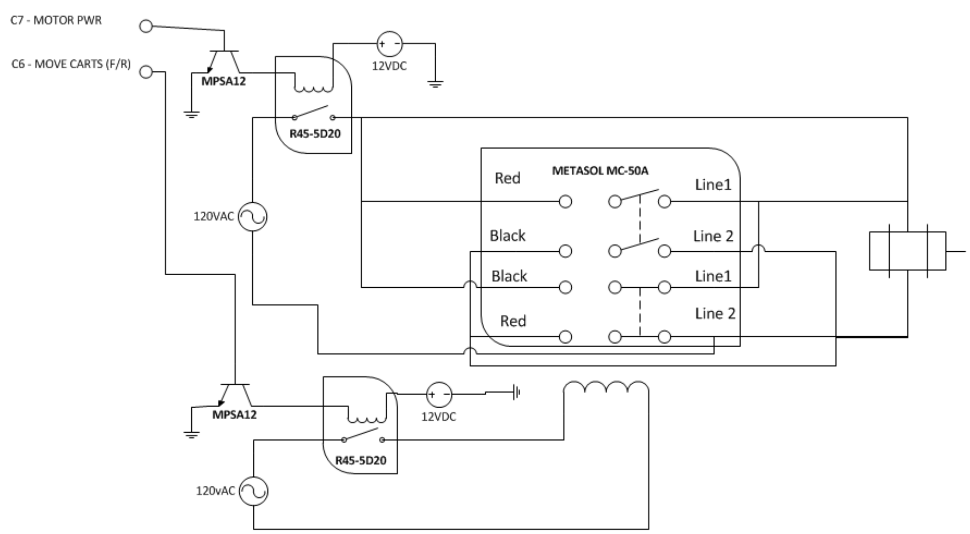

Figure 4: AC Motor Complete Control Schematic

Lift Controls

The lift controls involved a much more simplistic circuit than the rest. An investigation of the lifts manual controls shown in Figure 5 show that there are three leads being to control the rising and lowering operation of the lift. Continuity tests and voltage tests were used to determine the behavior

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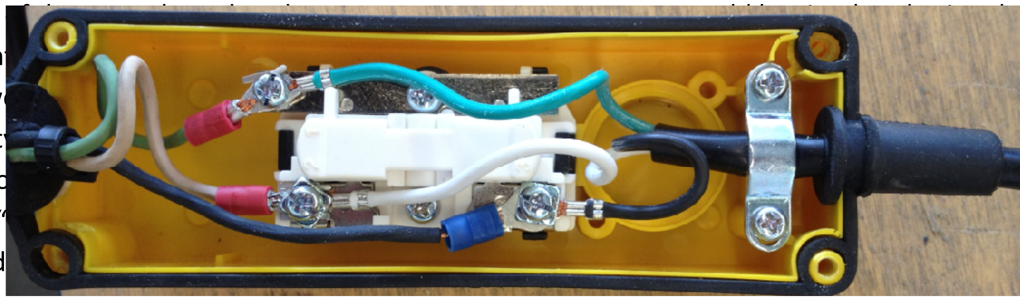

Figure 5: Lift Manual Control Box

original wiring of the manual control box as shown in Figure 5. A simple TRIAC circuit shown in Figure 6 was used to provide this behavior, a MOC3022 opto-coupler was used to provide isolation between the DC signal of the micro controller and the AC signals provided by the lift. In Figure 6 we can see that there is a 200 ohm resistor is place on the “AC Side” of the circuit. This was initially put in place as a 10kohm resistor. Initial tests for this circuit proved to be negative as the TRIAC was not

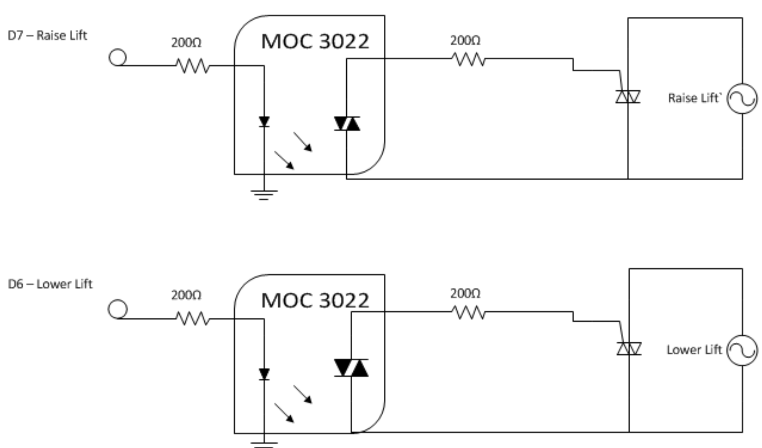

Figure 6: Lift Control Circuit

being activated. It was determined empirically that the TRIAC was not sourcing enough current. Subsequently this resistor was replaced with a lower value circuit which would in effect provide a more significant current to the TRIAC in order to inhibit a response.

V. Test Plans

Testing of the aforementioned systems was done with the utmost care, seeing as how our circuits are designed to source up to 15 amps at a time we have taken the proper precautions to ensure that out circuits work as designed on the first run-through. The first design that was tested was the 5 volt regulator that was to provide a voltage on the board to the microcontrollers and to the 5 volt rail used on the actuators as well.

5 Volt Regulator Test

1. Breadboard the components
2. Feed a 12 volt signal to the regulator input
3. Observe that 5 volts comes out
4. Place and solder onto protoboard
5. Repeat test

Actuator Control Test

1. Breadboard the components
2. Simulate the potentiometer using a 10 kΩ potentiometer.
3. Feed a 5 volt signal to each of the microcontroller pins specified to simulate the microcontroller controls
4. Probe the node at which the actuator power leads will be attached for all actuators
5. Observe that the correct voltage is being sourced from the center H-bridge nodes of the corresponding actuator
6. Place and solder circuit onto proto board
7. Repeat steps 1-5

Note: Upon completion of step 6, we found that the only actuator circuit that worked was the circuit for actuator 1. The subsequent circuits did not function, this was attributed to manufacturing defects as the result of our work. To find a solution we set all of the actuators to provide a signal to extend all actuators. All transistor and resistor nodes were probed using the first actuator circuit as a reference. 12 transistors were found to be malfunctioning and were removed. Upon replacement the circuit functioned as intended.

AC Motor Control Test

Being a primarily relay controlled circuit, the appropriate microcontroller pins were activated as continuity was tested on the relay output controls.

1. Provide 12 volts to the red lead of the AC motor control circuit.
2. Have a grounding element present to ground the blue and green leads of this circuit.
3. Plug in the two 120VAC plugs associated with this circuit.
4. Activate the green lead.

5. Ensure that the Metasol contactor is deactivated.
6. Activate the green lead as well as the blue lead.
7. Ensure that the Metasol contactor is activated.
8. Attach the motor to the aforementioned circuitry.
9. Repeat steps 1-6 while ensuring that the motor participates in both CW as well as CCW operation.

Since the Metasol contactor is what determines CW and CCW operation of the AC motor, we want to ensure that is operating properly. In addition to this test voltages may be taken to ensure that the 120VAC is provided to the CW configuration leads as desired and vice versa.

Lift Motor Test

1. Provide 12 volts to the lift circuit.
2. Provide 5 volts to the B0 pin
3. Ensure there is continuity on the output “RAISE” port
4. Provide 5 volts to the B1 pin
5. Ensure there is continuity on the output “LOWER” port

The lift circuit is one of the most simplistic and straight forward of the three. Operation was achieved with no issues.

VI. Development and Construction

Development of the circuitry and controls occurred in 5 phases, each phase is indicated by a different color shown in Figure 7. This was done in order to ensure that the first portion of the circuit was functioning properly prior to moving onto the next. The 12 volt input was an off the shelf module so

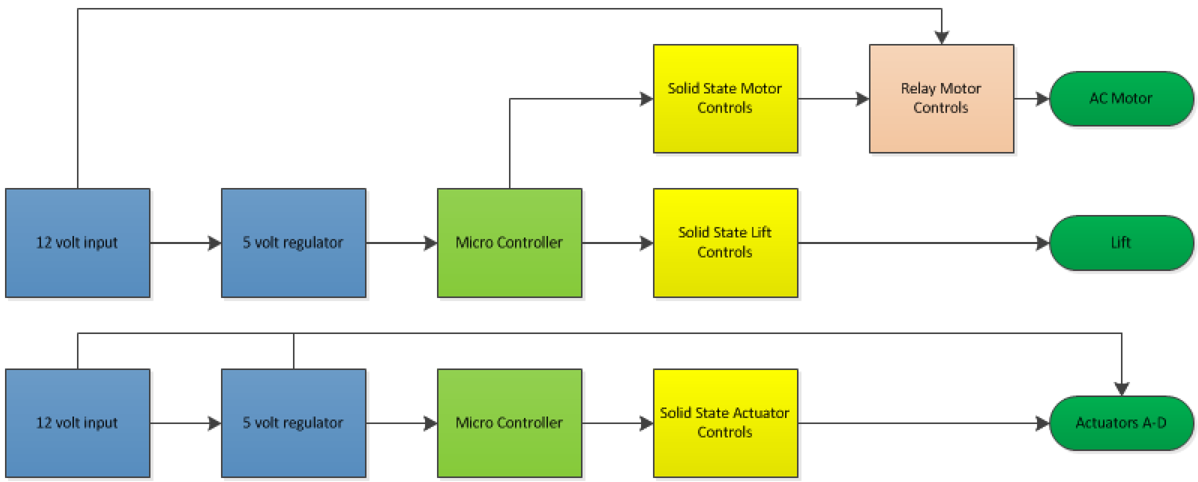

Figure 7: Sequence of Construction

that required no construction of any sort. The 5 volt regulator however was constructed from scratch using components purchased at Radioshack. Our 5 volt regulator circuits were fairly straightforward and functioned as designed. Our microcontroller was simply placed in a breakout board which was soldered onto the board. Next were the solid state controls, these were placed on the protoboard and soldered. Next the wiring was placed. Wiring was placed on top of the board with the following reasoning: Since this was the first time that this circuit was being fabricated I wanted it to be easy to troubleshoot this board in case something was to malfunction. The wiring was placed on top so that each pin of the transistors could be easily located and troubleshot. Next the relay motor controls were placed into the ramp. The fabrication of this was the most simplistic the most difficult portion was the soldering of the wires. The final portion was setting the interconnects, these proved to be more difficult than initially perceived. The interconnects are yet to be completed as the completion of the interconnects rely on the completion of the mechanical portion of the ramp.

VII. Integration and Test Results

Integration of the control systems into the ramp proved to have its ups and downs. Special considerations had to be taken with the interconnects that were used to interface between the AC motor, actuator, lift controls and the circuitry. These interconnects had to be mechanically sound as well as capable of enduring the elements. The connector shown in Figure 8 was used for the actuator controls due to its capability of housing the entirety of the actuator leads. These were tucked into the NEMA rated polycarbonate enclosures that were holding the circuitry and controls. Weatherpack components shown in Figure 9 were found in the clubroom and used to interconnect any high current devices such as the lift wiring and the AC motor controls.

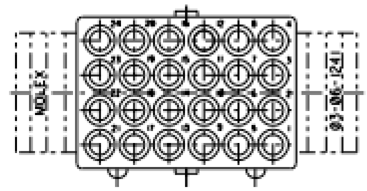

Figure 8: Molex Receptacle 03-06-1241

Weatherpack components proved to be a great solution as the crimps provided a strong mechanical connection as well as a weatherproof solution. Improvements can be made by using their WPT-6 connector as opposed to their WPT-2 counter parts which only provide connection for two leads. A six

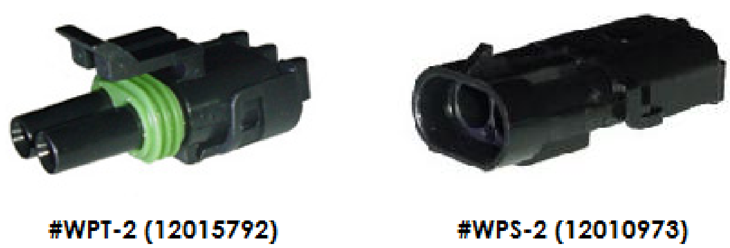

Figure 9: High Current Interconnects

lead solution would be more practical as our AC motor has 6 cables used for its control systems. Flex tubing was used to run the wiring through the ramp. This was done to protect the wires from the metal bolts which were exposed in the ramp as well as the rails on the exterior of the ramp.

VIII. Conclusion

Working on the Rapid Battery Interchange in coordination with the Electric Vehicle Engineering Club has provided me with a wealth of knowledge far beyond my expectations. Working to interface with the AC Motor and the Lift provided me a foundation in AC circuits prior to my power electronics classes. Working with the actuators helped strengthen my knowledge of BJT circuits that I had gained in my microelectronics classes. The fact that the team that we had worked with was a multidisciplinary team helped to provide me with a foundation of team work that I had not experienced in my EE coursework. I was placed in a position where I had to put the functions of my circuits in terms where the Mechanical, Industrial, and Computer Engineers could understand. This was a completely fresh experience for me which forced me to reconsider how I approached the discussions in our group meetings. In addition to this I was provided with four lower class electrical engineers which I had to place on the electrical system team. This placed me in a position to divide and delegate the tasks which were remaining, something that I also had no previous knowledge of.

With regards to the practicality of a Rapid Battery System, I have found that a simple system like the one we have constructed is something practical that we can implement into our current infrastructure. The largest challenges however remain with the business plan of this system. The widespread integration of Rapid Battery Interchange is something beyond my expertise, but after a few brief conversations with a few experts in the field I was convinced that the largest task was in convincing the municipalities that Rapid Battery Interchange was something worth investing in. That aside I feel that we as a team have brought attention to the idea that it is imperative that we find an alternative means of fueling our vehicles and that alone is enough to bring me satisfaction in the completion of this project.

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X. Appendices

A. Senior Project Analysis—see Appendix D on p. 19

Project Title: Rapid Battery Interchange System

Student's Name: Mason Borda

Student's Signature:

Advisor's Name: Dr. Art MacCarley

Advisor's Initials:

Date:

Summary of Functional Requirements:

The general function of our project is to create a fully automated system which can replace the depleted battery pack of an electric vehicle with a fresh one. Narrowing the scope a bit the electrical portion of this project was something that merely provided the nervous system to the skeleton that was to be the ramp, receptacle, and van. My system was specifically mean to provide a means of controlling the AC motor, actuators, and lift which was to be used for the automation of this ramp. I was faced with the challenge of using a 0-5 volt signal provided from the microcontroller to coerce the moving components to behave as desired.

Economic:

Fortunately the scope of this project is maintained within the sustainable and green sector of technology, providing us with a more ethical and accountable basis for which this project is implemented. To explore the economic impacts of the Rapid Battery Interchange System we can look at the human capital, financial capital, manufactured capital and the natural capital involved in constructing and maintaining such a system.

The people involved are at the very heart of any system as they are the thinking beings which can perform the work that otherwise we would have a computer perform. In our project we had humans construct and build our fully automated system, this involved a significant amount of manual labor (for 5-10 people). Fortunately having a very mature risk management division at Cal Poly no humans were injured in the making of this project, nor will there be any humans involved in the normal operation of this system. Thus the human capital involved in the manufacturing and operation of the Rapid Battery Interchange System is fairly minimal, especially during normal operation of the system.

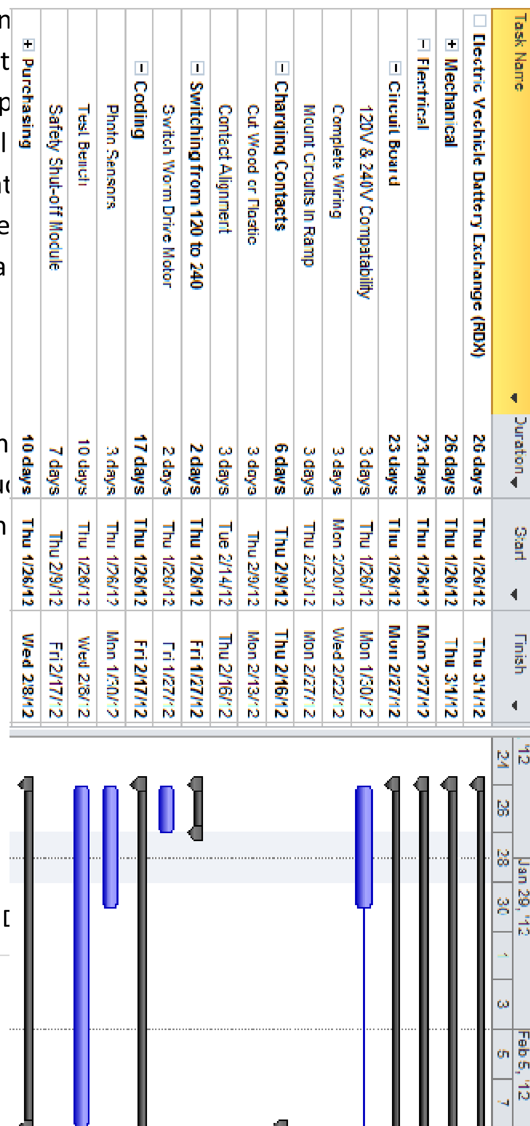
Unfortunately the Rapid Battery Interchange System in its purest form will be a significant alteration to our current transportation infrastructure system for internal combustion engine vehicle needs. The

financial capital is fairly significant for projects such as this, although our project was constructed with less than $15,000 of funding, our project does not involve the question of mass battery storage to provide for a more practical fleet of vehicles(more than one). When the question of how to store a supply or batteries in order to supply a significant urban fuel demand comes into play, the financial model of this project is significantly impacted. The integration of a rapid battery interchange system into our current infrastructure would have to be funded by municipal bonds due to significant amount of capital necessary for construction and startup. A more thorough investigation and business plan would be necessary to answer such questions.

When taking the bio-capacity for accommodating the needs of this system it is obvious that there is a great demand for lithium ion batteries. When considering the lithium specific needs of this system we need to take into consideration the world supply of lithium. The current world supply is estimated to be about 197.4-231.9 million tons of lithium[3]. This supply alone will guarantee resources for a maximum of 14.5 billion electric vehicles; this is ten times the current number of automobiles on the road today. This alone is a comfortable number to be working with, especially considering how quickly new battery technologies with different chemistries are being developed.

Although initial capital costs are high, typical business models for Rapid Battery Interchange Systems are present in circulation. The typical model involves a battery leasing program where the battery is owned by an institution and the vehicle owner pays a monthly/yearly fee to lease on the battery. These battery packs will be maintained by the in from the user. This leaves the user without a responsibility t ch can be a large burden for the typical user. The turning p when the infrastructure is switched from a reliance on fossil urce. This replenishable resource being the lithium ion bat een technologies such as wind, geo-thermal, solar, or nucle f-sustaining system is a system in which can provide for a es not harm our ecosystem.

Table 3 features our original gann sion to a 240 VAC system was omitted due to the lack of su as completed ahead of schedule as I had completed it on t completed as it followed



Task Name	Duration	Start	Finish
Electric Vechicle Battery Exchange (RBX)	26 days	Thu 1/26/12	Thu 3/1/12
Mechanical	26 days	Thu 1/26/12	Thu 3/1/12
Electrical	23 days	Thu 1/26/12	Mon 2/27/12
Circuit Board	23 days	Thu 1/26/12	Mon 2/27/12
120V & 240V Compatability	3 days	Thu 1/26/12	Mon 1/30/12
Complete Wiring	3 days	Mon 2/20/12	Wed 2/22/12
Mount Circuits in Ramp	3 days	Thu 2/23/12	Mon 2/27/12
Charging Contacts	6 days	Thu 2/9/12	Thu 2/16/12
Cut Wood or Plastic	3 days	Thu 2/9/12	Mon 2/13/12
Contact Alignment	3 days	Tue 2/14/12	Thu 2/16/12
Switching from 120 to 240	2 days	Thu 1/26/12	Fri 1/27/12
Switch Worm Drive Motor	2 days	Thu 1/26/12	Fri 1/27/12
Coding	17 days	Thu 1/26/12	Fri 2/17/12
Photo Sensors	3 days	Thu 1/26/12	Mon 1/30/12
Test Bench	10 days	Thu 1/26/12	Wed 2/8/12
Safety Shut-off Module	7 days	Thu 2/9/12	Fri 2/17/12
Purchasing	10 days	Thu 1/26/12	Wed 2/8/12

[3] (National Institute of Solar Energy, [Electricity Storage, 2011)

closely with the completion of the mechanical portion of the ramp.

After the completion of this project, I hope that the remaining Electric Vehicle Engineering Club can take this project and work to enhance its performance. Tesla has offered to donate to our club and I hope to pursue that offer to acquire lithium ion batteries for our project. This would provide students with a more modern version of our ramp and could lead to projects in battery management, battery cooling, and quicker running system.

If manufactured on a commercial basis:

If manufactured on a commercial basis this project would need one hell of a business as it is difficult to cut through the government policies as well as the public perception on the necessity for electric vehicles. Essentially if this is to be integrated into our infrastructure, it will require municipal bonds potentially exceeding the market caps of Exxon and Apple combined.

It is estimated that we will require one Rapid Battery Interchange system for every gas station in operation as the Rapid Battery Exchange is intended to be a "gas station" for the electric vehicle.

Our manufacturing costs for this project were $10,000 however if considered for commercial use, mass battery storage will have to be taken into consideration. Normal operation of this system will require enough supply to meet the demand of the consumer, much like the operation of the energy grid. This will require subterranean structures to store the battery packs which in turn will lead to higher costs.

Estimated purchase price of the entire project as constructed would be estimated to be $20,000 if constructed in the ATL. Estimated profit per year will be $0 since our project is not aimed towards the commercial markets.

Manufacturability

The manufacturing of the Rapid Battery Exchange System is fairly straightforward. The manufacturing of the electrical components can be likened to the construction of a power supply. Fairly straightforward, if placed on a pre-etched board construction time for the circuits alone can be less than one hour for an experienced manufacturer. Integration into the ramp will provide a more significant challenge as crimping and packaging the circuits is a more time consuming task. Estimates for completion of his by two people would be 4-5 hours if all paths in the ramp are pre-routed. Integration into the van will take 1-2 hours due to the simplicity of the van controls.

Sustainability

Our system was designed with portability in mind, hence our system is one that can be broken down into a few separate entities for ease of transportation. Being a portable system, our circuitry can be swapped out easily in the event that something goes wrong. If the aforementioned unlikely event does occur, down time should not exceed more than 10-15 minutes for electrical issues. This product does involve an initial investment in rare earth metals, more specifically lithium or lead. If lithium is used, it was previously mentioned that the world contains about ten times the capacity to provide energy

storage for the world population. This project, if commercially available, would in effect remove us from our dependency from fossil fuels. The benefits of this would be tremendous this would remove 17,000 pounds of CO_2[4] from the environment annually from passenger cars and light trucks. The savings of such a system would be immense in addition to this as electric vehicles are significantly easier to maintain and cheaper to fuel.

Being the first time that I have made a rapid battery interchange system, there is significant room for improvement. The circuits that we are using feature components that are better suited for high current applications which can be replaced with more appropriate transistors. The battery packs can be replaced with lighter lithium ion battery packs which would decrease the power used in the entire system and therefore the current used to support such a system. A more sophisticated battery management system would also enhance the system by prolonging the life of our battery packs. Connectors that were used can also be integrated into a more efficient package as there are more practical commercially available interconnects than the ones that we used.

There should be minimal challenges with upgrading the designs as the circuits can have components replaced with a minimal financial impact.

Ethical Impacts

The underlying motivations for wanting to integrate a rapid battery interchange system into our current infrastructure are to preserve and promote the well-being of our environment. Therefore we cannot foresee any obvious negative implications of integrating such a system. Any unethical behavior relating to this system would occur on the financial side of the mining operations overseas, unfortunately this is typical of mining in third world countries for rare earth metals.

Health and Safety

Any health and safety concerns noted thus far occur on the manufacture side. Soldering the components can lead to respiratory effects such as asthma[5]. The inhalation of dust produced during the drilling of the ramp can also lead to similar effects. Precautions were taken against such concerns as they were well known within our group. Masks were work during drilling and solder fume extractors were used during board layout.

Social and Political

There will be significant social issues involved with the development of this system as the mining of rare earth materials necessary for this project come from third world countries. This project will impact those in the mining regions involved. Being funded by municipal bonds hopefully all stakeholders will be compensated proportionally to what their initial investment as is consistent with the nature of bonds. This project will create inequities as with any large scale project, those that have more money will make more money. This is consistent with the general model of capitalism and I do not expect any

[4] (Agency, 2010)
[5] (Executive, 2002)

controversy regarding this topic. This will be a great driver of middle class jobs as is what is needed in times like these, I am a strong proponent of domestic manufacturing jobs provided by the government as they are what have gotten us out of recessions in the past, and I feel as if the widespread adoption of this project will create those jobs that we needs to bolster up the pockets of the middle class. With increased liquidity in the middle class the adoption of Rapid Battery Exchange cars will be more rapid than expected. Significant aggregate support and political prestige will go to and politician who supports the widespread acceptance of this system of infrastructure for our vehicles. I predict it will be a democrat who will undertake this as it is typically the democrats who understand the value of providing middle class jobs through government spending.

Development

Tools used for this project were your typical engineering tools, we made use of solder irons, crimpers, and wire strippers and cutters for this project. These are all tools that have been in use as long as the manufacturing of electronics has been around. I also was placed in the position where I had to design circuits, this involved a significant amount of research to locate the circuits with the behavior that fit our situation. Independently I was put into a new world where I had to design and think on my own as opposed to what is taught in classes. I was able to pick up people skills that I would otherwise be oblivious to, allocating tasks and engaging newer members proved to be a very difficult task for me to adjust to. I also attribute these skills and this project to me having a job to move onto after graduating. My work with the Electric Vehicle Club and this project tend to align themselves as the focal point of any job interview as it is the one occurrence in my college career which has taught me the most and has forced me grow the most as an engineer.