LOGBOOK

A comparison of Li-ion cells and supercapacitors in the efficiency of a regenerative braking system for EVs

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Initial ideas

This section contains:

- Early ideas of what the project would be/look like
- Alternatives to be taken if it is not possible to design a PCB
- Preliminary diagrams

First ideas

07 October 2020 20:38

I want this project to revolve around the topic of electric vehicles as that is one of the many aspects of engineering that led me to study EEE.

I was recently introduced to supercapacitors (about 2 years ago) and I believe they have a great potential in relation with increased efficiency of Evs in the near future. They are more expensive than Li-ion cells (currently used in Evs) but they present great electrical properties.

I think it would be great to do a comparison using both of these battery technologies and see which one is more efficient. Something I wanted to do since foundation year (2017) when I first started gathering ideas for this final year project was to build a regenerative braking system.

> Ideally I would want to use a 3-phase AC induction motor as that is what is used in Evs such as Teslas but due to the nature of the project: the fact that it's just me working on it and I have limited time and am on a budget, it is best to use DC motor. An AC motor would cost much more and functions with very high (mains) voltages and requires an inverter; dealing with AC if I don't know what I'm doing is not the safest thing in the world

Something else that really interests me is sustainability and helping save the planet. I want to not just investigate which battery would be a more viable solution for a more efficient EV but also I want to have a look at the environmental and ethical issues regarding the manufacturing and transport processes of these technologies.

> For example, Lithium needs to be extracted from mines and miners doesn't always have the best working conditions and are underpaid etc.
>
> Lithium batteries are used for many industrial and commercial applications so it means that there will always be a high demand for LI-ion batteries; at least until a new battery technology is introduced into the market and is deemed more viable (could it be supercapacitors?)
>
> Only a small few countries around the world are large extractors of Lithium for Li-ion battery production and it means there will always be a demand for the mineral which will result in a huge production of batteries. The extraction, production and exportation of these all contribute to a carbon footprint.

I am currently not sure about the manufacturing process that is involved in the production of supercapacitors but I believe it does not have such a large carbon footprint as Li-ion batteries because it requires more locally available resources (including copper for the plates). However there is a difference between supercapacitors and regular electrolytic capacitors that are used in small RC circuits

I want the theme of efficiency to be a recurring idea in my final report, not just in terms of the back-emf generated by the motor but also the manufacturing process of each of the batteries.

I'm thinking that the result of this will be that the supercapacitor is the ideal of the two because of how easy it would charge and discharge but maybe it will not be viable due to other factors

The hardware will be something like what I did in engineering workshop in year 1. A small enclosure containing all the components (μC, DC motor and bidirectional DC-DC converter) the PIC18F25K22 will be used as the brain of the entire operation. The DC-DC converter uses mosfets to determine the flow of current, they can be controlled by the PWM generated by the PIC. Their duty cycle determines the input and output voltages which will be important when switching between the Li-ion and supercapacitor batteries and their nominal voltages are slightly different.

I like the way the Arduino UNO devboard PCB is laid out and I plan to have a very similar layout when it comes to placing the components on ultiboard.

Plan B

31 October 2020 17:55

If the main idea does not occur due to COVID pandemic, the entire project can be built using the Simscape and Simscape electrical and specialized power system libraries included in Simulink. This would be easier to build and data acquisition would be much easier than the hardware.

If I need to resort to plan B then I would still like to make a schematic, PCB showing what the finished product would've looked like as well as a list of components to ensure that the total cost of the project would've been less than 75 pounds

Required Measurements

30 October 2020 20:16

This project will require some measurements. The idea for the regenerative braking system is that the motor is sped up to x speed and then the back-emf as well as the temperature of each of the batteries will be measured. Once the data can be recorded, it can be graphically represented on excel or MATLAB and then that can be used for analysis within the report.

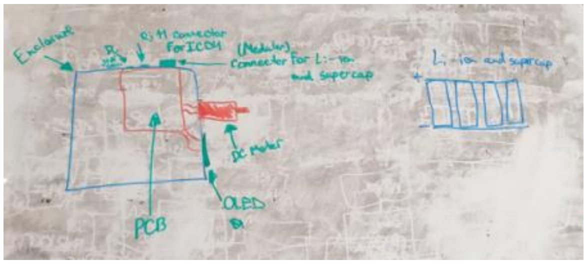
These are the necessary measurements

- Back-emf for each battery (using ADC from PIC)
- Temperature, possibly with an NTC thermistor (might require INA) (also using ADC from PIC)
- RPM speed - to speed up the motor to x speed before back-emf is generated (an octocoupler can be used, if this is the case then a marker of some kind will be needed to indicate 1 revolution, from this the speed in km/h or mph can be calculated.

I would like to display the information on a blue OLED screen because Dave likes blue LEDs and it will look cool. The problem is this uses I2C which may pose some difficulties when programming the displaying of data and also I would need to find a way to make it visible when it is a finished product so I would need to cut a hole in the enclosure somehow. Fortunately for me, money is not much of a problem because I've seen blue text OLED screens for as low as 3 or 4 pounds on amazon.co.uk

First sketches

31 October 2020 19:49

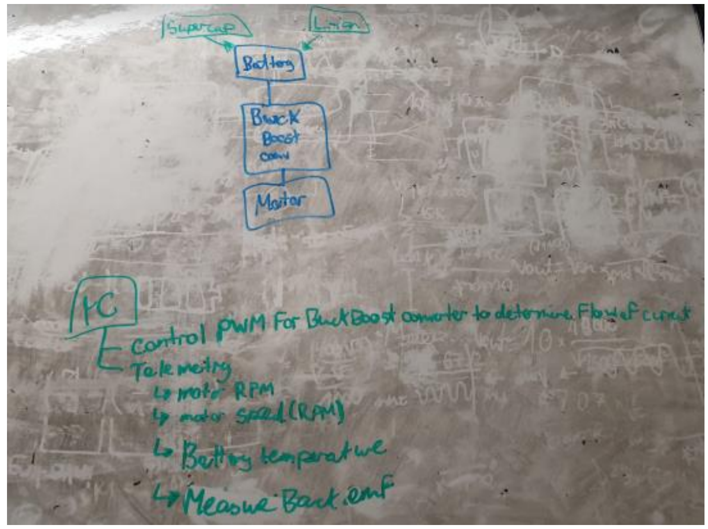


Here is a rough design of the hardware design. It shows the PCB inside the enclosure with all the peripherals
To reduce the costs, I plan to have a modular design where the Li-ion cell(s) and supercapacitor is attached to the input of the buck-boost converter though I am yet unsure as to how exactly I will make the connection. I don't want to make 3 PCBs as it will be time consuming and would cost more resources to make but I think the idea of having a modular (plug and play) design could work.

> I am also unsure of how many Li-ion cells and supercapacitors I will use, I will need to take into account the price when it comes to the shopping list. Li-ion cells have far greater capacity (mAh) per cell than supercapacitors so I'm not sure if it's best to have similar capacities or if I should just get one of each to reduce costs; I think I will go for the latter option.

The design also includes the OLED to display the measured data and the RJ11 connector to connect with the ICD4 to program the PIC

Check DESIGNS tab for the final conceptual, hardware and software designs



This was an attempt at drawing a block diagram aka the conceptual design. This was the very first thing drawn for the final year project and does not have a lot of the details but it is a start

30 April 2021 19:41

Designs

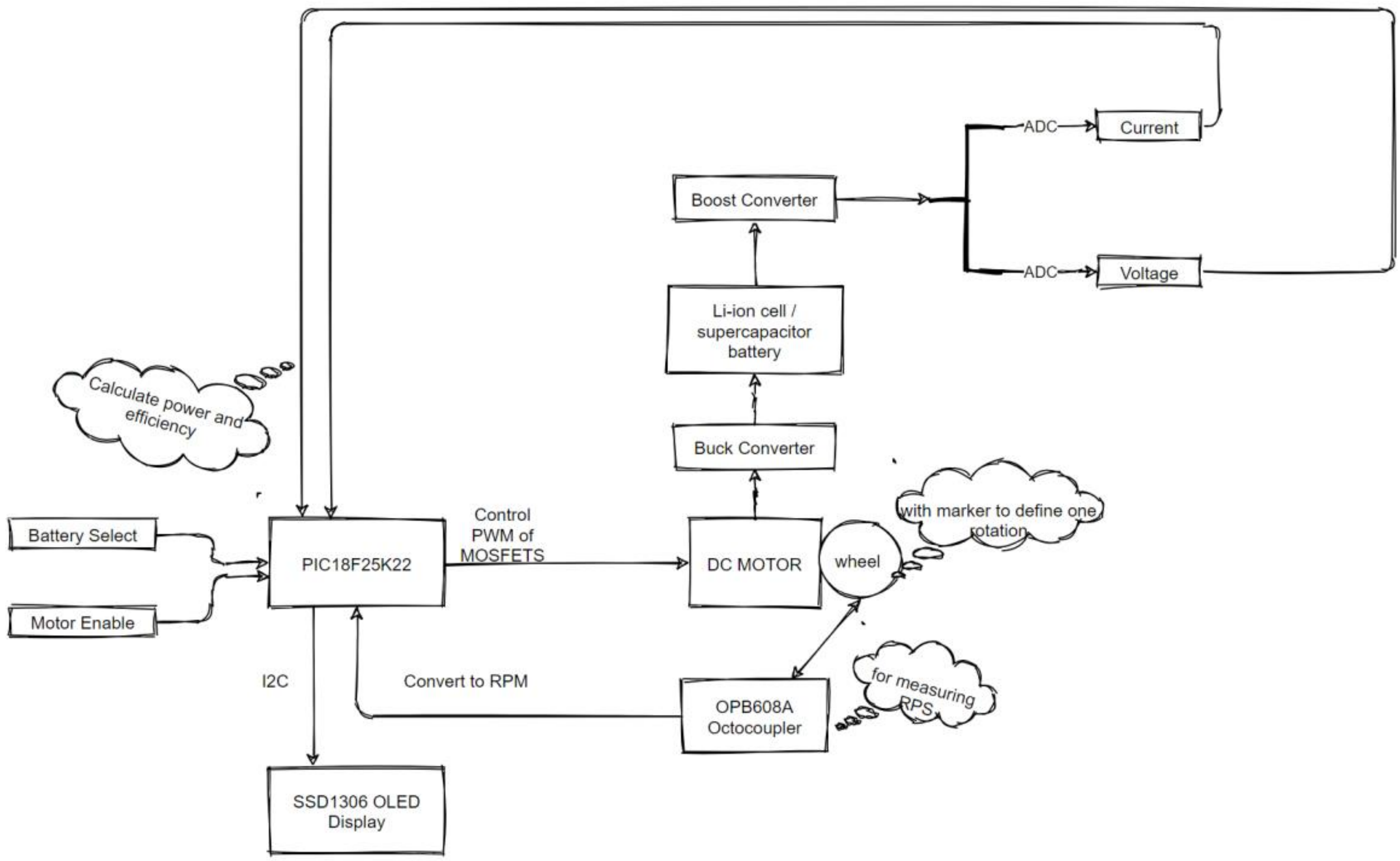
This section contains:

- Different stages of the design process
- Schematic design
- PCB design

Conceptual design

29 October 2020 20:41

This is the conceptual diagram of the project, I first made this as soon as the project supervisors were assigned. It shows all aspects of what the project needs to do and how. I believe this is self-explanatory and I can always look back to this if I am lost

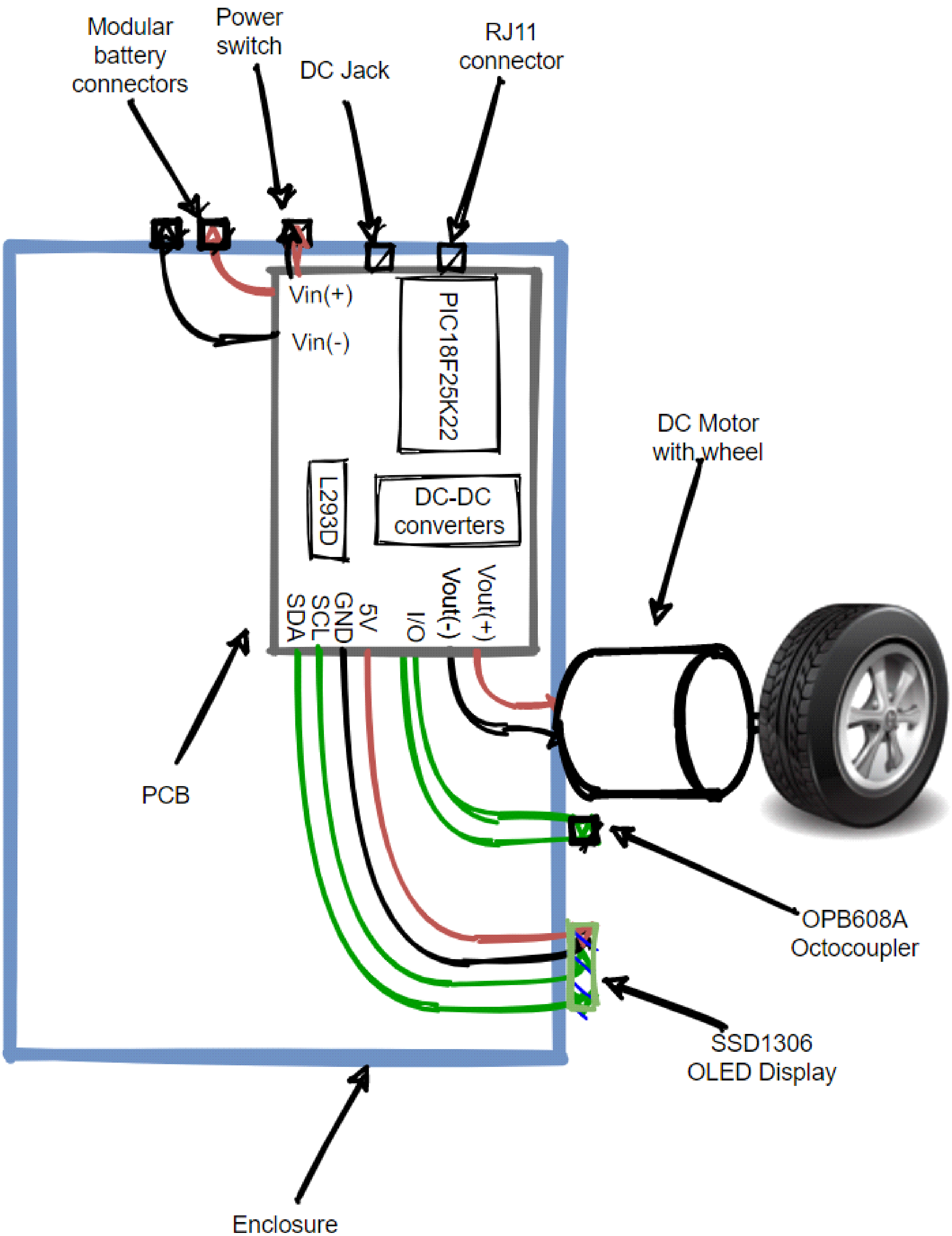


Hardware Design

30 October 2020 01:10

This diagram is the hardware schematic. This was the first diagram that was made after the initial idea for the IEP. I added as much structure and order to the hardware as possible, meaning that nothing will be out of place and i/o is placed accordingly.

The PCB was designed as close as possible to this (CHECK PCB TAB FOR DESIGNS). Headers were placed on the edge of the PCB as to make it easy to solder wires leaving the board



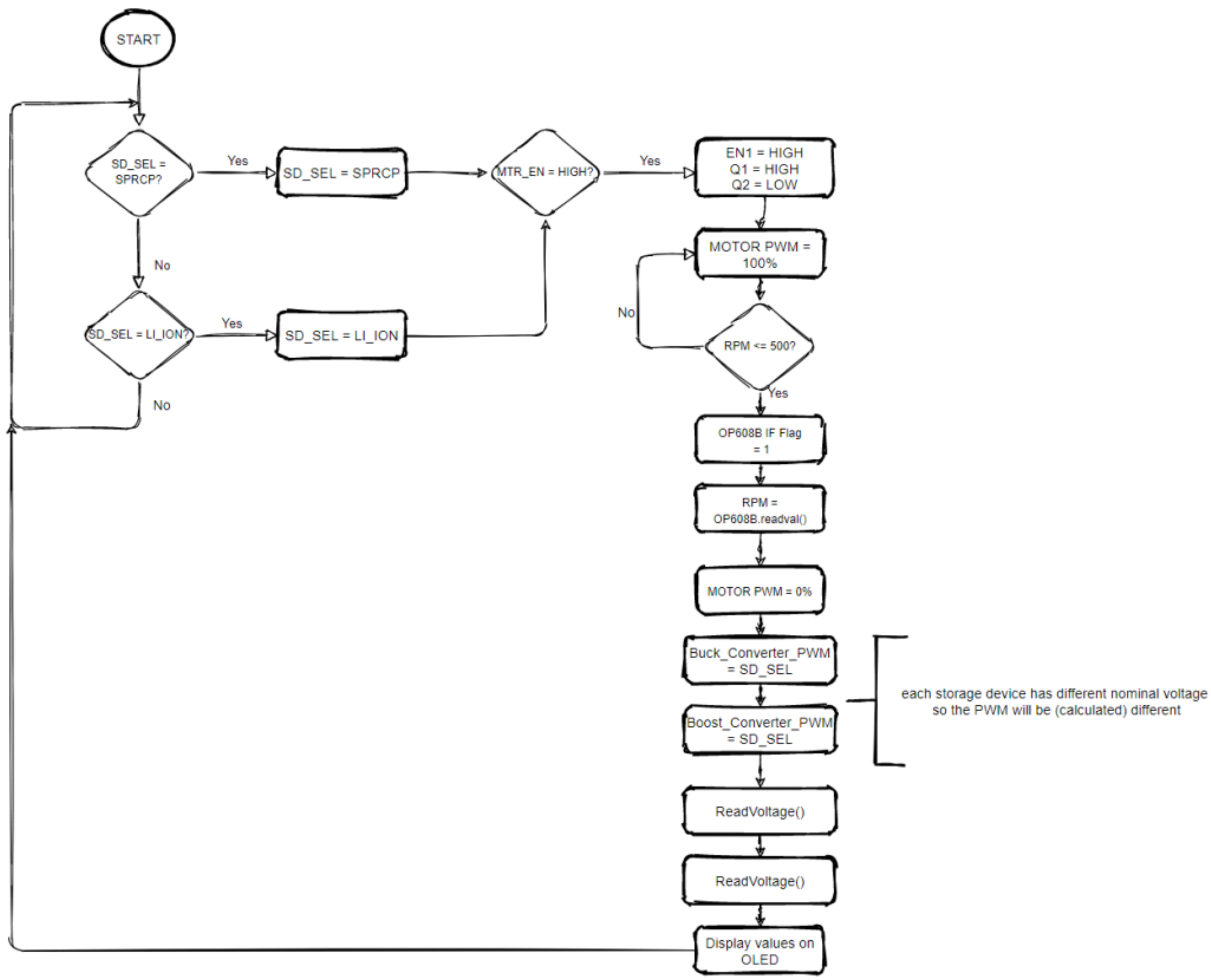
Modular battery connectors
Power switch
DC Jack
RJ11 connector
Vin(+)
Vin(-)
PIC18F25K22
DC Motor with wheel
L293D
DC-DC converters
SDA
SCL
GND
5V
I/O
Vout(-)
Vout(+)
PCB
OPB608A Octocoupler
SSD1306 OLED Display
Enclosure

Software design

30 October 2020 01:11

This shows the flowchart for the software side of the project. This is a very simple descprition of the process start to finish. The storage device is selected, the motor is turned then the back-emf goes through the buck converter, into the battery itself then finally into the boost converter where the voltage and current measurements are taken. Finally, the data is displayed in an OLED display

To make this fair, the same experiment will be carried out for both the Li-ion cell as well as the supercapacitor. The duty cycle of the PWM signals to the buck and boost converters determine the output voltage of each. This will be calculated for each of the storage devices, taking into account that the nominal voltage of the Li-ion cell is 3.7V and for the supercapacitor it is 2.5V



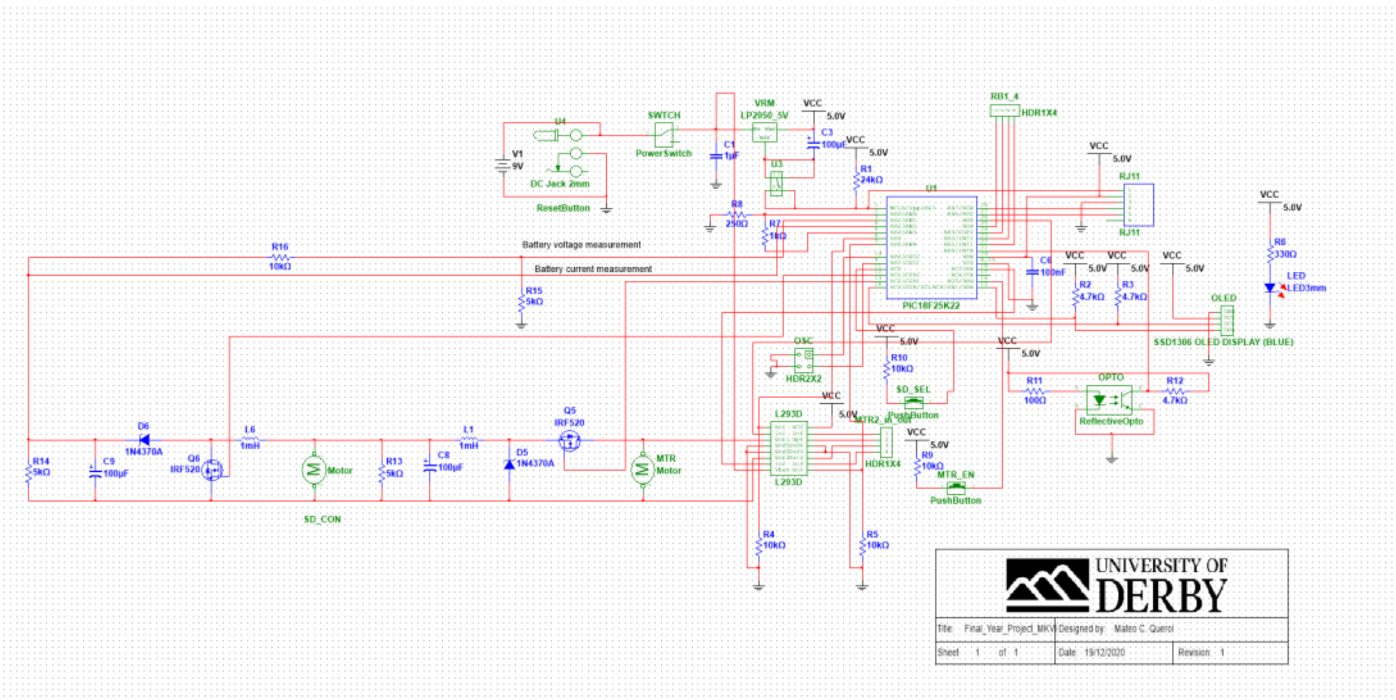
Schematic

30 October 2020 01:13

This is the 6th and final iteration for this project's schematic. Each iteration added a bit more than the next or changed it slightly.

The buck and boost converters were tested on a separate multisim schematic to ensure that they accommodated the nominal voltages for both a Li-ion cell and supercapacitors used (3.7 and 2.5V respectively)

Not all pins were used, because of this, headers were connected to ports such as OSC1 and OSC2 (4MHz crystal oscillator was not available so internal oscillator of PIC18F25K22 will be used as clock) and B ports 1 through 4 as well as a second motor inputs and outputs on the L293D. These are clearly labeled in the refdes which make it easier to identify certain pins when the pcb is printed



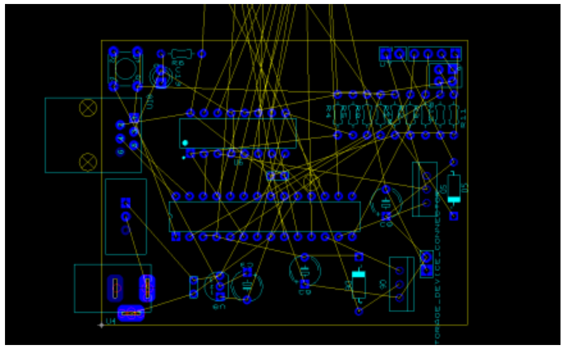
PCB

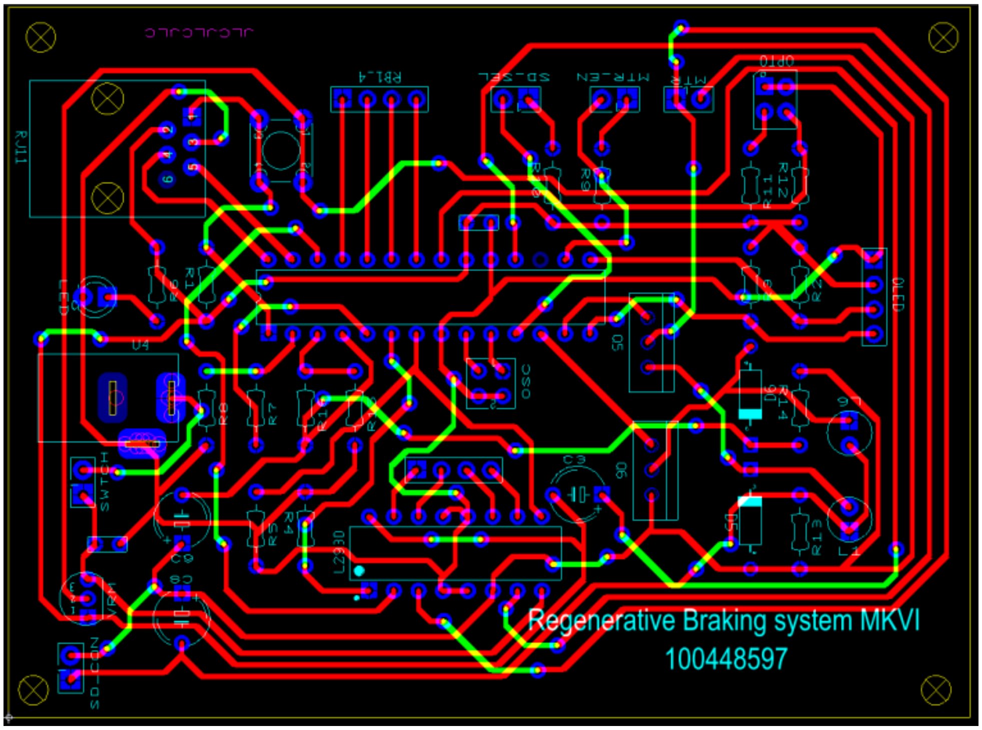
19 December 2020 01:07

This is the final PCB, the 6th iteration. It was initially going to be the size of an arduino (63x58mm) as that is very small and compact. However, after a few tries it was deemed very difficult due to having 2 ic's (PIC+L293D) as well as the many resistors going all over the place.

As in the schematic, unused pins were assigned to headers and will be there for future use, the refdes helps identify those pins; such as RB1_4 or the input and output pins on the L293D for the use of a second motor

The final dimensions of the PCB is 99x73mm, an enclosure was bought initially to house the first pcb design's dimensions but after the final PCB was made, a new box had to be bought which could fit the new dimensions. Thankfully, this new box was not very expensive and there was still room in the budget to spend on components





Shopping Lists

This section contains:

- Stock component order form
- Rapid online component order form
- OLED from Amazon.co.uk
- PCB from JLCPCB.com

Stock components

29 October 2020 21:29

Store Request for Stock Items				
When Completed send to your tutor for approval, who will then send it to eeetech@derby.ac.uk for processing				
You will be notified by email when the parts are ready for collection				
Name:	[redacted]		**Student ID:**	100448597
e-mail:	100448597@unimail.derby.ac.uk		**Course:**	Beng (Hons) Electri

ItemNo.	Quantity	Description including type where applicable e.g. ceramic or electrolytic	Value/Size	Store location Cabinet/Row/Draw
1	1	2.1mm DC power connector plug	-	11/4/4a
2	1	2.1mm DC power connector PCB socket	-	11/4/4b
3	1	PCB Slide switch SPDT - 3A	-	11/7/3-
4	1	Capacitor - tantalum, 25V	1uF	3/11/5a
5	2	Capacitor - electrolityc radial, 10V	100uF	3/9/3a
6	1	5V0 100mA Voltage regulator LP2950CZ-5.0	-	11/3/4b
7	1	PCB miniature pushbutton - reset switch	-	11/5/4a
8	1	Metal film resistor 0.25W (1%)	24k	2/6/4a
9	2	Metal film resistor 0.25W (1%)	10k	2/5/4b
10	3	Metal film resistor 0.25W (1%)	4.7k	2/4/5b
11	2	Metal film resistor 0.25W (1%)	1k	2/3/2b
12	1	Metal film resistor 0.25W (1%)	1k2	2/3/3b
13	1	Metal film resistor 0.25W (1%)	330R	2/2/1b
14	1	Metal film resistor 0.25W (1%)	270R	2/1/5b
15	1	Metal film resistor 0.25W (1%)	100R	1/5/5b
16	2	ceramic miniature low K	33pF	3/2/1b
17	1	ceramic - resin ripped - long lead	100nF	3/4/3b
18	1	4MHz Xtal low profile	-	11/4/2-
19	1	3mm blue LED clear lens	-	6/7/3a
20	1	RJ11 Receptible 6/6 PCB mount short fitting	-	7/1/3-
21	1	PIC18F25K22	-	11/1/4b
22	1	28 Pin Dual Wipe DIL Socket 0.3"	-	5/4/5b
23	1	16 Pin Dual Wipe DIL Socket 0.3"	-	5/4/3-
24	1	14 Pin Dual Wipe DIL Socket 0.3"	-	5/4/2-
25	1	OPB608A Reflective opto sensors	-	11/7/1-
26	1	74HC14 Hex Inverter Schmitt Trigger	-	9/3/1b
27	2	MOSFET IRF520	-	6/6/3b
28	2	1N914 fast signal diode	75V	5/9/1b
29	2	inductor 1mH radial	1mH	7/3/3a
30	1	supercap electrolytic radial	10F	3/11/3b

This is the stock component ordering from the university of derby. The quantity, description, value (if any) and the location in storage.

Total cost of everything including the non-stock components/items came to £60.25

Rapid-online

01 November 2020 12:15

Purchase Requisition (Student Projects) Approved Suppliers
(NB - if your supplier is not on the drop down lists, add the correct information in the first few lines of the part description area and refer to the Technicians in room MS235)

Student Name	Student Number	Email	Contact No
[redacted]	100448597	100448597@unimail.derby.ac.uk	[redacted]

Vendor Rapid Electronics — Account No: 400600
Address: Severalls Lane, Colchester
Post Code: CO4 5JS — Tel/Fax No: 01206 751166
Email address: sales@rapidelec.co.uk — Web site: www.rapidelectronics.co.uk

Row	Qty	Description (include quotes, specifications, drawings, supporting information)	Product Code	Unit Price	Total Price
11	1	Emmerich LI26650 Li-Ion Battery 3.7V 4500mAh	**64-6801**	12.01	12.01
12	1	CambdenBoss BIM2000/10-BLK/BLK ABS Case Black 75 x 50 x 27mm 2000 Series	**30-3720**	1.65	1.65
13	1	MFA 918D30112/1 Gearbox and Motor 30:1 4mm Shaft 12-24V	**37-1228**	12.27	12.27
14					
15					
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43					
44		Delivery			
45			**Total exc Discounts**		25.93
46			Discount %	0	
47			**Total exc VAT**		25.93
48		**Enter VAT rate:** 20	**VAT**		5.19
49			**TOTAL (inc any VAT)**		31.12

Only 4 items were not bought from the stock component's list. These three from rapid online: the Li-ion battery, the enclosure and the motor.

Amazon.co.uk

01 November 2020 15:58

Roll over image to zoom in

I2 °C IIC Serial OLED LCD LED Blue Display Module 0.96 128 * 64 For Arduino and 40pcs Dupont Wire 20 cm 40 Pin Woman To Woman by Maker Hawk

Brand: MakerHawk

106 ratings

Price: €3.99 **FREE Delivery** on orders over €29.00 shipped by Amazon. Delivery Details

Prices for items sold by Amazon include VAT (reduced in Germany until 31 Dec 2020). Depending on your delivery address, VAT may vary at Checkout. For other items, please see details. Information on the reduced VAT in Germany.

Extended holiday return window till Jan 31, 2021

- High quality, low price, 40pcs DUPON wires are accessible.
- I2 °C IIC Serial OLED LCD LED Blue display module, Interface: VCC: 3.3 – 5 V, GND: Mass, SCL: Serial Serial Data clock, SDA:
- Size: 0.96 inches, Resolution: 128 * 64, Colour: Blue, viewing angle: larger than 160 ° supported platforms: for Arduino, 51 Series, MSP430 Series, STIM32/2, SCR chips
- Low power consumption: 0.04 W up during normal operation, support, Voltage: 3.3 V – 5 V DC; Operating Temperature: -30 – 80 degree, volume: 27 mm * 27 mm * 4.1 mm, Driver IC: SSD1306, communication: IIC, only two I/O ports, a font isn't: The software word Modulo, backlight: OLED even light, no backlight
- DuPont wire – Quantity: 40 Pieces, Length: 20 cm/7,87 inches, 1 1P 1P pen head. Compatible with 0.1 pin headers. Compatible with 2.54 mm spacers. Can be used for N Project, PC motherboard.

› See more product details

Report incorrect product information.

Want to recycle your electrical or electronic appliance for free? (Do it here.)

This 4th item is the oled display and will be used to display the data such as rpm, voltage, current and efficiency

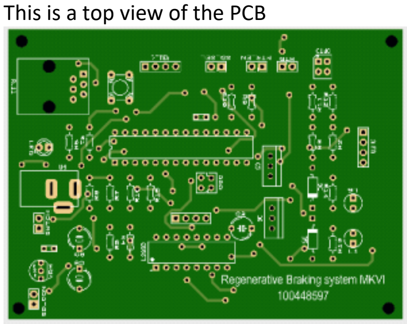
PCB

19 December 2020 18:44

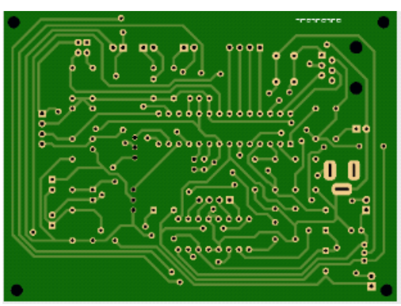
Product Detail		Product File	Price	Order Status	Operate
2020-12-12 | W202012120136217					
	PCB Prototype Order #: Y2-2496202A Build Time: 1-2 days 5 pcs £2.35 Product Details	IEP_FINAL_Y2 Production Completed Quality Complaint	Merchandise Total: £1.59 Shipping Charge: £1.50 Order Total: £3.09	Shipped DHL Express Priority Shipment Tracking	Reorder Order Details Invoice

The PCB for this project was not obtained from the university of derby but from an external company, JLCPCB. This adds to the overall cost of the project but there is still room left within the budget of 75 pounds if necessary

This is a top view of the PCB



This is a bottom view of the PCB



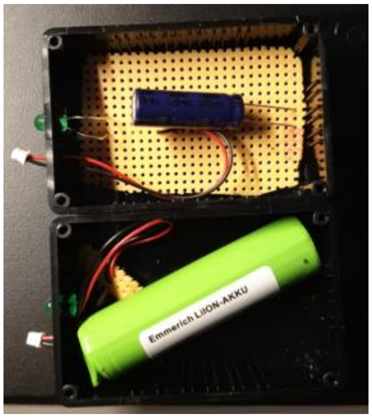
Prototype

This section contains:

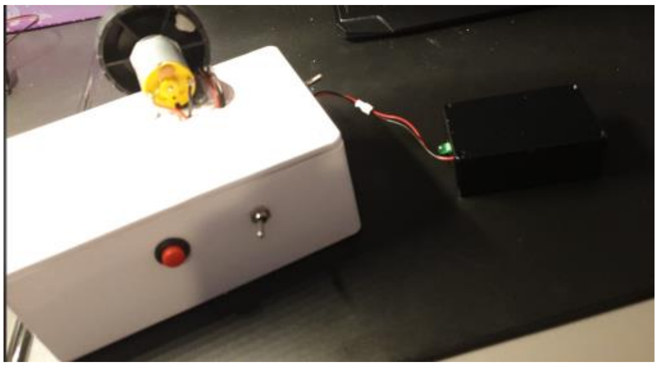
- Images of the final prototype
- PIC peripherals used/ mcc

Prototype photos

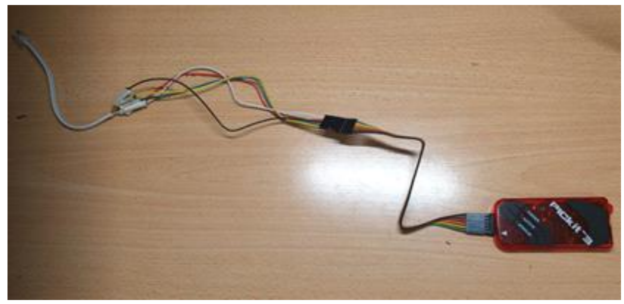
07 April 2021 20:22



This image shows the two storage devices placed in their own little boxes. They connect to the main board through that micro connector



This is a final image of the prototype with one of the batteries attached. If it was not for the hardware design, this would not have been possible and it probably would not work



Unfortunately I was not able to use an ICD4 so instead I used an RJ11 cable and cut it in half and soldered each of the cables to its respective cable on the PCKit3. While this did not allow for debug mode, it allowed for me to program the PIC

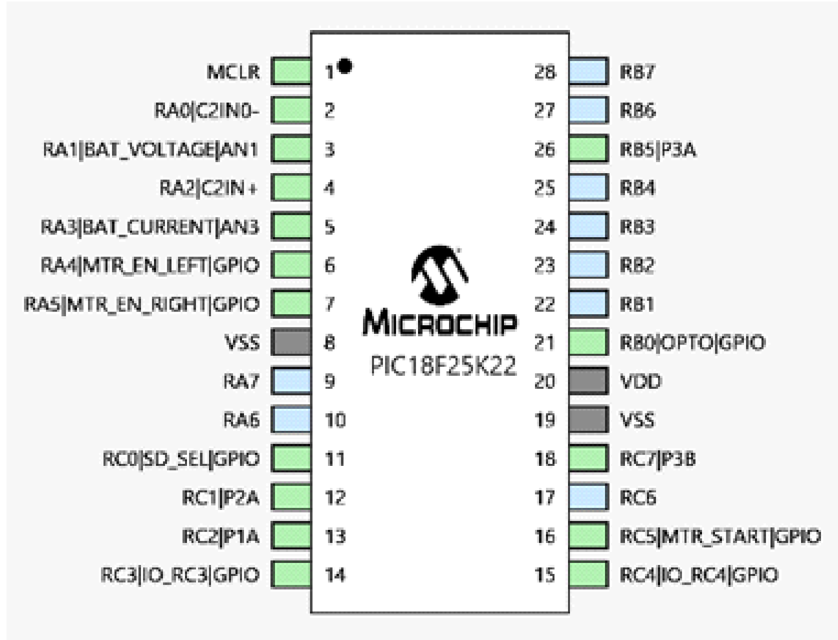
MCC resources

10 March 2021 20:22

Peripheral	Function	Use in the prototype
ADC	Convert analogue signals into digital values	The ADC was used to measure the voltage across and the current through the boost converter
CPM2	Selects the signal to be connected to the positive terminal of the Comparator module.	Used as a replacement for an op-amp, external resistors are connected to form a transimpedance amplifier.
ECCP1	Enhanced PWM mode 1	This PWM signal is what will control the MOSFET of the buck converter
ECCP2	Enhanced PWM mode 2	This PWM signal is what will control the MOSFET of the boost converter
ECCP3	Enhanced PWM mode 3	This PWM signal is what will control the motor.
TMR0	Internal timer 0	This is the internal timer used for counting the number of turns the wheel makes in 1 second
TMR2	Internal timer 2	This timer is used by the 3 ECCP
GPIO	General Purpose Input Output pins	These are other I/O that was used in the project such as: storage device select switch, motor start button and RCL&SDA

This is a summary of the peripherals used in the PIC with their functions and uses

My idea with the PIC is to measure the current and then for each of the storage devices plot how much % of the max capacity has been regenerated vs the speed of the motor. I expect it to be proportional and I hope to get large regeneration values



This diagram is a visual representation of the PIN layout of the PIC. The blue pins are either unused (RA6&7, RC6, RB1-RB4) or reserved (RB6&7)

I did this as soon as the proposal was approved, that way, for the next time I opened MPLAB X I would know what I'm doing.