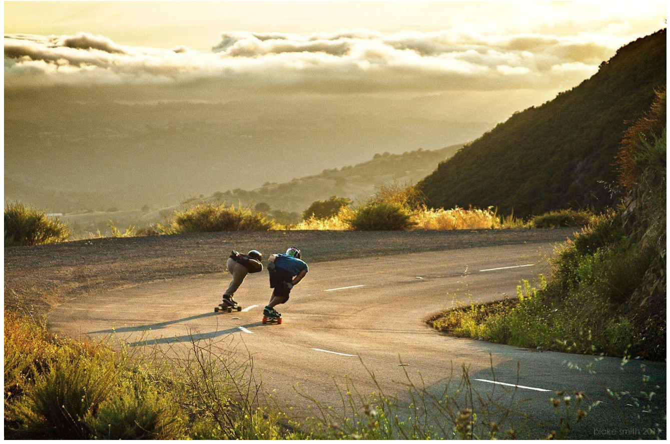
Electric Skateboard Regenerative Braking



Team:

Ryan Hawkins - Electrical Engineering

Brad George - Mechanical Engineering

Fawzi Al Hadrab - Electrical Engineering

Brendan DeJonge - Mechanical Engineering

Faculty Advisor: Ali Pezeshki

Summary:
The electric skateboard has exponentially increased in popularity, quality, and capability in recent years, proving itself valuable to everyone from college commuters to professional racers. While there are many great electric skateboard brands out there, we believe there is still significant room for improvement. First, most electric boards with regenerative braking don't allow the rider to brake when the battery is full (bad for starting a commute down a hill) or when too much current is generated (bad for really steep hills). Our team seeks to resolve this issue by designing an electronics system that will redirect the excess current under braking away from the main battery.

The next issue concerns the trucks (which control steering sensitivity) Normally, a rider has to manually adjust the skateboard trucks. If the trucks are loose, the board will be highly maneuverable at low speeds, but will be incredibly unstable at high speeds. Conversely, if the trucks are tight, the board will be stable at high speeds, but hard to maneuver at low speeds. Our team seeks to resolve this by developing a system that will autonomously adjust the trucks while riding according to the speed of the board or input of the rider.

Our project is broken down into two separate but equally important parts. We will be building two prototype boards. One board will primarily focus on the entrepreneurial aspect of our project. Existing parts will be bought where available so that the focus of the board can be on the regenerative braking capabilities as well as the automatic adaptive truck system. We will be focusing on making this board as competitively viable as possible, while putting considerable effort into an easy to install, separate system which will control the truck adjustment.

For the second board, we will be using a larger board itself, and the primary focus will be to build as much from scratch as possible. We plan to learn as much as possible by building from the ground up. This should allow us to better understand the power system, the motors, and the speed controller. This means we will be building an open source ESC that suits our purposes as well as designing the controller. The

first board will use a prebuilt ESC as well as a controller so that we will be able to focus more heavily on the improvements, while the second board will be focused on learning.

Why is This Project Important:
While electric boarding is thrilling and practical, it can be very dangerous. In 2012 alone, 5 people in the US and Canada died from electric skateboarding accidents. Furthermore, many riders have been seriously injured from the inability to brake down hills and from improper steering sensitivity in the trucks. This project, if implemented well, has the potential to vastly improve the safety of electric boards by addressing the above problems, which could literally save lives.

Revision History

Date	Description	Revision Num	Approved By
9/17/21	**Initial Rough Draft**	**1.0**	**Team**
9/26/21	**Budget Revision**	**1.1**	**Ryan**
10/8/21	**Objective Revision**	**1.2**	**Team**
10/15/21	**Risk Analysis and Contingency Plan**	**2.0**	**Team**

Problem Statement:
The modern electric skateboard does not have adequate braking ability with a full battery or down very steep hills. Furthermore, there is currently no technology to enable in-ride steering sensitivity control, which can be dangerous. This team will design two add-on systems to electric skateboards to address these problems. The first will consistently and effectively divert excess current away from the battery under braking, and the second will autonomously or remotely adjust the tightness of the trucks at speed.

Objectives:
Electric Board as a Whole:

Objective	Description	Priority (1-5)	Metric	Objective Direction	Target
Maximize Speed	Maximize the top velocity of the board.	5	mph	Maximize	30-35
Maximize Range	Maximize the average distance the board can travel on a single charge	5	mi	Maximize	15-20
Maximize Hill Climb Ability	Maximize the angle of hill steepness the board can climb	3	degrees	Maximize	30
Minimize Weight	Minimize the total weight of the board	2	lbs	Minimize	20
Maximize Aesthetic Attractiveness	Make board look appealing	2	subjective	Maximize	N/A

Regenerative Braking System:

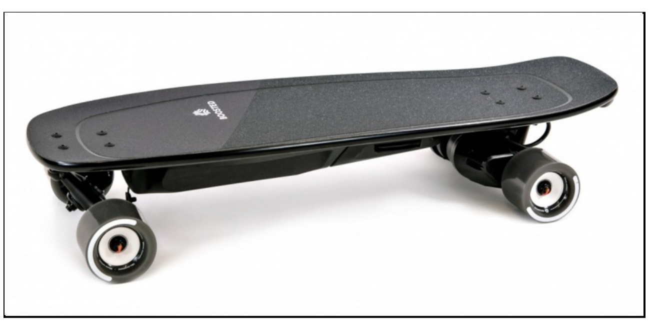
Objective	Description	Priority (1-5)	Metric	Objective Direction	Target
Maximize Torque	System should have adequate torque to rotate the nut	5	ft-lb	Maximize	15
Maximize Water/Dust Resistance	System should be splash proof and dust proof	4	IP rating system	Maximize	67
Maximize Reliability of Braking Capabilities	Braking system should work safely at all times during a ride	5	#	Maximize	1/10000
Maximize Efficiency of Regenerative Braking System	Regenerative system should effectively re-charge the batteries	4	%	Maximize	70

Adaptive Steering Sensitivity Control:

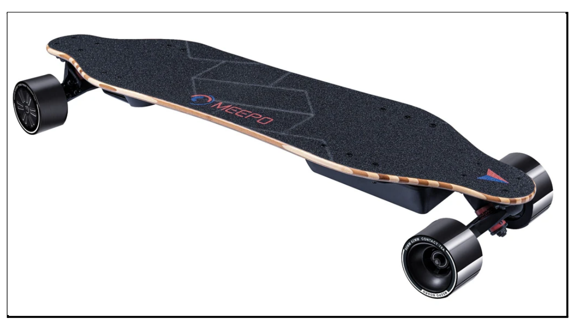
Objective	Description	Priority (1-5)	Metric	Objective Direction	Target
Maximize torque	Has adequate torque to help maneuvering and cornering	4	Nm	Maximize	10
Maximize Live Speed Data	Maximizing live speed data to help autonomously adjust stiffness	3	ms	Maximize	5

Background Research and Competitive Analysis:

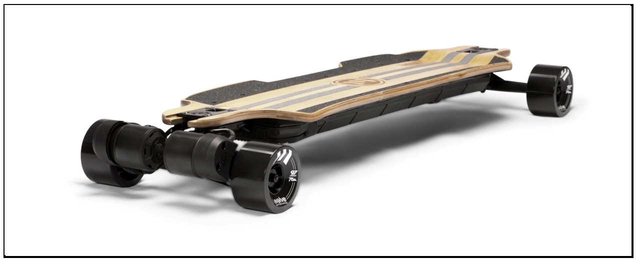
At this point, there are dozens of companies that make high quality electric skateboards. Among these are Trampa Boards, Boosted Boards, Evolve Boards, Halo Boards, and Meepo Boards.



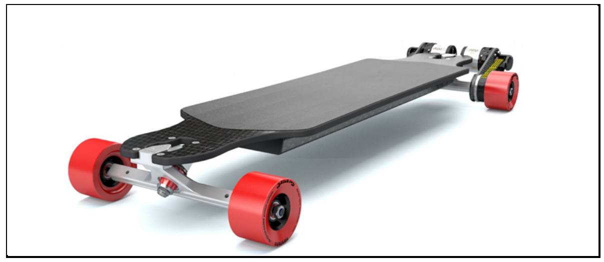
Boosted Mini X



Meepo Board V3



Evolve Hadean Bamboo Street



Trampa Electric Longboard

Lots of these boards have some regenerative braking capabilities, but none of them address the issues specified previously. There is also a huge online community for DIY electric boards, which vary over a broad spectrum in quality and capability.

In general, these boards have a wide range of capabilities that we will attempt to match in our design. In terms of maximum speed, good boards will go between 20 (Boosted Mini X) and 32 miles per hour (Meepo NLS Pro). In terms of battery range, good boards will last from between 14 miles (Boosted Mini X) to 31 miles (Evolve GTX Street). And in terms of cost, quality boards go from $1000 (Boosted Mini X) to $1950 (Evolve GT Carbon Street). Additionally, most boards weigh between 15 and 25 pounds.

There are also a couple different styles of boards most manufacturers produce. The main two (which we will replicate) are cruisers and longboards. The cruisers (Boosted Mini, Meepo Mini) are shorter and usually feature a kicktail for added maneuverability. They often feature a lower range and slower top speed, but they are also lighter, stiffer and more portable. The longboards on the other hand are longer (Evolve GTX, Boosted Stealth), which makes them more stable at high speed, but harder to maneuver around sharp corners. These boards have higher top speeds, longer ranges, bigger price tags, flexier decks, and heavier weights. Some of these boards are compatible with larger offroad wheels, which allows the rider to ride in all sorts of terrains.

In terms of rider control, most boards feature a wireless remote control which communicates with a VESC controller via a radio receiver. These controllers will have an analog input to manage speed, and will often have an LED display to monitor battery. Nearly all of these boards have battery packs enclosed under the deck, and some have separate enclosures for the VESC.

Most boards on the market today incorporate a single or dual motor drivetrain that consists of a motor pulley, wheel pulley, drive belt, motor, battery, and wheels. Between these components, the gear reduction ratio, motor KV, battery voltage, and wheel diameter have a direct impact on the boards top speed. These all need to be calculated and decided before beginning of design to ensure the board can operate as it is intended. For example, decreasing the wheel diameter will increase the velocity; however, higher board velocity means there will be more current in the system and decreases its battery life. This increase in speed also comes at the cost of torque which will make it more difficult to get up hills or tackle obstacles. Some boards use a dual motor drivetrain in order to compensate for this decrease in torque, but using two motors instead of one could drastically decrease battery life once again. Correctly selecting proper parameters for the best range and battery life will be an important aspect of the project and will determine the overall performance specifications of our final product.

Regarding the other design aspect of the project (adaptive truck adjustment), it seems that no one has attempted it, at least no one has published any work online regarding it.

Final Design Info and Design Constraints:

Electric Board as a Whole:

Constraint	**Description**	**Metric**	**Limit**
Top Speed	Maximum velocity	mph	20
Range	Maximum distance travelled on one charge	mi	10
Weight	Total mass of system	lbs	35
Cost	Total cost per board	$	$2500
Wireless Remote Control	Physical device that wirelessly communicates with board to ensure control	Y/N	Y
Smooth Acceleration and Braking	Avoids jerky motion for rider safety	Y/N	Y
Easily Rechargeable	Must have easy access to main battery to recharge	Y/N	Y
Does not overheat	Under normal operating conditions, the system should maintain an adequate temperature	Y/N	Y

Regenerative Braking System:

Constraint	**Description**	**Metric**	**Limit**
Can brake with full battery	The system must work with a completely full primary battery	Y/N	Y
Can brake down steep hills	The system must be able to brake smoothly on extremely steep hills	degrees	40
Integrated with other electronics	This system must function well with the other electronic components	Y/N	Y

Adaptive Steering Sensitivity Control:

Constraint	**Description**	**Metric**	**Limit**

Speed-based autonomous adjustment	The system must be able to adjust the trucks without input from the user according to the velocity of the board	Y/N	Y
Rider-based adjustment	The system must be able to be controlled remotely by the user from the controller smoothly	Y/N	Y
Both trucks in sync	Both the truck adjusters must operate together to ensure safety	Y/N	Y
Powered by main battery	The truck system must draw its power from the main battery	Y/N	Y
Removable	System can be mounted and removed with relative ease	Y/N	Y
Operates independently	Does not interfere in any negative way with any other portion of the system.	Y/N	Y

Budget Justification:

Unit 1: Cruiser	
Loaded Omakase Grip N Rip (Complete)	$300.00
Battery Pack	$400.00
Motors	$500.00
VESC ^ MkV-12s	$350.00
Unit 2: Longboard	
Loaded Vanguard Monster Truck (Complete)	$360.00
Battery Pack	$400.00
Motors	$500.00
VESC ^ MkV-12s	$350.00
Other:	
Controller (x2)	$100.00
Arduinos (x3)	$90.00
Miscellaneous	$600.00
Machined Components	$1,200.00
Total Cost:	$5,150.00

Prices include any shipping and handling fees on any parts that need to be ordered online. We have also included an estimated cost for any machined parts in the budget. This budget is also for two skateboards, both varying in size, weight and length to help achieve our goal of stability, control and efficiency. We will also be receiving fundings from the ECE department of $200.00 per person. Further funding of $5,000 will be provided through the Entrepreneurship Program. This brings our final cost to an estimate of $5,150.00, with $5800.00 in funding already provided for.

Simplified FMEA:

FMEA

Process/Product Name: Regenerative Braking Electric Skateboard
Organization Name:
Team Member Names: Brad George, Brendan DeJonge, Ryan Hawkins, Fawzi Al Hadrab

Prepared By: Brad George
Checked By: Brenden Dejonge
Approved By: Fawzi Al Hadrab, Ryan Hawkins
FMEA Date (Orig.): 16-Sep (Rev.):

Process Step/Input	Potential Failure Mode	Potential Failure Effects	SEVERITY (1 - 10)	Potential Causes	OCCURRENCE (1 - 10)	Current Controls	DETECTION (1 - 10)	RPN	Action Recommended	Resp.	Actions Taken	SEVERITY (1 - 10)	OCCURRENCE (1 - 10)	DETECTION (1 - 10)	RPN
What is the process step, change or feature under investigation?	In what ways could the step, change or feature go wrong?	What is the impact on the customer if this failure is not prevented or corrected?		What causes the step, change or feature to go wrong? (how could it occur?)		What controls exist that either prevent or detect the failure?			What are the recommended actions for reducing the occurrence of the cause or improving detection?	Who is responsible for making sure the actions are completed?	What actions were completed (and when) with respect to the RPN?				
Fill carafe with water	*Wrong amount of water*	*Coffee too strong or weak*	*8*	*Faded level marks on carafe*	*4*	*Visual Inspection*	*4*	*128*	*Replace old carafes*	*Mel*	*Carafe replaced 9/15*	*8*	*1*	*3*	*24*
Battery	Battery Is Full	Braking System Failure - Potential unexpected crashes	6	Regenerative Braking System	5	Manual Braking, Detect Battery Charge level	4	120	Dissipate extra energy as heat	Ryan, Fawzi					0
	Too much current sent to the battery	Braking System Failure - Potential unexpected crashes	6	Regenerative Braking System generates too much current down hills	2	Arduino	3	36	Resistor array to dissipate excess current	Ryan, Fawzi					0
Truck Adjustment System	Tightening or Loosening the trucks too much	Unstable and uncomfortable riding	5	Vibrations from riding could alter bolt position	3	Visual Inspection	4	60	Consistent visual inspections, ensure manual truck adjustment is still possible	Brendan, Brad					0
	Both trucks are not in sync	Unstable and uncomfortable riding	3	Communication between servos is inconsistent	1	Arduino/Encoder	4	12	Consistent visual inspections, ensure manual truck adjustment is still possible	Brendan, Brad					0
Motors	Overheating the motors	Unexpected motor failure (includes braking and acceleration)	6	Riding too fast for too long	3	Temperature Sensor/Arduino RPM limiter	3	54	Install cooling system, adaptive motors (switch between motors when one gets hot/use both when going up hills)	Brendan, Brad					0
Electronics System	Water, Dust, Ice Danger	Damaged electronics and complete system failure	8	User rides through puddles or wet grass	2	User needs to avoid puddles. Sealant and water resistance casing	3	48	Water deflection system, waterproof casing	Brendan, Brad, Fawzi, Ryan					0

Project Timeline:

Task	Assigned for	Assigned on	Due by	Dependencies
Design (mechanical)	Brendan DeJonge & Brad George	09/16/2021	10/20/2021	None

Design (electrical)	Fawzi Al Hadrab & Ryan Hawkins	09/16/2021	10/20/2021	None
Select and Order Individual Longboards	Brendan DeJonge	09/16/2021	10/25/2021	Design (mechanical and electrical)
Electrical Components Ordering	Fawzi Al Hadrab	09/16/2021	10/31/2021	Design (mechanical and electrical)
Mechanical Components Ordering	Brad George	09/16/2021	10/31/2021	Design (mechanical and electrical)
ESC Assembly	Ryan Hawkins & Fawzi Al Hadrab	10/8/2021	11/15/2021	Design and component ordering
Controller Design and Assembly	Brad George & Brendan DeJonge	10/8/2021	11/15/2021	Design and component ordering
Manufacturing and Machining	Brendan DeJonge	09/16/2021	11/20/2021	Design (mechanical and electrical)
3D Printing	Brad George	09/16/2021	11/30/2021	Design (mechanical and electrical)
Testing individual components	Team	09/16/2021	12/10/2021	Ordering components, manufacturing parts and 3D printing
Electrical Assembly	Ryan Hawkins	09/16/2021	01/15/2022	Testing individual components
Mechanical Assembly	Brendan DeJonge Brad George	09/16/2021	01/15/2022	Testing individual components
Insulating	Fawzi Al Hadrab	09/16/2021	01/25/2022	Electrical and mechanical assembly
Programing and Coding	Fawzi Al Hadrab & Ryan Hawkins	09/16/2021	01/25/2022	Electrical assembly
Entrepreneurship Improvements	Team	10/8/2021		
Physical Testing	Team	09/16/2021	02/20/2022	Programming and assembly
Fixing Testing Failures	Team	09/16/2021	03/1/2022	Physical testing

Risk Analysis and Contingency:

Risk	Probability	Impact	Action
Unsuccessful completion of custom ESC	Medium	Medium	Upon unsuccessful implementation and given time constraints, a premade ESC will be bought and installed
Unsuccessful completion of custom ESC	Low	Low	If a controller is not successfully implemented, a premade controller will be bought
Failure of individual parts	High	Medium	Multiples of parts will be ordered in case of failures, but these will add more time
Failure to build working prototype for entrepreneurship improvements	Low	Medium	A completed replacement board will be bought to make the improvements upon, but will present considerable time constraints

Contingency Plan:

The largest roadblocks we can foresee causing delays are the custom made ESC, controller, as well as the components assembled before we can begin to improve upon the pre-existing regenerative braking capabilities as well as truck adjustment system. This is why if we are unable to complete either the custom made ESC or the controller by 1/1/2022, we will order these components to move ahead with the project. As for our entrepreneurship aspect of our project, buying premade components should simplify the process and allow us to focus on the improvements to be made. However, if we do not have a working unimproved prototype by 2/1/2022, we will order a complete, premade electric longboard and design our improvements using this.