

EE & CPE Senior Project

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Weight Controlled Electric Skateboard

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1 Acknowledgements

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We would also like to give very special gratitude to Paul Hummel. Dr. Hummel agreed to advise this project out of the goodness of his heart as he was not obligated to advise projects as a lecturer at Cal Poly. What he did not know he was agreeing to was being constantly being berated by Carson seeking affirmation on every move that we were making. Dr. Hummel was instrumental in this project being as successful as it is. He pushed us to keep moving forward and was always *happy* to help by providing us hardware for testing or ideas on how to proceed forward.

2 Abstract

Technology and the way that humans interact is becoming more vital and omnipresent with every passing day. However, human interface device designers suffer from the increasingly popular “designed for me or people like me” syndrome. This design philosophy inherently limits accessibility and usability of technology to those like the designer. This places severe limits of usability to those who are not fully able as well as leaves non-traditional human interface devices unexplored. This project set out to explore a previously uncharted human interface device, on an electric skateboard, and compare its end user experience with industry leading human interface devices.

3 Introduction

The purpose of this project was to build an electric skateboard that changes its speed thresholds based on the weight distribution of the rider between the front and back.

3.1 Stakeholders

Stakeholders would be people who don't own a car looking to find a way to travel the last mile from a public transit station to their actual destination, skateboard hobbyists, and high school and college students. A successful product would give these people a convenient tool for transportation or a new device to hack and play with.

3.2 Project Goals and Objectives

The goal of this project is to build a weight-controlled electric skateboard that match an already assembled boosted boards functionality, affordability, and safety. The skateboard will be designed to control the speed thresholds based on the natural body positions of the rider as they ride on the board. For example, leaning forward will enable the board to go faster, leaning backward will engage the brakes, and an even weight distribution across the board will coast. The skateboard will also account for changes in terrain, and adjust its speed thresholds accordingly. For example, it will allow for more speed going up a hill, and will cap the maximum speed going downhill in order to ensure the rider's safety.

3.3 Project Outcomes and Deliverables

A functional skateboard that meets the aforementioned requirements will be delivered, along with an operator's manual giving a brief overview on how the board works. A working product would help to solve the last mile problem, give college and high school students a new way to easily get around campus, and give skateboard hobbyists a new device to enjoy.

4 Background

4.1 Last Mile Transportation

The “Last Mile” has been a problem cities have been trying to solve for years. Getting around a city is fairly straightforward, with subways and buses and other forms of public transportation, but rarely do these methods bring a person to their exact desired location; rather, they just drop them off at a station or something equivalent and leave it up to them to get home from there. As a result, people have been devising safe, convenient, portable, and green methods to transport themselves over that last mile to their destination. One of these solutions is an electric skateboard.

4.2 Current Industry

Initially starting out as a toy for the wealthy, electric skateboards have slowly been dipping in price, making them an actually reasonable investment for someone like a college student who needs a convenient method to get around without owning a car. Their cost comes in at anywhere between 200–1700, depending on how high-end of a board the consumer is looking for.

Hobbyists often purchase parts (wheels, motors, deck, battery, etc.) and construct their own boards themselves, although there are tradeoffs to be made when planning a design, and different users build for their own specific needs. For example, a beginner would want a board that’s cheaper and less powerful so that they can get comfortable with riding an electric skateboard, a user in a hilly neighborhood would want a board with power, a user that uses their board for easy transportation would want a board that’s lighter and portable.

One goal of this project was to build a board that would stack up with other boards already on the market in terms of affordability and functionality, while adding its own features that set it apart.

5 Requirements and Technical Specifications

5.1 Requirements

As this project is focused on human interface devices, the needs of the end user were stringently studied and followed. This data was compiled and is summarized below.

The board and its accompanying control system must:

- Match or exceed the speed of industry leading electric skateboards
- Match or exceed the acceleration of industry leading electric skateboards
- Match or exceed the battery range of industry leading electric skateboards
- Accept all weights and sizes of riders
- Be a viable last mile transportation vehicle

5.2 Technical Specifications

Below is a list of the technical specifications that satisfy the above requirements.

- Dual 190kv motors
- 3:1 gearing ratio
- 85mm wheels 77a hardness
- 42V 10s battery

6 Design

6.1 Design Review

This is a review of the primary subsystems of the project. These components are the Electric Skateboard, Sensors, and the Digital Systems.

6.1.1 Electric Skateboard

The Electric Skateboard uses two 190kv motors each running with max 80 Amps of current on each motor. The motors have a gear ratio of 3:1. These motors allow the skateboard to accelerate to a max speed of 28 mph which is faster than most commercial electric skateboards. The motors are powered from a 30Ah lithium ion battery. The charge time for the battery is approximately 4hr, giving the board a range of approximately 10 miles, which is close to the average range of electric skateboards on the market. This battery is connected to a programmable controller that regulates the amount of current delivered to the batteries based on a PWM signal coming from the microcontroller. The motors are mounted to the back of the board and are connected to 85mm wheels with a hardness of 77A. The battery and motor controller are shielded by an aluminum cover attached to the bottom. The front wheels are attached to 63mm single bolt on mounted trucks. To bring it all together, the deck of the board is a long-board covered in grip tape.

6.1.2 Sensors

The sensors are composed of a piece of Velostat sandwiched between two pieces of aluminum foil. Velostat is a material that changes its resistance when it is folded or pressure is applied to it. There are no official characteristics for this material, and the underlying cause for its properties are unknown, but for the purpose of this project, the resistive range was found to be around $2k\Omega$ with no pressure applied to a flat 5 inch by 8 inch rectangle of the material, and around 30Ω with 200 pounds applied to the same flat rectangle. The sensors were measured by creating a voltage divider with the sensor connected to 3.3V and a 47Ω resistor connected to ground. The central node between these two components was measured for its voltage.

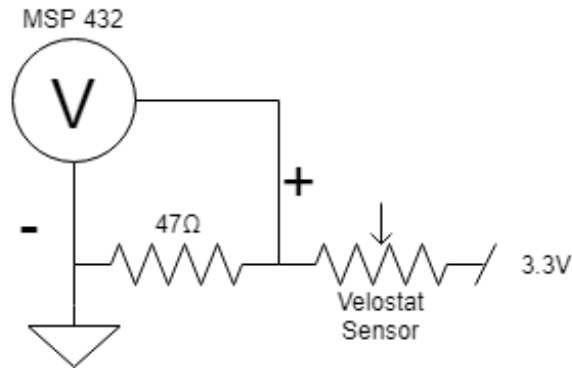


Figure 1: Circuit Diagram of Sensor

The 47Ω resistor was chosen because it was close to the range of values of the Velostat sensor when a user was applying their weight to it. The sensor was attached to the top of the board where the user will put their feet. The size of the Velostat was chosen to be 5 inches by 8 inches. This size was chosen because it gives users enough space to comfortably stand with a variety of positions on the board. The sensors are secured to the board with electrical tape. The sensors have a layer of plastic covering them. This layer of plastic protects the sensor and prevents it from tearing. The sensors are wired to the microcontroller which is attached to the bottom of the board. There are two sensors on the board, one above each of the board's trucks.

6.1.3 Digital Systems

The system uses a Texas Instruments MSP432P401R Launchpad Dev Board. This board was chosen because of team members' experience with the microcontroller. The microcontroller was also chosen because of its low power draw of $80\ \mu\text{A}/\text{MHz}$. This low power draw for the microcontroller means that the board's range is barely impacted. This microcontroller is connected to the the Velostat sensors and a radio receiver. The radio receiver communicates with a hand-held remote controller. The hand-held controller allows the user to manually control the upper limit of their speed. This is done by using the signal from the controller to cap the signal coming from the Velostat sensors. This gives the user the control to lower or increase the max speed of the skateboard. The two sensors on the board are

used to gather a difference in the amount of weight being applied to the front and back of the board. This difference is crucial for allowing the board to work properly with any user. The system uses this difference to calculate the percentage of weight being applied to the front or the back of the board. The system also uses a gyroscope to sense the slope of the incline that the board is riding on. This gyroscope is used by the microcontroller to increase the power delivered to the motors when going up an incline.

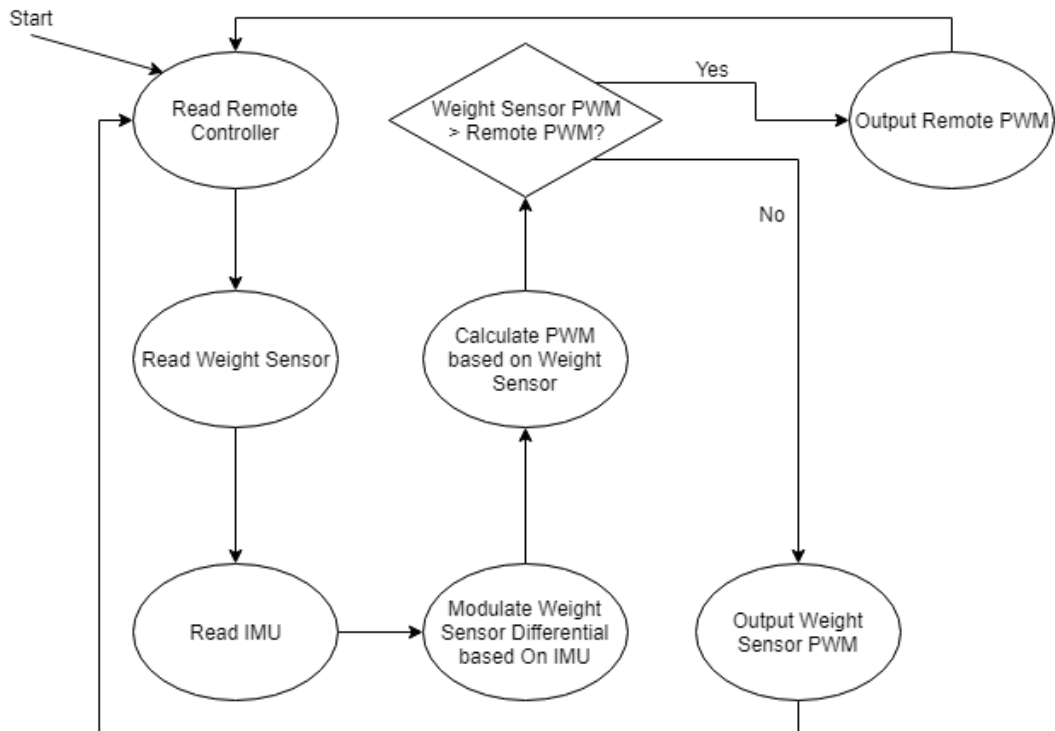


Figure 2: Software Flowchart

7 Test Plans

7.1 Sensors

In order to drive the skateboard based off of weight, weight sensors were needed. To fulfill this requirement, three options were devised. The first option was using a HX711 breakout board that

communicated via SPI that was hooked up to a load cell located underneath the trucks in the front and back of the board. The second option was using a configuration of four load sensors underneath the same trucks, hooked up to the same HX711 breakout board. The third option was to create a voltage divider using a material that varied its resistance based off of pressure - called Velostat - and read in the central node voltage using an ADC. To test how well each of these worked, the raw values read from the breakout board in the first two cases and from the ADC in the third case were printed out to the terminal via UART.

7.2 Stepping Onto the Board

Since the board uses a weight based system, a case would arise upon startup where the user would step onto the board, setting a high weight differential and potentially causing the board to fly off in one direction. The weight differential algorithm would then have to be modified to catch this condition. To test this, the skateboard's back wheels were elevated off of the ground by wooden blocks to ensure the board did not drive anywhere, and the test user (Carson) would step onto the board to make sure that the wheels did not start spinning.

7.3 Drive

It was imperative that actually riding the skateboard felt correct, and safe. Before actually riding, the drive system was disengaged and the PWM signals generated by the microcontroller to feed into the voltage controllers were read by an oscilloscope, and the waveforms were observed by the team to determine if the skateboard's behavior was the expected behavior. When driving, the microcontroller was hooked up with a six foot cable to an external battery that was used as a kill switch in case something went haywire and the board needed to be forced to power down.

7.4 Users of different weights

Initially, the board was tested with just one sensor on the front to ensure that the drive system worked. However, as a result, a heavier user could put more weight on the sensor, and therefore drive faster

than a lighter user. In order to keep speeds consistent across differently weighted users, then, an algorithm was developed to determine the speed window based off of the weight differential between the front and back of the board. The algorithm was tested by disconnecting the drive system and simply applying pressure on the front and back sensors and tracking the output of the algorithm, which was printed out to the terminal via UART.

7.5 Different Terrain

The weight differential gives a window for the range of possible speed. However, this window teams with gravity on a slope and makes for either a slow ascent when riding uphill or a rapid descent when riding downhill. In order to adjust for this, it was necessary for an accelerometer to be integrated into the system to shift the window given by the weight differential algorithm. To test this, the accelerometer was held level on a table and moved back and forth, while reading the Euler angles and printing the value onto the terminal via UART.

8 System Testing and Analysis

8.1 Sensors

Three sensors were tested to determine which would suit the system the best. First, load cells were placed under the trucks and connected to the HX711 breakout board. The sensor's readings were output to a UART console. These readings were then analyzed to determine if they could detect the full range of the user's weight. These load cells were maxed out at far too low of a value to be used in this project. The second sensors that were tried were four scale weight sensors placed under the board. These sensors had a variety of issues. The scale sensors could not fit in between the trucks and the deck of the board. The sensor could be made to fit if a spacer piece was placed in between the deck and the trucks. These sensors also were maxed out by a person's full body weight. So these sensors could not be used in the system. The final option was the use of a material called Velostat. This is a material that changes its resistance based on the amount of pressure applied to it. Velostat

can be used to construct a weight sensor. This sensor was tested by measuring the resistance of the material as more pressure was applied to it. The resistance of the sensor ranged from a value of $30\text{k}\Omega$ with no weight on it to 50Ω with around two hundred pounds of weight. It was determined that the change in resistance was exponential.

8.2 Stepping Onto the Board

The initial startup of the board when the user first gets on was tested to make sure that the board was safe. There was a bug in the system where the board would retain its previous settings after a rider had dismounted the board. This meant that if a board were traveling quickly and then rapidly dismounted, the next time a rider mounted the board it would use the acceleration value from before the rapid dismount. This was solved by resetting the board's speed value when the weight detected by the sensors fell below a lower threshold. Early in development, the board would default to coasting when the user stepped on the board. This feature was later changed so that the board allowed the user to apply the brakes to the system while mounting the board. This led to a more user friendly experience.

8.3 Drive

The PWM signal coming from the microcontroller was tested using an oscilloscope. This allowed for verification of the signal before connecting the microcontroller to the speed controllers. During development, the system used two different methods for determining the speed of the board. Initially, the board used strictly the hand controller to determine the speed of the board. This is the standard method of controlling electric skateboards. It allows for precise control of the board. This method was tested with system test runs. By using the board on a variety of terrains it allowed for the gathering of data and user feedback. While driving, the micro-controller's battery was held by the user. This allowed the user to pull the charging cable out of the battery. Pulling the charging cable out of the battery causes the system to coast. Remote control operation was tested and worked properly. The sensors were then added to the system, and this was tested separately. Testing with the

sensors revealed that many small changes needed to be made to the algorithm to make the system feel comfortable to the user. The weight percentages were altered to make it so that the user did not have to lean as much to get the change in acceleration that the user needed. A PID controller was added to the algorithm to make changes in acceleration more gradual. The board's top speed was tested and it was found to be 28 mph, which is faster than most electric skateboards on the market. This mean that we have met the speed requirement for this board. Acceleration exceeds other skateboard's accelerations on the market. The board's traveling range is approximately 10 miles. As a last mile transportation vehicle the board successfully fulfills the criteria of being convenient, portable, green, and safe. The board is 15 pounds. This makes the boards comfortably portable for most users. This portability and that the board charges in 4 hours makes the board a convenient option for short travel distances. The board has two braking options which adds to the safety of a regular electric skateboard. The board is an electric vehicle which makes it greener than gas powered alternatives.

8.4 Users of different weights

Several different users were tested on the board. This was to verify that the board would not need any adjustment for users of different sizes. The algorithm used to determine the weight differential does not use absolute weight values. Instead, the algorithm uses the difference in weight being applied to the two sensors. This means that any user regardless of weight can operate the board. The users tested varied in weight from one hundred fifteen pounds to two hundred pounds. All the users were able to operate the board.

8.5 Different Terrain

The board was tested on a variety of inclinations. Inclinations caused the board to be too fast on downward slopes and struggle to climb upward slopes. This bug was solved by using a gyroscope/accelerometer that could determine the slope that the board was operating on. When the board goes up a slope, it increases the amount of power being delivered to the motors, and on a downward slope, it reduces the amount of power. This makes traversing a variety of terrains feasible.

9 Conclusion and Future Work

The project succeeded in some of its goals and failed in others. The goal of creating a viable last mile transportation vehicle was realised. The skateboard on its own meets every requirement. It is portable enough to be stored with a rider on a bus or train. It is safe to use as long as the rider has the appropriate skill set. It is green due to it being entirely electrically powered. It is convenient because its speed provides the rider with an effortless and fast way to commute. The project also succeeded in the goal of exploring a previously unexplored human interface device, unfortunately that is where the successes end.

The project failed in one key goal - creating a better human interface device on an electric skateboard than the current industry available ones. One of the fundamental characteristics that make electric skateboards both fun and safe to use as a commuting vehicle is their extremely high acceleration and deceleration. The acceleration and deceleration allows the rider to get themselves out of a situation where a car is coming up behind them or pulling in front of them without noticing that the rider is there. The point of failure for the explored human interface device is that the weight based control mechanism fundamentally can not safely function at the high levels of acceleration and deceleration that is required for the board to be both safe and fun. As the levels of acceleration and deceleration are increased the rider gets pushed back during acceleration and forward during deceleration to the point that the control mechanism can not safely account for the change in rider position. This causes the control mechanism to be unstable and ultimately not viable.

If there were to be future work done on this project or in this space there is an obvious point of entry. That point is to use the newly added accelerometer to categorize the acceleration characteristics of the system with a rider and use that to modulate the existing weight based control system. These characteristics could be used to modify the control system which could enable the system to smoothly and stably handle the acceleration and deceleration required to make a safe and fun electric skateboard. This can be coupled with making the ending product more polished to the point that it can potentially

be a product that is ready for market.

10 Teaming

Below is a list of the contributing members on the team and their individual roles.

Carson Bertozzi - Project Lead

- Headed the project and made decisions about what direction the project went when difficulties were encountered.
- Handled assigning tasks based on the strengths of each individual team member.
- Designed and coded the mains system architecture
- Designed and built the electric skateboard itself

Zach Barram

- Sensor testing and construction.
- Assisted in writing the program for the board.
- Wrote code for communication with and initialization of the BNO055 IC.

Vishnu Dodballapur

- Assisted in constructing the electric skateboard
- Assisted in writing the hardware abstraction code for the microcontroller
- Assisted in designing the algorithm to drive the skateboard based off of weight differential

11 Reflection

Carson Bertozzi:

In this project, I got the chance to spec, design, build, and test a system as a whole. This experience was invaluable as it was one of the first times that I was able to set parameters as I saw fit which made me feel like I was making decisions and putting my engineering degree to use. I also got the chance

to manage the project, which was a new experience. I had a small "team" that I was responsible for dividing tasks between to best utilize their strengths. This was an introduction to project management for me and in particular an engineering project. In order to be an effective manager I had be able to gain a working knowledge of any new topic that the team brought up. Through this project I found that I very much enjoy being an engineer and that project management may be something that I persue in the future.

Vishnu Dodballapur:

In this project, I got a chance to build and test a whole system from the ground up. I got experience with a whole bunch of hardware I had never used before. I learned how important it is to write readable, clean code, since we're working on the same project over such a long period of time, and it's critical that we understand why we did what we did when we did it. I also learned some techniques in safely testing potentially dangerous systems. Overall, I was able to take away a lot of knowledge from this project.

Zachary Barram:

For this team project, I worked with sensors more than I ever had before. This project required sensors that were accurate and precise. This required us to do a lot of testing that I had never done before. We found that the sensors available for purchase were not precise enough for this project. We developed our own sensors that worked better than the manufactured sensors. This whole project ended up being a lesson in why it may not always be the best to just buy a product; sometimes, it is better to build them yourself. In this project I had to use a lot of unfamiliar code. My teammates had already developed some code, and I had to understand and add to it. This required communication with my team and careful analysis of the code base.

12 Bibliography

“Are Electric Skateboards the Solution to the ‘Last Mile’ Challenge?” CleanTechnica, 20 Mar. 2016, cleantechnica.com/2016/03/20/electric-skateboards-solution-last-mile-challenge/.

13 Appendices

13.1 code

```
#include "msp.h"
#include "delay.h"
#include "ADC.h"
#include "USB_UART.h"
#include "BNO055.h"
#include "PWM.h"
#include "Skateboard.h"
#include <stdio.h>
#define MAX_DIFF_ACCEL 65
#define MAX_DIFF_DECEL 90
#define INITIAL_WEIGHT_SPLIT_MIN -.55
#define INITIAL_WEIGHT_SPLIT_MAX .35

/**
 * main.c
 */
void main(void)
{
    WDT_A->CTL = WDT_A_CTL_PW | WDT_A_CTL_HOLD; // stop watchdog timer
    delay_ms(1000,FREQ_3MHz);
    setDCO(FREQ_12MHz);
    InitBNO055(BNO055_ADDRESS);
    ConfigureBNO055();
    ADCInit();
    USB_UARTInit();
    InitPWM();
    RunSkateboard();
}
```

```
/*
 * delay.h
 *
 * Created on: Apr 5, 2018
 * Author: carsonbertozzi
 */

#ifndef DELAY_H_
#define DELAY_H_

#define FREQ_32KHz 32768.0
#define FREQ_1500KHz 1500000
#define FREQ_3MHz 3000000
#define FREQ_6MHz 6000000
#define FREQ_12MHz 12000000 //min delay 5us, gives ~7us
```

```

#define FREQ_24MHz 24000000 //min delay 3us, gives ~5us
#define FREQ_48MHz 48000000 //min delay 1us, gives ~3us

void delay_ms(int msDelay, int freq);
void delay_us(int usDelay, int freq);
int setDCO(int freq);

#endif /* DELAY_H_ */

```

```

/*
 * delay.c
 *
 * Created on: Apr 9, 2018
 * Author: Vishnu
 */

#include "msp.h"
#include "delay.h"
#include <stdint.h>

void delay_ms(int msDelay, int freq){

    uint32_t i = freq / 10000 * msDelay;

    for ( ; i > 0; i--);

}

void delay_us(int usDelay, int freq){

    uint32_t i = 0;
    if (usDelay < 20){
        switch(freq){
            case FREQ_1500KHz:
            case FREQ_3MHz:
                i = freq / 10000 * usDelay / 1000 / 50;
                break;
            case FREQ_6MHz:
                i = freq / 10000 * usDelay / 1000 / 5;
                break;
            case FREQ_12MHz:
                i = freq / 10000 * usDelay / 1000 - 6 ;
                break;
            case FREQ_24MHz:
            case FREQ_48MHz:
                i = freq / 10000 * usDelay / 1000 - 4;
                break;
        }
    }
    else if (usDelay < 40 && usDelay >= 20){
        i = freq / 10000 * usDelay / 1000 - 6;
    }
    else if (usDelay <= 500 && usDelay >= 40){
        i = freq / 10000 * usDelay / 1000 - 5;
    }
    else{
        i = freq / 10000 * usDelay / 1000 + 1;
    }
    for ( ; i > 0; i--);

}

```

```

int setDCO(int freq){
    uint32_t hold;
    CS->KEY = CS_KEY_VAL; // unlock CS registers
    hold = CS->CTL0;
    CS->CTL0 = 0; // clear register CTL0

    switch(freq){

    case 1500KHz:
        CS->CTL0 |= CS_CTL0_DCORSEL_0;
        break;
    case 3MHz:
        CS->CTL0 |= CS_CTL0_DCORSEL_1;
        break;
    case 6MHz:
        CS->CTL0 |= CS_CTL0_DCORSEL_2;
        break;
    case 12MHz:
        CS->CTL0 |= CS_CTL0_DCORSEL_3;
        break;
    case 24MHz:
        CS->CTL0 |= CS_CTL0_DCORSEL_4;
        break;
    case 48MHz:
        /* Transition to VCORE Level 1: AM0.LDO --> AM1.LDO */
        while ((PCM->CTL1 & PCM_CTL1_PMR_BUSY));

        PCM->CTL0 = PCM_CTL0_KEY_VAL | PCM_CTL0_AMR_1;

        while ((PCM->CTL1 & PCM_CTL1_PMR_BUSY));

        /* Configure Flash wait-state to 1 for both banks 0 & 1 */
        FLCTL->BANK0_RDCTL = (FLCTL->BANK0_RDCTL &
            ~(FLCTL_BANK0_RDCTL_WAIT_MASK)) | FLCTL_BANK0_RDCTL_WAIT_1;

        FLCTL->BANK1_RDCTL = (FLCTL->BANK0_RDCTL &
            ~(FLCTL_BANK1_RDCTL_WAIT_MASK)) | FLCTL_BANK1_RDCTL_WAIT_1;

        CS->CTL0 |= CS_CTL0_DCORSEL_5;

        break;
    default :
        CS->CTL0 = hold; //If value is not valid, put back original value
        CS->KEY = 0; //Lock the CS register
        return -1;
    }

    CS->CTL1 = CS_CTL1_SELML_DCOCLK | CS_CTL1_SELSEL_DCOCLK | CS_CTL1_SELA_REFOCLK; //Set the SMCLK
    signal to the DCO clock
    CS->KEY = 0;

    return 0;
}
}

/*
 * ADC.h
 *
 * Created on: May 9, 2018
 * Author: Vishnu
 */

```

```

#ifndef ADC_H_
#define ADC_H_

#include "msp.h"

#define ADC_V_MAX 3.3
#define RMS_SAMPLE_36 36
#define ADC_RESOLUTION 16384
#define ECCFF 495 //Extremely Carefully Calculated Fudge Factor

static uint8_t ADCFlag = 0;
static uint16_t ADCSample = 0;
static uint16_t ADCSample_1 = 0;

void ADCInit(void);
void clearADCFlag(void);
uint8_t getADCFlag(void);
uint16_t getADCSample(void);
uint16_t getADCSample_1(void);

#endif /* ADC_H_ */

```

```

/*
 * ADC.c
 *
 * Created on: May 9, 2018
 * Author: Vishnu
 */

#include "ADC.h"

void ADCInit(void){
    P5->SEL0 |= BIT4 | BIT5;
    P5->SEL1 |= BIT4 | BIT5;

    ADC14->CTL0 &= ~ADC14_CTL0_ENC;
    ADC14->CTL0 = ADC14_CTL0_SHT0_16 | ADC14_CTL0_ON | ADC14_CTL0_SHP | ADC14_CTL0_CONSEQ_1;
    //sample for 16 clock cycles, turn on, sample manually, default clock, sequence of channels
    ADC14->CTL1 = ADC14_CTL1_RES_3; //set resolution to 14 bits
    ADC14->MCTL[0] = ADC14_MCTLN_INCH_1; //hook up A1, save in MEM0
    ADC14->MCTL[1] = ADC14_MCTLN_INCH_0 | ADC14_MCTLN_EOS; //hook up A0, save in MEM1

    ADC14->IER0 |= ADC14_IER0_IE0 | ADC14_IER0_IE1; //enables interrupt for MEM[0] and MEM[1]
    ADC14->CTL0 |= ADC14_CTL0_ENC;

    __enable_irq();
    NVIC->ISER[0] = (1 << ADC14_IRQn);
}

void clearADCFlag(void){
    ADCFlag = 0;
}

uint16_t getADCSample(void){
    return ADCSample;
}

uint16_t getADCSample_1(void){
    return ADCSample_1;
}

```

```

uint8_t getADCFlag(void){
    return ADCFlag;
}

void ADC14_IRQHandler(){
    if (ADC14->IFGR0 & ADC14_IFGR0_IFG0){
        ADCSample = ADC14->MEM[0];
        ADCFlag = 1;
    }
    else if (ADC14->IFGR0 & ADC14_IFGR0_IFG1){
        ADCSample_1 = ADC14->MEM[1];
        ADCFlag = 1;
    }
}

void readFromBoard(uint16_t * back_input, uint16_t * front_input){
    ADC14->CTL0 |= ADC14_CTL0_SC; //gets one front and back input
    while (!getADCFlag());
    clearADCFlag();
    *back_input = getADCSample();
    *front_input = getADCSample_1();
}

void calculateWeightDiff(float * weight_split , uint16_t back_input, uint16_t front_input){
    *weight_split = (float)(front_input - back_input) / (front_input + back_input);

    if ((*weight_split) > WEIGHT_SPLIT_MAX){
        *weight_split = WEIGHT_SPLIT_MAX;
    }
    else if ((*weight_split) < WEIGHT_SPLIT_MIN){
        *weight_split = WEIGHT_SPLIT_MIN;
    }
}

```

```

#ifndef PWM_H_
#define PWM_H_

```

```
void PWMInit();
```

```
#endif
```

```
#include "PWM.h"
```

```

void PWMInit(){
    /* Timer input capture pins
     * P2.6 is capture, P2.4 is PWM out for V-Controllers
     */
    P2->SEL0 |= (BIT6 | BIT4); //setting throttle and turning inputs
    P2->SEL1 &= ~(BIT6);
    P2->DIR &= ~(BIT6);
    P2->DIR |= BIT4;

    TIMER_A0->CTL |= TIMER_A_CTL_SSEL__SMCLK | TIMER_A_CTL_MC__CONTINUOUS
        | TIMER_A_CTL_CLR;

    TIMER_A0->CCTL[1] |= TIMER_A_CCTLN_OUTMOD_7;

    TIMER_A0->CCTL[3] |= TIMER_A_CCTLN_CM_BOTH | TIMER_A_CCTLN_CCIS__CCIA
        | TIMER_A_CCTLN_CAP | TIMER_A_CCTLN_CCIE

```

```

        | TIMER_A_CCTLN_SCS;

    __enable_irq();
    NVIC->ISER[0] = (1 << TA0_N_IRQn);
}

void calculatePWM(uint16_t * calc_pwm_output, uint16_t * prev_pwm_output, float slope, float weight_split){
    *calc_pwm_output = (int)PWM_MIN + slope * (weight_split - WEIGHT_SPLIT_MIN);
    if ((*calc_pwm_output) > (*prev_pwm_output) + MAX_DIFF_ACCEL){
        *calc_pwm_output = *prev_pwm_output + MAX_DIFF_ACCEL;
    }
    else if ((*calc_pwm_output) < (*prev_pwm_output) - MAX_DIFF_DECEL){
        *calc_pwm_output = *prev_pwm_output - MAX_DIFF_DECEL;
    }
}

void outputSignal(uint16_t front_input, uint16_t back_input, uint16_t *calc_pwm_output, uint16_t *throttle_diff){
    if (front_input + back_input < 1000){ //sets a minimum weight threshold
        TIMER_A0->CCR[1] = 18000;
        *calc_pwm_output = 18000;
    }

    else if (throttle_diff > (*calc_pwm_output)){
        TIMER_A0->CCR[1] = *calc_pwm_output;
    }

    else{
        TIMER_A0->CCR[1] = *throttle_diff;
    }
}
}

#include "msp.h"
#include "delay.h"
#include "ADC.h"
#include "USB_UART.h"
#include "BNO055.h"
#include "PWM.h"
#include "Skateboard.h"
/*
 * Skateboard.c
 *
 */
uint16_t throttle_diff;
uint16_t sampled_flag;
void RunSkateboard(void)
{
    int16_t signed_int_gyro_value;
    uint16_t back_input, front_input, calc_pwm_output, prev_pwm_output = PWM_MIN;

    float weight_split_min;
    float weight_split_max;
    float weight_split, acc_weight_shift;
    float slope = 1.0 * (PWM_MAX - PWM_MIN) / (INITIAL_WEIGHT_SPLIT_MAX - INITIAL_WEIGHT_SPLIT_MIN);

    while(1){
        readFromBoard(&back_input, &front_input)

        if (sampled_flag){
            //the flags ensure that the data is only edited all in one go,
            //instead of potentially sporadically changing based whenever
            calculateWeightDiff(&weight_split, back_input, front_input);
            calculatePWM(&calc_pwm_output, &prev_pwm_output, slope, weight_split);
        }
    }
}

```

```

        outputSignal(front_input, back_input, &calc_pwm_output, &throttle_diff)
        prev_pwm_output = calc_pwm_output;
        sampled_flag = 0;
    }
}

void TA0_N_IRQHandler(void){
    static uint16_t turnRising, turnFalling;
    static uint16_t turnCaps = 0;

    if (TIMER_A0->CCTL[3] & TIMER_A_CCTLN_CCIFG){
        if (turnCaps == 0){
            turnRising = TIMER_A0->CCR[3];
            turnCaps++;
        }
        else if (turnCaps == 1){
            turnFalling = TIMER_A0->CCR[3];
            throttle_diff = turnFalling - turnRising;
            sampled_flag = 1;
            turnCaps = 0;
        }
    }
    TIMER_A0->CCTL[3] &= ~TIMER_A_CCTLN_CCIFG;
}

```
