The Concen-Training System

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***Abstract* — Technological advancements have made our lives easier in many ways, but have also become a distraction. The objective of The Concen-Training System is to improve user focus while working at the computer. Positive reinforcement in the form of a smartphone lockbox is used to encourage good study habits with a rewards system. Negative reinforcement in the form of a gentle seat vibration notification deters poor habits from developing by reminding the user to return their focus. An eye-tracking camera monitors the user's gaze. All elements working together aids in the development of good study habits and better concentration.**

***Index Terms* — Gaze Tracking, Microcontrollers, Force Sensors, Electromagnetic device, Bluetooth, Driver circuits, Power MOSFET**

I. Introduction

These days, students can have trouble focusing on their studies as a result of their dependency on cell phones. They may find themselves staring off into the distance or looking down at their phones, losing valuable time they could have spent studying.

The Concen-Training System is a smart reinforcement apparatus whose primary goal is to aid in the development of good study/work habits. It consists of three primary hardware components: an eye-tracking camera, a magnetic locking phone jail, and a vibration chair module. The eye-tracking camera monitors the user's eye movement, checking to make sure they are focusing their attention on the screen. The phone jail module acts as a barrier for the user to stop looking at their cellular device, as well as a positive reinforcement tool, allowing them phone study breaks when a good study streak occurs. The vibration chair module acts as a negative reinforcement tool, lightly buzzing the user when they are not paying attention for a time.

This project can be useful for students of all ages and even professionals needing an extra push to focus better in general. There are no existing products on the market that use both eye tracking and reinforcement to focus. The only existing competitors are time-based reminders that can become nuisances or distractions if the student is focusing at the time they go off. Our system is much more customized to an individual's needs and performance. It is also compatible with most computer systems containing at least two USB ports.

Aside from helping students who struggle in school or professionals aiming to better themselves, the Concen-Training System can be used to gather important data on how its users focus. How long can people do a task such as reading, watching a video or following a presentation before their gaze wanders? While our project does not record data in its current form, it opens the path to a larger number of possibilities for tracking attention trends over an extended period.

II. Standards

For our project to be able to function properly and safely, certain standards must be met. Standards can relate to a variety of subjects, such as standardized electrical housings for environmental protection, power supply standards for correct operation and security standards for keeping data private. Organizations that provide the standards to be used in electrical, mechanical and computer engineering include ANSI, IEEE and IEC among others.

As creating a printed circuit board (PCB) was a necessity for our project, we had to keep in mind some related standards. The IPC-2221A "Generic Standard on Printed Board Design" was created to provide information on the basic requirements for organic printed board design. The standard also addresses concerns regarding mounting and interconnecting electronic structures. IPC breaks down three classes of electronics/PCBs. Those three classifications are also relevant to IPC J-STD-001G "Requirements for Soldered Electrical and Electronic Assemblies". This standard covers requirements of materials, processes and acceptability.

As our product is something that someone could potentially buy for use in their own home, we need to consider the fact that a person may not be familiar with how to use or maintain the product on their own. The IEEE/IEC 82079-1-2019 is titled "International Standard for Preparation of information for use (instructions for use) of products - Part 1: Principles and general requirements". This standard discusses the general requirements that the producer needs to supply to consumers with their product to help them understand how to properly use the product.

Other standards relating to wireless communication, security and electromagnetic locks were also researched

TABLE I
REQUIREMENT SPECIFICATIONS

Spec Number	Item	Specification	Acceptable Range
1	Eye-Tracking Accuracy	>90% accuracy	+/- 5%
2	Eye-Tracking Registration Distance	1 meter	+/- 20 cm
3	Eye-Tracking Response Time	Within 2 seconds	+/- 0.5 seconds
4	Weight registration (chair)	~50 lbs	+/- 10 lbs
5	Weight registration (lock box item)	~0.1875 lbs	+/- .1 lbs
6	Weight Limit	~300 lbs	+/- 20 lbs
7	Set-up Time	<10 minutes	+/- 2 minutes
8	Chair Module Size	<1 Square Foot	+/- 3 inches (length)
9	Bluetooth Connectivity	Within 3 meters	+/- 1 foot
10	Inactivity Threshold	~10 seconds	+/- 5 seconds
11	Alerting Threshold	~3 seconds	+/- 1 second
12	Vibration Module Power	3.3-5 Volts	N/A
13	Communication Module Power	3.3-5 Volts	N/A
14	Vibration Module Battery Life	>=8 hours	+/- 30 minutes
15	Smart Lock Box Size	9" x 9" x 9"	+/- 2 inches in each dimension
16	Cable Length (Computer to Box)	~1 meter	+/- 30 cm

throughout this process and taken into consideration when executing this project.

III. SPECIFICATIONS

A list of our desirable specifications associated with the completion of our Concen-Training System are shown in Table 1. These specifications give us a way to determine how effective our end product is and whether or not we met our initial goals.

One of the major functions of our Concen-Training apparatus determining successful concentration training is through accurate eye tracking and registration. Therefore, we have set our target eye-tracking accuracy quite high, around 90% give or take. The more accurate the eye tracker is able to make this registration, the better the entire system will perform, and the less frustrated the user will be. Inaccuracies with this type of apparatus can lead to false flags to be raised, causing vibration stimulation without cause or even extending smart-lock durations, confusing and irritating the user.

To achieve the most accurate eye-tracking results, the system should register the user's gaze when they are within one meter of their computer. This specification gives the user a more flexible experience with the overall system.

The Concen-Training system involves two different types of weight sensors. One of these is housed within the phone lock box and therefore needs to be able to register items with a low weight. To assure users with a wide range of cell phones could use this aspect of our design, the lightest cell phone on the market was used as our minimum weight rating. The size of the lock box was also determined by the largest cell phone on the market to assure ample room for users to place their phone inside and have the lid close fully.

The second weight sensor will be housed in the chair seat and need to withstand the user sitting on this module. For our design needs, we set a weight range of 50 to 300 pounds. This range could be adjusted in the future to create a more inclusive product.

IV. SYSTEM COMPONENTS

A. Lock Box

The main form of positive reinforcement for our design is the phone lockbox. This is used to store the user's phone during their determined study period, minimizing the distractions that the phone will offer to the user when they should be focusing. The positive reinforcement aspect of this is the access to the phone after spending a set period focusing, as it promotes good study habits and rewards the user for their hard work.

The lockbox holds multiple components that perform certain functions in the overall design. Inside the lockbox, there is a weight sensor that is used to tell when the user has placed their cell phone inside. The electromagnetic lock is used to keep the box shut to prevent the user from getting to their phone when they should be focused. Multiple LEDs on the box notify the user when they have reached the set study time and are allowed access to their phone. Lastly, a small compartment beneath the phone lockbox holds the PCB that controls the functions of all the components that the box contains.

B. Chair Module

The chair module acts as the negative reinforcement aspect of the design. When the user loses focus and their gaze wanders from the screen for a set period, motors in the chair module will vibrate to alert the user that they need to regain their focus. This vibration acts as the negative reinforcement as it is a form of "punishment" to let the user know when they are not maintaining their focus.

Multiple components are contained within the chair module. This limits the number of wires hanging out from the chair module, making it easier to implement for use into any study space. Inside the chair module, weight sensors are mounted that read the weight applied to the chair, determining whether or not the user is seated and ready to begin their study session. Vibration motors mounted underneath the top of the seat alert the user when they need to regain their focus. A PCB that controls these components is also mounted within the seat, along with a battery pack to power all the chair components.

C. Eye Tracking Software

The primary driver for the physical components of this project is the Eye Tracking Software. The goal for this software is to recognize where the user is looking and register when the user is not looking at the screen. When the user does not look at the screen, a timer begins, and after an appropriate threshold time is reached, the user is given feedback from the chair module via vibration to refocus their attention.

Similarly, when the user looks at the screen, the program runs a separate timer. When the user holds focus for an appropriate amount of time (chosen by the user), the lockbox gives the user positive feedback by granting them access to their stored device for a short period of time.

The weight sensors in the two prior subsystems act as entry gates for the Eye Tracking software, preventing the software from being circumvented or tricked.

V. Hardware Overview

A. Microcontrollers

After researching different computational devices, we ultimately chose the Texas Instruments MSP430G2553 for both the lock box and the chair module.

One of these microcontrollers (MCUs) will be housed in the lock box and the other will be housed in the chair module. The MCU in the lock box will be connected to the user's computer via a USB cable. This will be able to power the device and allow for communication between the MCU and computer. This MCU will be responsible for controlling the electromagnetic lock on the lock box and the LEDs on the box. It will also receive input from the pressure sensor inside the box and communicate with the second MCU in the chair module wirelessly via Bluetooth.

The second MCU, housed in the chair module, will control the vibration motors and receive input from the weight sensors. The data from these weight sensors will be sent back to the main MCU to signify if a person is seated in the chair or not.

Since we chose the MSP430G2553 as our microcontrollers, we were able to perform testing on the TI LaunchPad Development Board using Code Composer Studio. We were also able to program the chips on our PCBs by using the built-in emulator on the LaunchPad.

B. Bluetooth Modules

In order to communicate between the lock box and the chair module, both microcontrollers will be connected to an HC-05 Bluetooth module. This module allows the MCUs to tell each other when someone is seated in the chair and when to activate the vibration motors. The Bluetooth modules use UART to communicate information back to the microcontroller.

Table 2 shows the pin configurations for the HC-05 Bluetooth module used in the Concen-Training system. The Enable/Key pin is used to switch between data mode and command mode. In data mode, or operating mode, is used to send and receive data between devices and is the default mode. The command mode is used for changing the baud rate, password and name of the device. By default, the name of the device is HC-05, the password is 0000 or 1234 and the baud rate is 9600.

The HC-05 is connected to both MCUs in the same way. Ground is connected to ground on the MCU and VCC is connected to 5V. The receiving pin, RXD, is connected to P1.1 on the MCU and the transmitting pin, TXD, is connected to P1.2 on the MCU.

To test these modules, we used Arduino IDE. We were able to pair the modules (one as the master and one was the

TABLE 2
HC-05 PIN CONFIGURATIONS

Pin Number	Pin Name	Description
1	Enable/Key	Toggle between Data mode (set low) and AT command mode (set high). Default is Data mode
2	Vcc	Powers the module. Connect +5V supply voltage
3	Ground	Connect to system ground
4	Tx - Transmitter	Transmits Serial Data
5	Rx - Receiver	Receives Serial Data
6	State	Connected to an on board LED, can be used to check if Bluetooth is working properly
7	LED	Indicates status of module
		Blinks once in 2 sec = Command Mode
		Repeated Blinking = Waiting for a connection in Data Mode
		Blinks twice in 1 sec = Successful connection in Data Mode
8	Button	Used to control the Enable/Key pin to toggle between modes

slave). We were also successful at communicating between the two in the following way. One Arduino Mega was connected to a push button and an LED and an Arduino Uno was connected to a separate push button and LED. When the button connected to the Mega was pressed, the LED connected to the Uno would light up and vice versa. Although we got this to work, the connection was slow and inconsistent. One of the LEDs flickered most of the time and both had a varying delay between the button press and illuminating.

We are working hard to get a stable, working connection between our two PCBs using CCS, but are unsure if it will be possible in time. In order to have a working prototype, other methods are being considered, such as having a series of wires connected between the two PCBs to allow for the information to be transferred between the two systems.

C. Motors

The vibration motors contained within the chair module are key elements in our design as they are the primary method of negative reinforcement that will alert the user when they have lost focus for a prolonged period. With this in mind, we needed to choose vibration motors that are durable enough yet small enough to be contained completely within the chair module, while also having a strong enough vibration for the user to feel when alerted.

Upon researching potential candidates for vibration motors, we decided on using DC eccentric rotating mass (ERM) motors. This style of motor was easily available in sizes that would both fit within the chair module and create a strong enough vibration to alert the user. The motor that we used in our design is encased in a hard plastic shell, making it more robust and easier to implement within the chair module, as we do not have to worry about anything impeding the rotation of the eccentric mass.

D. Phone Weight Sensor

Inside of the lockbox, we wanted to have a weight sensor that would be able to detect when the user's phone was present inside and use that information to know when the box should be locked. Since this weight sensor would only be measuring the weight of a cell phone, we did not need to use a weight sensor that is designed for reaching weights that are much greater than a phone's weight. Also, we needed a sensor with a thin profile that could easily fit in the size of the lockbox.

Upon researching multiple options, we decided to utilize a material called velostat to create our own weight sensor. Velostat is a paper-thin material with piezoresistive properties, meaning that as more pressure is applied to it, the resistance across it changes. In the case of our sensor, the velostat was placed between two layers of card stock. On the sides of the card stock that touch the velostat, layers of copper tape were attached to act as conductive surfaces. A wire on one surface was attached to a supply of five volts, and a wire on the other surface was attached to a pin on our microcontroller that would function as an analog-to-digital converter. The voltage read on this surface was converted into a value between 0-1024.

Upon testing our sensor, we found the sensor to have a reading of approximately 750 when no weight was applied to it. When we placed the lightest cell phone of all our group members (iPhone 8 weighing approximately 0.32 lbs.) on the sensor, the reading went up to approximately 850. Using these values, we determined a reasonable threshold reading to know when a phone was present or not would be 800. This value was used in our program to determine when the user's phone was placed inside the lockbox.

E. Chair Weight Sensor

In the chair module, there is a weight sensor that would determine when the user was seated in the chair. This information was passed on to the computer to let the program know that the user was ready to begin their study session. Since this sensor would be measuring the weight of a human, we needed a sensor that would be able to read human weight.

After researching different options of weight sensors, we chose a set of four strain gauge load cells, each of which being able to read up to 50 kg (about 110 lbs.). When all four load cells are combined, they can read weights up to 200 kg (about 440 lbs.). The load cells were connected to an HX711 amplifier circuit, which acts as an analog-to-digital converter, making it easier to integrate the load cells with a microcontroller to read weights.

In the end we were unable to get these weight sensors working. Instead of completely getting rid of the weight sensor in the chair module, we chose to use the same method used for the lock box. This will essentially provide the same effect by alerting us if a person is sitting in the chair or not, however, we will not have an accurate weight reading.

F. Eye Tracker

When choosing an Eye Tracker for this project there were three main choices.

Our first choice was to save time and increase accessibility by creating software that would work using the average webcam. Since most students already have a webcam, this would be a big convenience.

Our second choice was to sacrifice time and money but focus on ingenuity and design our own eye tracker. Though difficult, this would certainly have been a very impressive feat.

Our third choice was to purchase an infrared eye tracker from an established company. This was the final choice made for a few reasons. Our first choice, although cheap and accessible, presented many inconsistencies in the quality of the webcams students may have. Even the best webcams on the market cannot compare to Infrared eye trackers in terms of quality and reliability. Though the purchased eye tracker was not cheap, it was certainly affordable for the massive increases in quality and consistency it provided.

The reason we chose not to design our own eye tracker was reached after evaluating the purpose of this project. Though this project features an eye tracker, the primary objective is to design a system of hardware and software to create a new and unique use case for an eye tracker. Designing an eye tracker of our own that would come close to the quality and consistency of established eye trackers would have taken the entire length of the project time available to us if not more and at the end we would simply have another version of an existing product on the market rather than something new and innovative. It was also determined that the costs associated with creating our own infrared eye tracker would be significantly higher than buying an established eye tracker.

Among established eye trackers, our team chose a company called Tobii for their Eye Tracker 5. Tobii has a long history using eye trackers in both research and entertainment and has designed lines of eye trackers that are easy to use for gamers and students which made sense given the target market of this project. The Eye Tracker 5 is the latest in their line of eye trackers for gamers. Their other major line of eye trackers is known as Tobii Pro and it is their research grade eye tracking hardware, however, due to costing thousands of dollars our team deemed the research grade eye trackers too expensive to consider.

Though the Tobii Eye Tracker 5 is intended for use by gamers as an entertainment device, Tobii has full support for those interested in programming for the device and has a free software development kit as well as support in multiple programming languages. This versatility and ease of access was another reason the Tobii Eye Tracker was chosen for this project.

VI. Software Overview

A. Eye Tracking

The Tobii company, to support their Tobii Eye Tracker 5, created support for programmers in three languages, namely C, C++ and C#. Because of the role of C programming in Microcontroller code, the decision to use C programming for the eye tracking code as well was easy.

The program works using a series of timers and flags. There are 2 main timers, one that controls the total time the user would like to spend focusing and another to measure any time the user spends looking away from their computer screen. If the user's eyes are looking at the screen the first of these two timers will be counting down, but any time the user looks away the count will stop and wait for the user to resume looking again. When the count reaches zero for the primary timer, the eye tracking program will end and the lockbox will be sent a signal to unlock, allowing the user a break from their task as a reward for time well spent.

When the user looks away the second counter will count down from a preset value and if the second counter reaches zero, a Bluetooth signal will be sent to the microcontroller in the chair module to vibrate the user's seat and remind them to focus.

B. Microcontrollers

The microcontrollers being used are from Texas Instruments and are part of the MSP430 family. TI offers their own IDE designed for projects using these microcontrollers called Code Composer Studio (CCS). This

IDE supports C/C++ and we will be using C to write programs for our microcontrollers.

C. Bluetooth

To program the microcontroller to receive bluetooth commands via the HC-05 module, C programming was used alongside Code Composer Studio and the Energia IDE for easier communication between PC and PCB. To connect the eye tracking code to the microcontroller several options have been explored including BlueZ and Bettercap in C programming on Linux and PyBluez in Python programming on windows. Though each of these solutions has strengths and weaknesses, our team is working hard to find the solution that best fits as many devices and operating systems as possible.

If necessary, we will create a wired connection between the lock box and chair module to avoid having to use Bluetooth at all. While this would be a last resort, we are willing to make this change if necessary to create a working prototype of our design.

D. User Interface

In order to make the UI more intuitive and presentable, a Java GUI (graphic user interface) was created so that users of the product could activate the eye tracker by clicking a button rather than by having to interact with any code directly. Adjusting the settings of the eye tracking code is also done via this GUI for simplicity for the user.

VII. Board Design

There are two major subsystems for this project that require custom printed circuit boards: the smartphone lock box and the vibration chair module. Both share certain circuitry characteristics while retaining differences for respective functions.

A. Shared Characteristics

Both custom PCBs utilize a similar switching mechanism: the MOSFET switching circuit. Included in this design is a power grade MOSFET (N-Channel), a pull-down resistor to protect the current intake at the gate of the MOSFET and a flyback diode used to protect the element being switched. This MOSFET switching circuit allows for higher voltage components to switch on and off rapidly with little room for mechanical fatigue. In addition, a MOSFET driver is implemented to up the gate voltage of the MOSFET switch to an acceptable range, allowing the switch to toggle appropriately. This was essential to include since the 3.3V signal from the microcontroller pin is not enough to activate a MOSFET; the driver is able to increase it to around 5V.

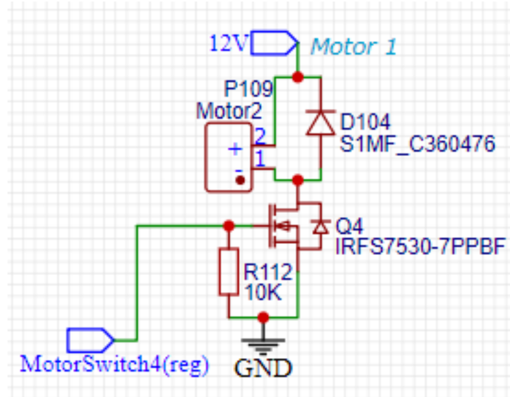


Fig 1. MOSFET Switching Circuit

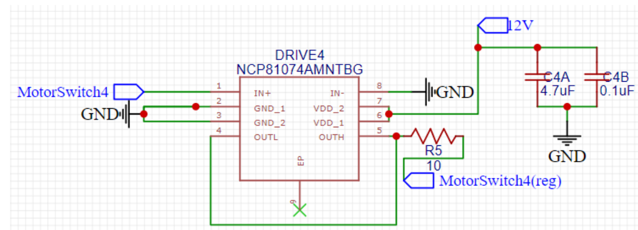


Fig 2. MOSFET Driver Circuit

This circuit can be applied to any 12V operational device to our knowledge, as they work with our 12V vibration motors and magnetic lock. A 12V battery is needed to supply power to the component in question, as well as to the MOSFET driver circuit component.

Both circuits also contain designations and pins for Bluetooth communication, as well as open pins for testing, programming and any possible alterations to the design post fabrication.

B. Smartphone Lock Box

The Smartphone lockbox is connected via USB to power the microcontroller straight from the computer. For the microcontroller to receive sufficient operating power, a 5V to 3.3V 1A converter, as crafted through Texas Instrument's WEBENCH design tool, was utilized, as seen in Figure 3.

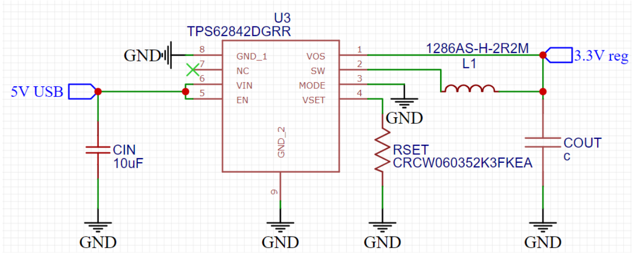


Fig 3. Maglock Board 5V – 3.3V 1A DC-DC Converter

The bluetooth module runs on 5V power, so this is supplied directly from the USB's power pin.

In addition to this, a simple LED notification circuit was crafted, consisting of a collection of parallel LEDs connected to their respective pin in order to notify the user of the beginning or end of their smartphone break.

Lastly, a small circuit for the smartphone lockbox weight sensor was crafted, consisting of a diode connected in parallel to ensure an analog reading is generated and readable by the microcontroller.

C. Vibration Chair Module

Unlike the maglock board, the chair vibration module is designed to be completely remote and solely powered by a 12V battery pack. Therefore, 2 different DC-DC converter circuits were utilized to step down the voltage to appropriate levels. Again, utilizing the Texas Instruments WEBENCH Design tool, a 12V to 3.3V 1A converter was utilized to step the voltage of the battery pack down to a level operable by our microcontroller device. A simple 12V-5V DC-DC converter, utilizing an LM1117 chip was used in order to have power operable by the Bluetooth device. As a precaution, a small section of this PCB was dedicated to another LM1117 chip, but for a 5V-3.3V conversion, as a back-up plan in case the original converter was inoperable for whatever reason.

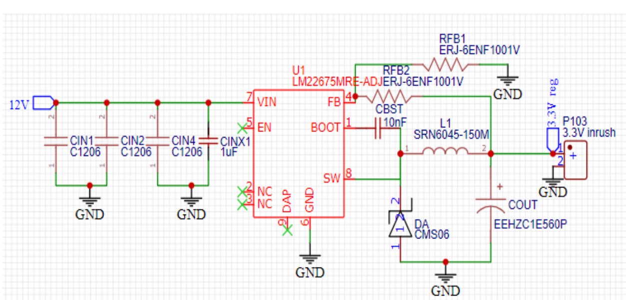


Fig 4. 12V – 3.3V Power Converter

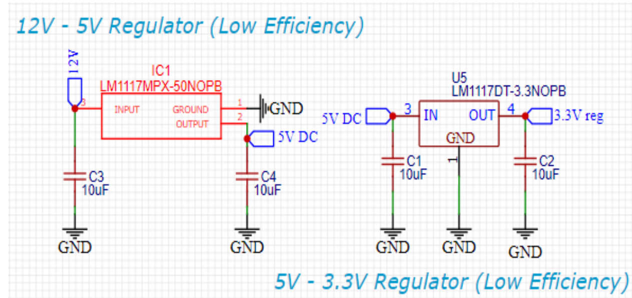


Fig 5. 12V – 5V & 5V – 3.3V Power Converters (Low Efficiency)

In order to utilize the weight sensor gate feature of the chair, a circuit for the weight sensor was integrated into our PCB design, as seen in Figure 6. The primary proponent of this circuit is the HX711 chip, utilized for standard pressure sensing applications, such as in food scales. The component layout for this circuit is provided by Avia Semiconductor.

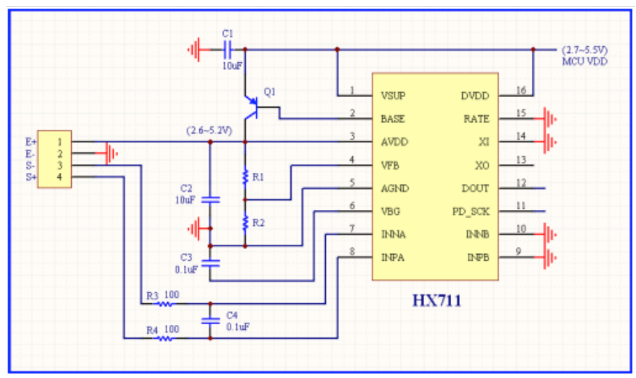


Fig 6. Analog-to-Digital Converter for Weight Scales

VIII. Integration Difficulties

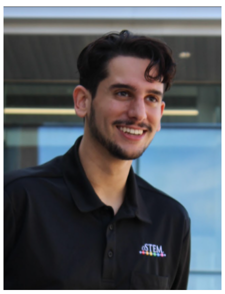
After successfully testing all our components individually, a few problems were encountered while attempting to integrate all components into on functions Concen-Training System. Therefore, a series of design alterations were made in order to yield a functioning prototype. One major decision was to cut out the Bluetooth aspect and hard wire the PCBs together. Although this was not ideal, it was necessary given the time constraints of the class. Another decision, made for the same reasons, was to swap out the chair weight sensor for the same method used in the lock box: a velostat sensor.

VIIII. Conclusion

The previous sections describe the key elements needed to create a functioning Concen-Training System prototype.

Throughout the year this project was worked on, the trials and tribulations of working in the engineering field were experienced by all members of the team. Some gained experience through working in hardware and PCB design, while others expanded their skillset in software design and coding. In the context of soft skill building, all members of the team were able to work together to achieve the end product, therefore training their own interpersonal skills in a professional environment. The members of the Concen-Training System Senior Design Team showcase their engineering gusto in their ability to adapt and devise new solutions, as seen in the various design revisions.

THE ENGINEERS



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