U.P.R.I.G.H.T.

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***Abstract* — This document details the design and functionality of the UPRIGHT (User Position Recognition Integrated Guiding Height Table). The purpose of this project is to address the significant issue of workplace injuries caused by prolonged sedentary behavior in office environments. The UPRIGHT desk automatically adjusts its height based on whether the user is sitting or standing, using a webcam for facial tracking and a weight-sensitive mat for accurate detection. The system is enhanced by a mobile application that communicates via Bluetooth, allowing for user profile customization, ergonomic reminders, and real-time updates. The desk is equipped with linear actuators, an LCD screen for displaying key information, and manual controls for height adjustments.**

Index Terms — Microcontroller, Motor Driver, AC/DC Power Converter, Object Detection, Bluetooth, Automation

I. Introduction

The design of our project began with the desire to create something practical and beneficial for everyone in our group. As engineering students, we spend a significant amount of time at desks or behind computers. Workplace ergonomics are crucial to us, so we aimed to create a solution beyond a typical standing desk. This is how our idea was born.

A study on musculoskeletal issues among office workers concluded that lower back pain is a common problem for those with at least one year of experience, with an incidence rate ranging from 23% to 38% [1]. It is also the most common cause of work-related disability in people under the age of 45[2]. Since we are likely to spend our careers in office environments, this issue was of great concern to us.

Existing standing desks lack special features that make the transition process seamless and provide users with tools to track and monitor their daily use. Our desk, the UPRIGHT, is designed to automatically adjust its height depending on whether the user is sitting or standing. This is achieved through a system that includes a webcam for facial tracking and a weight-sensitive mat to accurately detect the user's presence and position.

We chose to incorporate both the webcam as well as the weight sensitive mat in order to minimize false positives and ensure the desk transitions only when the user intends. This dual-detection system prevents the desk from moving unnecessarily.

A prominent feature of the UPRIGHT system is its mobile application, which enhances user interaction and customization. The app allows users to set and save their preferred sitting and standing heights, receive ergonomic reminders, and monitor their usage statistics. Bluetooth connectivity ensures seamless communication between the desk and the application, providing real-time updates and control.

Our desk, designed and constructed from scratch, ensures smooth and precise adjustments through the use of linear actuators. An LCD screen, placed for easy visibility, displays important information such as the current desk height, and connection status. Manual controls are also available, allowing users to adjust the desk height or toggle automatic features as needed. This project not only addresses the immediate need for a healthier workspace but also aims to improve productivity and well-being among office workers.

No other product on the market combines all these features, and we seek to fill this gap with a specialized standing desk like no other. We have achieved the goals set for this project, focusing on encouraging users to alternate between sitting and standing during their workday with minimal effort or hassle.

II. Engineering Requirements

Keeping in mind the desired end goal for our project, the group decided on a series of design specifications that would show effective operation of the desk. These decisions were made in order to illustrate that the project would be able to cater to a wide range of potential users.

The table below illustrates the key engineering specifications with quantitative measures for parts that will be used to construct the desk. These three specifications will be demoed live at the end of the semester.

TABLE I
KEY ENGINEERING REQUIREMENTS

System(s)	Value
Vertical Adjustability System	25 mm/sec
Weight Sensing Functionality	90% Accuracy
Face Tracking	80% - 90% Accuracy

The vertical adjustability system is responsible for providing the up/down action for the legs of the desk. The weight sensing functionality in conjunction with the facial tracking, is used to accurately detect whether the user is standing up or sitting down.

II. System Concept

Detailing the concept of how the UPRIGHT operates is important. A software block diagram helps to illustrate the overall predicted actions of the system.

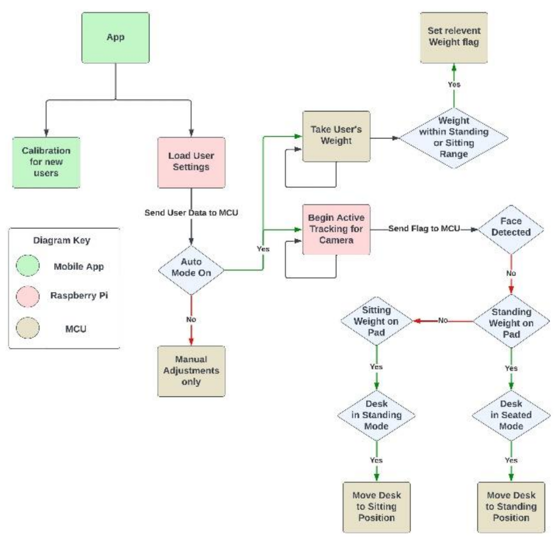

Fig. 1 Software Block Diagram

The process first starts when the user connects to the desk through the mobile application. If the user is already registered, this will prompt the app to send the user's personalized settings for desk sitting and standing height, as well as references for the weight on the standing pad when the user is sitting or standing to the Raspberry Pi. If the user connected to the app is a new user, they will be prompted through a calibration process where these data values will be collected and stored for future use.

We will then ensure the user wants to use the automatic features of the desk. If so, we begin active tracking of the user. The Raspberry Pi is responsible for facial tracking via the webcam, which will continuously send a flag to our MCU indicating if a face is detected at the desk. At the same time, the standing pad will be measuring the user's weight and, based on whether this correlates to their specific standing or sitting weight, will raise a relevant flag.

Under normal conditions, if a user's face is within view of the webcam, no action needs to be taken. When the user stands from a sitting position, their face will no longer be in view, and the same applies when moving from a standing to a sitting position. The only exception to this is when the user first connects to the desk after someone with different height settings used it. In this case, their face might still be in view, but the desk wouldn't be exactly at their personalized height setting.

If no face is detected, we will check to see if there has been a change in the weight detected by the mat. If the desk was standing, but now there is a sitting weight on the pad, it will transition to sitting mode. Conversely, if the desk was sitting, but there is now a standing weight on the pad, it will rise. The desk will move up and down quickly, adhering to our engineering specification for the actuators, to ensure a seamless and timely transition. The facial tracking and weight sensing functionality work together to ensure the desk only moves when intended. This cycle will continue until the user disconnects from the app or manually turns off the auto feature through one of the physical buttons on the desk.

IV. PCB Design & Overall Schematic

The PCB for our project was responsible for powering all the required components on the desk including the actuators, load cells, and included peripherals. The desired functionality was achieved by wiring the pins from the MCU with the corresponding components on the desk. A more detailed breakdown of each component has been included in this section.

A. Linear Actuator ADC Connections

The linear actuator ADC connections on the board were provided in order to make it possible to take the readings from the internal potentiometers on the actuators. This was accomplished through the use of the ADC pins on our microcontroller. ADC functionality was needed for our project so that the position of each leg could be tracked by our MCU. Higher values from the ADC correspond to higher desk leg positions. Multiple users will require different height settings, so having a reliable way to track these values ensures that our project will meet the requirements for automatic functionality. We were able to achieve this by providing a voltage across each ADC pin to get a corresponding resistance value from the potentiometers.

B. Off-Board Buttons

The off-board buttons on our PCB will be responsible for providing manual control of the desk height. One button will be used to move the desk up and one button will be used to move the desk down. The third button will be included for pairing Bluetooth and for turning on and off the automatic functionality of the desk.

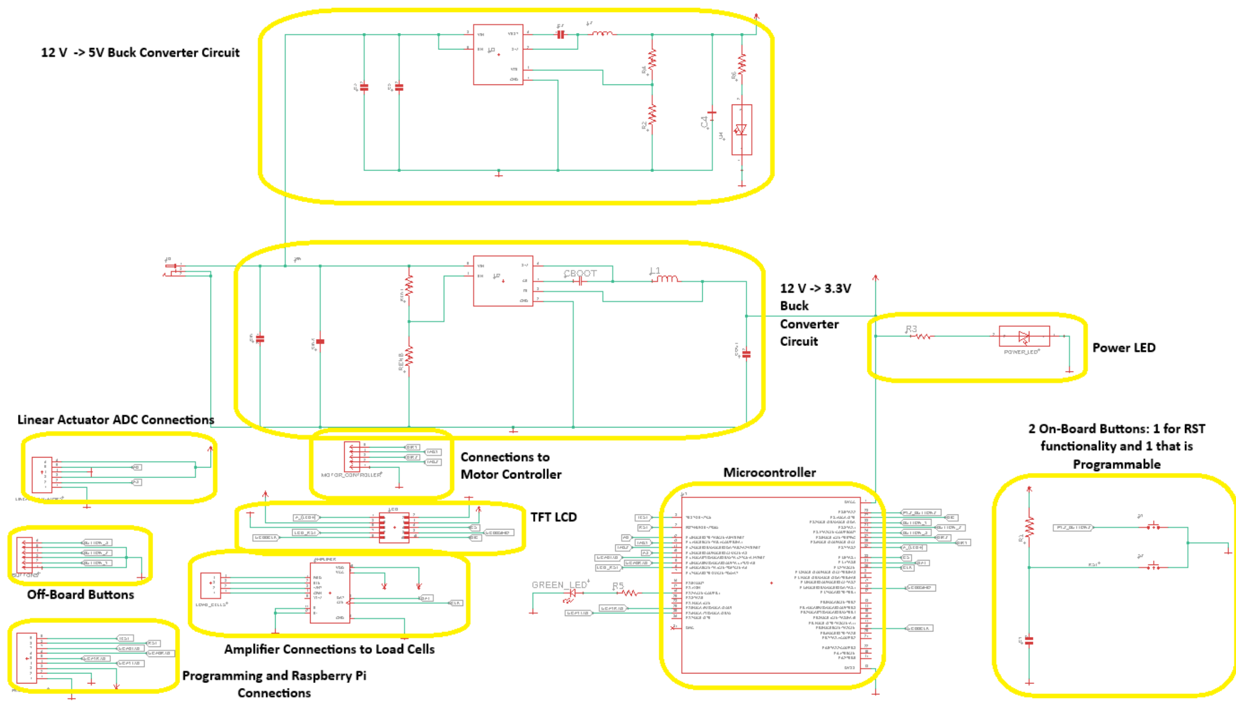

Fig. 2 Overall Schematic

C. Programming and Raspberry Pi Connection

Headers were included on our PCB for programming of our MCU as well as Raspberry Pi communication. The programming is achieved by interfacing the ez_FET Onbaord Emulator of our development board with the MCU for convenient loading and debugging of software. This is done by connecting the TEST/SBWTCK pin, the RST/NMI/SBWTDIO pin, and ground pin between both devices. We also have RXD and TXD pins for Raspberry Pi UART communication.

D. Connections to Motor Controller

Connections to the motor controller were responsible for wiring the actuators to the controller and from the controller to the MCU. DIR1 and DIR2 are responsible for providing the direction inputs for the two actuators. The other pins on the headers are connected to PWM1 and PWM2, which are responsible for the speed control of each actuator. In addition to this, the final pin on the header is reserved for ground, to ensure that both the controller and the MCU share a common ground.

E. TFT LCD

The TFT LCD for our project was chosen to display relevant information to the user to improve the functionality of our desk. Information that can be shown on the LCD includes the height of the desk and Bluetooth connection status. Decisions that were made for our LCD were ensuring there were readily available libraries and drivers for our chosen MCU as well as making sure the supply voltage for the LCD was compatible with the logic supply for our MCU. In addition to this, considerations were made concerning the current draw of the LCD to ensure that power consumption was kept to a minimum.

F. HX711 Connections to Load Cells

The connections here are responsible for allowing us to interface our load cells with the microcontroller. This was accomplished through the use of the HX711 24-bit ADC and amplifier module. The module was used to retrieve digital readings from the load cells and amplify them to be read clearly by our MCU.

G. Power LED

This part of our schematic is wired from the output of our buck converters. These are so that the LEDs light up when the board is plugged in to determine proper operation of the voltage regulators and board.

H. MSP430FR2476 Microcontroller

The MSP430FR2476 was responsible for interfacing the Raspberry Pi, load cells, actuators, and other peripherals, such as the LCD. Our chosen MSP430 was picked for its ample 48-pin package to support the multiple components connected to it, 12-bit ADC capability to handle the values from the internal potentiometers in our actuators, and low current draw in the active mode (135uA/MHz) which led to low power consumption at its 3.3V supply.

I. On-Board Buttons

These were included on the board for differing purposes. One is directly wired to the reset circuit of the MCU so that clicking the button resets the code loaded on the PCB, while the other one has been included for general purposes such as debugging during development.

J. Voltage Regulators

Texas Instrument's Webench was utilized in the selection and design of the buck regulators. Switching topology was chosen for its overall efficiency, however the number of components and footprint were the ultimate factors in deciding upon a specific IC. The main reason for this was the low power consumption of the PCB components needing 3.3V or 5V, (Less than 30mW) eliminating the need for strict thermal management. Ultimately the TPS561208DDCR was chosen for the 5V output, and the IC chosen for 3.3V output was the TPS560430X3FDBVR. [3]

V. Facial Detection

Detecting the user is important in determining when the desk should automatically transition between sitting and standing. This will be used as an additional check in conjunction with the sensing mat. This software will be executing on the Raspberry Pi and will be used as the main communication relay between the MCU and the mobile application.

E. Raspberry Pi 4

The project goal is to create a smart ergonomic tracking desk. One such feature discussed was to determine if a user is present using facial tracking. The software and library selected was face_recognition library which is an open course library aimed at face tracking and recognition. To run the facial tracking software, Raspberry Pi 4 was selected because of the wide capabilities, price, no need of CUDA, team experience with the device and the community support.

F. Raspberry Pi 4 software Design

There are three main scripts that will be running on the Raspberry Pi 4. The initialize script always runs on the startup of the device. This script will act as the trigger that will start the rest of the scripts. The purpose of this script is to provide automation to the software that will run on the device. Any additional function can be added to this first script if there needs to be additional features in the future. Next, two scripts will be launched. The order of launch does not matter but they both need to be running for the system to be working correctly.

One of these scripts is for facial tracking. The open-source libraries used for this portion will be preinstalled on the device. Face_recognition is dependent on the dlib library and was also installed at the same time. Lastly the OpenCV library was used to access the camera and video feed for processing. Together all three of these libraries are used in the facial tracking script to determine if there is a user present at the desk. This information will then be sent to the MCU for additional processing.

The next script that will be processed is the Bluetooth connection script. It's main purpose is to automate the Bluetooth connection between the user's device and the Raspberry Pi. This script will also be used for processing, sending, and accessing information between the two devices. The main data that will be transferred during this process is the height of the desk and the save presets that were stored in the online database.

G. Facial Tracking Software

This portion of the project is going to be running on Raspberry pi so the software selected was picked with this device in mind. Face_recognition is simple and lightweight with an accuracy of 99.38%. The purpose of facial tracking for this project is as an additional check on whether the user is sitting or standing. To accomplish this, we only needed simple facial tracking and had no need for some of the additional computer vision capabilities that some of these other libraries provided. OpenCV and Dlib will also be used in this project but won't be the main source of the tracking. OpenCV will be used to access the camera and Dlib library is used by face_recognition library.

VI. Desk Design

Design for the Upright began with the procurement of treated lumber and a pine tabletop, making for easy staining. Regarding the desk's movement functionality, each side of the desk used (2) 24" pieces of lumber that were placed together and connected with a 24" ball bearing drawer slider for smooth transitions as the desk moved. Diagonal braces were added for overall stability and aesthetic appeal. The top side of the desk was supported by a 4' piece of lumber and a cross section of (4) 2' wooden ribs. Both linear actuators were designed for mounting to the stationary portion of the desk legs, while the actuators' shafts would extend the other portion of the desk leg connected to the tabletop.

A plastic junction box, mounted to the underside of the desk, held the PCB and motor controller. While the Raspberry Pi came with its own enclosure, it was mounted next to the PCB. All wiring was strategically placed and securely fastened to the underside of desk to minimize exposure to the user. Coiled cords were utilized for easy transitions of the desk from sitting and standing positions to avoid any stress on the wiring. The standing mat was installed with a 4-pin lead for a quick connection with a coiled cable deriving from the PCB. The overall range of movement for the UPRIGHT began at the lowest sitting position of 29" and extended to a maximum of 47". This range should comfortably accommodate users with a height of 5 foot to 6 foot, 4 inches. The completed version of the desk can be seen in the picture below.

A custom housing to hold the LCD and three push buttons will be positioned on the right underside of the desk for easy access for the user.

Fig. 3 Completed UPRIGHT Standing Desk

VII. Application Design

Conveying information and saving user data is crucial for this project design because the weight sensing pad requires an initial calibration. For this a mobile application was created so that the user can walk through the process of calibrating the desk and at the same time this information will be saved to an external database. This data will be loaded for the next time the user signs in to the desk.

A. Frontend Application Functionality

The mobile application is going to be used as the main median between the tracking system and the database. To be able to service different users there needs to be a way to differentiate between everyone. One such method is by creating an account system that is tied to the email of the user. This will allow each user to be able to connect to the desk and save their settings. The frontend was created using flutter which uses the Dart programming language.

When the application is opened it will start out on the landing page. From here there will be two options available to the user. One of the options is the user sign-up page that can be used to create a new account. The other option is the login page. After signing up, the user will be able to login into the application. Initially they will be marked in the system as a user that still needs to complete the initial setup.

The setup starts with connecting the application to the desk through Bluetooth. This step was chosen as the initial setup screen because the application needs to be able to communicate with the desk to receive information. Once this step is completed the screens will move to the setup steps for the heights and the weight sensing pad. There will be four pages for setup that will be used for sitting height, sitting weight, standing height and standing weight respectively. On each of these pages the user will be prompted to interact with the desk using the buttons and then retrieve the values from the desk through the app. Once satisfied with the calibrated weights and heights, the users will have the option to save each of these values separately. After these initial setup steps are completed, the user will be redirected to the home page. In the system, the user will then be marked as a returning user and in the future will be directed to the home page of the application every time once they login.

The user will automatically land in the metrics page which will serve as the home page. This section will have four total tabs including the metrics page. This page will display the total amount of time that the user spends in each position. The next tab available to the user is setting reminders to change positions. This will work as a push notification system. The user can set a specific reminder to send a push notification to switch positions. The third tab available to the user is the desk settings page. This is to allow the user to save new height preferences for sitting and standing. As preferences change the user may want to set new height presets for ease of access.

The next tab that will be available to the user is the ability to update user and system information in the settings tab. This includes updating the user's name and email. Another setting that will be available on this screen is the ability to connect to a new desk. While there is going to be only one desk for this project, this was designed with the idea that it could potentially be used for multiple expansions. This setting will also give the users the ability to reconnect to the desk if the connection was lost for one reason or another. The settings tab will also have the option to log out of the application.

B. Backend Application

The backend for UPRIGHT was created using the Express framework and NodeJS. These handle the routes to communicate between the frontend and backend. For the database MongoDB was used to store user information and settings. To deploy the server Heroku was used. This allows the backend to be accessible by the application from any device.

VIII. COMMUNICATION

The two communication protocols we will be using for our project are UART, which stands for Universal Asynchronous Reception and Transmission, and Bluetooth. The UART communication will be for serial communication between the Raspberry Pi and the MSP430. Bluetooth will be for wireless communication between the mobile application and the Raspberry Pi.

A. UART Serial Communication

When it came to deciding on a communication protocol between our MSP430 and the Raspberry Pi, UART was the clear choice due to its simplicity and compatibility on both sides. UART is capable of sending and receiving one byte of data at a time. It was critical to ensure reliable communication for both receiving and transmitting data between both devices.

There are three distinct states that determine the data sent between the two devices. They are new user calibration, existing user connection, and normal operation.

1) New User Calibration: The Raspberry Pi will prompt the MCU at the appropriate time to record either the current desk height, or the user's weight on the standing pad. These values are then sent back one at a time to the Raspberry Pi, which stores them for future use. This process translates to storing values for sitting and standing height as well as sitting and standing weight.

2) Existing User Connection: The Raspberry Pi will send the previously stored data to the MCU to load into its memory.

3) Normal Operation: The Raspberry Pi continuously sends a flag to the MCU indicating if a face is detected by the webcam. It also informs the MCU of an active connection, which can be displayed on the LCD for the user. Additionally, the MCU sends a flag back to the Raspberry Pi whenever the desk transitions, allowing us to track and monitor the time spent in sitting and standing modes for the app.

Each command includes a dedicated value to use as a start byte, ensuring the receiving device knows exactly what to do, whether it is executing a command or processing received data.

B. Bluetooth Communication Design

Bluetooth will be the main communication between the application and the Raspberry Pi 4. The application will be responsible for initiating the data communication for the initial setup of the desk. This information will then be saved in the database and includes the height presets and mat calibration.

IX. POWER

This section will showcase the power requirements for the UPRIGHT, and the chosen design to reliably distribute power to all the various systems utilized within the desk.

A. Power Requirements

Looking through the table below, it can be observed that there are three main voltage levels that need to be supplied for full power distribution throughout UPRIGHT, which include 12V for the linear actuators, amplifier, and webcam, and lastly 3.3V for the MCU, Raspberry Pi and LCD display. Other peripherals that will be controlled by the MCU, namely the buttons, load cells, and linear actuator potentiometers require minimal additional power or will be fed directly from another component. Both the actuators and Raspberry Pi will have a significant max load requirement of 12A and 3.5A respectively, or in watts: 144W and 17.5W. These levels make up the majority of the needed power distribution within the desk. 3.3V will be needed for the electronics, however they will collectively draw less than 10mA and consume 30mW.

B. Power Source

With the actual parameters set, the particular primary source decided upon also needed to consider how it would affect any user interaction. Batteries were not recommended for a few reasons, namely the requirement from the user to charge the batteries as they died. Additionally, because of the power requirements, the actual weight of the needed battery would strain the actuators. Instead, it was decided that the desk would be fed from a 120V AC source that would then be converted down to 12V by an AC/DC adapter. This adapter would need to be sufficiently rated for the entire system.

C. AC/DC Adapter

The major consideration for the adapter came down to wattage rating and linear vs switching converters. Linear converters were chosen because of the lack of noise generated, while switching converters could distract or annoy users with the sound that they generate, even if it is only a slight disturbance.

TABLE II
SYSTEM HARDWARE RATINGS

Design Parameters	Rated Voltage and Rated Current
Raspberry Pi 4B	5 V 2.5 – 3 A
Microsoft LifeCam HD-3000	5 V 0.5 A
Linear Actuator #1	12V 1.5 – 6A
Linear Actuator #2	12V 1.5 – 6A
Motor Controller: Cytron Model # MDD10A	Motor: 5 – 30 V Logic: 3.3 – 5 V Max Continuous: 10 A Max Peak: 30 A
MCU: MSP-430FR2476	1.8 – 3.6 V 135uA/MHz Active Mode 0.66uA (typical) Standby 0.37uA (typical) Shutdown
LCD Display: CFAF128128B1-0145T	2.7 – 3.3 V -Supply Current for LCM 1.7mA Typ, 2.55 Max mA,
HX711 Amplifier	2.6 – 5.5 V Normal Operation: 1.5mA Power down mode: 1.0uA

Regarding the wattage rating, the overall system power requirements around 160W were the bare minimum. Selection of this watt rating could lead to overheating and damage if the system was under full load for an extended period of time. To circumvent any possible issues, a regulated linear adapter was chosen with the ratings of 240W/20A. This provided safety assurance for the adapter, while the specific model chosen also included short circuit protection and automatic thermal and overload cut-offs. [4]

D. Distribution Design

Power distribution was critical in relation to the PCB design. In order to limit large amounts of current flow within our PCB, the design separated all the main power consumers from the printed circuit board. For this reason, the Raspberry Pi and webcam were fed directly from their own 5.1V/3A USB-C power supply. However, this approach would require two separate power cords. Overall power for the UPRIGHT was still provided via 120V typical AC duplex outlet from the wall. However, to eliminate the need for two cords, the solution included the integration of a 120V/20A NEMA 5-20R duplex receptacle that was mounted underneath the desk where both the USB-C power supply and AC/DC adapter could both plug in. From that point the main adapter was connected to an insulated 6-screw terminal that split the power distribution between the actuators and the PCB.

E. Voltage Regulators

Buck voltage regulators were utilized to drop the 12V input to the 3.3V and 5V levels needed for the various PCB components. The design came down to two regulator topologies, switching and linear. Switching regulators' basic design premise is that transistors act as a switch to control the flow of current into energy storage components (capacitors and inductors) in order to transform the input signal to a different voltage. More modern IC chips use high frequency switching from MOSFETs. This method of regulating voltage is much more complex than linear regulators, but the result is a much more efficient circuit regardless of the input to output voltage difference. Linear regulator design allows for a noise-free, stable output build vs. switching regulators. However, their ideal efficiency occurs when there is only a small differential between input and output voltage. As that differential grows, however, efficiency will steadily drop. Take the necessary voltage levels of the UPRIGHT for instance: a 12V to 5V linear regulator will have an efficiency of 5/12 = 42%, while 12V to 3.3V will be even worse: 3.3/12 = 27.5%. Ultimately, utilization of switching regulators maximized efficiency of the desk when dropping the 12V source. After testing and prototyping, it was found that the ripple voltage from switching was tolerable and did not affect other PCB components. [5] [6]

X. CONCLUSION

Our project aims to develop a fully automated standing desk that seamlessly and dynamically adjusts its height based on individual user needs, enhancing comfort and productivity by promoting better posture. By using UPRIGHT, users can avoid injuries and improve their experience with ergonomic desks.

ACKNOWLEDGEMENTS

The authors would like to express their gratitude to the University of Central Florida faculty who generously reviewed this project. We also wish to acknowledge the senior design professors, Dr. Chan, Dr. Wei, and Dr. Weeks, for their invaluable assistance and support throughout this class.

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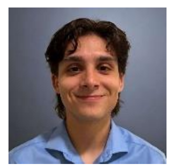
BIOGRAPHY

Mike Dumas Jr is an Electrical Engineering student at the University of Central Florida. He is currently employed as a Project Manager at Royal Electric Co of Central Florida. After graduation, he hopes to continue pursuing a career path in hardware or power design.



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