Detailed Hardware Design

Video-Based Control System for Automatic Standing Desks

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Version History

Revision 2: April 10th

-Included details, comments, and photos on the completed first prototype

Revision 1: February 27th

-Updated references to linear motion sensors to new IR sensors

-Finalized selection of camera

-Finalized exact relay model

Originally Created: December 8th

Our system has three (3) subsystems which require additional hardware to be specified and designed for. The linear actuators and their requisite drive electronics, input button debouncing circuitry, and the camera module that will be used to provide images to the system. These subsystems are highlighted in the high-level block diagram of Figure 1.

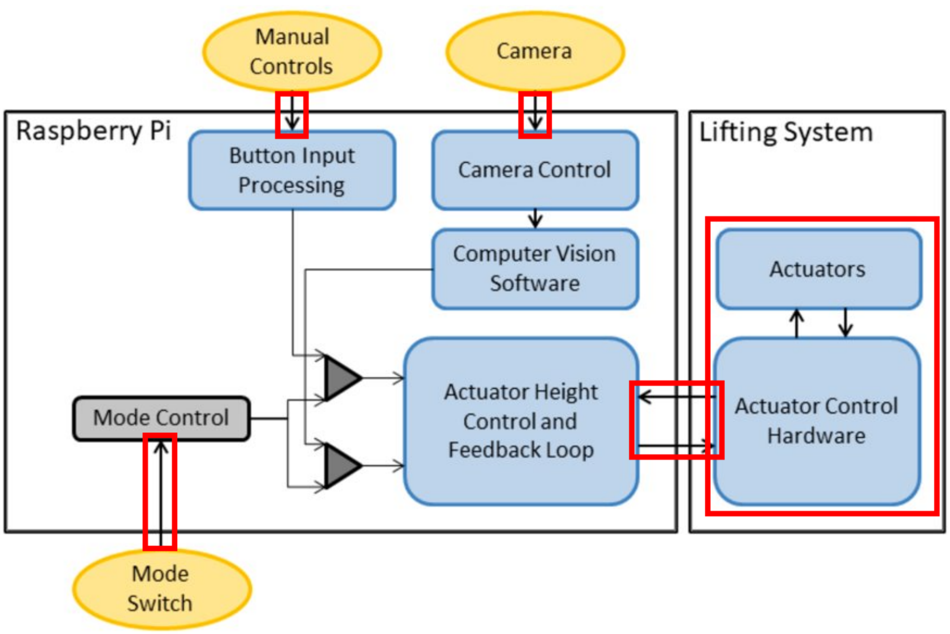


Figure 1: High-level block diagram of the complete system. Hardware dependent subsystems highlighted in red.

System 1: Linear actuator electronics

The actuator electronics comprise all necessary components for powering and controlling the movement of the actuators, and for receiving position feedback from their sensors. A complete diagram is provided in Figure 2. The actuators and a corresponding 120VAC-12VDC power supply are supplied by the school via Michel (the lab tech) and are therefore not a part of our design which we can control. All other components are selected based around these provided components.

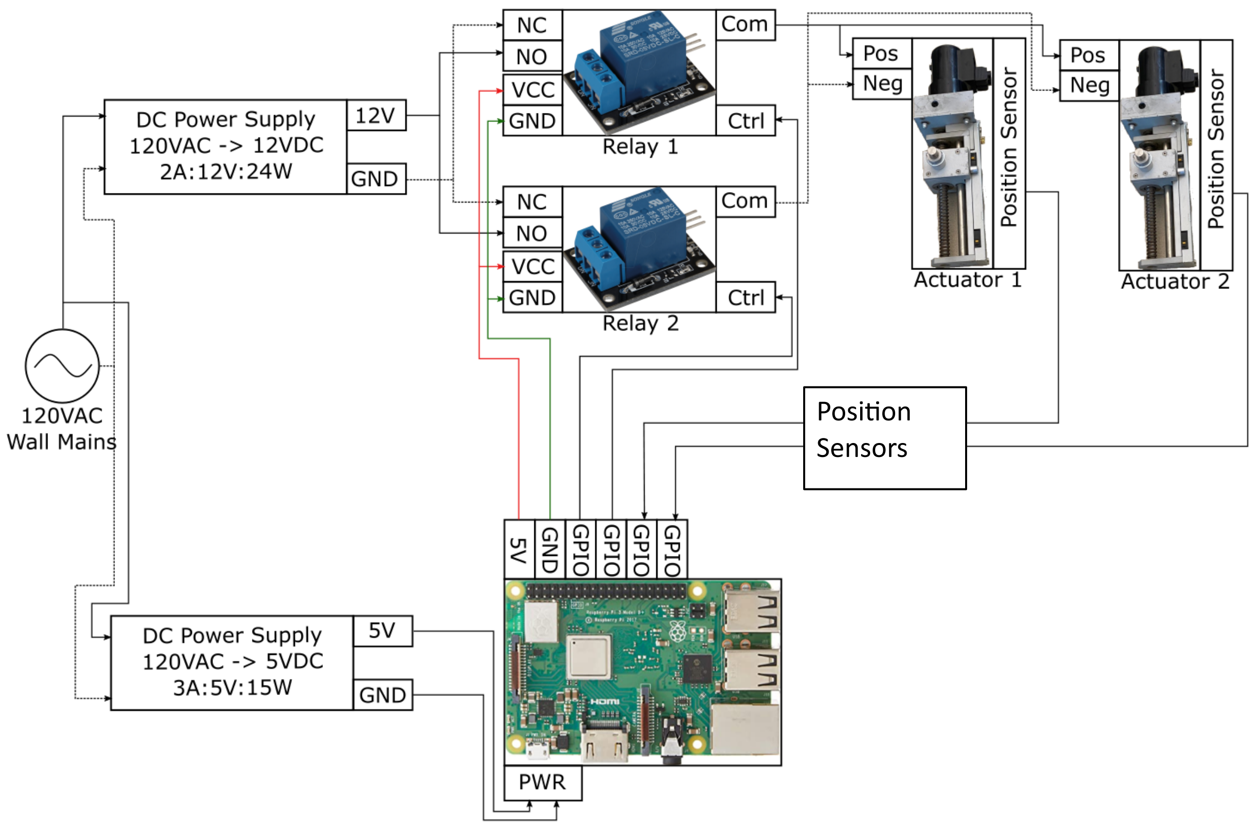


Figure 2: Diagram of the actuator power, control, and feedback circuit

The basic design is 12VDC power, from the 120VAC -> 12VDC supply, is switched to the actuators by a 3V3 control signal from the controller. The configuration of the relays allows for forward, reverse, and no motion states for the actuators, using two GPIO pins from the Raspberry Pi to control their switching. Position data from infrared distance sensors on the actuators is returned to the controller as feedback.

The selected relays are rated for 10A 28V, which is both the smallest we were able to spec for a reasonable price and significantly more than required by the actuators. With their supply only outputting 2A at 12V. The relays are single-pole-double-throw (SPDT) which allows for us to switch not only the on/off state of the power to the actuators, but also to switch the polarity, as seen by the motors. Which is how we achieve both forward and reverse operation.

The relays operate on 5V power, and we use a very simple BJT switching circuit to allow the 3V3 GPIO pins from the Raspberry Pi to be able to switch this 5V power to the relays.

Components

Part	Name	Operating Voltage	Notes
Relays	**Songle SRD-05VDC-SL-C**	**5V**	**5V powered, but switched by 3V3 from the controller via a BJT circuit** **https://www.amazon.ca/gp/product/B07Y8H79Q6/ref=ox_sc_act_title_1?smid=AYCXRUP942PA5&th=1**
Actuators		**12V**	**2**
12V Supply		**120VAC, 12V**	
IR Position Sensors		**3V3**	**2, one for each actuator** **https://www.amazon.ca/dp/B00XAGSWR4?ref=ppx_pop_mob_ap_share**
Controller	**Raspberry Pi**	**5V**	**Model 4 2GB**
5V Supply	**Raspberry Pi Power Supply**	**120VAC, 5V**	

System 2: Input button debouncing

Our controller has several different buttons that it will use for taking inputs from the user. Buttons do not switch smoothly and generate rapid fluctuations when pressed and depressed. To prevent these rapid changes from reaching the controller and causing incorrect inputs to be registered we use a debouncing circuit. We are using a standard RC low-pass filter as our debouncing circuits, with a duplicate of the circuit used for each of the three inputs. The circuit diagram is shown in Figure 3.

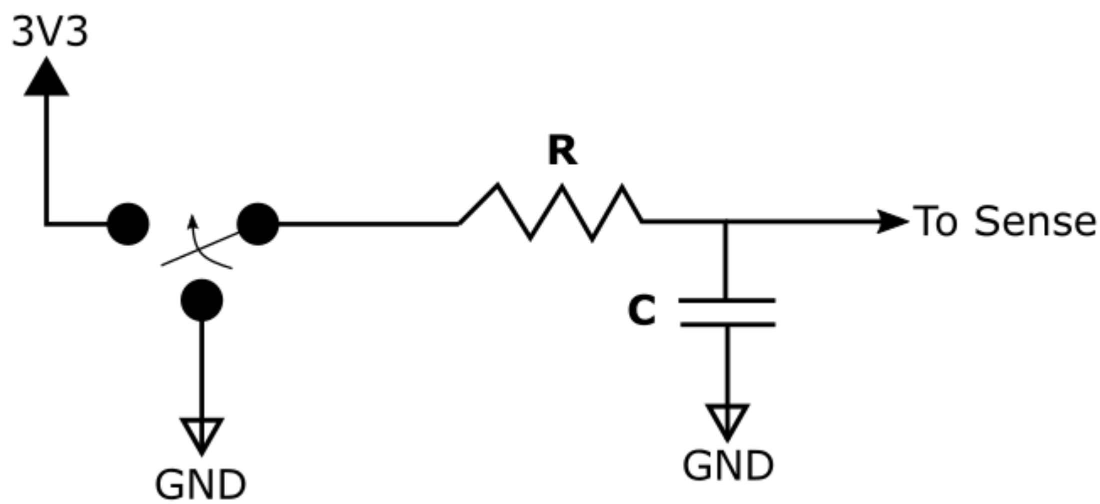


Figure 3: The RC debouncing circuit, with a double-throw switch

When designing our circuit, we selected a time constant of 20ms as a design target. This was selected as most button bouncing happens on the order of 10’s of nano seconds up to a few milliseconds. While the 5tau (99%) rise time will be 100ms, a time scale that seems instant for humans and won’t cause users to feel like the system is slow.

For an RC circuit the time constant, or tau, is the product of the resistance and the capacitance.

We selected C as 1 microFarad, as that is a common capacitor size and found that R should be 20k Ohms.

System 3: Camera

Our system requires a camera to provide the video input for user height tracking that forms the basis of our system's operation. Our camera should provide images of a resolution that is high enough to distinguish the shape of human body parts at a short distance and has a high enough framerate to not cause excessive blurring or distortion when the user moves. The camera should also have a wide-angle lens, as it may need to be placed close to the user, depending on the final arrangement of the device based on testing. However, it should also provide an undistorted image, so fisheye lenses and the like are unacceptable. Our final camera selection was decided by the University having a standard Raspberry Pi brand camera on hand to provide to our group. Thus we are using:

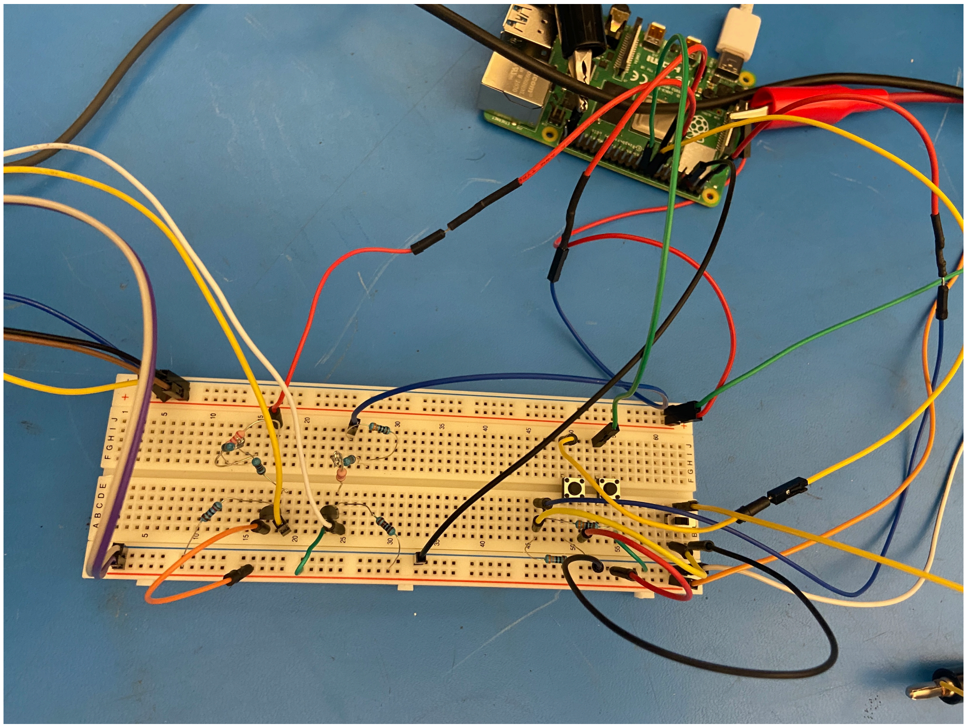
1) Raspberry Pi 8MP wide-angle camera module

The camera module will be connected to our controller using the MIPI CSI-2 camera serial interface standard. This is an industry standard for hardware connections and data formatting that is widely used for many digital cameras. And is readily supported by the Raspberry Pi CoB.

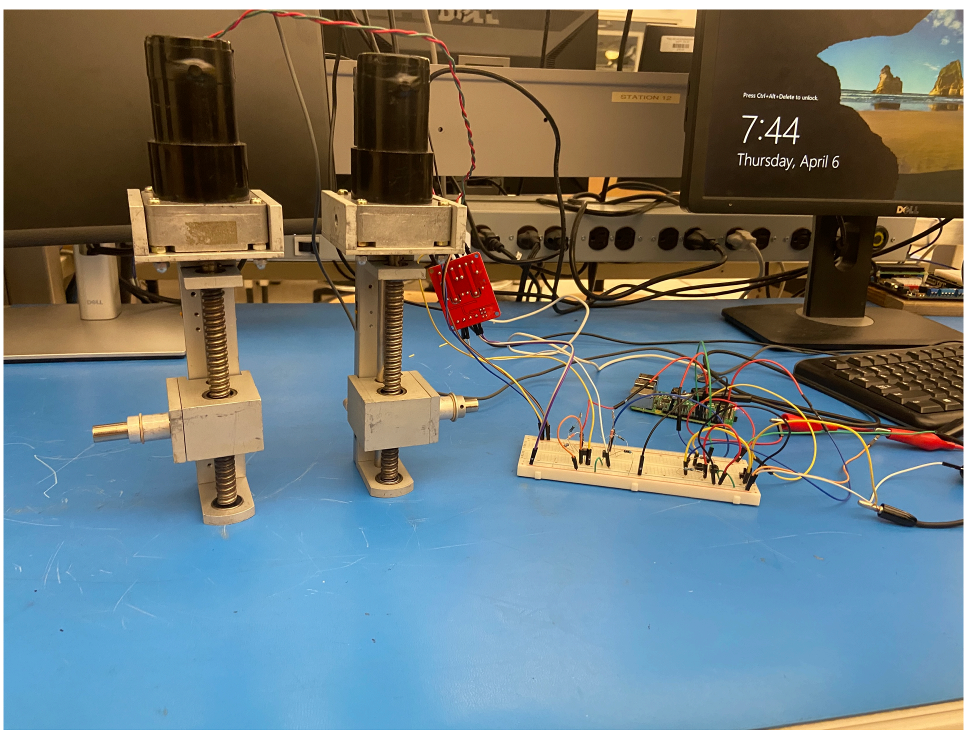
Functional Prototype

Note about the camera: In assembling the final prototype it was found that the specified camera did not produce a good quality image and further had many unforeseen technical challenges being integrated with the computer vision software. Due to time constraints, it was decided to operate the computer vision on a laptop as had been done in the initial stages of the project, rather than sink time into solving these challenges. Then remotely stream that collected data to the Raspberry Pi.

The final prototype was assembled using a breadboard and jumper wires to connect everything. The breadboard as built can be seen in the image below. The buttons and mode switch are visible on the right-hand side of the board. While the transistor switching circuits for each relay can be seen on the left side. The Raspberry Pi is towards the top-centre of the image.



In the below image the actuators are visible to the left, and the red relay board can be seen in the middle, connecting them to the breadboard.



The power supplies for the prototype were provided by a bench top power supply in the lab. This is different from the planned schematic as Michel, the lab tech, was not available for the last several weeks to provide us with the power supplies he promised us.