DEPARTMENT OF MECHANICAL ENGINEERING

# TEAM 34

## The Ligament Legends

*Morgan Donohoe, Joseph Kirby, Samuel O'Connor, Mark Rosser, Kaitlyn Shaw*

A. JAMES CLARK SCHOOL OF ENGINEERING

## Problem Definition

Many veterans suffer from lower back pain and are unable to visit the doctor in person because of weakened immune systems, lack of transportation, mobility issues, or PTSD. Telehealth appointments through online video calls have been increasingly popular recently. However, the standard tests are not easily recreated at home. One test that could help patients start the diagnosis process and justify further expensive tests is the patella tendon reflex test. Self-administering the test is not reliable as patients are not trained to evaluate their knee response. Also, video calls may have lag that makes it difficult for the doctor to accurately see the reflex response. Therefore, we have been tasked to create a device that reliably triggers the reflex response and ranks the response on the NINDS (National Institute of Neurological Disorders and Stroke) scale.

## Prototype and Test Results

We tested our tendon reflex device on several healthy individuals with no back pains or relevant health issues. We focused heavily on ensuring correct strike force, strike placement, and strike measurements to ensure the correct core functionality of our product. As these are directly related to the performance of the solenoid actuator, we spent a significant portion of our time measuring its performance. We also collected a large data set from our own knee reflexes with the MPU to approximate a cutoff for a healthy patient's response. We currently do not have access to disabled and injured patients so we cannot provide full functionality of NINDS scale rating unless there is a large-scale clinical trial alongside medical professionals to ensure the accuracy and reliability of the results.

The prototyping process generated numerous versions as we made many changes along the way. Initially, we had a small and weak solenoid actuator that was not capable of generating enough force to reliably trigger the reflex response. To fix that we upgraded to a stronger solenoid and increased the voltage from 9 to 11.1 Volts which was able to give us reliable results. We also ran into several setbacks along the way. For example, our 3D printed plastic housing broke when the strap slots were designed too close together. The shear force generated from the strap holding the device firmly in place was able to shear off the entire portion between the strap slots. Additionally, we destroyed several MOSFETs as they are sensitive to extreme heat (700°F) and the pins cannot be in contact with a soldering iron for more than a few seconds.

## Final Design

Our device is secured to the upper calf with a Velcro strap, so it sits between the tibia and patella. A simple button will activate the device and an indicator LED, pictured in Figure 2, will turn on. In response to the button push, the Arduino Nano starts a randomized countdown between 3 and 8 seconds, so the patient cannot tense their leg in anticipation before the strike. After the short delay, it sends a high voltage signal to the MOSFET gate which will allow our high-powered linear actuator to run without destroying the sensitive microcontroller. To achieve the quick patella tendon strike, we chose a solenoid that quickly charges and discharges magnetic energy in its coils to generate the push force on a metal rod that slides forward. An on board MPU (Motion Processing Unit) will then begin collecting orientation data to determine the NINDS (National Institute of Neurological Disorders and Stroke) scale rating, which is commonly used to grade the patient response. Additionally, these electrical components are all powered by an 11.1V rechargeable battery, as shown by the circuit modeled in Figure 3. The outside of the box has been modeled to have a charging port in the back, which can be easily accessed when the device is not in use.

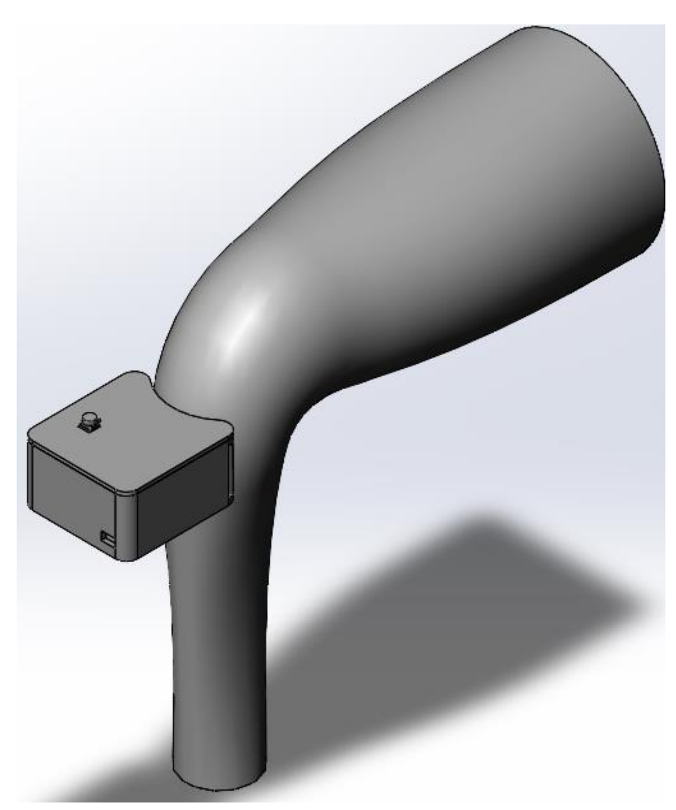

Figure 1: Image of the device mounted on the patient's knee.

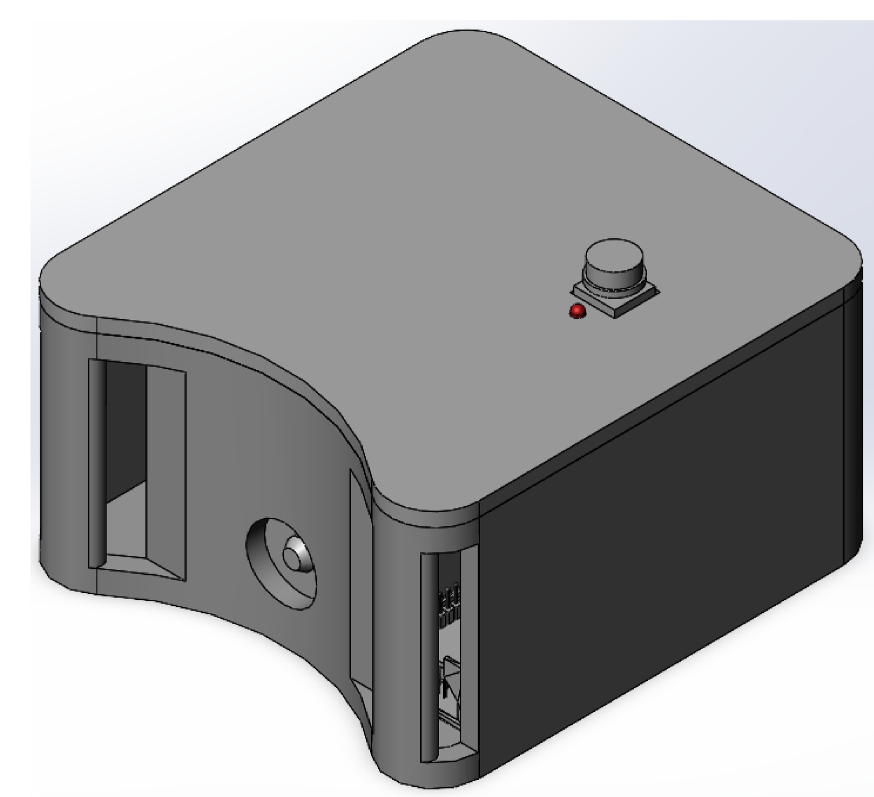

Figure 2: Isometric view of the front of the testing device.

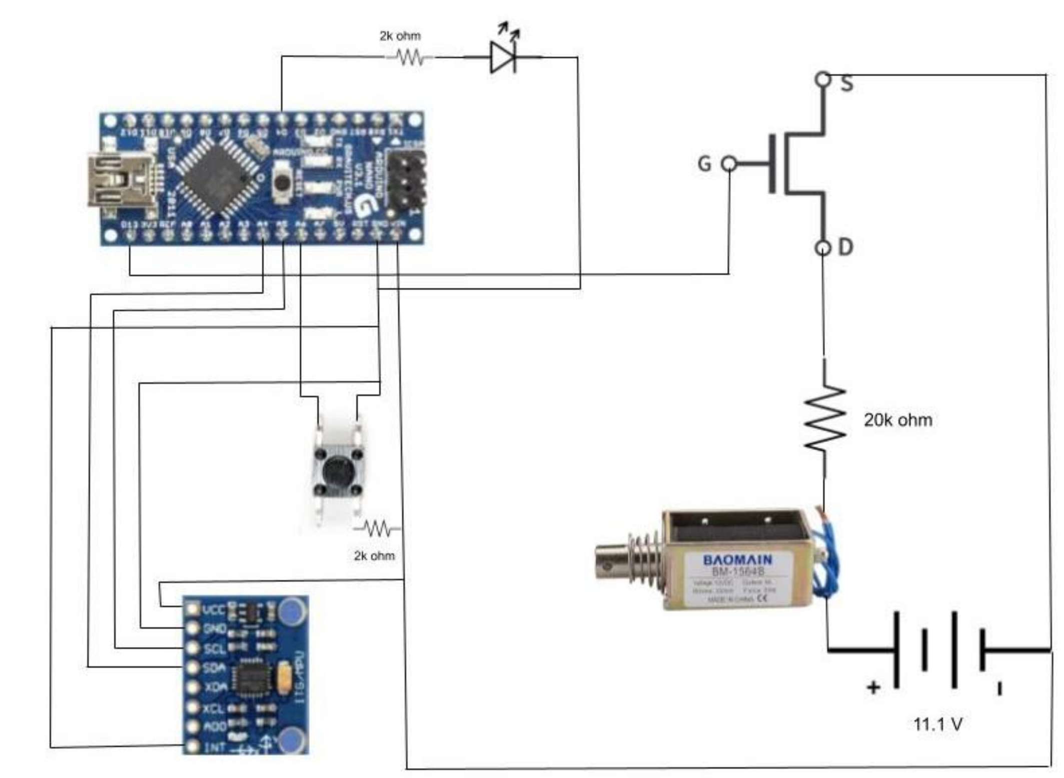


Figure 3: Circuit diagram representing the circuit that is contained in the housing.

## Design Calculations & Analysis

Solenoid Linear Actuator Stats:
Maximum Force: 55 Newtons
Current: 2.86 Ampere
Voltage: 10.8 V
Power Consumption: 30.89 Watts
Strike time: 1 second

Battery Stats:
Maximum Potential: 11.1 V
Energy Capacity: 9.44Wh

Battery Discharge:
Solenoid Running Time: 0.306 hr
Solenoid Running Seconds: 1100 s

Arduino Nano Power: .3 Watts
Total Running Time: 0.303 hr
Total Runing Seconds: 1089 s

Maximum Expected Strikes: 1089
Conservative Expected Strikes: 700

After determining a higher strike force was required to elicit a reflex response, we replaced our original 9V / 600mAh battery, which was underrated for this type of application. Higher voltage batteries proved to elicit a stronger response from the solenoid.