# ECE 4950 - Research
# Group 3

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**Executive Summary:**

The purpose of this project is to produce the portion of the final report entitled “Research”. In this portion of Senior Design, the students were tasked with understanding how an Arduino can be used to control an electromagnet as it will be used in the final project. This requires that the students find and implement a device in a design that can take the signal from the Arduino controller and use that signal to provide enough power to the electromagnet for the electromagnet to be able to pick up a washer. The students must also figure out how to control the Arduino through MATLAB. Different versions of MATLAB can result in somewhat different codes needing to be written. For this Senior Design project, MATLAB R2020a will be used throughout for the sake of continuity.

A further requirement of this portion of the Senior Design course was that the group of students develop a part which can be cut on the laser cutter. This allows the students to get familiar with the software that needs to be used to communicate a design to the laser cutter as well as learn some of the limitations of the laser cutter itself. For example, whatever is to be cut has to have certain properties - it cannot be too thick or be prone to melting, as these will cause the laser cutter to fail to reproduce the design, and if something were to melt, or even worse, catch fire, the laser cutter could be damaged. Another limitation is the design. Whatever is to be cut will be a three-dimensional object as is simply common sense - we have access to nothing that is infinitely thin, but the design will be limited to being two-dimensional in practicality. This should serve to introduce the students to the laser cutter and illustrate how the laser cutter can be used to make parts, be they individual parts or parts to be assembled into a more complex object.

**Materials and Methods for the Experiments:**

The Arduino Mega and the 5 V electromagnet with 2.5 kg holding force, a 10,000 Ω, 0.5 W potentiometer to act as the sensor, a 2N3903/2N3904 NPN transistor, and a IN4001 diode were required for this project. Furthermore, software to communicate with the Arduino, namely MATLAB R2020a with the Simulink addon, were also required. In addition, three more addons had to be installed: the MinGW Compiler, MATLAB Support Package for Arduino Hardware, and Simulink Package for Arduino Hardware. These addons will enable interfacing and programming of the Arduino Mega.

The circuit shown in Figure 1 was constructed by the students to meet the design criteria for this portion of the Senior Design process. The elements used in this portion of the project were those available to the students from previous laboratory courses or those provided by the department for Senior Design 1. The device used to provide a variable input was the Trimpot. This device enabled the students to create a continuous gradient of input signals. The electromagnet was connected to the Arduino via the PWM2 port and powered via an external 5V source so that the current needed by the electromagnet could be provided. An NPN transistor was used to control the power flow to the electromagnet - when the output from the Arduino was high the transistor would allow for the flow of current through the electromagnet while a diode prevented any backwards current flow.

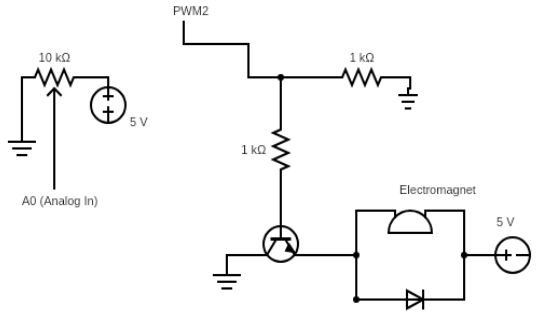


**Figure 1: Circuit Diagram, circuit-diagram.org**

The experiment was conducted by using a Lenovo Ideapad y700, running the Windows 10 operating system, as a real-time workstation. In order to connect the Arduino Mega to the workstation a USB type A/B cable was needed. A simple Simulink file as seen in **Figure 2: Simulink File, MATLAB** was created so that the electromagnet would turn on once the voltage read from the potentiometer reached a variable value. This Simulink file can be seen in Figure 2. For this experiment those values were: greater than 2.3 V turn on and remain off for all other values. To show that the electromagnet has been properly activated a small screw was placed underneath it and upon activation it would be picked up by the electromagnet.

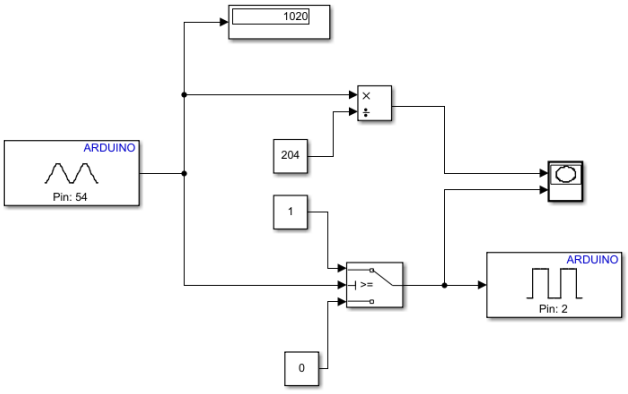


**Figure 2: Simulink File, MATLAB**

**Results and Discussion:**

Two test runs of this experiment were performed, once when the threshold voltage was set to 2 V and another where it was set to 4 V. The objective of this test is to demonstrate that the arduino can be used to trigger a secondary source to provide power once a certain threshold value has been reached; this is substantially different from having a 0 or 1 type of input as the system must be able to check the current value versus the threshold and when the threshold has been reached switch from off to on. This circuit is designed to correlate to the circuit that will be needed when the final project is being constructed as different colors will need to be determined by the photosensor. The photosensor will provide a gradient of values and the arduino will need to maintain a cutoff range for what values are indicative of what color. For the test cases performed for this portion of the Senior Design project the students opted to have only one threshold and to have the arduino power the electromagnet after that threshold is reached. In each test case the potentiometer was initially set to output 0 V, with this value slowly and consistently increased until the output voltage was 5 V. Once the threshold voltage was reached the electromagnet was activated and it was able to pick up a small screw. The graphs of the output signal for these tests can be seen in **Figure 3: 2 V Test Plot** for the 2 V test and **Figure 4: 4 V Test Plot** for the 4 V test.

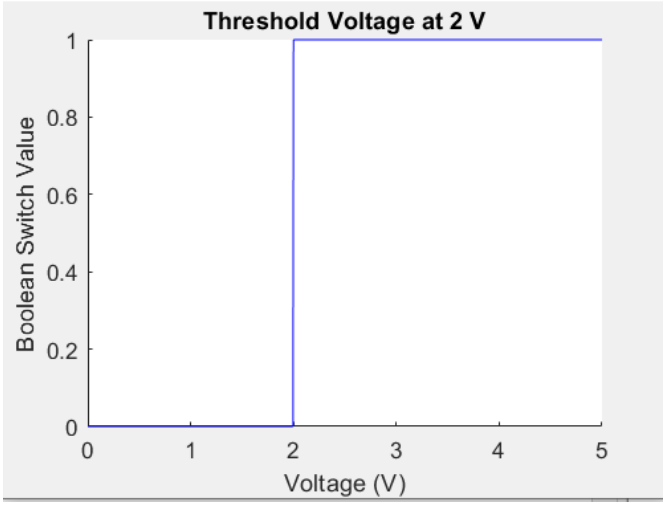


**Figure 3: 2 V Test Plot**

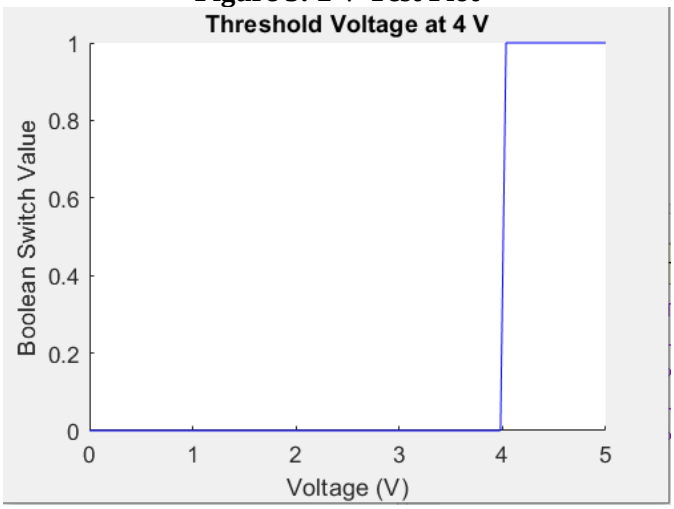


**Figure 4: 4 V Test Plot**

From these results it can be seen that until the threshold voltage is reached the electromagnet will remain off and it will only be powered once the threshold is reached. While the ideal response would be instantaneous, this is not possible due to the non-ideal nature of real components and even such small but present effects of propagation delays. Despite this, as can be seen from the above figures the response of the circuit is quite fast and the amount of time during which the state is in transition remains minimal. This is important for the stability of the system as well as the future ability of the robot to pick up an object and then move without having to wait a significant amount of time. The electromagnet will remain powered no matter how much higher the voltage goes. Significantly, the threshold voltage was able to be adjusted without causing errors. This setup allows a sensor capable of providing a small signal only to communicate with a device requiring much more power than even the arduino can supply and affect change via that device based on an external condition. This will be crucial to later portions of the Senior Design project when the robot must sense the colors of the washers and rearrange those washers based on their color, as the same electromagnet will be used, and the same setup will be needed in order to power the electromagnet. It may prove beneficial to the design of the project to use a power transistor of a MOSFET type rather than the BJT transistor used herein, as a power transistor would be more suited to the task of supplying power to the electromagnet and would be less prone to overheating. Were a larger circuit to be implemented by the students, it may also be of concern as to how much power is used by the transistor as this is power that is not available to perform functions that are required by the design but is instead wasted as heat.

The initial phase of Senior Design was a success, and the testing format worked as intended with no observed damage to any components. The arduino was able to be configured to enable a secondary source to provide power once a threshold was reached as is demonstrated in both **Figure 3: 2 V Test Plot** and **Figure 4: 4 V Test Plot**. It was also observed that the power supply setup constructed was able to supply the necessary current to the electromagnet, and that the current supply was able to be sustained to hold an object for an arbitrary length of time once the power supply was triggered. As the supplies needed for the final design project have not yet been provided to the students, it was impossible to test whether or not the setup as implemented here will be capable of handling the washers which will be used in the final iteration, but a stand-in was able to be successfully substituted in the form of a screw. The MATLAB interface for the arduino was also successfully used in this portion of Senior Design to create the threshold voltage values and the response of the circuit to these values being attained. As the threshold value was able to be manipulated without causing an error, it can be safely stated that the MATLAB code for this portion of Senior Design is correct and not merely hardcoded or otherwise fixed. As the constructed circuit performs as intended and the user can change the value of the threshold in the MATLAB interface to any reasonable value and the circuit will still behave accordingly, the students believe that they have configured and used the equipment properly.

**Conclusions and References:**

The equipment utilized in this project is suitable for a small-scale robotics control project as is detailed in the above report and as will be pursued in future projects in this course. The ability of the equipment to perform to the user's desires are limited due to the small size and capacity of many components, such as the 2.5 kg holding force electromagnet - if a project needs to pick up a 5 pound weight, this will not work. Likewise, any power supply which is to be actuated by the arduino will need to be able to be operated on no more than 5 V as that is the maximum voltage that can be had from the output pins on the arduino controller utilized by the students. The interface with MATLAB presents a limitation as well - if one is unfamiliar with this software it could be difficult to develop a project using such an interface. Certainly another language, such as C or C++ could be used if the developer were to be more familiar with another language, but these languages present a steep learning curve to the novice developer and attempting to construct a project while simultaneously learning a new programming language could prove difficult. Other, more introductory robotic interfaces have a graphical interface such as ROBOTC's products; this should not be an issue for this course though since all students have been previously required to learn MATLAB, C, and microcontroller programming. Some of the components utilized in this portion of the design process were used simply for their availability and the student's familiarity with such components. For instance, the Trimpot was used as this was an equipment in which the students were familiarized with in ECE 3720, but such a device will not have an application in the final portion of the design where the robot must use a sensor to develop the input without the aid of human intervention. The Trimpot did, however, enable the students to develop an interface for the arduino that has to manage a wide range of input values as would be realized from the implementation of a photosensor. Other parts of the circuit design, such as the use of a power transistor to supply the electromagnet's energy and the use of a diode to protect the arduino from any backfeeding, will likely be copied verbatim in the final design.

The laser cutter is a useful tool for developing items that need accurate cuts on a side of an object. If any pieces need to be made to assemble into an arm or a platform, the laser cutter would seem ideal for this task. For the robotic device required in this project, a series of linked pieces, most likely in the form of "arms" as are observed on an excavator will be required so as to enable the robot to select a colored washer from the game board and deposit it somewhere else - be that in another location on the board or in an intermediary location so that the sorting can continue. It would seem beneficial therefore to have the ability for the arm to be able to contract so as to be smaller than the radius from the central location of the gameboard to the holes where the washers are to be located. The laser cutter could be used to make precise linkages which could be connected on pins in order to enable this type of motion. A further use of the laser cutter would be to develop any sections needed to construct a housing, base, or any other similar type of assembly for the robot as needed. These pieces would need to be translated into their planar components for the laser cutter, but the precise dimensions of which the laser cutter is capable would make assembly straightforward once all of the pieces and their connections had been determined and acquired by the students.