

MICHIGAN STATE UNIVERSITY
ECE 480 - TEAM 6
How to use Solenoids to Display Images
An Application Note

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04/05/2013

Executive Summary

Solenoids are well-known electro-magnetic components and are widely use to implement functions in numerous devices. In order to create a physical implementation of images on a computer, this team will create solenoids and utilize them as actuators. This document will briefly outline how solenoids work, important factors to consider when designing a solenoid, and the process of making a pin display from a solenoid.

Keywords

Solenoid, SolidWorks, Coil, Lathe, and Connex 350 3D Printer

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Introduction and Background

Solenoids are a very popular electro-magnetic component and have a wide variety of uses. Here are a few interesting products that the use of solenoids are in conjunction with. Solenoids are used in car starters and railroads, where they function as an electric switch. They are also used as valves to control fluid flow in appliances such as washing machines and dishwashers.

To begin, let's define what a solenoid is. A solenoid is an electric conductor wound as a helix with small pitch, or as two or more coaxial helices, so that the current through the conduct establishes a magnetic field within the conductor. In short, solenoids are special types of electro-magnetic device. They are quite a few coil manufactures that are able to provide us with us solenoids. The prices can be really cheap or expensive depending on the unit size. The prices are determined by a number of factors, including size and coil windings. Below is figure1 of solenoid:

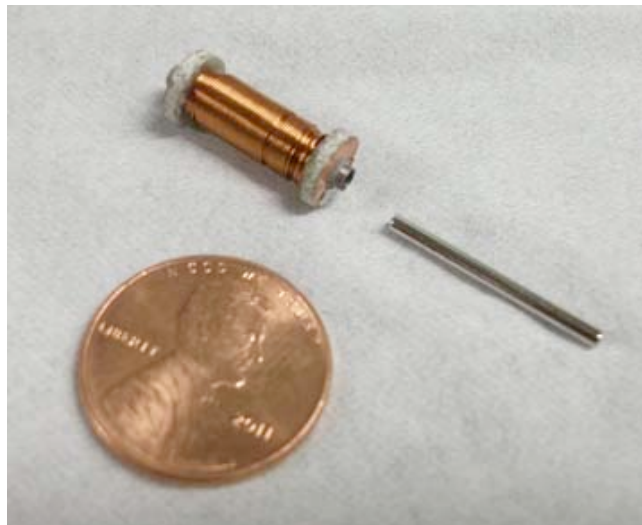


Figure 1: Solenoid

Design Team 06 was tasked with the unique challenge of creating a method for visually impaired students to feel an image. The project is currently in Phase II and is intended to build off of the previous team's work. The current team introduced the use of solenoids as actuators, where the solenoid is used as a driving force to keep the pins stabilized using a wedge. The wedge will eliminate the vibration that the previous design had and will make it easier for the pins to stay up for higher resolution. Below Figure 2 shows how the solenoid in conjunction with a wedge will provide a pin display. The team decided to use private equipment¹ to create our own prototype solenoids to save cost and keep the size small. In this document, the steps for creating a custom solenoid will be covered in detail.

¹ Equipment is personal property of Mr. Blosser, title of RCPD at Michigan State University. Mr. Blosser is the Team 6 Haptic user Interface project sponsor.

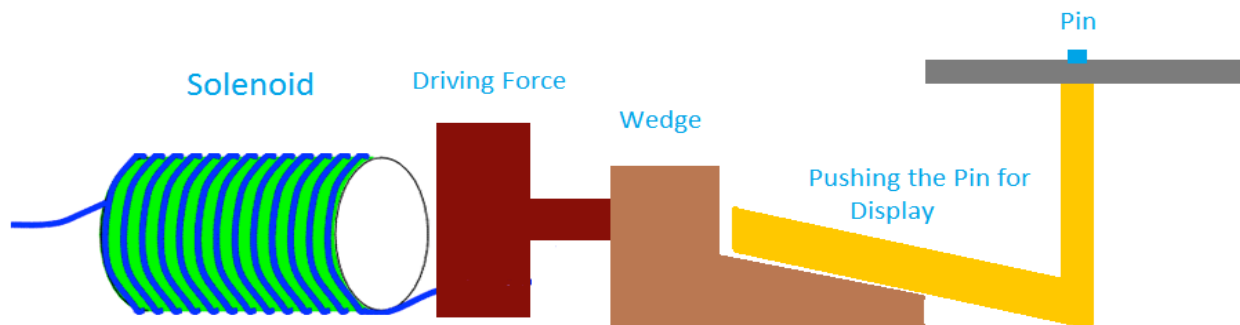


Figure 2: Haptic User Interface Design

Procedures

Designing the Solenoid Base

The team's priority was on small size and low cost. After researching the many manufactures and numerous suppliers available, we came to a conclusion that the cost was too high to purchase the solenoids that were commercially available. The team decided to create and design our own solenoids to control size and cost. The team decided on the dimensions of the solenoids after researching the sizes that were currently on the market and making the base as small as possible while maintain durability. To design our own solenoid, we are using SolidWorks to create a solenoid base and have it machined at the MSU ECE shop. Solid Works helped to design our solenoid in 3D and bring our designs to life.

Using Solid Works

SolidWorks is a computer aided design software package available from the XX Corporation, which is licensed to Michigan State University with unrestricted student access. SolidWorks is popular application that most engineers utilize. This software package is used throughout the engineering industry, including in the automotive and aerospace fields. SolidWorks features are easy to learn and use, and help the user design products better, faster, and more cost-effectively. Below are some basic steps to a simple 3D model in Solid

1. Design a sketch of the part by connecting lines or using built in shape functions
2. Constrain the sketch with dimensions desired. The software will help to show the user which areas of the drawing still need to be constrained, which means that the drawing is not fully dimensioned, or which parts are over constrained, meaning there are confliction dimension.

3. After completing the sketch by finishing constraints, extrude the sketches. This is where we are able to create the third dimension of the drawing. In this step, we can create holes and other features as well.
4. After creating the desired features through the extrusions and other tools, we should have a complete drawing. An example of a complete solenoid using the SolidWorks application shown in Figure 3 below

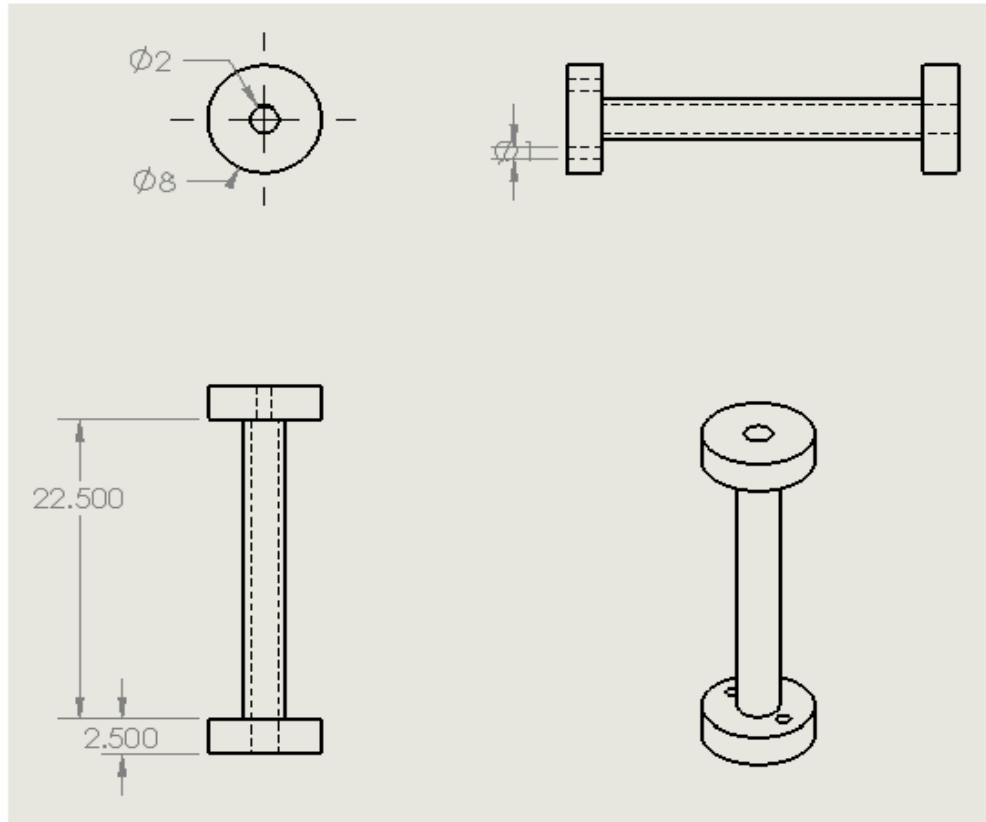


Figure 3 – Solid Works Drawing of Solenoid Base.

Machining the Drawing

After completing our CAD (Computer Aided Drafting) design using the SolidWorks application, we will now use the Connex 350 (shown in Figure 4) at Michigan State ECE Shop to manufacture our drawing.

CONNEX350

High accuracy multi-material 3D printing.



Figure 4: Connex 350 3D Printer

The advantage of CAD drawing is that manufacturing machines can read the constraints and data from the electronic drawing and automatically create a precise model of the drawing. The basic structure of the machine is that it has a chamber, which is filled with a powder-like material. It receives the data from the CAD drawing and carves the shape of the drawing in the powder, which then hardens, forming the 3D model of the part. Once completed, the chamber can be opened and the parts removed. Because the entire chamber is filled with the material, the part must be cleaned off and any holes must be cleared of excess material. To clean this material so that the solenoid was prepared for use, we used a drill with a drill bit slightly smaller than the 2mm diameter of the hole in the solenoid, and we drilled out the excess material. This gave us a quick and efficient way to prepare the solenoids for use.

Winding the Coils

Determining the Number of Turns

A very important factor while considering a solenoid is the number of turns that are wound around the base. By increasing the number of turns, a larger magnetic field is created because of the added length of the wire wound in the helix. This number is directly related to the magnetic flux density and force created by the electromagnetic field.

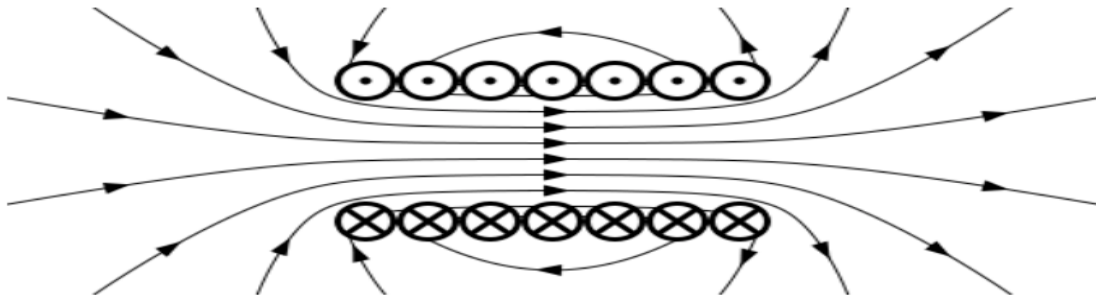
Magnetic Flux Density (Measured in Teslas, or Newton-seconds/coloumb-meters):

$$\Phi = \mu_0 \frac{N i A}{l}$$

Force (Measured in Newtons):

$$F = (N * i)^2 * \mu_0 * A / (2 * g^2)$$

Where μ_0 is the magnetic constant, N is the number of turns, i is the current, l is the length of the coil, A is the cross sectional area, and g is the length of the gap between the solenoid and a piece of metal.



Last semester's team found it difficult to precisely count the number of turns for each solenoid. After winding their solenoids, the previous team noticed that they were not getting the amount of force that they desired. For this semester, Mr. Blosser graciously volunteered to wind the solenoids using a special small-scale lathe in his lab to ensure precise, tight, and accurate windings. Figure 5 below shows the Mini Lathe machine.



Figure 5: Mini Lathe Machine

Winding Technique

A solenoid often requires in the thousands of turns to create a desired effect. Clearly, it is impractical to wind each turn by hand for up to 24 solenoids, so this is the method we chose to wind the coils quickly and efficiently:

1. Place one end of the base of lathe machine spinning tip so it can prepare the coil winding.
2. Start the first few turns by hand

3. Ensuring there is enough wire slack, turn on the machine and guides the coil back and forth from each base on the stainless tubing.

Testing

Now that we have a completed custom solenoid, and all that's left to do is test it. The solenoid will work for a DC or AC source. For a DC supply, consider starting at low voltage and slowly increasing the voltage supply until the desired force is met. For an AC supply, set the power supply to output a square wave with 5vpp and a 1v dc offset. Any frequency from 1-25Hz is recommended. After 25Hz, there is very little noticeable visual difference in switching speed. If everything is correct, when the power supply is on, the current running through the wire will create the magnetic field and the actuating pin to force the pin up.

Conclusion

In this document, a brief background of a solenoid was given, as well as steps to create your own solenoid. By creating a custom solenoid, cost and size can be minimized. The major steps that were outlined in this document were creating the base of the solenoid using a CAD tool such as SolidWorks, calculating the number of windings to achieve the desired force, winding the solenoid base, and testing the device. Using up to 24 of these custom created solenoids, our team will be able to create an array of solenoids to display an image from a computer screen as a reconfigurable Braille pin-dot haptic user interface.

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