Degaussing Watch Winder

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1 Executive Summary

The intent of this project is to design a watch winder containing a coil degausser. Watch winders have become an essential accessory amongst watch collectors. Watches have become increasingly accessible across the economic classes. Collaborations with companies such as Omega and Swatch have shown this to be true. Omega watches start around 6,000 USD whereas the average cost of a Swatch is 200 USD. The Omega x Swatch Bioceramic MoonSwatch collection cost 260 USD. The growing interest of watches and their accessibility has sparked interest in the market for watch accessories. Currently, the market sells degaussers and watch winders as two separate accessories.

The standard design of a watch winder consists of a box that holds and winds an automatic watch to prevent the power reserve from expending when the watch is not worn. This will ensure a watch winder's goal in maintaining a high-quality watch as a watch winder will preserve the correct time and dates after it has been worn. Watch winders are however not compatible with manual, or quartz watches as manual watches are hand operated and quartz watches are wound from the battery it contains.

Operating a watch winder is quite simple as it will be powered by either a battery or an outlet. Once powered, the watch will be placed in the designated place within the watch winders' box. The watch winder will simulate wrist movements maintaining a wound mainspring. Watch winders can be manufactured to rotate clockwise, counterclockwise, and bi-directionally. It is ideal to purchase watch winders that rotate similarly to wrist movements therefore bi-directional watch winders are not ideal.

Watches worn occasionally should be regularly wound to prevent the oils on the mainspring from settling. However excessive use of a watch winder can cause damage to a watch. Watch winders are not meant to hold and wind a watch for extensive periods of time such as for months as this can damage the watch.

The function and operation of a coil degausser is to correct a watch's magnetism by its coils. When a watch is worn often, there is a great amount of energy, magnetism, being stored within the watch's spring creating an overwound watch. When a watch is overwound the hands of the watch move faster or slower. This causes an inaccurate measurement and display of time. To correct the watch's accuracy, the watch must undergo demagnetization. The degausser relieves the excessive energy, magnetism, stored in the spring resulting in an accurate timepiece.

The project will explore the best combination between types of motors, microcontrollers, motor drivers, degaussers, relays, gaussmeters, power supplies, displays, and keypads in hopes of creating a multipurpose watch winder for automatic watches. The goal of this project is to combine these two accessories, a watch winder and degausser, into one versatile product.

2 Project Description

Designing a watch winder with a degausser began with our motivation in hope to achieve all our goals and objectives. The following will discuss what motivated our group and the project's specifications to achieve our goals.

2.1 Motivation

As the majority of our group are active watch collectors and enthusiasts, we had discussed the nuisance of separately winding and degaussing watches and purchasing two separate accessories that can be costly when additional settings are included. Senior Design has given us the perfect opportunity to hone in the knowledge and skills we have accumulated over our time at University of Central Florida to create a singular accessory that is versatile, cost effective, and desired in the watch collector community.

2.2 Goals & Objectives

The goal and objective of this project is to design and build a watch winder that records turn per day (TPD), rotation direction, a degausser, and read magnetic fields using a gaussmeter. The function of a watch winder is to keep an automatic watch fully wound while the function of a degausser is to demagnetize a watch that has been over-wound. Usually when an automatic watch is worn, the motion of the individual wearing it, provides energy to wind the mainspring. This in turn makes manual winding obsolete. Once the watch is fully wound, there is ample energy in the mainspring to keep the watch ticking approximately 12 to 48 hours. However, if the watch is not worn everyday it can be placed in a watch winder. A watch winder will slowly rotate the watch in a case. Rotation count can be set between 400 to 1200 TPD depending on the watch’s need. Including rotation direction will deliver the option of a watch to be set clockwise, counterclockwise, or bidirectional. The benefit of having a watch winder is that it prevents a watch from draining the stored energy, which can lead to damage to the timepiece. This is ideal for individuals who own multiple automatic watches.

Advance Goal: The goal is to create a website to communicate with the watch winder. Have a database that can store functions as well as erasing the functions. It will be a full-stack website so users can interact back and forth with the watch winder.

Stretch Goal: Once we can complete the basic goal and advance goal then the cherry on top would be to create a mobile app which can interact with the watch winder.

2.3 Related Work

Currently, Amazon only sells watch winders and degaussers as separate accessories. There are no degaussing watch winders on the market. However, customer input of these two products seems to be consistent. Constructive feedback of Amazon’s “Best Selling” watch winder has consistently mentioned the noise output and power source. The watch winder is known to be loud. Patrons have also expressed interest in a watch winder that can be powered via batteries and AC power. This will ensure a power source if the batteries die. Regarding Amazon’s Best Selling degausser, there is no constructive criticism on current models on the market. Customers overall have agreed having a degausser at home is much more economically stable than to have ones’ watch serviced by the watch’s manufacturer. Amazon’s best-selling degausser costs 20 USD whereas Omega will charge 600 USD to have a watch degaussed one time. Customers have expressed their appreciation of both products being lightweight, portable, and user friendly. We intend to implement this feedback into our design to create the perfect watch accessory.

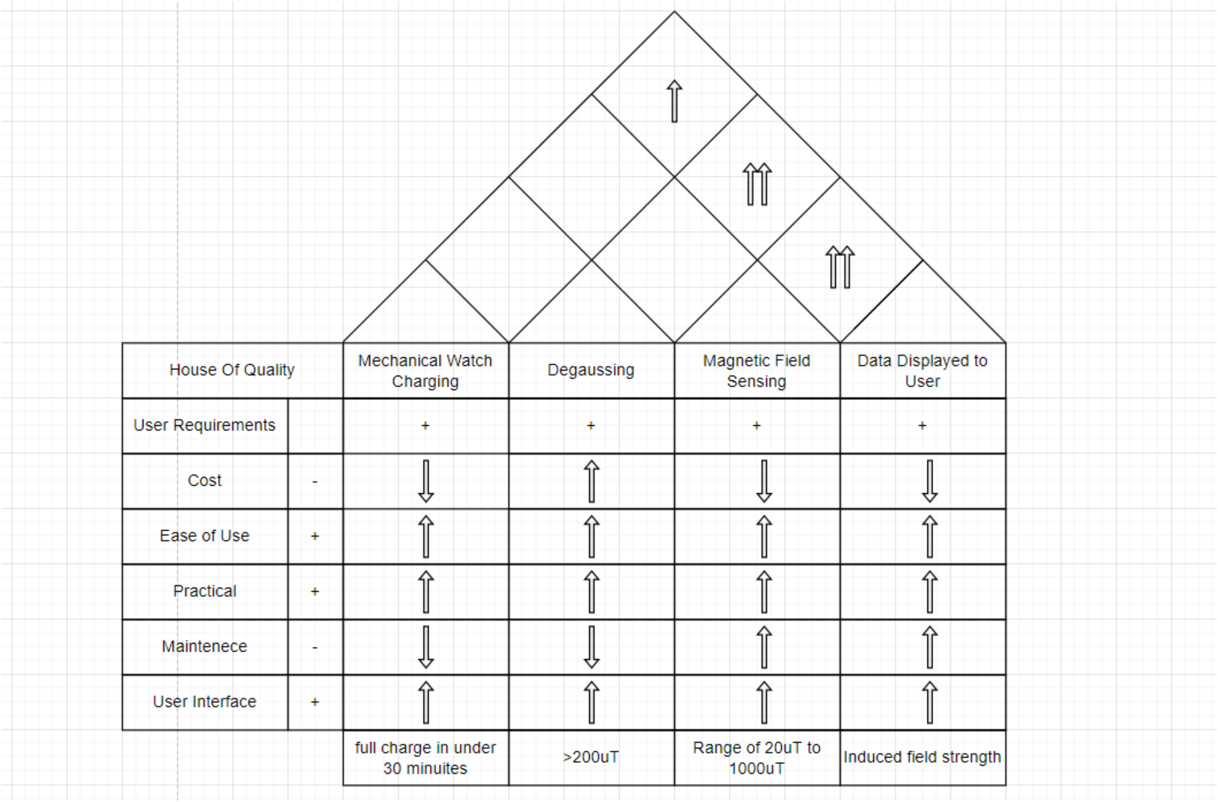
2.4 Requirements and Specifications

Some project restraints are lack of data on levels of magnetization picked up by casual watch users. ISO 764 states that a watch must resist exposure to magnetic fields of 4800 A/m but at the moment we have no quantitative data on levels casual watch wearers experience.

Device shall rotate and charge an automatic watch.	<20 minutes
Device should be able to read magnetic fields associated with the watch using a magnetometer.	<200uT
Device shall have a user interface to see data and selections.	OLED Display
Device should rotate bidirectional	360 Degrees
Device should be able to remove magnetic fields from the watch when the user chooses.	<200uT

Table 1

2.5 House of Quality



House Of Quality		Mechanical Watch Charging	Degaussing	Magnetic Field Sensing	Data Displayed to User
User Requirements		+	+	+	+
Cost	-	↓	↑	↓	↓
Ease of Use	+	↑	↑	↑	↑
Practical	+	↑	↑	↑	↑
Maintenece	-	↓	↓	↑	↑
User Interface	+	↑	↑	↑	↑
		full charge in under 30 minuites	>200uT	Range of 20uT to 1000uT	Induced field strength

Figure – 1

2.6 Hardware Block Diagram

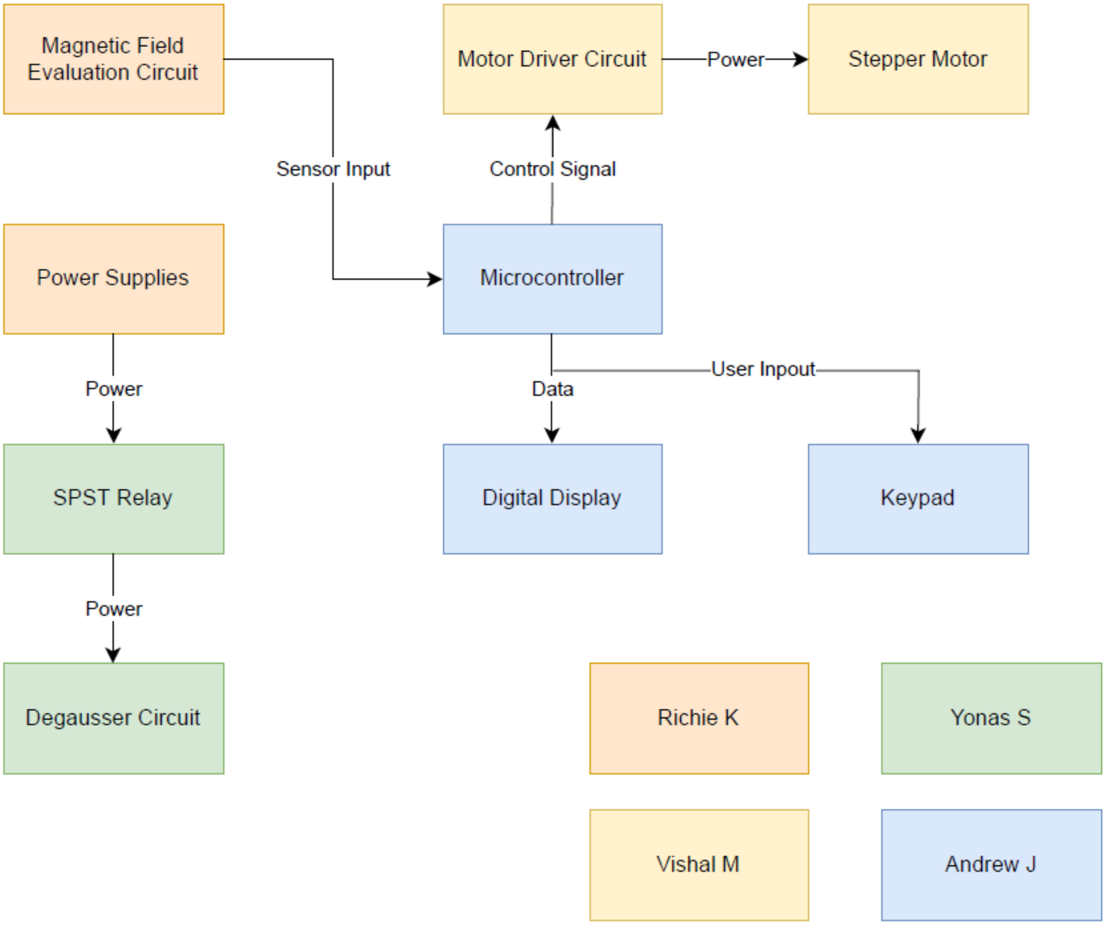


Figure – 2

3 Research and Background Information

3.1 Degaussers

In this day and time magnets are everywhere. Practically everything around us like televisions, cellphones, sound systems and tablets have magnetic fields. Magnetism affects watches and especially the components found inside the watch called hairspring. Hairspring or balance spring is a spring attached to the balance wheel to oscillate with a resonant frequency. This magnetism causes the hairspring to stick together which results in the watch not working accurately. Therefore, there is a solution to fix such a problem with a device called a degausser. A degausser is a machine that disrupts and eliminates magnetic fields stored on watches, tapes and disk media. It uses an alternating current to remove the magnetic field from the device.

How it works

Magnetization can be removed by a degausser by exposing a device to a very strong alternating magnetic field 60 times a second. In the case of an alternating current degausser in order to fully demagnetize the hairspring, we need to start with an alternating magnetic field that is strong enough to eliminate the pre-existing magnetism and gradually decrease the strength of the magnetic field until it approaches zero. This process makes the object to be demagnetized. Also, in the case of a permanent magnet degausser, we need a strong natural magnet.

Types of Degaussers

Based on the electromagnetic technology and permanent magnet technology, there are different types of degausser technologies that have been developed. Both types can generate powerful magnetic fields. The three types are:

i. coil degausser
ii. impulse degausser
iii. permanent magnet degausser

Degausser Technology Comparison

Degausser	**Duration of Demagnetizing**	**weight**	**Power Source**	**Example**
Coil	30 seconds	Light	230V , 0.65A	DMC70-B
Impulse Degausser	40 seconds	Heavy	120V, 3A	HD-5T
Permanent Magnet	8 seconds	Heavy	No-power It is manual	HPM-2

Table 2

The coil degausser is a simple form of degausser powered by alternating current line voltage. It is lightweight and its duration of demagnetization takes 30 seconds. This rapidly alternating magnetic field tends to overcome magnetism that is present in mechanical watches. With coil degaussing, eliminating a magnetic field is achieved by moving the demagnetized object away from the coil while the power is on. Once the object is far enough, the power is off watch and the other accessories are demagnetized in this manner. For instance, this DMC70-B 70mm Small Aperture Demagnetiser is a powerful device that satisfies small tools and low volume demagnetization. The unit is resistant to impact of wearing and corrosion because it is enclosed in a hard polimer. To mention some other future include:

- demagnetization capability in excess of 200 gauss at center
- Single button operation for ease of use

Impulse degaussers also demagnetized objects in a fraction of a second without having to move them away. These are sold demagnetizing watches and other things. Impulse degaussers use a capacitor that is charged to a high direct current voltage using power from an alternating current line. When a button on a device is pressed, the capacitor is disconnected from the power source and connected to a coil. The capacitor’s high voltage produces a high current in the coil which produces a strong initial magnetic field. The energy keeps the current flowing in the same direction which charges the capacitor and the capacitor discharges into the coil again until the coil and the capacitor form a resonant circuit. This produces a magnetic field that reduces exponentially in amplitude over a period of a fraction of a second. Any object near the coil is demagnetized without moving it. For example, HD-ST is compact and energy efficient, the HD-ST degausser erases multiple tapes and hard disks drives per cycle and contains an automatic internal magnetic field checker that ensures the degausser is performing properly.

Unlike coil degausser or impulse degausser technology, the permanent magnet degausser uses strong and natural magnets. They do not generate heat, some do not require electricity to operate, and never require technical upgrades. Permanent magnet degausser is very big in size and less portable. For instance, HPM-2 Degausser type is portable, compact, lightweight, and is designed for use in any environment or conditions. It operates manually by simply inserting the media into the drawer and rotating the effortless handle. The unit is pulled inside the degausser when it passes a shielded permanent magnet that is completely demagnetized.

Based on the research, the technology that best suits our project is coil degausser. The reason is that the duration of the demagnetizing and demagnetizing performance is excellent. Also, the coil degausser has the advantage of being lightweight which is easy to construct. Moreover, the 230 v, 0.65A power supply would be a great selection for our project.

Therefore, based on these advantages and disadvantages, we decided to build the degausser using an alternating current coil degausser as shown in the figure below.

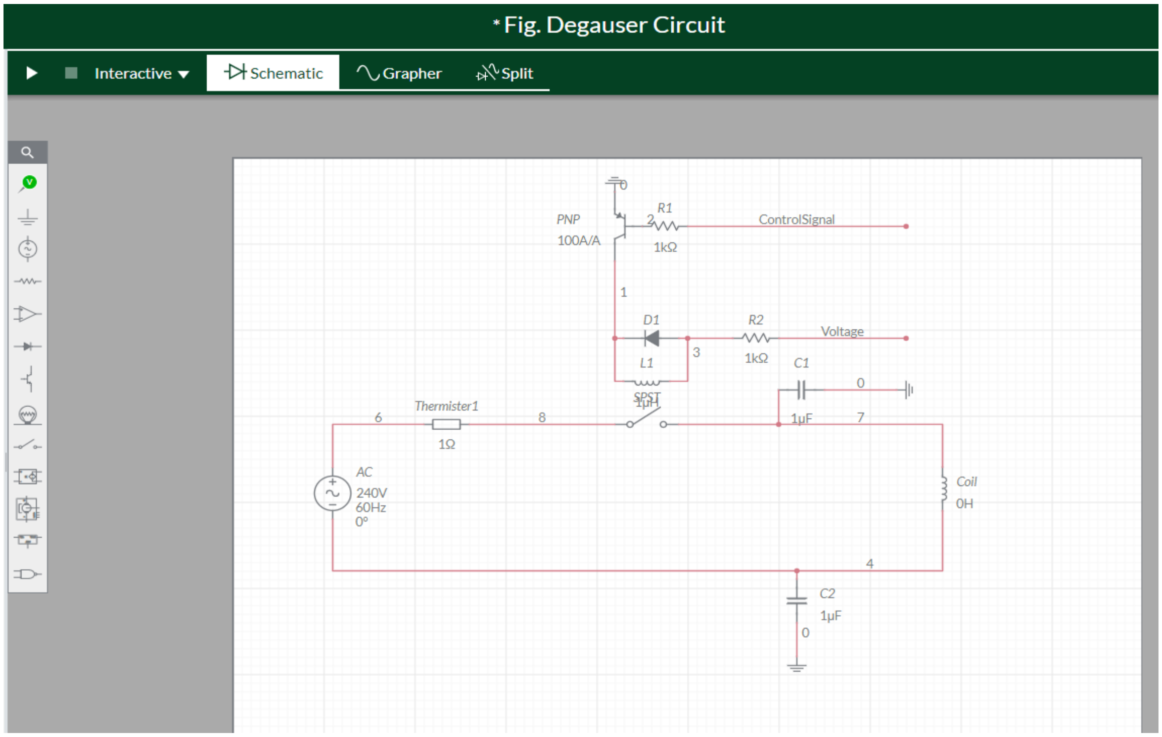


Figure 3 – Degausser Circuit

The figure illustrates the degaussing circuit. It has only a single coil and its core has been cut open. This means the alternating magnetic field lines generated by the coil would diverge out to the space above the coil. One end of the coil is connected to a terminal of an alternating current source through contacts of SPST (single pole single throw) relay then through a positive temperature coefficient (PTC) thermistor and the other terminal of the degaussing circuit is connected to another terminal of the power supply. Also, in opposite ends of the degaussing coil, two capacitors are connected and grounded. These capacitors are charged by residual current in the degausser in order to prevent generation of electromagnetic fields. Moreover, one end of an actuator coil of the SPST relay is connected to a 12 V voltage source through a resistor R2 and another end of actuator coil is connected to a collector terminal of the PNP transistor. The actuator coil of the SPST relay is turned on when the PNP transistor is on. A diode D1 is connected in parallel to the actuator coil in order to dissipate energy stored in the actuator coil when the relay is turned off.

There is a thermistor added to the circuit in order to make this device safe. There are two types of thermistors, negative temperature coefficient thermistor (PTC) and negative temperature coefficient thermistor (NTC). The resistance of NTC falls with rising temperature so they are used to decrease the flow of current from the power source when it is turned on. The negative temperature coefficient has high resistance in the beginning and this lets in few current flows and heats up the thermistor. Then it gradually reduces its resistance in order to allow more current flow. The positive temperature coefficient thermistor (PTC) works exactly the opposite of NTC. The resistance begins low and then rapidly increases with rising temperature. Initially, the positive temperature coefficient thermistor allows more alternating current flow and the magnetic field produced will be very strong. The current causes the PTC to increase its heat and raise its resistance. This narrows the flow of current to the degaussing coil. Then the internal resistance of the thermistor increases causing them to cut off the current flowing into the degaussing coil to stop the degaussing operation.

The PNP transistor is turned on/off by low/high degaussing control signals generated from the microcontroller when a user wants to perform the degaussing operation. The low/high degaussing control signal is supplied to a base terminal of the transistor through an input voltage and resistor R1. The emitter terminal of the transistor is connected to the ground. If a low signal is supplied from the microcontroller to the PNP transistor, then PNP transistor operates the relay. When the SPST relay is operated, power is supplied and alternating current starts to flow to the degaussing coil.

Components needed for Degausser

Transformer

The lamination used in the half transformer is E lamination,very thin strips of insulated material metal joined together to produce a solid but laminated core. The permiability of the core is approximately 2.5 *10^-7 H/m. The dimension of the E lamination core is 4 cm by 2.5 cm and the size of left, right, and center legs are 0.65cm, 0.65cm and 1.5cm respectively. At this time we don’t have any data on the number of turns in this half transformer.first we are going to measure the current and the magnetic field in tesla using degauss meter then we are going to calculate the reluctance of the E lamination core using the given dimensions and permeability by:

$$\textbf{Reluctance} = l/\mu A$$

where: l is the length
A is area
μ permeability constant

finally, we are going to calculate N(number of turns) using the formula:

$$\textbf{N} = (B * \text{Reluctance} * \text{Area})/I$$

Therefore, based on these calculations we are going to use the transformer for the safe and effective degausser.

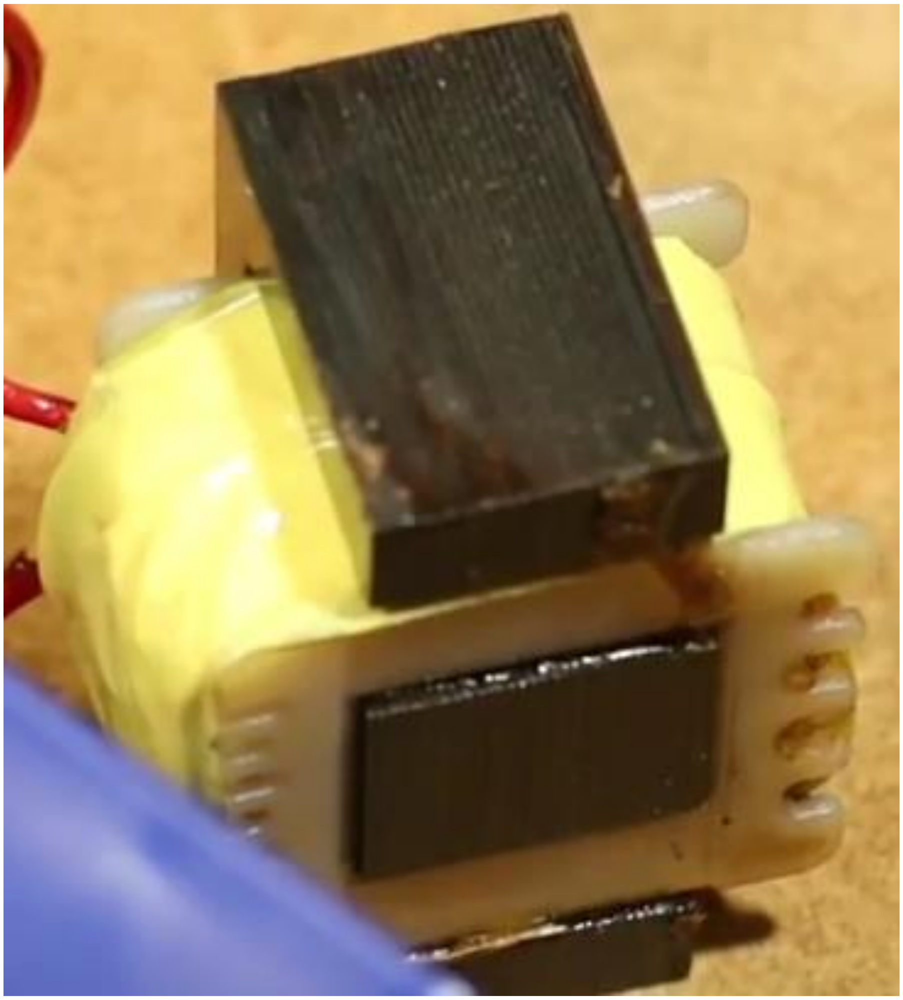


Figure 4 – Degausser

Thermistor

To pick the right PTC, first we need to know what current the unit can draw. In order to find out this, we used an oscilloscope which is an easy and safe way to measure. Then, the unit draws around 0.215Amp when the degausser circuit is on. During this period of time, when the thermistor gets really hot, current flow gets reduced. We picked PTCCL-265V Series PTC thermistor for this project because, based on the datasheet, it is rated up to 265 rms voltage and 0.8Amp to 5Amp maximum overload current. This is suitable for mains voltage application. In the case of a degausser coil, the normal current draw is 0.215Amp. We can not use any PTC thermistor that can not handle this current. Moreover, we considered how fast the ptc thermistor can reduce the current when the degausser circuit is on. The trip-time or switching time is approximately 1.5 second and the price is very cheap which is $1.37 a piece.

LED and RESISTOR

LED stands for light emitting diodes. If we pass a current through one LED, it produces light. If we exceed the voltage and current limit, it could be destroyed. The LED has a tiny wire inside that can handle a certain amount of current passing through it. To keep the LEDs safe, we use resistors that make it hard for the electrons to pass through it and connect on the positive side of the source voltage because the resistor restricts how many electrons can flow in the circuit. In addition,LEDs only allow current to flow in one direction.

Transistor

A transistor is a switch that is controlled by a current flow. We are going to use standard bipolar transistors. The first thing we did when picking a transistor was to decide whether NPN or PNP. Here are two diagrams that help us which one we are going to use.

Figure 5 — Transistor

In the conventional current flow, if the arrow in the transistors points from collector to base then to emitter, called NPN and if the transistor points emitter base collector is called PNP. The two terminals of the switch are a collector and emittor or emitter and collector depending where we put in the circuit and way we get these switches to turn on and off by either pouring current into the base in the case of NPN or drawing current out of the base in the case of PNP transistor. Therefore, it is a switch that is controlled by a current. The thing that makes decisions for us is our control signal, that is the 0v or 5v logic signal that comes from the controller. We decided to pick the BD912 PNP transistor which is a really great low medium power very inexpensive and easy to use switching transistor.

3.2 Relay

A product or component may fail for many reasons. A faulty part is one of those reasons that cause product failure. A component is exposed to failure when it is used improperly or is damaged. Therefore, careful selection of parts is an essential and fundamental process of designing high quality projects. This part selection process provided us with a balance between safety, functionality, reliability, manufacturability, and cost. Poor part selection exposes us to different risks such as incompatibility, cost increase and unavailability. For instance, the part selected should not only work for the functional requirement of the design but must also work with the product assembly and maintenance. Therefore, in this section we are going to select parts that fulfill the necessary standards and requirements and play an important role in building an excellent project such as: relay and degaussing circuit.

Introduction

As we know, most industrial application devices have relays for their effective working. Relays are simple switches which are operated electrically and mechanically.
Relays use electromechanical or electronic mechanisms to control an electrical circuit by opening and closing the contacts. Relays are generally used to switch for altering the transmission of current in a control circuit. For example, in case of an air conditioning unit the electrical circuits are closed and opened according to the temperature of the surroundings. This process is enabled using a relay. Also, the main operation of a relay can be in places where a low power signal is used to control the circuit. It is also used in different places where only one signal is used to control a lot of circuits. The basic principle of relay is the same to all relays.

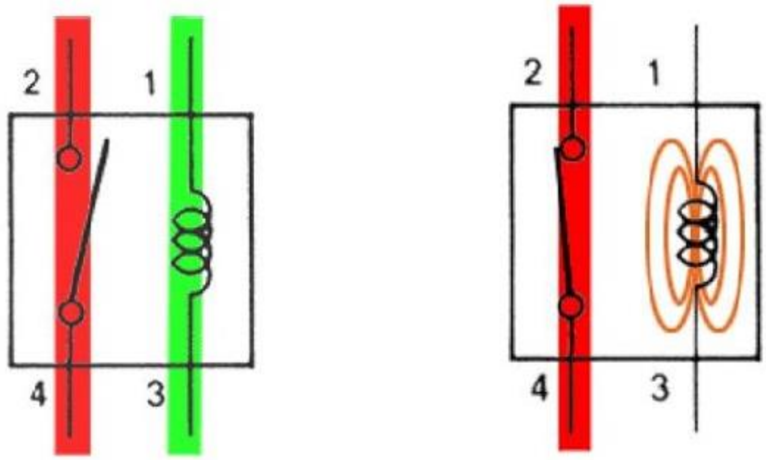


Figure 6 – Relay

For instance, the four pin relay as shown above has two colors. The green color pins 1 and 3 represent the control circuit which is connected to the low power dc source and the red color pins 2 and 4 represent the load circuit. The switch is controlled by the coil in the control circuit when current flow through the coil causes a magnetic field to be induced. This magnetic field causes the closing of the switch in pins 2 and 4.

Relay Applications

Relays have a wide range of applications starting from washing machines at homes to computers and telecommunication systems. They can be found everywhere and are used to control high power or voltage circuits with a low power circuit. The first application of relay was in long telegraph line systems. The following are some key examples of application.

- They are the backbone of the industrial process automation systems

- They are used in substations and power distribution centers for sensing faults and operating the circuit breaker.

- They are used in electronic circuits and home appliances for isolating low power circuits from high power circuits.

Types of Relays Technology

Even though several types of relays are available in the market and can be classified according to their performance, switch contact, durability and cost. The three most frequently used types of relays are: solid-state relay, reed relays, and electromechanical relays.

SPST Relay Comparison

SPST Relay	**Switch contact**	**Switching performance**	**Durability**	**Cost**	**Example**
Electromechanical	Physical contact	5 to 15 ms	1Million cycle	Cheap	P251003E
Reed	Electromagnet contact	200 to 500 microsecond	100 Million cycle	Moderate	P711004E
Solid State	Solid State devices	100 microseconds	>100 Million cycle	Expensive	1611001E

Table 3

1. Solid-State Relay

In solid-state relay devices the switching can be achieved by field effect transistors. They are usually the smallest in size of all relays. They come with a wide range of current ratings. From a few micro-amps for low powered packages up to 100 amps for high power packages. Solid-state relays have a long operating lifespan, faster switching system and increased reliability because they have no moving parts. One disadvantage of solid-state relays is that they have lower resistance compared to electromechanical relays.

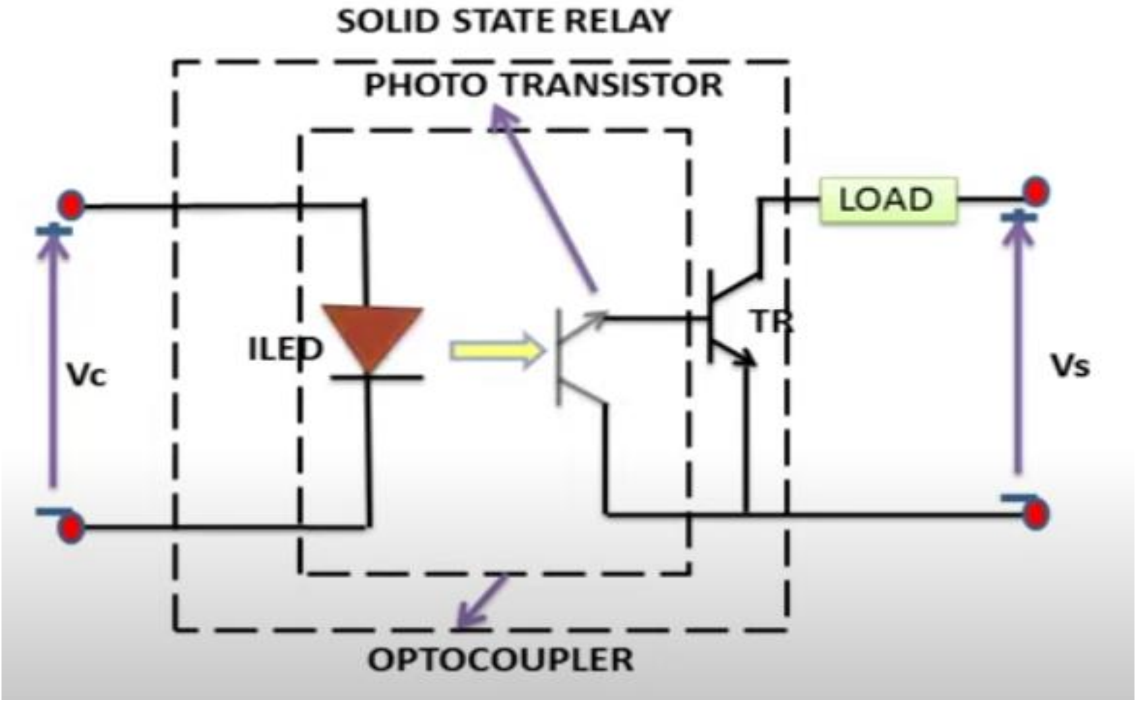


Figure 7 – Solid State Relay

As we said, solid state relays or SSR has no moving parts but, instead it uses the electrical and optical properties of solid state semiconductors to perform its input to output isolation and switching functions. Solid state relays can be designed to switch both alternating current and direct currents by using switching transistor output. One of the main components of a solid state relay is an optocoupler which contains one or more infrared light emitting diodes or LED light source.

In this case when the rated voltage is applied to the input section, current flows through the optocoupler. The output of the optocoupler is used to operate the switching circuit of the transistor. Switching circuit applies a gate pulse to the transistor and the transistor starts conducting. Similarly, when the input voltage is removed, the optocoupler turns off the transistor switching circuit and turns off the gate pulse to the transistor and the transistor stops conducting.

0. Reed Relay

Reed relays are made up of a reed switch and an electromagnetic coil with a diode for back EMF. A reed switch is made up of two ferromagnetic metal blades sealed in a glass tube which also supports the metal blades. The cool is energized, the ferromagnetic metal blades attract each other and form a closed path. As there is no moving armature there is no contact wear out problem. The glass tube is also filled with inert gas which helps to prolong its life.

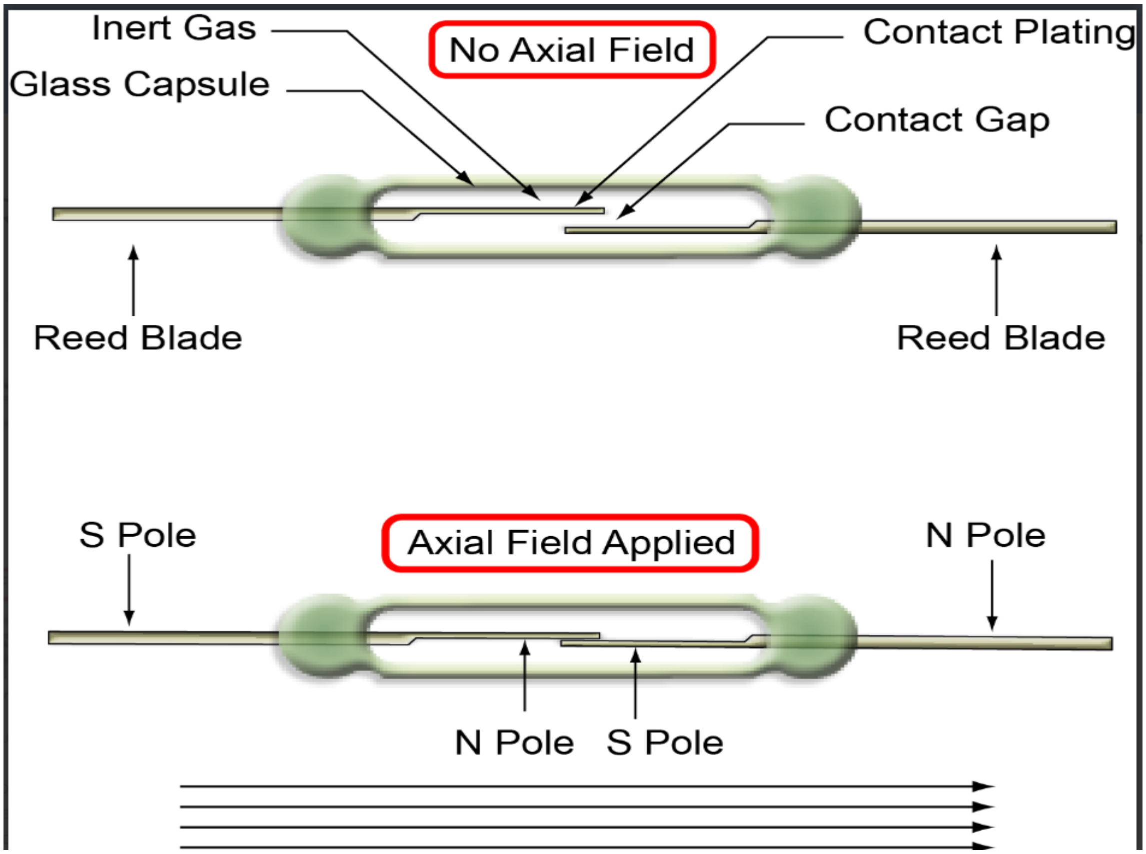


Figure 8 – Reed Relay

The reeds are supported at only one end from the glass to metal seal. In the presence of a magnetic field, the reeds are attracted together by closing the switch. A reed relay is simply a coil mounted around a reed switch with a basic arrangement as shown in figure. When a current is passed through the coil a magnetic field (measured in amp-turns) is generated and the switch operated. The geometry of the switch and coil affects the electromechanical efficiency and operating characteristics of reed relay.

0. Electromechanical Relays

This type of relay has an electromagnetic coil and a mechanical movable contact. When the coil is energized it produces a magnetic field. This magnetic field attracts the armature movable contact. When the coil is demagnetized, the coil loses the magnetic field and a spring retracts the armature to its normal position. Three parameters namely the number of breaks, poles and throws, determine the configuration of the electromechanical relay. The electromechanical relay has switching performance of 5ms to 15ms, durability of up to one million cycles, and is considered to be fair in price.

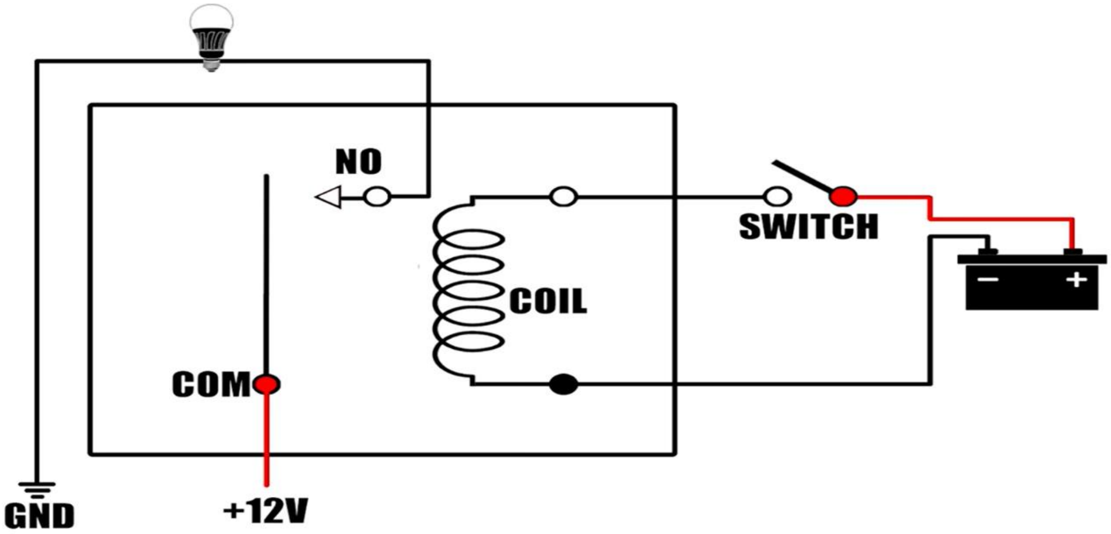


Figure 9 – Electromechanical Relay

There are pros and cons to each kind of relay. For instance, in the case of electromechanical relays, a solenoid sub-assembly is energized to attract an armature. This attraction is used to disconnect the electrical circuit. When the solenoid sub assembly is not energized, the spring attached to the armature pulls back to establish the electrical connection. Also, electromechanical relays are designed for high current typically 2 amps to 15 amps and switching performance 5 milliseconds to 15 milliseconds. However, in the case of reed relays, they are smaller than most mechanical relays and are somewhere in the middle between mechanical and solid-state relays in size. They are designed for moderate currents, typically 500 milliamps to 1 amp. Reed relays have moderately fast switching time of 0.2 milliseconds to 2 milliseconds. On the other hand, in the case of solid-state relays, the sub-assemblies are not moved when the electrical circuit is either connected or disconnected. When the electrical circuit is required to be either opened or closed, the electrical signals are passed from one sub assembly to another sub assembly in solid state relays. In solid state relays there is no mechanical contact made to either disconnect or connect the electrical circuit.

In the case of electromechanical relays physical contact is established to connect the electrical circuit. Unlike in the case of solid state and reed relays the problem of wear doesn’t occur but in the electromechanical relays wear does occur. Therefore, it is advantageous to use solid state relays and reed relays over electromechanical relays to overcome the problem of wearing away. However, when wear occurs in the electromechanical relay, the contact points can be replaced to prolong its life. On the other hand, in the case of solid-state relay and reed relay, if any failure occurs, we must replace the entire relay because the relay stops operation. Electromechanical relays were chosen for this project due to the stated advantages.

ELECTROMECHANICAL RELAY

Based on their contact configuration, the electromechanical relays can be described as:

- Single-Pole Single-Throw (SPST)

This type of relay has a total of four terminals. Out of these four terminals, the two terminals can be connected or disconnected. The other two terminals are connected to the coil.

- Single-Pole Double-Throw (SPDT)

This type of relay has a total of five terminals. Out of these five terminals, these two terminals are the coil terminals. A common terminal is also included which connects to either of two other terminals.

- Double-Pole Single-Throw (DPST)

This type of relay has a total of six terminals. These terminals are further divided in to two pairs. Therefore, they can act as two SPST which are actuated by a single coil. Out of the six terminals, two of them are coil terminals.

- Double-Pole Double-Throw (DPDT)

This type of relay is the biggest of all types. It has mainly eight relay terminals. Out of these eight terminals, two rows are designed to be changed over terminals. They are designed to act as two SPDT relays which are actuated by a single coil.

These are the overall specifications of electromechanical relays.

.Break: is a function of an electromagnetic relay which facilitates opening or closing a single electrical circuit contact. A single break contact breaks an electrical circuit at one location whereas a double break contact breaks at two locations.

ii. Pole: indicates the isolated electrical circuit that an electromechanical relay can pass through a switch. A single pole contact can carry current through only one electrical circuit at a time whereas a double pole contact can carry current through an isolated electrical circuit simultaneously.

iii. Throw: is a term referring to the closed contact position per pole that is available on a switch. A switch with a single throw contact can control only one electrical circuit whereas a double throw contact can control two electrical circuits. These parameters imply the design and function of different types of electromechanical relays.

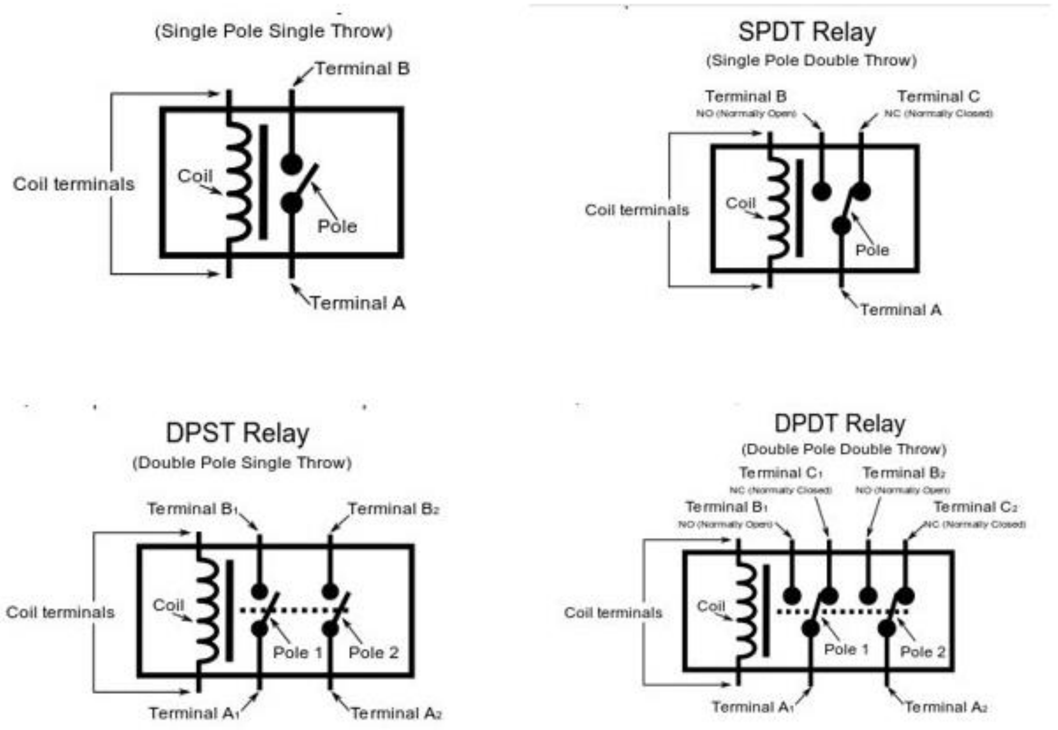


Figure 10 – Pole Relay

Selection of Electromechanical Relay

Electromechanical relays are used for detecting and isolating faults in transmission and distribution lines by opening and closing electrical circuits. The relays in this project will be used to detect and isolate faults and will serve as a switch for the degausser. Selection of an appropriate electromechanical relay for a particular application requires the consideration of main factors such as number and types of contacts, contact sequence, rating of contacts, coil voltage, sensitivity and speed of operation. Based on this parameter we chose to design our project using a single pole single throw relay.

Relay Parts Comparison

Contact arrangement	Maximum operating time	Life, mechanical	Cost	Weight	Current/ Voltage rating	Example
SPST	10ms	100million	$1.55	12g	10A/ 12V	G5LE-1A4 DC12
SPDT	15ms	2million	$2.98	13g	10A/ 5V	JW1FSN-DC5V
DPST	10ms	1million	$6.96	4.5g	5A/12V	DSP2A-DC12V
DPDT	15ms	1million	$3.12	13g	5A / 5V	JW2SN-DC5V

Table 4

Specification of selected Relay

- SPST Relay
- 12 V Coil
- 10 A Capacity
- Non-Latching

3.3 Magnetic Field Sensing Technology Comparison

Based on the research,the technology that best suits our magnetic sensor would be Anisotropic magnetoresistance due to our market research on currently available sensors. Many of the sensors on the market seem to use anisotropic magnetoresistance.

Magnetic Sensor Technology Study	**Hall effect sensor**	**Anisotropic magnetoresistance (AMR)**	**Giant Magnetoresistance (GMR)**	**Tunnel Magnetoresistance (TMR)**
Typical Applications	Current and position sensing	Oxygen sensing, linear position systems	Orientation, navigation, position sensing	Contactless current measurements
Design Theory	Lorentz force	Anisotropic magnetoresistance	Giant Magnetoresistance	Tunnel Magnetoresistance
Cost				Highest cost
Pros	Weak output signal, finite offset	Fabrication of sensor is easier, widely used.	High sensitivity and resolution, Higher bandwidth, lower operational noise	Highest sensitivity, Consume less power than GMR
Cons	Expensive for higher sensitivity devices	Low sensitivity		Easily affected by noise

Table 5

Magnetic Field Evaluation

A device that measures the magnetic field strength is typically known as a gaussmeter. There are many different IC’s that function as gauss meters on the market today. From my research I gathered that there are two main types of sensor technologies typically used in the market today, magnetoresistive and Hall Effect Sensors. Magneto resistive sensors use magnetoresistance effects to measure magnetic fields and hall effect sensors use the hall effect to measure magnetic fields. This section will detail the differences between the two types of sensors.

Magnetoresistance Sensors

Magnetoresistance sensors use magnetoresistance materials to detect an applied magnetic field. In the presence of an applied magnetic field the resistance of the material changes and the sensor can extrapolate the applied magnetic field from the data from the change in resistance. Magnetoresistance sensors detect a magnetic field applied parallel to the sensor, imagine a surface mounted part with a bar magnet hovering directly above it with north and south poles oriented parallel to the mounted part. The magnetic field lines extend from north to south above the sensor and the sensor is able to detect the magnetic field. Because of this topology when it comes to field detection magnetoresistance sensors have a wider span of detectable area than hall effect sensors do. The magneto resistive element is sensitive to the angle of the applied magnetic field and as a result these sensors are used to relay magnetic field position information. Typically, current through the magnetoresistive element is what is monitored as any change in that can calculate the change in resistance. Typically Wheatstone bridges are used as part of the signal processing circuit to eliminate any temperature dependances.

Hall Effect Sensors

Hall effect sensors use the hall effect to measure magnetic field strengths. The hall effect is the phenomenon where a hall voltage is generated across a material when a magnetic field is applied perpendicular to that material. Typically, the hall voltage is a few micro volts and is directly proportional to the strength of the applied magnetic field. Because of this hall effect sensors can give information about the magnetic fields pole type and magnitude. Because the hall voltage is so small many hall effect sensors come equipped with onboard amplification circuits so that the signal output is of a measurable level. Hall effect sensors are available with either linear or digital outputs making them usable in many different situations.

Characteristics of Magnetic Field Sensors

There are a few notable specifications that we would like to take note of when we compare the characteristics of the different magnetic field sensors. First, we will discuss characteristics of Magnetoresistive sensors briefly, then we will discuss the characteristics of hall effect sensors, and finally we will compare the two types of sensor characteristics.

Sensitivity is an important aspect of magnetic field sensor design. Magnetoresistive sensors are very sensitive to magnetic field strengths and can work well in low magnetic field applications. Another characteristic of Magneto resistive sensors is they are also very rugged and reliable. Because of the ruggedness of magnetoresistive sensors they are often used in industrial settings and machinery applications. Most available magnetoresistive sensors offer low and stable offsets and are not very sensitive to vibrations. Although Magnetoresistive sensors have some great qualities they also have some drawbacks. Magnetoresistive sensors are so sensitive that they can be overly sensitive to unwanted interfering magnetic fields. Another drawback of magnetoresistive sensors is they have a very limited linear range potentially creating issues with signal processing. Magnetoresistive senors also have some issues with temperature and can have poor temperature characteristics. Temperature drift can also be an issue with magnetoresistive sensors. There are many common typical applications of magnetoresistive sensors in the industry currently. Magnetoresistive sensors can be use to measure wheel speed by placing a magnet at a know spot on a wheel and calculating the revolutions per minute. Another typical application is linear displacement measurements, the sensor can measure how far away something has moved. Magnetoresistive sensors are also used in compass applications where the earths magnetic field must be measured. The application that we will be needing a magnetic field sensor for is to read and measure the magnetic field strength and magnetoresistive sensors are typically used for that application.

Now we will discuss the characteristics of Hall effect sensors. As mentioned before hall effect sensors are available with either linear or digital outputs making them convenient for signal processing. Another thing that makes signal processing easier is the fact that many hall effect sensors come with onboard amplifier circuits. Hall effect sensors are typically lower cost solutions to measuring magnetic fields. Hall effect sensors are also rugged and can be used in harsh situations.

Parts Selection

For our project we chose to use the Mikroe Gaussmeter Click. We chose to use this for a couple of different reasons. The resolution range is a great range for our application. A great feature of the Gaussmeter Click is that the onboard ADC and MLX90393 handles all the signal processing. The Gaussmeter click is convenient to use to interface to our microcontroller because it gives us the option to use either i2c or SPI communications protocols. Another great feature of the Gaussmeter click is that it is packaged on its own PCB and we can physically locate it in a more ideal location close to the device we choose to measure. One of the challenges we faced early on was a solution on how to get our magnetic field sensor closer to the watch and away from our degausser circuit. Using this module solves the location issue and we are able to place it right next to the watch.

We compared the gaussmeter click to two other gaussmeters and the advantages of the Gaussmeter Click were clear. The Memsic MMC5603NJ chipset seems very sensitive and offers very high resolution, possibly because it utilizes magnetoresistive technology. Four our application we are not looking for insanely high resolution and the tradeoff of placing this chipset on our PCB located away from the device we want to measure makes the MMC5603NJ a no go. Similarly, the Diodes Inc AH8503-FDC-7 has an analog output so we would have to do all the signal conditioning onboard. Part of our circuit involves powerful magnetic fields being generated and keeping the routes for these very sensitive analog signals could be difficult to avoid the high power ac lines as well as the large copper pours used to contain the DC voltages out of the noisy switched mode power supplies

Magnetic Field Sensor Parts Comparsion

Manufacture Part Number	Chipset	Interface protocols	Topology	Pros	Cons
Mikroe Gaussmeter Click	**MLX90393**	**I2C and SPI**	**Hall effect**	**Onboard ADC** **Easy communication** **Able to locate close to sensor** **0.161 uT/LSB resolution**	
Memsic MMC5603NJ	**MMC5603 NJ**	**I2C**	**Magnetoresistive**	**0.00625uT/LSB resolution**	**Would have to design circuit on our custom pcb. Located not near watch.**
Diodes Inc AH8503-FDC-7	**AH8503 FDC-7**	**Analog Output**	**Hall Effect**		**Analog output Chipset not as convenient** **322uT/LSB resolution**

Table 6

3.4 Microcontroller Technology Comparison

The microcontroller is a very specific piece of hardware, and as such there is not a huge variation in technologies available for said hardware. The primary differences in microcontrollers are the programming interfaces and the peripherals supported by the devices, the device's manufacturer also matters as some companies are better at supplying development tools and documentation for working with their specific chips. Popularity is an important trait regarding microcontrollers as the more popular a platform is, the more resources tend to be available online, in turn making development and troubleshooting significantly easier. Upon researching microcontrollers on the internet, we found the 3 most popular platforms are AVR, 8051, and PIC MCUs.

AVR Microcontroller

AVR (or Advanced Virtual RISC) is an 8-bit family of microcontrollers developed by Atmel, operating off the Harvard computing architecture, meaning that the chip has separate busses to control data and program instructions. AVR chips utilize a Reduced Instruction Set Computer (RISC), which compared to Complex Instruction Set Computer (CISC), eliminates complex instruction built into the chip and focuses on providing more silicon real-estate for other things like program registers and cache memory.

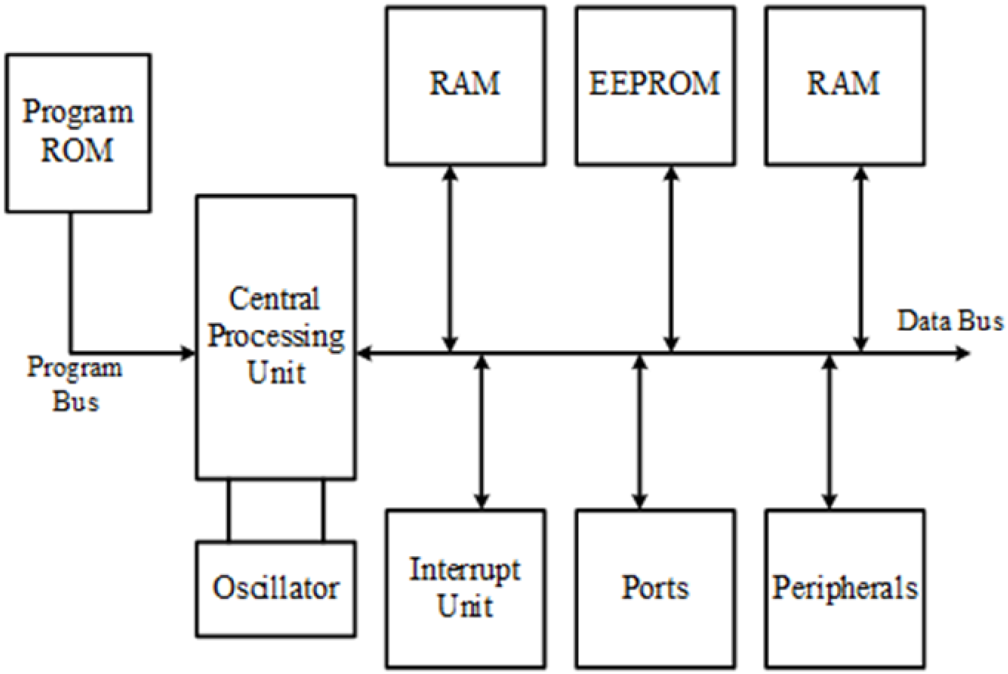


Figure 11: Block diagram of AVR microcontroller

One of the characteristics in which AVR microcontrollers stand out amongst other microcontrollers in the speed of their execution time, the architecture of AVR microcontrollers allow them to execute almost all instructions within a single execution style, meaning the number of instructions executed per second can be as high as the clock frequency governing the microcontroller, although typically this is scaled back for power-saving purposes. As far as peripherals are concerned AVR chips, particularly the MegaAVR series, excel at offering a wide array of built-in features on the chip such as SPI serial interfaces, ADCs, timers, programmable USART, PWM channels, and more. Sophisticated peripherals like displays, sensors, and the like often use communication protocols like SPI, I2C, and U(S)ART in order to exchange I/O with whatever device is connected to them, so having a microcontroller that can support as many protocols as possible is a huge boon for development. The AVR series features multiple power-saving modes; namely power-down, standby, idle and active; having this flexibility in power distribution is especially important for our project as the power supply for the chip will likely be an exhaustible DC source. The final major benefit of the AVR platform is the immense amount of support from the hobbyist electronic community, given the AVR chip's almost exclusive use in the popular prototyping platform Arduino; as such there is a plethora of documentation, software, and overall wisdom to be found on the internet for working with the platform in whatever capacity is sought.

8051 Microcontroller

The 8051 microcontroller is a 8-bit SOC (System on Chip, meaning many of the components of a system are built onto a single chip) created by Intel in 1981 that is based on the Harvard architecture, meaning it uses separate busses for data and program instruction.

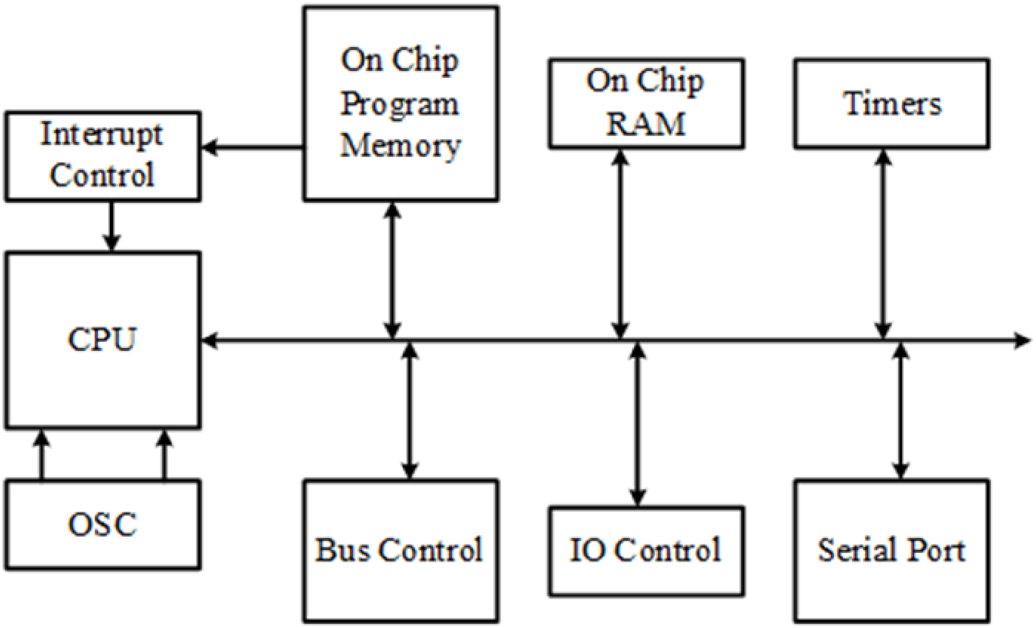


Figure 12: Block diagram for 8051 controller

The 8051 chip was intended to be utilized in embedded systems, and utilizes embedded C programming for the programming of the chip itself. Intel has allowed other manufacturers to make and market their own versions of the 8051 chip and as such many different varieties of the 8051 chip are available on the market, meaning that the peripheral choices available can range from timers, interrupts, UART, op-amps etc. The 8051 microcontroller platform has seen significant improvements in design since its release in 1981 with size, memory, peripherals, and reduced power consumption. The 8051 platform has seen a fairly significant adoption among the hobbyist community, however success is not as widespread as other platforms, and as such the resources available for the platform are dwarfed by more popular options. Intel releasing the design to the public is a massive boon for expanding the and because of the wide variety of chips that can be found on the market, availability can be more scarce and reliable documentation more difficult to find.

PIC Microcontroller

The PIC microcontroller family, originally Peripheral Interface Controller but was changed to Programmable Intelligent Computer, was created in 1993 by Microchip technology. PIC microcontrollers are based on the Harvard design, using separate busses for data and program instruction, with the architecture being an 8-bit minimalist onboard instruction RISC pattern.

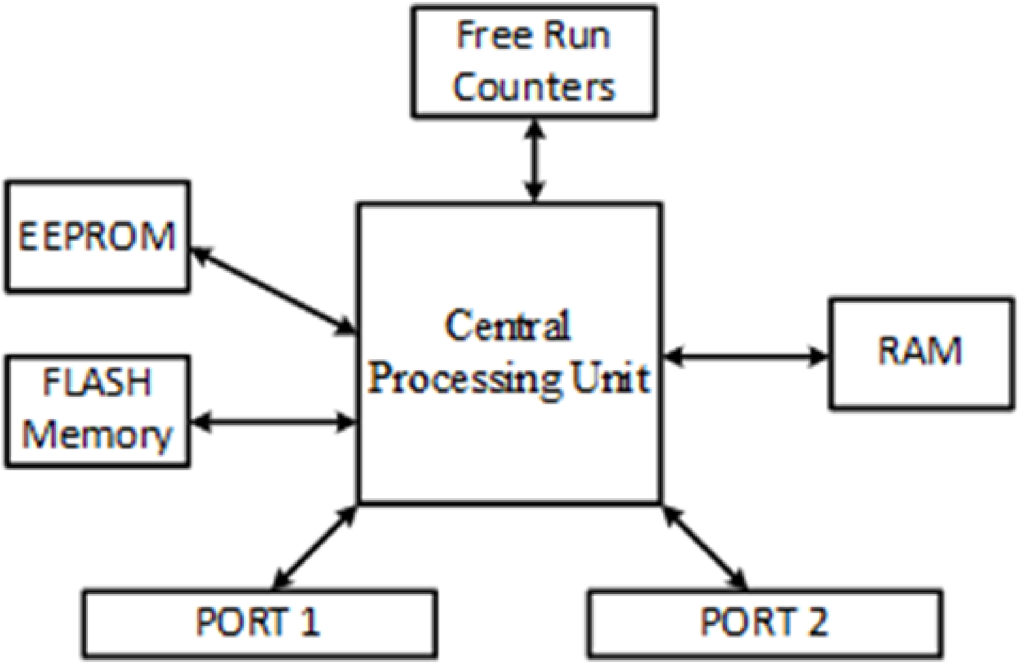


Figure 13: Block diagram for PIC microcontroller

PIC microcontrollers are often found in industrial applications as they are efficient, offer a wide variety of interfaces for working with peripherals like SPI and UART. Possibly due to the fact that PIC microcontrollers were one of the first chips to be marketed to hobbyists and students, PIC microcontrollers have a wealth of quality of life software that can make development easier (namely compilers, debuggers and simulators.) Simulators for PIC microcontrollers are especially useful as you can test and develop code for the chip while not actually flashing anything to the board, but rather utilizing the software to emulate the performance expected from a real PIC MCU. PIC microcontrollers are offered in multiple types: base line, mid-range, enhanced mid-range and PIC18; each utilizing different word lengths, offering different memory sizes, and a host of other features. While PIC microcontrollers still see use today, their prevalence is dwarfed by other more popular microcontroller platforms.

Microcontroller Technology Comparison

Family	Architecture	Memory	Peripherals	Cost	Examples
8051	**8-bit**	· **4-8KB ROM** · **128-256B RAM**	· **timers** · **serial ports** · **UART** · **ADCs**	**~$3**	· **8031** · **8051** · **8052**
AVR	**8-bit**	· **.5-256 KB Flash** · **1-32KB SRAM** · **64-4096B EEPROM**	· **timers** · **ADCs** · **U(S)ART** · **I2C** · **SPI**	**~$5**	· **tinyAVR** · **megaAVR** · **AVR Dx** · **XMEGA**
PIC	**8-bit**	· **32-64 B SRAM**	· **timers** · **EUSART** · **I2C**	**<$1**	· **PIC16** · **PIC18**

Table 7

Ultimately we decided on the AVR family of microcontrollers for this project, primarily because of the extensive support it offers in terms of communication protocols. Having access to these built in communication hardware blocks gives us much needed flexibility in choosing sensors, since we will be able to accommodate whatever specific part we choose in the end. The availability of programming resources available for the AVR development platform Microchip Studio turned out to be a huge boon in writing the software for the microcontroller, normally starting from scratch with a brand new chip would mean developing the libraries to actually implement various functionalities like the System Control Interface or the Interrupt Controller.

Microcontroller Parts Comparison

For the microcontroller we decided on the ATUC256L3U-AUT chip offered by Microchip Technology. Part selection was straightforward for the MCU, with supplies as limited as they are, no other options that fit the project requirements were available at the time. Beyond availability, the existence of a datasheet for the component was also an critical factor, thus limiting the number of choices further. The main deciding factor for our selection of MCU was the supported peripheral interfaces; we wanted to have all the major ones like SPI and USART/UART built in to be able to use any peripheral we want, as well as USB in case we finish our basic project goal early and have to implement web connectivity into our design for the stretch goal. The chip has 51 I/O pins, so we have plenty of headroom if we need any additional control signals for the project. The chip has 256 KB of program memory space, which upon researching is the recommended minimum amount for controlling a display. One especially notable feature of the chip is the brown-out detect/reset feature, this will make it so that issues with the DC power supply don't appear as issues with the microcontroller or the programming, thus helping to prevent confusion on the source of any issues for the project. The final point of interest is the form factor, leads are desired in order to make soldering to the PCB easier, and thus we do not want a chip with an exposed pad, ultimately culminating in the MCU we chose. Coming to the end of the project we had to remove a lot of functionality due to lack of available development time, so in retrospect the chip chosen far surpassed the needs of the project in it's final form.

Part Number	Program Memory	I/O Pin Count	Peripheral Support	RAM	Form Factor
ATUC256L3U-AUT	256 KB(256K x 8)	51	I²C, SPI, U(S)ART, USB	32 KB(32K x 8)	64-TQFP

Table 8

3.5 Motors Technology Comparison

When strategizing a design there are several motors to consider. Amongst the many motors we will discuss the comparisons of DC motors, stepper motors, and servo motors. We will thoroughly examine these three types of motors to conclude which of these motors will be most compatible to be implemented in our project. An electric motor converts electricity into mechanical energy. It is known for electric motors to be utilized in a magnetic field. Motors can be powered by either AC and or DC sources. As technology has developed and electricity is available in many parts of the world, electric motors make up fifty percent of the earth's electricity. Simple DC motors have become so advanced it can be a category of its own, where they all have the means to transform DC current into mechanical energy in various and distinctive ways.

Motor	DC Motor	Stepper Motor	Servo Motor
Types	Brushed & Brushless	PM Motor, VR Motor, and HY Motor	Positional Rotation, Continuous Rotation, & Linear
Efficiency	Brushed:75–80%; Brushless:85-90%	60-70%	50-80%
Design	Brushed: Complex Brushless: Simple	PM Motor: Moderate VR Motor: Simple HY Motor: Complex	Varies but not as complex as Stepper Motors
Cost	Brushed: Cheapest Brushless: Expensive	PM Motor: Cheapest VR Motor: Cheapest HY Motor: Expensive	Moderate

Table 9

3.5.1 DC Brushed vs DC Brushless Motors

Permanent magnet DC motors are a type of motor that is user friendly and used most when controlling torque, speed, and or positioning. Amongst DC motors, there are two types of motors, brushed and brushless. The differences between the two are in the names. Brushed motors contain brushes while brushless motors use electronic controllers instead of brushes causing the motor to rotate.

In practice, the DC brushed and brushless motor can be used interchangeably. These motors use the same theories to function. They contain permanent magnets and coils causing attraction and repulsion to work.

DC Brushed Motors

The design of DC brushed motors contain coils that spin freely to drive the rotor. The coils are woven around an iron core or in a coreless design, the coils spin onto itself. It is however more common to find DC brushed motors with iron cores.

As previously mentioned, permanent magnets are needed to cause attraction and repulsion between the magnets and coils. These magnets are located on the stator. The stator is the stationary part of the motor. Applying permanent magnets to the stator's inner walls generates a fixed magnetic field.

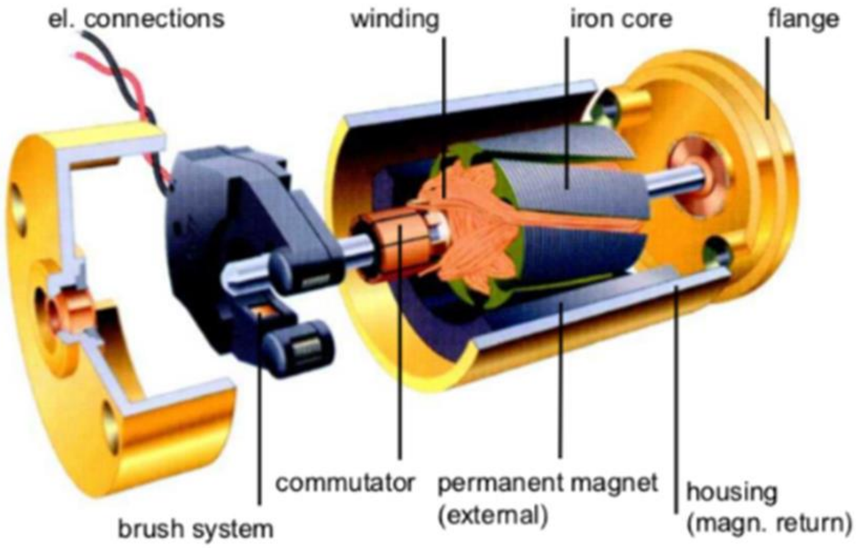


Figure 14 – Brushed Motor

For the rotor to rotate, torque must be generated. Torque is generated when the rotor is constantly spinning in its magnetic field while it attracts and repels the stator's fixed magnetic field. In the event where the field is desired to be rotated or needs to be rotated, an electrical switch, containing a commutator, is utilized. The commutator is attached to the rotor while the brushes are attached to the stator.

The rotor’s commutator is continuously turning the rotor windings on and off. This is done simultaneously as the rotor is spinning and is what causes the rotor to spin. The constant exchange of switches turned on and off creates magnetic attraction and repulsion between the stators' magnets and rotor coils, allowing for the rotor to rotate.

Drawbacks of DC brushed motors include wear of the brushes and commutator, later resulting in an obsolete motor. The wear is caused by the constant friction between the commutator and brushes that cannot be lubricated due to its electrical nature. Most brushed motors have now been designed to replace nonfunctional brushes with carbon brushes. However, eventually the commutator becomes obsolete and the motor itself has to be replaced.

Operating a brushed motor consists of exerting DC voltage onto the brushes. This allows the motor to spin as it is passing a current along the rotor’s coils.

In practice, many motorized toys use DC brushed motors to spin the toy motor in a singular direction. When a motor is used to spin in a singular direction without speed or torque, a motor driver is not required. The simplicity of a singular spin without torque and speed allows for the motor to be cost effective for its job is to only run and stop the motor. However, if the product requires reversed motor spin, double switches are needed.

As previously stated, H-bridges consist of switches such as transistors that aid in controlling the DC brushed motors torque, speed, and direction. The H-bridge allows the motor to be driven in any given direction when the voltage is inputted to either a positive or negative terminal of the motor.

DC Brushless Motors

DC Brushless motors function on the same theory that brushed DC motors operate on, magnetic attraction and repulsion, however, brushless DC motors are designed mechanically different. Brushless DC motors demand active control devices to use an electronic commutator in order to spin the stators magnetic field.

Similarly, to brushed motors, brushless DC motors permanent magnets are necessary, however in brushless motors, the magnets are attached to the rotor and the stator contains coil windings. Designing a brushless motor can include the rotor inside the winding or outside the coil winding. When the rotor is outside the winding, it is known as an outrunner.

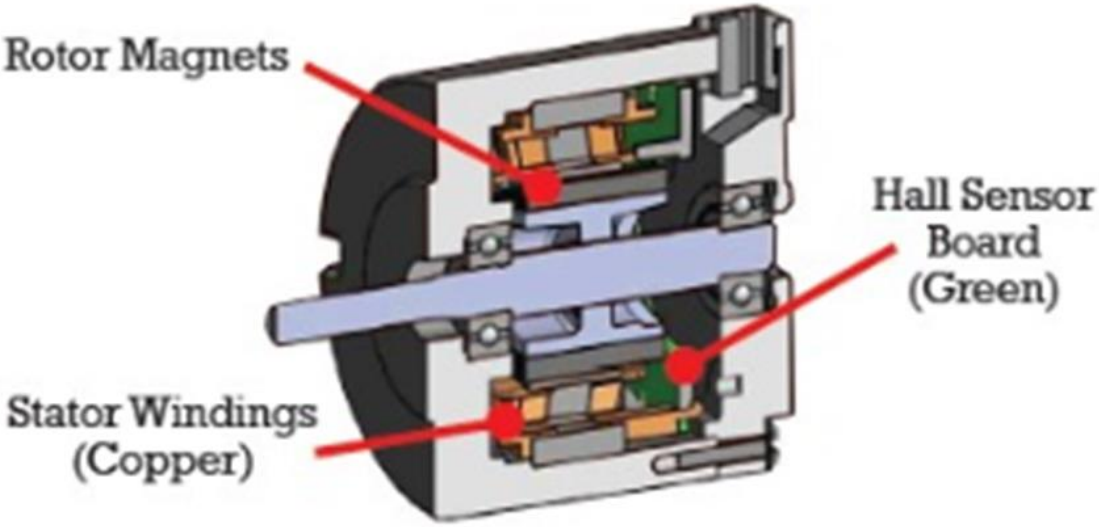


Figure 15 – Brushless Motor

Phases in a brushless motor are the number of windings the motor contains; one winding is equivalent to one phase. The most common constructive design of a brushless motor consists of three phases. The three phases are attached in either a delta or star design with three wires connected to the motor.

Poles are the various magnetic arrangements that a three-phase brushless motor can be designed as. The most basic design of a three-phase brushless motor contains a single pair of poles in the rotor, North and South poles. When adding poles to motors, the performance of the poles tends to perform better, however it requires more magnetic sections and windings within the rotor and stator. The two-pole design allows for higher speed performance.

Driving three phase brushless motors require each phase to be driven by either input supply voltage or ground by using three “half-bridge” drive circuits. Contingent on the necessary voltage and current required, each circuit contains a pair of switches that can be MOSFETs, IGBT’s, or bipolar transistors.

Regarding the method to rotate the magnetic field, the rotor magnet's physical position in relation to the stator must be known to the control electronics. Hall sensors are attached to the stator allowing the position to be known by sensing the rotor's magnetic field as the rotor spins. The driving electronics are able to flow currents to the stator coils allowing the rotor to rotate with the information collected by the Hall sensors.

Utilizing simple control electronics, trapezoidal communication and combination logic can be achieved by using three Hall sensors. In cases where simple control electronics cannot be utilized, the sine commutation can be used with more elaborate control electronics in addition to a microcontroller.

Without Hall sensors, there are other methods to locate the rotor's position. One method in particular is Field Oriented Control, also known as FOC. FOC executes position location by computing the rotor's currents and other specifications. This method however is costly as it requires a robust processor to swiftly compute numerous calculations.

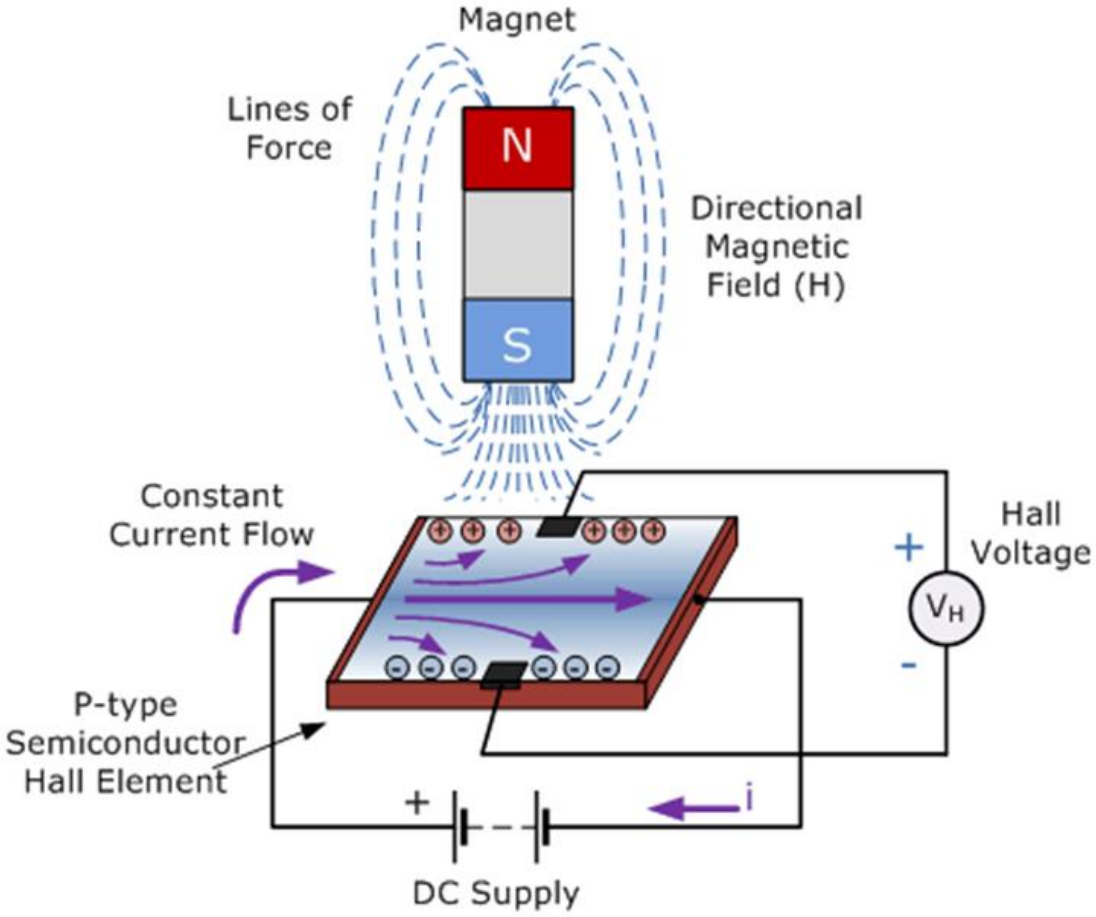


Figure 16 – Hall Sensor Theory

Advantages and Disadvantages of Brushed and Brushless Motors

Brushed motors and brushless motors include a plethora of similar, but also individualistic, advantages and disadvantages. It is important to understand these advantages and disadvantages when selecting the most compatible DC motor for particular applications.

Regarding the life of brushed and brushless motors, brushed motors are notorious for requiring brush replacements. As mentioned before, brushed motors are constantly wearing down due to their mechanical nature. Although carbon brush replacements are available, once the commutator is worn, the motor will become obsolete, and a new motor is needed. Nevertheless, brushless motors are a solution to refrain from utilizing a motor that requires brush replacements as brushless motors function electronically without mechanical contact.

Calling attention to the speed and acceleration amongst brushed and brushless motors, they both seem to be at a disadvantage. To start, the brushes and commutator on the brushed motors contribute to chaotic behavior performing at higher speeds. As previously mentioned, many brushed motors contain an iron core rotor. This core restricts the motor's ability to accelerate and decelerate as the core contains immense rotational inertia. Brushless motors can be designed to spin at higher speeds. This however would require precious natural magnets attached to the rotor, in turn becoming a costly motor.

Despite brushless motors relying on electrical commutation, brushed motors produce electrical noise. As powerful current passes the rotor’s windings, the motor's brushes and commutator act as an electrical switch that opens and closes while the motor spins, developing brush arcing. Arcing creates massive electrical noise. Although capacitors can resolve or minimize arcing, commutators will always produce electrical noise when the commutator is being switched rapidly between open and closed.

Brushed motors cause an acoustic noise as current is shifted from one phase to the next phase, suddenly embodying the term “hard switched". During the spinning of the rotor, the torque that is created fluctuates when phases in the brushed motor are turned on and off. Brushless motors can slowly shift current from one phase to the next phase causing a torque ripple. At lower speeds, this contributes to acoustic noise.

Brushed motors have been historically more cost effective than brushless motors since the technology and design behind brushless motors are complex. However, the attraction of brushless motors has contributed to a decline in cost. The lower costs of manufacturing brushless motors can also be accredited to electrical parts such as microcontrollers becoming more cost effective. Automotive manufacturers have slowly made the switch from brushed to brushless.

Summary

Brushless DC motors are on the rise and are slowly replacing DC brushed motors. Brushless DC motors are becoming less costly while operating at a better performance. The gradual change that automotive manufactures have made from DC brushed to brushless motors have contributed to less maintenance requirements since there are no carbon brushes to be replaced.

In applications where the motors application is sparse, such as motors in vehicle powered seats, brushed motors have been the constant design choice. These motors will not run excessively during the vehicle’s lifetime and therefore are unlikely to need brushed replacements or fail.

When it comes to brushed and brushless motors, they can be used in a wide array of products ranging from household products, toys, and cars. Regarding our project, it is too noisy to work with on the watch winder so we could not move forward with brushed and brushless motors.

3.5.2 Servomotors

Servomotors are utilized for accurate control of acceleration, velocity, and angular position. Mostly applied in a closed loop system, servomotors can be either a rotational motor or a translational motor where power is sourced by a servo amplifier to employ torque to a mechanical system. These mechanical systems include actuators and brakes. The closed loop system calculates the current output and modifies the current to the preferred state. Servomotors assert control supported by the output of the motor by implementing a positive feedback system. In the positive feedback system determines the motion and ultimate position of the shaft.

Servomotors allow for two varieties of currents, AC and DC, to pass through the motor. The first type is an AC servomotor. AC servomotors can withstand high current surges. High current surges are typically found in heavy industrial equipment like, aircrafts. The second type of servo motor is a DC servomotors. DC servomotors are commonly utilized in smaller implementations. DC servomotors are commonly used for their outstanding ability to control feedback. Frequency of the exerted voltage and number of magnetic poles are the deciding factors in a servo motor’s speed.

Servo motors have a plethora of applications including conveyor belts, automation systems, robotics, and the list can continue. Each uses different types of servomotor to best achieve the desired application.

Servomotor Design

The design of a basic servo motor contains two windings. The first winding is a stator winding, also referred to as field winding. As mentioned in its name, a stator winding is attached to the stator, the fixed part of the motor. The secondary winding is located on the rotor coining the name as rotor winding or the armature winding. This winding is attached to the rotor which is the spinning part of the motor. In addition to the two windings, a standard servomotor also contains two bearings, the first located in the rear and the second in the front. The bearings allow for unrestricted movement of the shaft.

Figure 17 – Servomotor Design

Estimation of a servomotors revolutions per minute (RPM) and or its rotational speed is calculated by the encoder.

Types of Servomotors & Application

There are many different servomotors best suited for a multitude of applications. The three basic types of servomotors are continuous rotation motors, linear motors, and positional rotation motors.

Continuous rotation servomotors are commonly utilized in radar dishes and driving mobile robots. Continuous rotation servomotors contain a shaft that is constantly rotating either clockwise or counterclockwise. This type of servomotor responds to demand signals regarding speed and direction of spins.

The second type of servomotor is a linear servomotor. A linear servomotor moves linearly by including additional gears, rack and pinions, to change the spinning nature of a rotor to a linear motion. Linear servomotors are not commonly applied in applications.

The most common servomotor found are positional rotation servomotors. Contrary to continuous motors, the shaft can only rotate approximately 180º. There are sensors that force the shaft to stop at 180º. Positional rotation servomotors can be found in numerous applications such as robotics and toys.

Advantages and Disadvantages of Servo Motors

Servomotors exert extraordinary power and efficiency despite their small size. These motors are also able to quickly speed loads and are able reach high speeds while maintaining a high torque with minimal sound. The attached encoders allow for high resolution and precision. Disadvantages include the necessity of safety circuits to halt passing currents throughout the circuit, to aid in servomotors transforming as undependable when a part becomes obsolete. As previously mentioned, servomotors use a positive feedback system to determine the ultimate shaft position and motion control. This feedback system contributes to a higher price and is not as cost effective as counterpart motors such as brushed or stepper motors.

Summary

Servomotors can be either rotational or translational motors that exhibit accurate position control despite their compact size. This type of motor particularly excels at accurately controlling acceleration, angular position, and velocity. They are compatible with AC and DC currents while also containing a variety of types, linear servomotors, continuous rotation servomotors, and positional rotation servomotors, suitable for different applications.

The servomotor would not be suitable for our project because they operate faster than stepper motors. The ideals feature we are interested in is precision rather than speed.

Stepper Motor Comparison

There are many factors that must be considered when choosing the most suitable stepper motor for the intended application. Factors include the stepper motors noise level and the cost of the stepper motor as the prices do significantly vary. Over the decades, technology has become increasingly advanced making it very difficult and sometimes overwhelming to choose a suitable stepper motor for a desired application. It is useful to understand that stepper motors produce their maximum torque at low speeds allowing them to be especially useful in high precision applications. The longevity of stepper motors can reach approximately 10,000 hours or 5 years of life when they are not run continuously.

Stepper Motors	Hybrid stepper motor (HY)	Permanent Magnet Stepper Motor (PM)	Variable Reluctance Stepper Motor (VR)
Design	Complex	Moderate	Simple
Step Angle	1.8°, 0.9° & smaller	1.8° to 30°	1.8°, 0.9° & smaller
Heat	Low temp	Low temp	High temp
Noise	Quiet	Quiet	Noisy
Speed & Torque	High torque at low speed, more torque at high speed	High torque at low speed, more torque at high speed	Less torque at high speed
Rotor Material	Neodymium Magnet	Neodymium/Ferrite Magnet	Iron/Silicon Steel
Driving Techniques	Full-Step, Half-Step, & Microstepping	Full-Step, Half-Step, & Microstepping	Usually runs in Full-Step only
Cost	Expensive ($20 to $300)	Cheap ($4 to $55)	Cheap ($4 to $55)

Table 10

3.5.3 Stepper Motors

The function of a stepper motor rotates the shaft by performing steps in a set amount of degrees. This function is achievable by the motors interior structure. This structure design calculates the precise angular position of the shaft without the need of a sensor by counting the number of steps performed. The design and function of a stepper motor can be applied to an array of applications.

Working Theory of Stepper Motors

Stepper motors contain two parts. The first a stationary mechanism, the stator, and second being a moving mechanism, the rotor. The stator contains teeth on wired coils in comparison to the rotor where it is manufactured with either a permanent magnet or by a variable reluctance iron core.

A stepper motor works by producing a magnetic field of an electric current flowing throughout the coil allowing the rotor to synthesize with said magnetic field. The rotor can be rotated at a specified number of turns when different phases in a sequence are distributed to reach the demanded angular position. Referring to Figure 1, coil A is first energized while the rotor is synthesizing with the generated magnetic field. However, in coil B, the magnetic field must be synthesized to the rotor rotated at 60 degrees to energize it, similarly to coil C. The winded stator teeth are color coordinated to demonstrate the direction of the produced magnetic field.

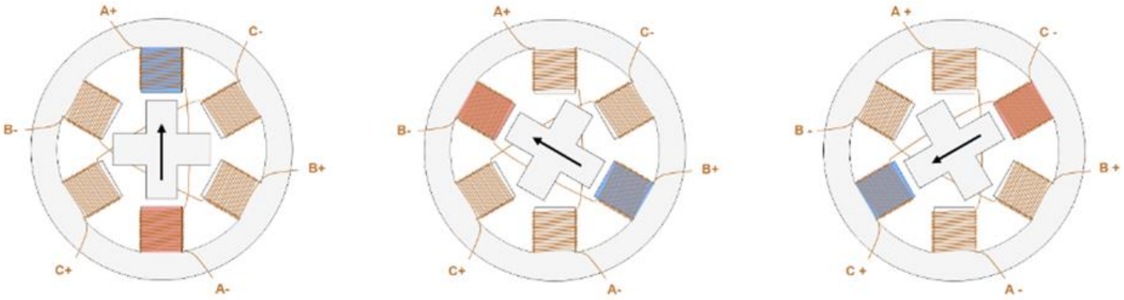


Figure 18 – Stepper Motor Working Theory

Types & Design of Stepper Motors

A stepper motor’s functionality is determined by its interior design, including, and not limited to resolution, speed, and torque. This simultaneously determines how the motor is controlled. There are multiple variations of a stepper motors interior design with a wide range of rotor and stator chemistry.

The three basic models of a rotor are permanent magnetic rotor (PM), variable reluctance rotor (VR), and a hybrid rotor (HY). A permanent magnetic rotor contains a stator circuit the creates and synthesizes with the magnetic field. A permanent magnetic rotor is designed to maintain good torque and restrain torque allowing the motor to repel, despite the coil being energized and or the strength, to change the angular position or the rotor. However, a permanent magnetic rotor functions at a lower speed and resolution. The second type of stepper motor is called a variable reluctance motor. A variable reluctance motor contains an iron core manufactured at a specified shape synthesized to the magnetic field. A variable reluctance motor can obtain a higher speed and resolution. This stepper motor does however create a torque that is low and is not resistant to torques. The last basic model of a stepper rotor is called a hybrid rotor. This rotor is a distinctive design as it is a "hybrid" of the permanent magnetic rotor and the variable reluctance rotor. Containing two caps with alternating teeth and a magnet determining the direction of the magnetization along an axis. A hybrid rotor carries the benefits of both permanent magnet rotor and the variable reluctance rotor including speed, torque, and high resolution. This high performance does come at the required cost of an elaborate design structure. This is attainable due to the hybrid rotors structural design.

Stator

To create a motor that will align the magnetic field and the rotor, a stator is necessary. A stator consists of numerous phases amongst poles pairs and wire configuration. Each numerical number of coils correspond to the number of phases of the stator. The number of pole pairs determine how many pairs of teeth reside within each phase. The most common stepper motor used is a two-phase motor in contrast to three-phase and five-phase motor which are not used as often.

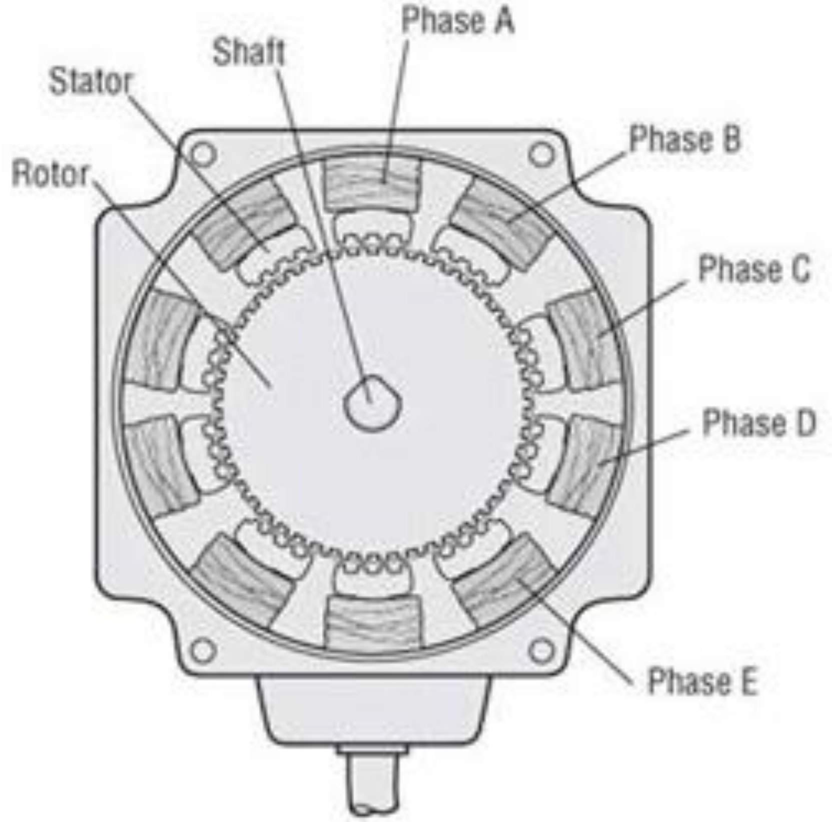


Figure 19 – Stator relative to the Shaft

Control of Stepper Motor

For a magnetic field to be created and aligned with a motor, motor coils must be energized in a specified sequence. To provide the required voltage to the motor coils to properly operate, devices include but are not limited to, a transition bridge, a pre-driver, and a microcontroller can be used. The first device, a transistor bridge, controls the electrical connection of the motor coils physically as controlled interrupts. Transistors can be looked at as interrupters, when closed, current flows through the coil. To function, each transistor bridge requires one motor phase. A pre-driver is the second type of device that supplies the necessary current and voltage to a motor coil. A pre-driver operates the ability for a transistor to activate. A pre-driver is operated by a microcontroller unit, the third type of stepper motor control. A microcontroller unit, MCU, creates distinctive signals for the pre-driver. The MCU's signals are programmed by its user. The manufactured signals allow the motor to operate on behalf of the user's needs. Figure 2 shows a general stepper motor control.

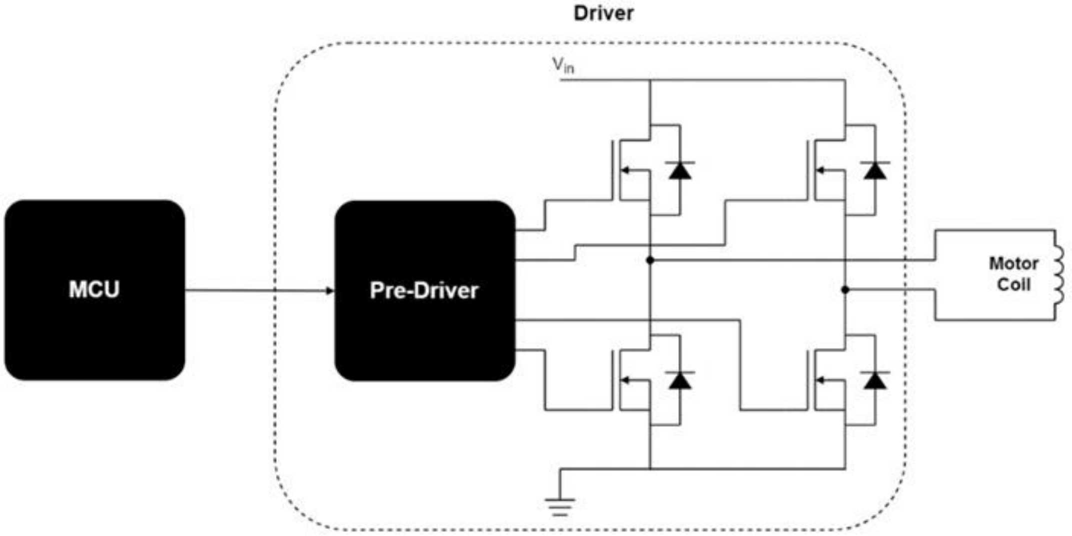


Figure 20 – Stepper Motor Control

Stepper Motor Drivers Features

Stepper motor drivers can vary for unique functions and features. There is an array of different types of stepper motor drivers for purchase, all with unique features based on the user's need. The two most important features of a stepper motor driver are arguably the input interface and the ability to control the voltage flowing throughout the device.

Commonly purchased stepper motor driver options include features such as step (direction), phase (enable), and pulse-width modulation (PWM). The step signals an electrical pulse to the step pin allowing the driver to reconfigure its output. This permits the motor to move towards a desired step dictated by the direction pin's level. Options such as phase, relay steps through channels of multiple coils. A collection of these coils is what is known as phases. Once a phase is electrically triggered, the motor will rotate one step per phase dictating the direction of the current. Another optional feature are pulse-width modules, PWM. PWM signal drives by managing the amount of pulses to regulate any angular displacement while also allowing for the motor to spin at a fixed angle in a desired direction.

Bipolar/Unipolar Motors

In an event where there is limited control of current direction, a unipolar/bipolar stepper motors aids regaining control. In a unipolar motor, there are two coils per phase. The electrified coils are limited to a current flowing in one direction amongst a singular switch or transistor per each individual coil. For a coil to be energized, the transistor must be closed. To regulate the direction of the motor, the transistors interchange between close and open. However, in bipolar motors, only a singular coil is necessary. The term bipolar, refers to the ability of an electrified coil to flow in two directions.

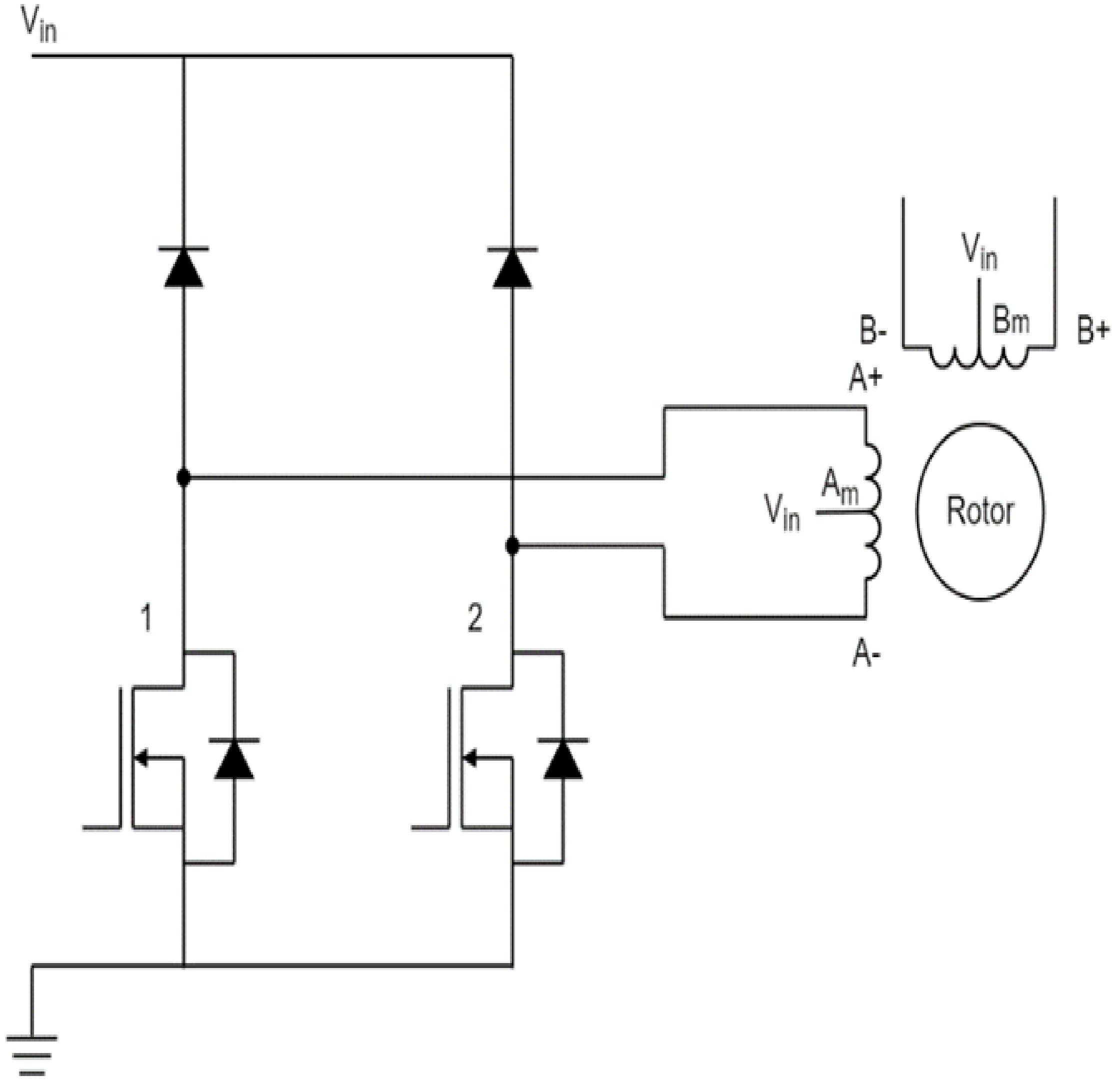


Figure 21 – Circuit of Unipolar Stepper Motor

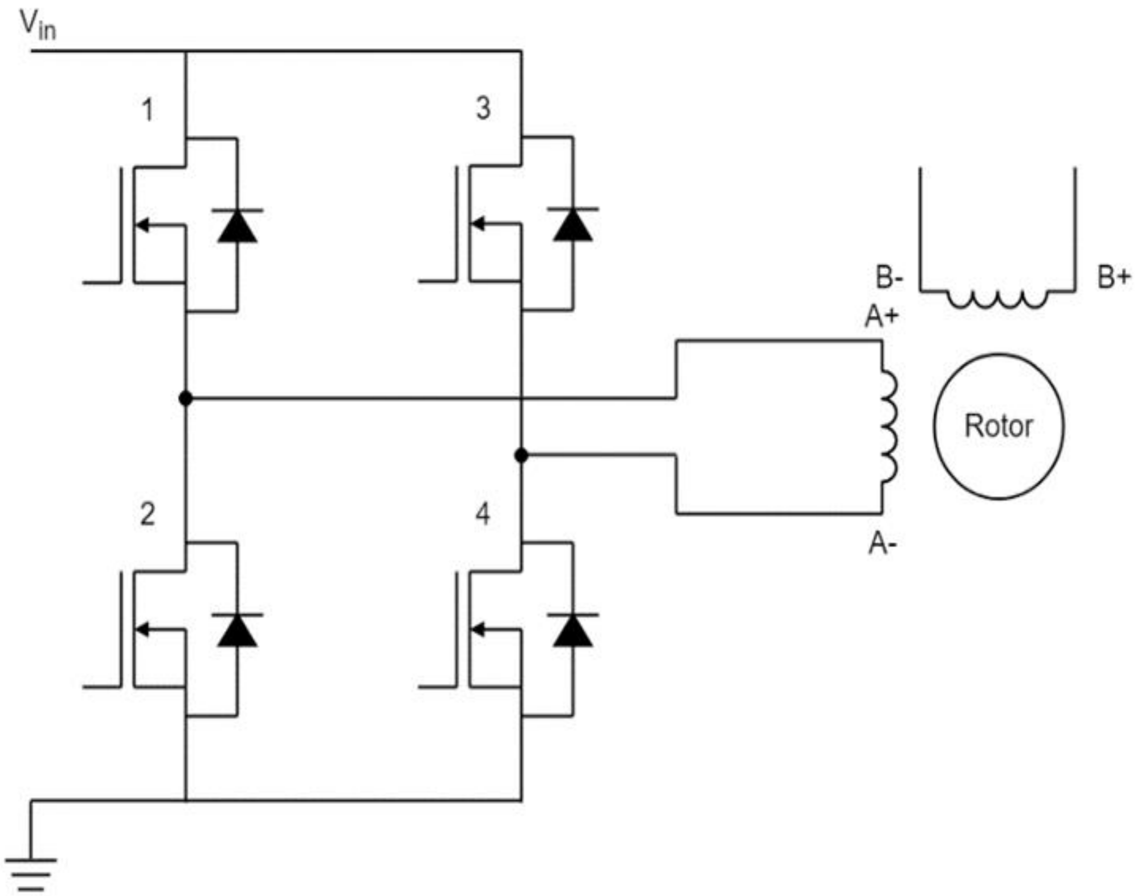


Figure 22 – Circuit of Bipolar Stepper Motor

Driving Techniques of Stepper Motors

To achieve optimal use of a stepper motor, there are three different driving techniques, half-step mode, full-step mode, and microstepping. To generate higher torque, it is best to drive the motor in full-step mode. In full-step mode, two motor coils must be electrified simultaneously. In other words, two phases are accessing a current concurrently allowing more electricity to pass through the motor generating a greater magnetic field. To attain a precise step with minimal vibration, half-step mode is the most suitable technique. Compared to full-step mode, half-step mode halts the rotor at one position in response to one phase jump. When the driver accumulates the next phase, the driver delivers two jumps stimulating the rotor to shift half a step then halting in between the two full steps. Half-step mode's name derives from its two phase to a single phase while jumping and stopping at a half step in between said pulses. Events in which smaller steps, smaller than half-stepping, is required, Microstepping motor driving is done to attain smaller steps and high position resolution. Microstepping is the best driving technique to limit vibration and use for noise reduction. Microstepping mode is achieved by slowly elevating electric current within each phase. Done correctly, the magnetic field will manipulate the rotor to gradually shift. In microstepping mode, there is a direct relationship between steps and torque. Smaller steps generate less torque.

Stepper Motor Advantages

- These motors are extremely cost effective.
- A stepper motor’s position is attained by counting steps therefore no sensor is required.
- Stepper motor requires a motor driver however the motor driver can either be controlled with straightforward calculations and by a simple tuning. Complicated calculations are not necessary to control a stepper motor.
- Microstepping allows for high position precision and ability to hold a position.
- Provide good torque at a low speed and great product cycle longevity.

Stepper Motor Disadvantages

- Counting steps is the only way without a sensor to know the motor position therefore if the torque is high, the motor can miss a step making the position of the motor unknown.
- Stepper motors continuously pull current, in motion and still. This negatively affects the motors efficiency and is the cause for overheating.
- When preforming at higher speeds, the stepper motor becomes loud due to low torque.

Summary

Stepper motors are user friendly and extremely cost effective. There are different stepper motors and different ways to drive them to attain different goals. Specifically, we picked a hybrid bipolar stepper motor to achieve our goals.

Parts Comparison

The list below of stepper motors are all compatible options to implement in this watch winder however some are more compatible than others. The PM stepper motor was not selected due to its lack of weight which would be detrimental to the watch winder. The PM stepper motor weighs 34 grams. The weight of this stepper motor could not have been able to physically support the weight of the winding mechanism nor the watch itself. The VR stepper motor was also omitted from the final design on the account that it does not have the power supply capacity required to power the stepper motor. This group had decided to move forward with the hybrid stepper motor as it appears to be the best choice based on its voltage and current rating. The selected motor driver would be compatible with the hybrid stepper motor as the motor driver is able to provide up to 0.9 A per phase without a demand for cooling. Ultimately our goal is to design a watch winder that is efficient and uses the minimal amount of current and voltage; our decision in selecting a hybrid stepper motor will achieve that goal.

Stepper Motor	Permanent Magnet Stepper	Hybrid Stepper	Variable Reluctance Stepper
Coil Type	Bipolar	Bipolar	Unipolar
Voltage Rating	5 V	12 V	24 V
Current Rating	250 mA	350 mA	850 mA
Weight (grams)	34.02 g	200.03 g	310 g
Operating Temperature	-20°C – 70°C	0°C – 50°C	-10°C – 50°C
Example	403-1005-ND	1528-1062-ND	GS0036-17M001-ND

Table 11

3.6 Motor Driver

A motor driver operates a motor acting as a median between a microcontroller and a motor. The motor driver uses a microcontroller to control a motor as both motor and microcontroller function on different current levels. For example, a motor is prescribed to work on a higher level of current compared with a microcontroller that requires a substantially lower amount of current. The motor drivers are the device that makes these two incompatible devices, the motor and microcontroller, compatible with one another by taking steps up or down to balance low and high current signals. When a motor driver receives a low current signal from a microcontroller, the driver surges the low current signal to a high current signal for the motor to be driven.

Characteristics of Motor Drivers

There are a plethora of motor drivers on the market however, these four characteristics are essential to understand a motor driver: voltage, current, compatibility, and interface.

The *voltage* and *current* of a motor driver must be able to withstand the application of use desired.

Compatibility is the third essential characteristic of motor drivers. Understanding compatibility is understanding there is no standard motor driver for all motors. There are different motors including stepper motors, servomotors, and DC motors. These three are compatible with different motor drivers. Most stepper, servo, and DC motors can operate with the same motor driver however, servo motors require a driver that can operate a motors position, speed, and torque.

Interface is the last characteristic of motor drivers. Interface refers to the application needed for a motor driver. Arduino works with most board motor drivers while the most common wireless interface for motor drivers is Bluetooth.

Types of Motor Drivers

Each type of motor driver is used differently based on their unique performance and ability of control. As previously mentioned, a motor driver can be used on multiple motors and a motor driver can also solely be used on a single motor type.

H-Bridge

An H-bridge is an electronic circuit that consists of two pairs of transistors, a motor, and input voltage. The pairs' transistors are connected to the motor where one pair is grounded to the motor while the other is attached at the opposite side of the motor receiving input voltage.

The two pairs of transistors act as a pair of switches controlling the motor’s polarity. This allows the motor to move in a backwards and forward’s motion. For example, when a positive voltage is introduced to the circuit, the motor will rotate in a specific direction.

However, when the polarity is reversed to a negative voltage the motor will turn in the opposite direction.

To attain positive polarity, one transistor pair must be turned on at a time. This allows for the current to flow to the motor’s positive terminal, then to the motors negative motor till the current hits the ground. To achieve a negative polarity, two transistors must be switched on when the current flows to the motor’s negative terminal, then to the motor’s positive terminal until it reaches the ground. In summary the polarity is dependent where the current flows from the voltage source and the number of transistors switched on.

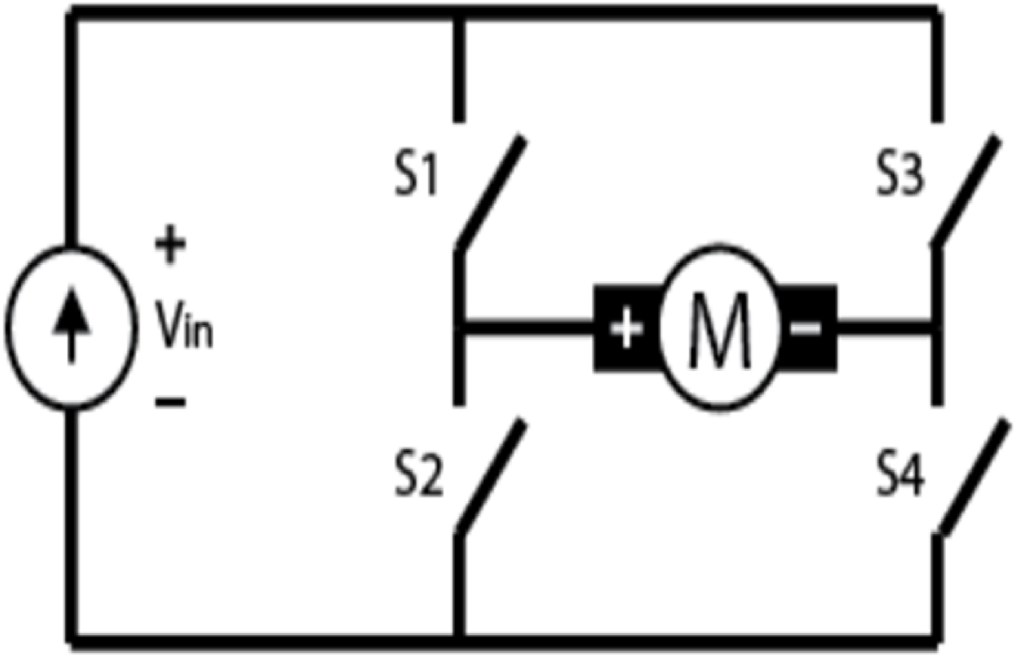


Figure 23 – H-Bridge Theory

Parts Comparison

The table below contains different motor drivers that have the potential to be implemented in the watch winder's design. Motor driver L298 is a standard motor driver commonly used to drive stepper motors and other DC motors however, motor driver L298 was not selected. The L298 lacks particular functions such as step resolution and short-circuit protection that is desired in the watch winder's design. Motor driver L293D was also considered to be the implemented motor driver as this motor driver has the ability to drive a set of motors in both directions. Motor driver L293D was ultimately eliminated as an option due to its inability to offer a full protection set and at times, when operating, can become extremely hot leading to failure in the design. The STSPIN820 motor driver is the most compatible motor driver for the watch winder's design. The STSPIN820 contains a plethora of options. Its features include but are not limited to short-circuit protection, full protection set, overcurrent protection, and overtemperature protection. After much deliberation the STSPIN820 was selected as the motor driver for the hybrid bipolar stepper motor that has been selected.

Motor Driver	L298	L293D	STSPIN820
Step Resolutions	None	None	1/256
Supply Voltage	7 V to 46 V	4.5 V to 36 V	0 V to 48 V
Max Output Current	4 A	1.2 A	1.5 A
Short-Circuit Protection	No	No	Yes
Max Operating Temperature	-25°C – 130°C	0°C – 70°C	-40°C – 150°C
Driver	Dual Full-H Driver	Quadruple Half-H Driver	STSPIN820

Table 12

AC Power Supply Technology Comparison

Based on the research,the technology that best suits our AC Power Source would be some form of linear AC/DC converter, possibly a wall plug. This method occurs in most consumer products and was chosen to simplify the design. If we use a wall plug the excess heat would be contained to the converter located outside of our unit.

AC Power Supply Technology study	**Linear**	**Switching**
Typical Applications	AC/DC Converter	AC/DC Converter
Design Theory	Excess power loss to heat	off/on switching
Cost	Relatively inexpensive	Relatively inexpensive
Pros	Simple, less noisy	Efficient
Cons	Inefficient, heat sinking	Can be noisy, circuitry more complex

Table 13

3.7 Power Supplies

Basics of an AC/DC Converter

An AC to DC converter is a device that inputs an AC voltage and current and outputs a DC voltage and current. AC/DC converters are used in almost every household appliance and piece of technology as most digital circuits are CMOS level DC logic and our power grid provides AC power to our homes. There are many different topologies of AC/DC converters and depending on the topology an AC/DC converter can output voltages that are either stepped down or stepped up from the input voltages. Common topologies of an AC/DC converter include Flyback, Buck, Boost, and Buck-Boost converters. Flyback topologies can be configured in isolated and non-isolated, step-up, and step-down configurations and the involved circuit is simple and contains only a few components resulting in a lower bill of material cost. Buck converters are circuits that step down the voltage levels but typically offer more current due to the conservation of energy. Boost converters are circuits that step up the output voltage in respect to the input voltage. Like the buck converter and any other converter, they must obey the law of conservation of energy and the total power out can never be greater than the power in, therefore the stepped-up voltage a boost converter supplies will typically offer less current to keep the current voltage power relation.

The two main types of AC to DC converters are Linear and switching mode power supplies. Linear supplies are typically cheaper and less efficient but offer cleaner dc output voltages whereas switching supplies can have substantial output ripple voltages. Switching power supplies involve a way more complex circuit than linear supplies do but can be far more efficient than linear power supplies. The basic operation principle of a linear power supply is first the AC input voltage is applied across the primary winding of a transformer. The turns ratio of the transformer is used to calculate the output waveforms peak to peak voltage and can either be stepped up or stepped down from the input but as described when talking about the buck and boost converters the power into the primary winding of the transformer must equal the power out of the secondary side of the transformer, therefore like with the buck and boost converters if the voltage is stepped up the current output will be less and if the voltage is stepped down there will be more current available. The waveform on the secondary winding of the transformer is still and AC waveform and must now be rectified into a DC waveform. Ratification is done using a diode bridge arrangement that only allows current to pass through the load in one direction only. After rectification only the positive half of the waveform exist and negative voltages and currents are eliminated but the waveform is still time varying. A capacitor is used to smooth out the rectified waveform and produce a dc wave. Switching mode power supplies are a more recent design method than linear power supplies due to advances in MOSFET technologies allowing more power to be switched. With switching mode power supplies the input AC voltage is not reduced like it was with linear power supplies but it is still rectified and filtered. The resulting DC voltage is now chopped up into a high frequency pulse train and eventually rectified and filtered into a DC output. The higher frequencies of the pulse train allow for the core of the transformer to become smaller and smaller resulting in a design with a much smaller transformer.

Characteristics of AC to DC Converters

As mentioned previously there are two main types of AC to DC converters widely used today; that is the Linear AC to DC converter and the Switching AC to DC converter. With these two options available and both having different strengths and weaknesses in performance the characteristics of AC to DC converters as a whole becomes broad. If a design specification calls for a power supply that offers higher efficiency, then a Switching mode AC to DC converter could be a viable solution as they can offer efficiencies of near 90%. If another hypothetical design specification calls for very low noise, then a switching mode AC to DC converter would not be the best option. For low noise environments an AC to DC converter can still be used but the engineer would be better suited using a linear AC to DC converter instead. Switching mode power supplies often have a “ripple voltage” on the DC output voltage that is high frequency and can be around 100mVpp. Linear AC to DC converters offer lower ripple voltage and are better suited for low noise applications. Linear AC to DC converters require the input transformer to be larger in size resulting in the overall power supply circuit consuming much more area than a switching mode AC to DC converter. Resistors are easily shrunken down to smaller form factors and even resistors in package sizes as small as 0603 can tolerate a quarter of a Watt, Capacitors can also get relatively small and have decent capacitance values and rated voltages although they are typically larger than resistors. Inductors and Transformers are typically the limiting factor when it comes to size in a power circuit, that is, the circuit overall PCB area is mostly dominated by the chosen transformers and or inductors. This is the reason linear AC to DC converters are larger in size as they require a bulky transformer for operation. Typically Linear supplies are located off of the PCB and many applications use “Wall Warts” switching to DC right at the AC plug in the wall and running a DC voltage thru the cable and into a barrel plug into the PCB.

Types of AC to DC Converters

The two types of AC to DC converters will be highlighted in this section to give an over view of both linear and switching power supply design and applications. High level flow charts are provided of both systems and the overall theory and operation is discussed. Typical applications of both types of AC to DC converters is discussed in this section as well.

Linear AC to DC Converter

A high-level overview of a linear AC to DC converter is shown in figure 1 below. An AC input voltage is applied to the primary side of the input transformer where the desired output voltage value is produced on the secondary terminals. The voltage on the secondary side of the transformer is still a AC but has been stepped up or down to the desired output. The output of the transformer is now rectified into a dc voltage by using one of the multiple rectification schemes but this waveform still has large swings in the output voltage and needs filtering. The rectified waveform is now filtered to be a stable DC output Voltage.

This DC output voltage has much lower ripple voltage than a switching AC to DC converter.

Linear AC to DC converters tends to dissipate a lot of energy as heat. The loss of this energy to heat lowers the efficiency of the regulator. The excess heat can be troublesome in some environments and must be managed. Careful PCB design with adequate power routing techniques can help manage the heat as well as heat sinks. Many Linear AC to Dc converters are sold as modules with all the internal circuits sealed in potting solution giving the user access to only a few crucial pins. Most applications of Linear AC to DC converters take it a step further and pot their module into an ac connector resulting in your typical “Wall Wart” plug used in many households. Another benefit of locating your Linear AC to DC converter external to the device it wishes to power is the size of the regulator. The limiting size dictated by the transformer is better located on your wall than on your iphone.

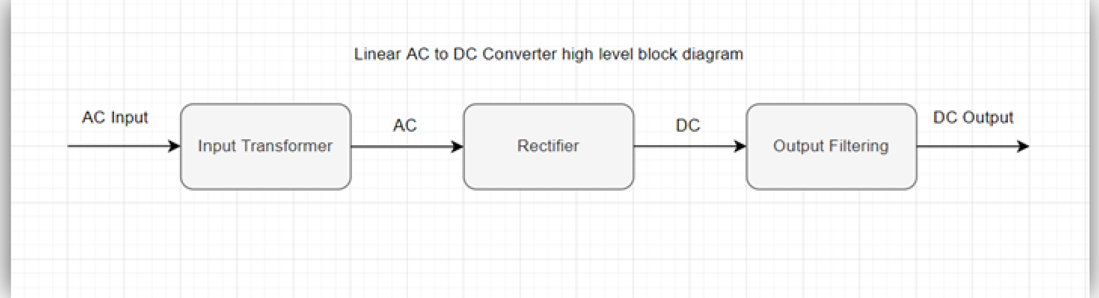


Figure 24 – AC to DC Converter Block Diagram

Switching AC to DC Converter

A high-level overview of a linear AC to DC converter is shown in figure 2 below. The basic principle of operation is the AC input is immediately rectified into a DC voltage. The DC voltage is then converted into a high frequency pulse train wave form. The high frequency of the pulse train is what allows the Switching AC to DC converter to be much smaller than Linear AC to DC converters. The high frequency allows the transformers core to become smaller as at higher frequencies it can transfer more power without reaching saturation. After the pulse train is applied to the primary side of the isolation transformer the waveform at the secondary side is then rectified and filtered to become the output voltage.

The switching topology not only allows for smaller transformers so therefore a smaller overall circuit, but also greatly increases the efficiency of the AC to DC converter by utilizing fast switching MOSFET technologies. Because of the form factor, efficiency, and high output capabilities switching mode power supplies are widely used on custom circuit cards. The high frequency switching of the MOSFET’s create a high frequency noise issue when using switching mode AC to DC converters. It is common to see designers using a switched mode power supply to convert to DC and then use linear DC to DC converters off of that regulated voltage from the AC to DC converter. Some companies make switching power supply modules. These modules are nice because all the circuitry of the power supply is enclosed inside a potted and shielded environment. When using the modules they typically have a common PCB footprint between multiple modules making them directly swappable for other supplies.

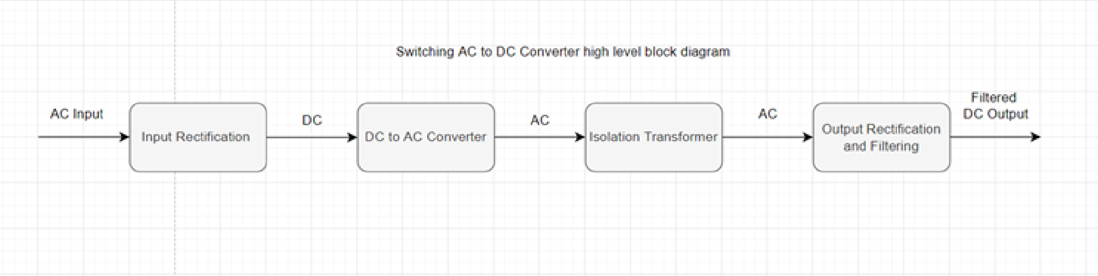


Figure 25 – Switching AC to DC Converter Block Diagram

Parts Comparison

Table 1 below is a parts comparison between four different power supplies considered for the design. The main considerations when selecting between the power supplies listed where; Voltage input, Voltage output, Current output, and output voltage ripple. A block diagram of our power section is provided below in Figure 3 to help explain the choices we have made on our power supplies. Our overall power architecture is to bring in 120VAC and use the Traco Power TMPS 15-112 to convert to a 12V DC voltage. This 12V DC voltage will feed Linear Drop Out regulators to output voltages to supply our discrete circuits. We chose the Traco Power TMPS 15-112 for multiple reasons. The first reason this part appealed to me is that I felt 12V DC is a good intermediate voltage that can be stepped down reasonably to logic levels using simple LDO’s. Additionally, we like the idea of having a barrel connector on our PCB that can feed into the 12V rail by populating a resistor that was previously DNP, giving the option of a back op offboard AC/DC converter if we need more output power. Converters that would fit this need are very common and come in multiple output power options. Another good feature is the TMPS 15-112 is a part of a large family of similar regulators that are footprint compatible, furthering the robustness of our designs power section.

For the DC to DC converters we chose the Microchip MIC5209YU. The MIC5209YU is a simple adjustable linear voltage regulator. The output voltage is set by a resistor divider feedback network and the user only needs to set the two resistors to change the output voltage. The MIC2509 comes in a TO-263-5 package and is a very common footprint used in the industry. The pinout of the MIC2509 is directly replaceable with numerous different LDO’s. Another reason the MIC5209 was chosen was because it offers very low output noise. We will have sensitive data lines on our PCB so the goal is to isolate the copper pours containing the noisy 12V rail from the clean digital rails provided by a series of LDO’s. Another great aspect of the MIC2509 is the wide input of 16V with a Dropout Voltage of only 0.6V. The MIC5209 is also a very cheap circuit. The MIC5209 is currently $0.84, the only other thing it needs to run are two resistors and two filtering capacitors totaling $0.40 resulting in an entire circuit cost of $1.24. The MIC5209 is also currently readily available at Digikey and Mouser.

Power Supplies Parts Comparison Table

Manufacture Manufacture Part Number	Output Voltage	Output Current	Topology	Pros	Cons
XP Power VEC40US12	12V	3.33A (40W Supply)	AC/DC Offboard converter, barrel plug interface	Barrell plug interface give many options	Offboard AC/DC conversion and we need AC voltage
Traco Power TMPS 15-112	12V	1.25A (15W Supply)	AC/DC Converter, PCB Mount	Footprint compatiable with other modules 12V is common if we use back up barrel plug option	Output current
Traco Power TMPS 15-124	24V	625Ma (15W Supply)	AC/DC Converter, PCB Mount	Footprint compatiable with other modules 12V is common if we use back up barrel plug option	24V too high to step down with LDO's Output current
Microchip MIC5209YU	Adjustable	500mA	DC/DC Converter, LDO, PCB Mount	Adjustable output voltages. Clean voltage output Cheap Wide input voltage range	Output Current

Table 14

3.8 Display

The 2 primary technologies available on the market are LCD and OLED panels, the major differences being color gamut, power usage, and cost. Visual performance is not an especially important characteristic for our project given that the UI will be simple and utilitarian, so color gamut is not an important characteristic to consider. Power usage and cost will be the primary drivers behind what display technology is chosen.

LCD:

LCDs, or Liquid Crystal Displays, are a display technology frequently found in many electronics today. The first and most basic LCD panel technology used in mass production is TN, or Twisted Nematic, and utilizes two polarizing layers on both sides of a liquid crystal layer to display images. The way the Twisted Nematic technology works is that when the Liquid Crystal Layer is not polarized the molecules in the Liquid Crystal Layer are twisted 90 degrees, such that when light passes through the first polarized layer and the liquid crystal layer it bends and does not pass through the second layer, thus the screen appears dark to the user. To activate the pixels, an electric field is applied to the liquid crystal molecules that cause them to be untwisted, thus allowing light to pass through both polarized layers and the liquid crystal layer.

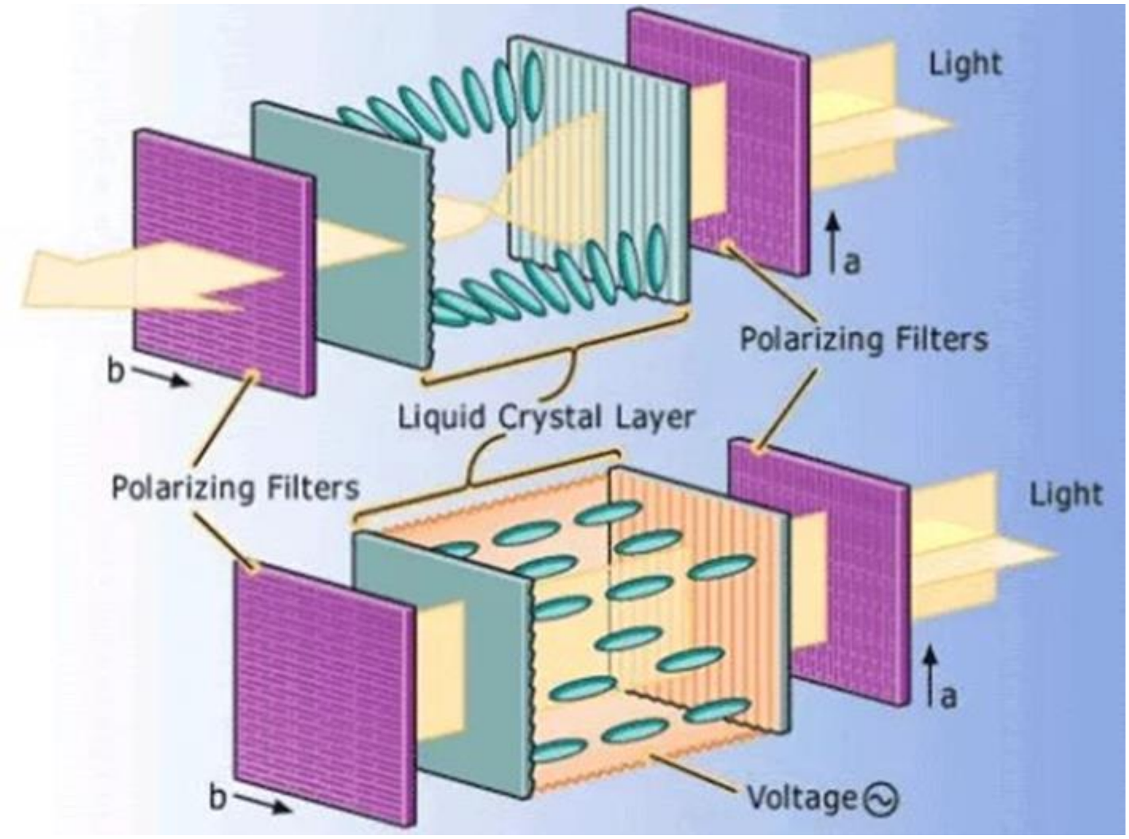


Figure 26: LCD TN tech demonstration

LCD screens are not capable of emitting light themselves, so a backlight must be present in order to actually see the pixels. The individual pixels on an LCD screen are composed of red, green, and blue subpixels which when powered on at varying levels can produce a wide array of colors for the display. The basic LCD screens use a passive matrix display in which there is a grid of conductors and pixels at each conductor intersection, and a current is sent across the conductors to control the light of the pixels. LCDs tend to be a little cheaper than OLED display; however they do suffer from lower contrast ratios, narrow viewing angles, and greater power consumption since the backlight is always on regardless of whether or not a pixel is "off."

OLED:

OLEDs, or Organic Light Emitting Diode displays, are a technology that uses organic (carbon containing) compounds to generate pictures. The basic structure of an OLED display is an emissive layer sandwiched between an anode and cathode layer, however modern OLED displays tend to have more layers in order to make the screen more durable, one of the most important of which being the encapsulation layer as OLED displays are sensitive to oxygen and moisture and thus encapsulating them is critical.

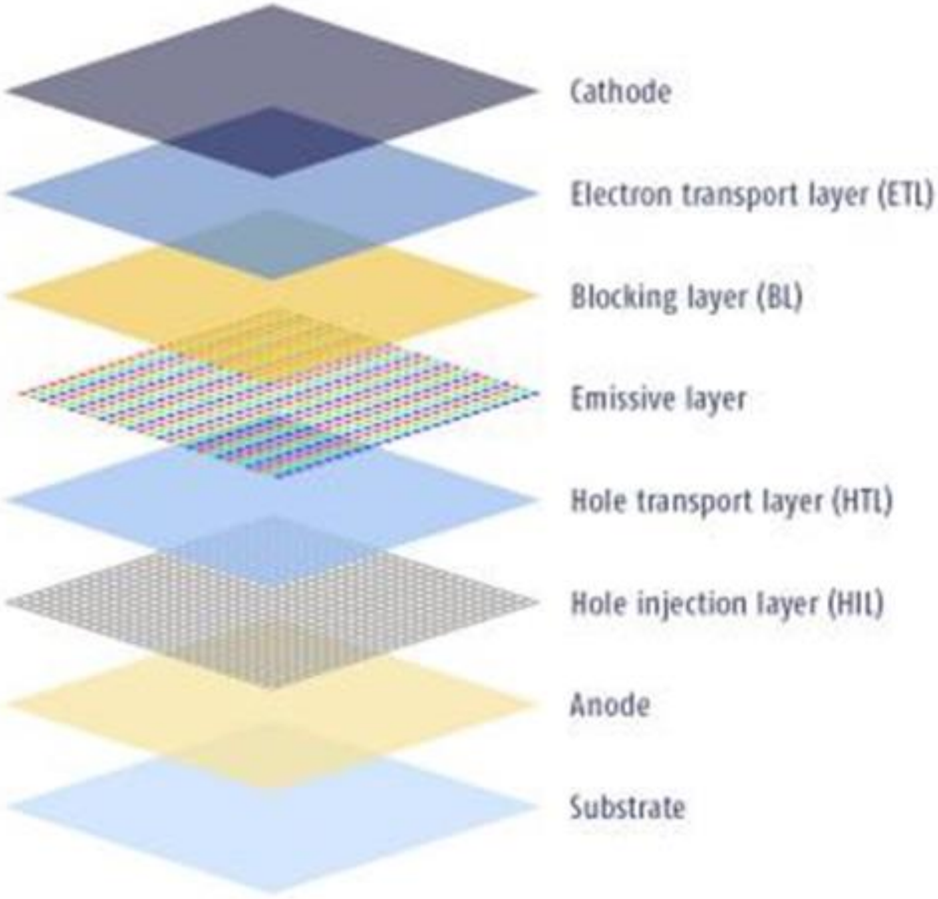


Figure 27: OLED display structure

OLEDs are different from typical LCD displays in that they do not require a backlight to generate light, the light comes from the organic compounds when current is passed through them, this improves color contrast due to lack of a persistent backlight washing out colors and makes them more energy efficient compared to LCD screens . Compared to LCD screens, OLED displays last much longer, with a lifespan of around 22 years if used for 6 hours a day. In summation, while OLED displays tend to be a bit more expensive than LCDs, overall OLED displays seem to be the better choice.

The choice in display is relatively inconsequential, we are only looking to display basic characters and no images, and both technologies can support multiple communication protocols. The price difference between the two is negligible, and with the more modest power consumption, OLED technology edges out LCD and will be the technology utilized in the project. The final project ended up not utilizing a user interface so the display technology chosen was inconsequential.

Type	**Communication Protocol**	**Cost**	**Examples**
LCD	I2C, Serial, SPI, GPIO	~$20	GDM1602K
OLED	SPI, I2C, Serial, GPIO	~$25	UG-2856KLBAG1

Table 15

Display Part Comparison

For the display we settled on the AOM12864A0-1.54WW OLED display. As with all parts we chose for this project, availability and the presence of a datasheet were absolute necessities. The main reason we chose this display is because it supports SPI, I2C, and parallel communication, so we have maximum flexibility when working with this display. The secondary reason for choosing this display was the pixel count, 128x64 offers a large amount of real-estate to represent all sorts of data we want to communicate to the user. The final reason I chose the display was the relatively small size, the display has a diagonal measurement of 1.54” measurement, so mounting this onto the chassis will be possible for almost any size case we decide to go with.The final project ended up not utilizing a user interface so the display part chosen was inconsequential.

Part Number	Communication Protocol	Pixel Count	Screen Size(Diagonal)	Display Controller
AOM12864A0-1.54WW	I2C, Parallel, SPI,	128 x 64	1.54”	SSD1309

Table 16

Keypad

Keypads are extremely rudimentary devices, typically just arrays of switches that are closed by some sort of force, the closing of which represents some unique predetermined input. Due to the simplistic nature of keypads, technology variation is almost nil from device to device, the technology discussed here is membrane keypad technology.

Membrane:

The most popular form of keypad technology is the membrane keypad. A membrane keypad is composed of three layers; the top layer which has the labels that designates what the buttons are to the user, the back layer which contains the conductive striped, and the space layer which separates the top and back layer. Keypads are typically constructed in a matrix format, where either the columns or the rows are pulled either high or low, and the rows or columns are polled for high or low, thus interpreting which key is pressed by the intersection of the engaged column and row.

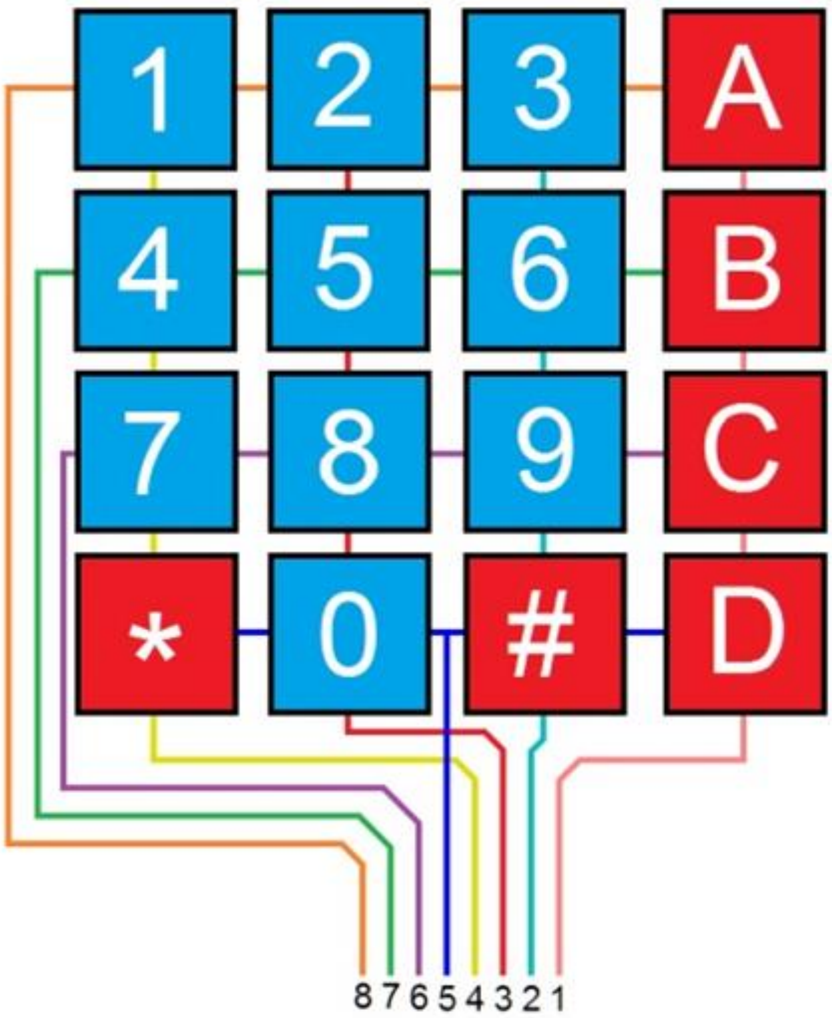


Figure 28: Layout for 4x4 Matrix keypad

With any mechanical input there exists the potential for noise, so debouncing the keypad may become necessary to prevent an unintended amount of key presses to be registered, however this will likely be handles software side with interrupts rather than a dedicated debouncing circuit.

There really are many characteristics to a keypad, at least not in any capacity that would significantly impact this project, switch debouncing will likely be handled software side so there really isn’t any need for additional hardware. The keypad technology will be a basic matrix membrane type. In retrospect we probably would have chosen a different type of keypad, as the keypad utilized in the final project was hesitant to return to its resting state after having its buttons pressed.

Keypad Technology Comparison

Type	# of buttons	Maximum Rating	Examples
matrix-membrane	4-n2	24 VDC, 30 mA	• 4x4 Matrix Membrane Keypad (#27899)

Table 17

Keypad Parts Selection

For the keypad we decided to use the Parallax 4x4 membrane keypad (#27899) commonly found in hobbyist electronics projects. The primary reason for using this component was because we already had a few laying around from various electronics kits we purchased over the years. The only other reason it was chosen was that the 4x4 membrane keypad yields a total of 16 keys, which will be enough for the user to effectively navigate the planned UI as well as input numerics. In the final project we ended up not being able to create the user interface we originally envisioned for the project, and only ended up using 3 of the 16 buttons available on the 4x4 keypad.

Part Number	# of buttons	Maximum Rating
Parallax 4x4 membrane keypad (#27899)	16	24 VDC, 30 mA

Table 18

4 Design Constraints & Standards

In this section, we will discuss the design constraints that apply to the watch winder. This section will also examine the required standards within our design.

4.1 Constraints

While constructing the watch winder, constraints had surfaced. Time, economic, safety, ethical, and marketing constraints are constraints this project has encountered. These constraints were addressed to the best of our ability while maintaining the integrity of the project‘s design.

4.1.1 Time Constraints

The most burdensome variable in designing this project was time. The time constraint given is approximately 25 weeks to accomplish this project from an idea to a final product. Due to being enrolled in Senior Design 1 for the summer semester, our group had 10 weeks in Senior Design 1 compared to a normal semester that consists of 15 weeks. Senior Design 2 consists of 15 weeks therefore our group was constrained to a 25 week timeline compared to 30 weeks. The second complication with time was the issue of scheduling amongst the group. Majority of the group works full-time and attends university part-time therefore scheduling weekly meetings on zoom was a task on its own let alone scheduling time to build the prototype together. We addressed this issue by creating a space on Discord to stay in constant contact with one another if any questions arose as well as sacrificing our evening and sleep to build the prototype collectively. The last time constraint regards the part selection availability and delivery process. Parts are hard to find as they are quite often sold out despite constant restocks. This took ample time out of constructing and added time in hunting down parts. Delivery has been difficult as there are currently less and less delivery drivers in employment and distance between warehouses and delivery addresses essentially prolonging our ability to construct.

4.1.2 Economic Constraints

Despite the lack of outside funding from major companies this semester, the economic constraints were minor. Despite the lack of outside funding from major companies this semester, the economic constraints were minor. As this project is heavily based on research, there have been incidents where our research was not sufficient enough leading the group in purchasing parts that were not most compatible as thought to be in theory. Senior Design 1 supplied the required texts therefore purchasing parts for the project was not a serious financial setback as it was also a divided financial responsibility amongst the group.

4.1.3 Ethical Constraints

Knowledge of how the selected parts are built and manufactured is quite limited. We as the consumers purchasing these parts from various websites, contain zero or limited information regarding the conditions of the factories and the working conditions for the employees. We strive to use ethically sourced products however it is a constraint that is difficult to overcome when there is limited information regarding this.

4.1.4 Safety Constraints

Regarding safety constraints, although it was a minor constraint, safety will always be a major concern even for the simplest of projects. The addition of a coil degausser did raise some concern when constructing the prototype as coil degaussers use AC power and high voltage. The combination of AC power and high voltage allows the engineers to be susceptible to electric shock when testing the product. To address this concern, electric safety gloves were used when designing and testing the prototype. The product for consumers does not require this level of safety precautions as the built and final product will have already been tested for the proper coil degausser.

4.1.5 Marketing Constraints

Initially marketing the idea of a watch winder as a Senior Design Project was difficult to formulate. Watch winders are used by a niche of individuals. There was a level of uncertainty of whether this project would be approved at face value. Refining the idea and the initial design helped us navigate the marketing aspect first, our professor and hopefully then to investors and consumers.

4.2 Standards

There are standards set forth to act in accordance with printed circuit boards (PCB), power supply, and software. This team has complied with all standards and protocols for this project. Complying with these standards and protocol is fundamental to this project as they are established for the safety of the engineers and consumers of products concerning PCB, power supply, and software.

4.2.1 Software Standards

While there are no widely recognized standards for writing code, particularly for the C language, we have decided on a number of coding conventions to use for this project:

- Code document will feature a comment preamble explaining the overall functionality of the program, as well as the day of the last edit.
- Camel casing for the names of all variables, definitions, and functions
- Functions must contain a descriptive paragraph of comments that clearly state the expected input(if any), what purpose the function serves, and what the expected output will be(if any)
- Definitions will have a comment alongside them to explain what the significance of the definition is
- All **#include** statements will feature a comment explaining what library is being imported and why

- Code will utilize indents, whitespacing, and comment lines between functions in order to denote association, break up large walls of text, and allow for easy identification of functions

Because our team is composed of only one programmer, the primary purpose of these standards is to make review and debugging of the code easier by emphasizing readability.

4.3 Magnetic Degausser Standards

Standards are extremely important technical documents in engineering. A technical standard is a formal document that establishes engineering or technical criteria, methods, and practices. The documents are prepared by professional organizations which are believed to be great engineering practices and contain mandatory requirements. There are thousands of standards in use all over the world. They cover from simple to complex technologies. For instance, the American National Standard Institute (ANSI) is the national coordinator of voluntary standards activities in the US. ANSI approves and publishes standards after they are developed by various engineering, industry and professional groups but ANSI does not produce standards. ANSI is the U.S. representative to the international organization for standardization (ISO) and the international electrotechnical commission (IEC).

The standards can help products and services be safe, compatible, and effective and also, affect all products or services in our daily lives. For example, if there were no presence of standards, it would be difficult and dangerous to replace a light bulb.
According to NSA-CSS standards and requirements, magnetic degausser required a multiple pass procedure such as:

- Electromagnetic degaussers must have a built-in capability for verifying that the magnitude of the magnetic field produced by the degausser is sufficient for eliminating the magnetic field in the watch.
- The magnitude of the magnetic field produced by a magnetic degausser must be large enough to permanently alter the magnetic alignment of all magnetized domains.

4.3.1 IEC 60335-1 Electrical Safety Standards

The evolution of home appliances made the safety aspect more important than ever. Devices that were once relatively basic, now include a variety of functionalities. Every additional functionality requires additional electrical circuits and specific power supplies. This influences the overall safety of the product. The IEC 60335-1 is an international standard that addresses the general requirements for electrical/electronic appliances for household and similar purposes. This standard focuses on devices with input voltages up to 250 VAC for single phases and up to 450 VAC for multi phase. As main concern to this electrical safety standards:

- The electromagnetic degausser must have an on/off mechanism that an operator or user can use safely.
- The electromagnetic degausser must have a power-on indecation display that the user can see.
- The electromagnetic degausser must have fault indecations. Suppose the degausser fails to produce the required peak magnetic field magnitude,in this case it must show some indications that make the user aware of it.

4.3.2 IEC 62233 Electromagnetic Fields of Household Appliances

The connection of a power supply and use of electricity, leads to the emission of electric field and magnetic field at frequencies typical for household appliances their fields are subject to limits based on recommendations by international bodies such as institute of electrical and electronics engineers (IEEE) and international committee on electromagnetic safety(ICES) (IEEE-2006). As a main consern, in these standards, the electromagnetic degausser must have an emergency stop mechanism. These stopping mechanisms should be able to be accomplished in a single action. In addition, the electromagnetic degausser must protect the user. The user must not contact dangerous electromagnetic fields during operation.

4.3.3 ISO 20816 Mechanical Vibration

American National Standards developed by accredited standards committees in the area of acoustics, mechanical vibration and noise establish general conditions and procedures to evaluate the vibration of various machine types. As a main concern in this standards:

- The sound levels for electromagnetic degaussers must meet both the national institute for occupational safety and health (NIOSH) and the occupational safety and health administration (OSHA) standards. The sound level of electromagnetic degaussers that create impulse noise is less than 120dB. Also, the effect of vibration can be severe and vibration can accelerate the rates of wear and damage the equipment.

According to OSHA occupational noise exposure, approximately twenty-two million workers in the United States are exposed to hazardous noise. Exposure to loud noise can lead to hearing loss. This regulation was developed and enforced by a number of government entities including the occupational safety and health administration (OSHA).

4.4. ASTM C1055 Heated System Standard

The standard guide for heated system surface conditions that produce contact burn injuries recommends that the surface temperatures remain at or below 44 degree celcius. An average, operator or user can touch a 44 degree celcius surface for up to six hours without causing damage to the skin. Therefore, as the main concern in this standard, our degausser will have maximum heat less than the required temperature in order for the operator to use it safely.

4.5 IPC-6011 Generic Performance Specification for Printed Boards

These standards cover generic pcb classifications and convention to be used in products. The documentation starts by covering 3 different performance classes of PCBs, and what performance and physical defects are to be expected out of each class. For the purpose of this project, performance Class 2 is most applicable to our design, that being the Dedicated Service Electronics Product class for instruments where high performance and extended life is required and for which uninterrupted service is desired but not critical. Certain cosmetic imperfections are also allowed for the class 2 of products, though no specific details are offered as far as what exactly these refer to, since the device we will be making is a prototype, function supersedes form.

IPC-6011 specifies that all dimensions are to be expressed in millimeters, and no such mixing of measurement systems should be utilized in a product. IPC-6011 also specifies conventions that the precision of measurements indicates the acceptability of rounding off to certain decimal place, example being that if measurements are all specified to a certain decimal place (i.e. 63.500, 47.525, 68.375 etc.), that indicates that measurements are to be rounded to the nearest thousandth digit.

IPC-6011 also covers the meaning of wording within a schematic, namely:

- “Shall” is meant to indicate a requirement within a specification that is binding
- “Should” and “may” are meant to express non-mandatory provisions
- “Will” is meant to express the declaration of purpose

IPC-6011 also specifies that if the stated parameters of a schematic are insufficient and/or inappropriate, alternate parameters may be agreed upon between the vendor and the user.

4.6 IPC-6012 Qualification and Performance Specification for Rigid Printed Boards

The purpose of IPC 6012 is to layout requirements for rigid printed circuit boards. The IPC-6012 documentation is meant to supplement the specifications provided by the IPC-6011 documentation, while providing specific requirements for the 3 performance classes listed in the IPC-6011 document. IPC-6012 documentation specifies material listing needed for the procurement documentation, such that the supplier can properly fabricate the PCB such that the user’s requests are satisfied.

IPC-6012 specifies proper codes to utilize in the procurement documentation to identify the laminate material, plating process and final finish which are detailed in table 3-2 in the IPC-6012 documentation. IPC-6012 specifies that metal clad laminates, unclad laminates and bonding material should be selected from IPC-4101, IPC-4202, IPC-4203, or NEMA

LI-1. For external bonding materials meant to affix heat sinks or stiffeners to the PCB shall be selected from IPC-4101, IPC-4203 or as specified in the procurement documentation. Photoimageable dielectric material shall be selected from IPC-DD-135 and specified in the procurement documentation, as well as any other dielectric materials. Copper foil utilized in the design must be in accordance with IPC-4562, if copper foil is critical to the function of the PCB, then all applicable measurements must be included within the master drawing such as foil type, foil grade, foil thickness, bond enhancement treatment and foil profile; resin coated copper foil must be selected in accordance with IPC-CF-148. IPC 6012 specifies that resistive metal foil must be specified in the procurement documentation, and metal planes/cores must be specified in the master drawing.

The metallic platings and coatings of a PCB must all be in accordance with Table 3-2 of IPC-6012, as well as the copper plating thickness on the surface, in plated-through holes, via holes and in blind and buried vias. Final finishes for a PCB must specify plating thickness except for fused tin-lead plating or solder coating which requires visual coverage and acceptable solderability testing per J-STD-003. IPC 6012 specifies that electroless depositions and conductive coatings shall be sufficient for subsequent plating process and may be either electroless metal, vacuum deposited metal, or metallic or nonmetallic conductive coatings; electroless nickel/immersion gold depositions must be in accordance with IPC-4552. Any additive copper depositions applied to the main conductor must meet the specifications of the main conductor. All tin-lead plating must meet the 50-70 percent tin composition required provided by ASTM B-579. For the solder coating of the PCB the solder used must be Sn60A, Sn60C, Pb40A, Pb36A, Pb36B, Pb36C, Sn63A, Sn63C or Pb37A per J-STD-006. Nickel plating must be in accordance with SAE-AMS-QQ-N-290 Class 2, with the thickness being governed by the specifications provided by Table 3-2 in IPC-6012. Electrodeposited gold plating must be in accordance with ASTM-B-488 with purity, hardness and thickness being specified in the procurement documentation; gold plating thickness on wire-bonded areas will be found in Table 3-2 in IPC-6012. Any other depositions used in the product must be specified in the procurement documentation. For electrodeposited copper, the depositions must meet the following requirements:

. When tested as specified in IPC-TM-650, Method 2.3.15, the purity of copper shall be no less than 99.50%.

A. When tested as specified in IPC-TM-650, Method 2.4.18.1, with the exception of removing the bake step in Section 5 within the test method, using 50 µm - 100 µm [1,969 µin - 3,937 µin] thick samples, the tensile strength shall be no less than 36,000 PSI [248 MPa] and the elongation shall be no less than 12%.

ISP-6012 has requirements for OSPs, which are anti-tarnish and solderability protectors applied to copper to withstand storage and assembly processes in order to maintain solderability of surfaces. The coating storage, preassembly baking and sequential soldering processes impact solderability. Specific solderability shelf-life and soldering cycle requirements, if applicable, must be specified in the procurement documentation. IPC-6012 requires that when permanent solder resist coating is specified, it shall be a polymer coating conforming to IPC-SM-840. IPC-6012 specifies that the composition of the fusing fluids and fluxes used in solder coating applications shall be capable of cleaning and fusing the tin-lead plating and bare copper to allow for a smooth adherent coating. The fusing fluid must act as a heat transfer and distribution medium to prevent damage to the bare laminate of the board, additionally the compatibility of the fusing fluid should be confirmed with the end user. IPC-6012 requires that marking inks shall be permanent, non-nutrient polymer inks, and shall be specified in the procurement documentation. Marking inks shall be applied to the board, or to a label applied to the board. Marking inks and labels must be capable of withstanding fluxes, cleaning solvents, soldering, cleaning and coating processes encountered in later manufacturing processes. If a conductive marking ink is used, the marking shall be treated as a conductive element on the board. IPC-6012 states that electrical insulation material used for hole-fill for metal core printed boards shall be as specified in the procurement documentation. Thickness and materials for construction of heatsink planes shall be as specified in Table 3-1 in the IPC-6012 document and/or the procurement documentation. Bonding material shall be as specified in 3.2.2 and/or the procurement documentation. Materials for accomplishing via protection method shall be as specified in the procurement documentation. IPC-6012 has standards for embedded passive materials which are defined as materials and processes which add capacitive, resistive and/or inductive functionality within the printed circuit board, and which may be used with conventional core materials for the manufacture of printed circuit boards. These include laminate materials, resistive metal foils, plated resistors, conductive pastes, protectant materials, etc. Embedded passive materials shall be as specified in the procurement documentation.

PCBs are also subject to a variety of standards confirmed upon visual inspection, PCBs are expected to be of uniform quality and conform to all standards. Nicks, crazing or haloing along the edge of the board, edge of cutouts and edges of nonplated-through holes are acceptable provided the penetration does not exceed 50% of the distance from the edge to the nearest conductor or 2.5 mm [0.0984 in], whichever is less. Edges shall be clean cut and without metallic burrs. Nonmetallic burrs are acceptable as long as they are not loose and/or do not affect fit and function. Panels, which are scored or routed with a breakaway tab, shall meet the depanelization requirements of the assembled board. Laminate imperfections include those characteristics that are both internal and external within the printed board but are visible from the surface. Measling is acceptable for all classes of end product, with the exception of high-voltage applications as defined by the customer. Crazing is acceptable for all classes of end product provided the imperfection does not reduce the conductor spacing below the minimum and there is no propagation of the imperfection as a result of thermal testing that replicates future assembly processes. For Class 2 and 3, the distance of crazing shall not span more than 50% of the distance between adjacent conductors.Delamination and blistering is acceptable for all classes of end product provided the area affected by imperfections does not exceed 1% of the board area on each side and does not reduce the spacing between conductive patterns below the minimum conductor spacing. There shall be no propagation of imperfections as a result of thermal testing that replicates future assembly processes. For Class 2 and 3, the blister or delamination shall not span more than 25% of the distance between adjacent conductive patterns.Translucent particles trapped within the board shall be acceptable. Other particles trapped within the board shall be acceptable, provided the particle does not reduce the spacing between adjacent conductors to below the minimum spacing specified in 3.5.2. Weave exposure or exposed/ disrupted fibers are acceptable for all Classes provided the imperfection does not reduce the remaining conductor spacing (excluding the area(s) with weave exposure) below the minimum. Scratches, dents, and tool marks are acceptable provided they do not bridge conductors or expose/disrupt fibers greater than allowed in other IPC-6012 parameters and do not reduce the dielectric spacing below the minimum specified. Surface voids are acceptable provided they do not exceed 0.8 mm [0.031 in] in the longest dimension; bridge conductors; or exceed 5% of the total board area per side. Mottled appearance or color variation in bond enhancement treatment is acceptable. Random missing areas of treatment shall not exceed 10% of the total conductor surface area of the affected layer. No evidence exists that pink ring affects functionality. The presence of pink ring may be considered an indicator of process or design variation but is not a cause for rejection. Plating and coating voids shall not exceed that allowed by Table 3-3 in the IPC-6012 documentation. When visually examined in accordance with visual inspection guide in Table 3.3, there shall be no lifted lands on the delivered (nonstressed) printed circuit board. The PCB shall be marked in order to ensure traceability between the boards/quality conformance test circuitry and the manufacturing history and to identify the supplier. The marking shall be produced by the same process as used in producing the conductive pattern, or by use of a permanent fungistatic ink or paint, LASER marker or by vibrating pencil marking on a metallic area provided for marking purposes or a permanently attached label. Conductive markings, either etched copper or conductive ink shall be considered as electrical elements of the circuit and shall not reduce the electrical spacing requirements. All markings shall be compatible with materials and parts, legible for all tests, and in no case affect board performance. Marking shall not cover areas of lands that are to be soldered. In addition to this marking, the use of bar code marking is permissible. When used, date code shall be formatted per the suppliers discretion in order to establish traceability as to when the manufacturing operations were performed. According to IPC-6012 only boards that require soldering in a subsequent assembly operation require solderability testing. Boards that do not require soldering do not require solderability testing and this shall be specified on the master drawing, as in the case where press-fit components are used. Boards to be used only for surface mount do not require hole solderability testing. When required by the procurement documentation, accelerated aging for coating durability shall be in accordance with J-STD-003. The category of durability shall be specified on the master drawing; however, if not specified, Category 2 shall be used. Test coupons or production boards to be tested shall be conditioned, if required, and evaluated for surface and hole solderability using J-STD-003. When solderability testing is required, consideration should be given to board thickness and copper thickness. As both increase, the amount of time to properly wet the sides of the holes and the tops of the lands increases proportionately. Printed boards shall be tested in accordance with IPC-TM-650, Method 2.4.1, using a strip of pressure sensitive tape applied to the surface and removed by manual force applied perpendicular to the circuit pattern. There shall be no evidence of any portion of the protective plating or the conductor pattern foil being removed, as shown by particles of the plating or pattern foil adhering to the tape. If overhanging metal (slivers) breaks off and adheres to the tape, it is evidence of overhang or slivers, but not of plating adhesion failure. Exposed copper/plating overlap between the solder finish and gold plate shall meet the requirements of Table 3-4 in the IPC-6012 documentation. The exposed copper/plating or gold overlap may exhibit a discolored or gray-black area which is acceptable. Printed boards shall be processed in such a manner as to be uniform in quality and show no visual evidence of dirt, foreign matter, oil, fingerprints, tin/ lead or solder smear transfer to the dielectric surface, flux residue and other contaminants that affect life, ability to assemble and serviceability. Visually dark appearances in non plated holes, which are seen when a metallic or nonmetallic semiconductive coating is used, are not foreign material and do not affect life or function. Printed boards shall be free of defects in excess of those allowed in this specification. There shall be no evidence of any lifting or separation of platings from the surface of the conductive pattern, or of the conductor from the base laminate in excess of that allowed. There shall be no loose plating slivers on the surface of the printed board.

IPC-6012 documentation has general requirements for dimensions on PCBs, however these are typically decided between the user and the supplier. The board shall meet the dimensional requirements specified in the procurement documentation. All dimensional characteristics such as, but not limited to, board periphery, thickness, cutouts, slots, notches, holes, scoring and edge board contacts to connector key area shall be as specified in the procurement documentation. However, in the event that dimensional tolerances are not specified in the procurement documentation, the applicable feature tolerances of the IPC-2220 design series shall apply. Board dimensional locations of basic or bilateral tolerance as defined in the procurement documentation shall be inspected in accordance with the applicable AQL classification as specified in Table 4-3 in the IPC-6012 documentation. The hole size tolerance, hole pattern accuracy and feature location accuracy shall be as specified in the procurement documentation. Finished hole size tolerance shall be verified on a sample basis across all hole sizes applicable to the design. The number of measures per hole size shall be determined by the manufacturer to adequately sample the quantity of holes within the population. Only specific dimensioned holes, to include both non plated-through and plated-through, shall be inspected for hole pattern accuracy to meet board dimensional requirements of 3.4. Unless required by the master drawing, hole pattern accuracy for other nonspecifically dimensioned holes, such as plated-through holes and vias, need not be checked as they are database supplied locations and are controlled by annular ring requirements to surface or internal lands. If required by master drawing, hole pattern accuracy may be certified by a statement of qualification or by AQL sampling per Table 3.4 in IPC-6012. Pattern feature accuracy shall be as specified in the procurement documentation. Pattern feature accuracy may be certified through a statement of qualification or by AQL sampling per Table 3.4 in IPC-6012. However, in the event that any of these characteristics are not specified in the procurement documentation, the applicable IPC-2220 design series shall apply. Automated inspection technology is allowed. Nodules or rough plating in plated-through holes shall not reduce the hole diameter below the minimum limits defined in the procurement document. The minimum external annular ring shall meet the requirements of Table 3-5. The measurement of the annular ring on external layers is from the inside surface (within the hole) of the plated hole, or unsupported hole, to the outer edge of the annular ring on the surface of the board as shown in Figure 3-1. For Class 1 and 2, external plated through holes identified as vias (not having a component) can have up to 90° breakout of the annular ring. Unless prohibited by the customer, the employment of filleting or ‘‘tear drops’’ to create additional land area at the conductor junction shall be acceptable for Class 1 and 2 and in accordance with general requirements for lands with holes detailed in IPC-2221.

Unless otherwise specified in the procurement documentation, when designed in accordance with 5.2.4 of IPC-2221, the printed board shall have a maximum bow and twist of 0.75% for boards that use surface mount components and 1.5% for all other boards. Panels which contain multiple printed boards which are assembled on the panel and later separated shall be assessed in panel form. Bow, twist, or any combination thereof, shall be determined by physical measurement and percentage calculation in accordance with IPC-TM-650. All conductive areas on printed boards including conductors, lands and planes shall meet the visual and dimensional requirements of the following sections. The conductor pattern shall be as specified in the procurement documentation. Verification of dimensional attributes shall be performed in accordance with Table 3.3 and IPC-A-600. AOI inspection methods are allowed. Internal conductors are examined during internal layer processing prior to multilayer lamination. When not specified on the master drawing the minimum conductor width shall be 80% of the conductor pattern supplied in the procurement documentation. When not specified on the master drawing, the minimum conductor thickness shall be in accordance with IPC-6012 standards. The conductor spacing shall be within the tolerance specified on the master drawing. Minimum spacing between the conductor and the edge of the board shall be as specified on the master drawing. If minimum spacing is not specified, the allowed reduction in the nominal conductor spacings shown in the engineering documentation due to processing shall be 30% for Class 1 and 2. The conductive pattern shall contain no cracks, splits or tears. The physical geometry of a conductor is defined by its width x thickness x length. Any combination of defects specified in previous IPC-6012 sections shall not reduce the equivalent cross sectional area (width x thickness) of the conductor by more than 20% of the minimum value (minimum thickness x minimum width) for Class 2 and 3. The total combination of defect area lengths on a conductor shall not be greater than 10% of the conductor length or 13 mm [0.512 in] (for Class 2 or 3), whichever is less. Allowable reduction of the minimum conductor width (specified or derived) due to misregistration or isolated defects (i.e., edge roughness, nicks, pinholes and scratches) which exposes base material shall not exceed 20% of the minimum conductor width for Class 2 and 3. Allowable reduction of the minimum conductor thickness due to isolated defects (i.e., edge roughness, nicks, pinholes, depressions and scratches) shall not exceed 20% of the minimum conductor thickness for Class 2 and 3. Nicks and pinholes are acceptable in ground or voltage planes for Class 2 and 3 if they do not exceed 1.0 mm [0.0394 in] in their longest dimension and there are no more than four per side per 625 cm2 [96.88 in^2]. Defects along the edge of the land or internal to the land shall not exceed the requirements listed in previous specifications. Defects such as nicks, dents, and pin holes along the external edge of the land shall not exceed 20% of either the length or width of the land for Class 2 or Class 3 boards and shall not encroach the pristine area, which is defined by the central 80% of the land width by 80% of the land length as shown in Figure 3-6. Defects internal to the land shall not exceed 10% of the length or width of the land for Class 2 or Class 3 boards and shall remain outside of the pristine area of the surface mount land. One electrical test probe ‘‘witness’’ mark is allowed within the pristine area for Class 1, 2 and 3.

5 Design

The watch winder's design can be divided into two sections. The sections include hardware design and software design. The hardware design process includes the power block diagram, schematic design, and printed circuit board design.

5.1 Power Block Diagram

To ensure our system has the appropriate power supplies for each device we decided to create a power block diagram. The power block diagram is an essential tool at the systems level of product development, without a proper power block diagram and accompanying power budget the end design could potentially attempt to consume more power than the supplies can source. The power block diagram represents each power supply in the design in a block diagram fashion and shows what each supply is sourced from and what each supply sources. Each supply block is labeled with its respective topology (ac/dc converter, linear voltage regulator, switching dc/dc regulator, etc..) to inform the reader of important features that might be characteristic of each topology. Each supply box is also labeled with its output voltage to make it clear and easy to see the power flow of our design. Each supply box additionally has the manufacturer listed and the unique manufacturer part number for each device. Between the blocks that represent each power supply the arrows show the flow of the power system. The voltage of the power rail is denoted on each line and if the supply supplies multiple supplies the voltage level text might be displayed multiple times for convenience. The current available on each power rail is also shown in text on that rail. Each major sub circuit is detailed in the block diagram with a box to represent it. For each major sub system, the input voltages are listed on its respective block to aid in identifying any holes that exist within the power system of the design. With the power systems design presented in a block diagram fashion it makes it easy to visually confirm if there is a device that does not have a voltage supply that can power it and that the current a power supply can source is greater than the current that that circuit will consume. Taking the time to develop this visual tool in the early stages of development can save a team big time in the end. Our power block diagram is shown in the figure below and detailed in the following text.

The high level flow of our power system is as follows; AC voltage is sourced from the power grid and introduced into our system. The AC power is immediately split into two different AC to DC converters and transformed into stable 12V and 5V DC voltages capable of supplying 1.25A and 3A respectively. The 12V supply is used to power the relay coil and the stepper motor. The 5V rail is fed into two separate 3.3V regulators, one exclusively powers the microcontroller and the other powers the gaussmeter circuit and motor driver circuit.

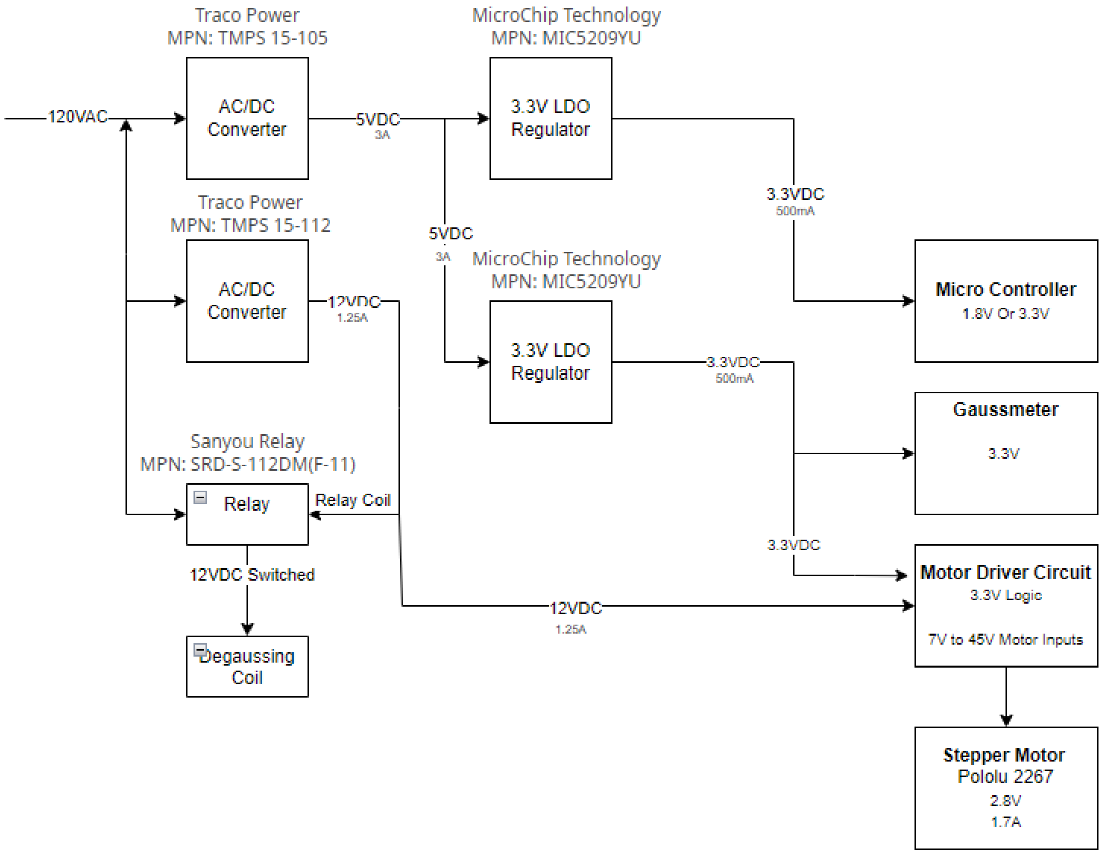


Figure 29 – Power Block Diagram

5.1.1 AC to DC Converters Design

Ac to Dc Converters are devices that take alternating current and voltage at the inputs and output direct current and voltage that do not alternate. AC to DC Converters come in many topologies and form factors giving flexibility to find a solution for design needs. In our design we needed a high Wattage output converter, the following section will describe how we solved that problem.

Careful design was put into the AC to DC portions of the power systems. Certain design parameters drove us to make the decisions we made in our selection of our power supplies from a systems level point of view. AC power has to be brought onto our PCB to run our degausser coil so taking advantage of that fact we decided to get our main power from an AC to DC converter. Because of the large amount of power available from the building's AC power we decided to use two AC to DC converters to produce both our 12V and 5V power rails. The output rails of the AC to DC converters will serve as intermediate voltages in our power system. Using the converters to drop down to low level DC voltages will give us the desired voltages but because of the efficiency of the regulators our PCB will not get as hot due to heat loss. One drawback is that the output voltages of the AC to DC converters have considerable amounts of noise. Our plan is to take noisy AC to DC converter output voltages and feed them into Linear Dropout Regulators to further drop the voltage to the intended levels.

The two AC to DC converters we picked are the TMPS 15-105 and the TMPS 15-112, both are made by Traco Power. The TMPS 15-105 is a single output 15W power supply that comes in a fully encapsulated package. Some notable features include less than 100 mW no load power, EN 60335 certified, UL62368-1 certified, and 4000 VAC isolation between the output and input. Being a 15W power supply the 5V output voltage can source 3A of current, 3A is more than sufficient to supply the circuits built off of the linear regulators this 5V supply will feed. The TMPS 15-105 offers a full range of input voltage spanning from 100 to 240 volts AC. The TMPS 15-105 is also tolerant to a large range of frequencies on the input voltage and can accommodate frequencies from 47 to 440Hz. The AC power our device will receive will be 120VAC at 60Hz so all of the design parameters regarding the input are met with the TMPS 15-105. The output of the TMPS 15-105 is a 5-volt DC voltage. The datasheet of the TMPS 15-105 states in the Output specifications section that the voltage set accuracy of the device is +/- 2% max, This gives us an output range of 4.9 to 5.1 volts DC. Because it is a switching mode power supply the device has ripple voltage on the output. According to the datasheet of the TMPS 15-105 the 5 volt output will have 80 mVpp max of noise riding on it. Since we are using sensitive sensors in this design we choose to filter this noise out using linear regulators. The output of the device offers output current limitation features and will limit the current at 150% of iout at a max. The output also offers overvoltage protection of 125% of Vout. The datasheet of the TMPS 15-105 states that the device has a typical efficiency of 79%, somewhat low but sufficient for our application. The package of this device is a PCB mounted plastic case using thru hole technology that is fully enclosed. The small form factor was ideal for us with the device having overall dimensions of just over 1” x 2”. Protruding from the enclosed plastic case are four PCB mount posts that are the pins of this device. The simplicity of this device was chosen to help our design be robust. Pin 1 of the device takes in the AC(N), Pin 2 is AC(L), together they are the entire input section of the device. Pin 3 is +Vout and pin 4 is -Vout, together they make up the entire output section of the device. In our application we will be setting the -Vout pin to our PCB’s ground. The ground plane on the PCB will be large and if possible will be planes on multiple layers. Pin 3 is the +Vout pin and this will be used to source our +5VDC rail on our PCB. As planned with the ground planes the +5VDC net will consist of large power planes that likely will span an entire layer. Using thru hole devices benefit us in this case because the power and ground planes can tie directly to the thru hole as opposed to running out on a trace to a via down to a power or ground plane like typically done when using surface mount technology, This gives us solid connections to the planes in question. The device only requires filter capacitors on the output and input power rails to function so it is simple and has a low bill of materials cost.

In addition to the TMPS 15-105 we are also using an additional separate AC to DC converter to power our 12V rail. The TMPS 15-112 is a 12 volt DC output AC to DC converter that is manufactured by Traco Power and is in the same product family line as the TMPS 15-105. The TMPS 15-112 is very similar to the TMPS 15-105 in many ways but the TMPS 15-112 is a single output 12V 15W supply. It has the same notable features as mentioned before with the TMPS 15-105 includeding less than 100 mW no load power, EN 60335 certified, UL62368-1 certified, and 4000 VAC isolation between the output and input. The TMPS 15-112 is a 15W 12V supply therefore using the P=IV relationship it is clear that the supply can output 1.25A. We plan on using the 12V to energize the relay coil and run the stepper motor. The stepper motor only takes 350mA so we will have plenty of headroom using the 1.25A supply. The TMPS 15-112 offers a full range of input voltage spanning from 100 to 240 volts AC. The TMPS 15-105 is also tolerant to a large range of frequencies on the input voltage and can accommodate frequencies from 47 to 440Hz. The AC power our device will receive will be 120VAC at 60Hz so all of the design parameters regarding the input are met with the TMPS 15-105. The output of the TMPS 15-112 is a 12 volt DC voltage. The datasheet of the TMPS 15-112 states in the Output specifications section that the voltage set accuracy of the device is +/- 2% max, This gives us an output range of 11.9 to 12.1 volts DC. Like the previous AC to DC converter this one is also a switching mode power supply and has some output ripple noise. The TMPS 15-112 datasheet states that it has 120mVpp of ripple noise. If you recall the TMPS 15-105 HAD 80mVpp of ripple noise so our 12V supply is substantially noisier than our 5V supply. This was realized when designing as the less noisy 5V supply feeds the regulators that will power our sensitive digital equipment whereas the 12V supply noise will not be an issue with our stepper motor or our relay that this supply feeds.

5.1.2 Linear Dropout Regulator Design

Linear regulators are commonly used to supply clean power in many solutions. Many linear regulators work by using a closed feedback loop to maintain a constant output voltage across its terminals. Linear regulators are step down devices that rely on a minimum difference between input and output voltages, this is known as the dropout voltage. Being a step down device and due to the dropout voltage the output voltage of the linear regulator will always be less than the input voltage. Power is lost due to the drop in voltage across the regulator and the excess power is converted to heat causing linear regulators to have a tendency to get warm. In our design we chose to use linear regulators to supply our digital circuitry. This section will detail our design methodology using linear regulators.

To power our Microcontroller, Gaussmeter, and motor driver circuit we need 3.3V DC power. We choose to get our 3.3V rails from linear dropout regulators for multiple reasons that will be described in this section. The power provided to these regulators inputs will be the 5 volt DC voltage output from our TMPS 15-105 AC to DC converter. This 5V voltage will be regulated down to 3.3 volts to source the devices listed previously. The 5 volt rail is a decent level to use a linear regulator to regulate down to 3.3V rail and is one of the reasons it was selected. Linear dropout voltage regulators burn off extra energy as heat and the larger the voltage difference between the input and the output the more energy that will be dissipated as heat into the PCB. Using the 5 volt rail we only need to drop 1.7 volts to achieve 3.3 volts as opposed to the 8.7 volt difference that would occur if we used our 12 volt supply rail. Careful consideration was also placed to make sure that the regulator's dropout voltage was less than the difference between the output and input voltages. In our design we are choosing to use the MIC5209YU linear voltage regulator manufactured by MicroChip Corp. The MIC5209YU is an adjustable single output linear voltage regulator in a surface mount TO263-5 package. Some notable feature of the MIC5209YU include a wide voltage input range of up to 16 volts DC, wide adjustable output range of 2.5 - 15 volts DC, Overcurrent Protection, Over temperature protection, extremely tight load and line regulation, low maximum dropout voltage of 500mV at full load, and ultra low output noise. One key feature we liked is the MIC5209YU is capable of supplying 500mA of current, this should be plenty to source our devices when we use two of these regulators. According to the datasheet the maximum dropout voltage of the regulator is 500mV and as stated before we have a 1.7 volt difference between our 5 volt and 3.3 volt rails so we have plenty of headroom for dropout voltage.

The pinout of the MIC5209YU is a very common pinout scheme within devices using the TO263-5 package and has many footprint compatible replacements available. Pin 1 of the device is the regulator enable function. Driving the enable pin high enables the regulator, we have no need for this regulator to ever be off so we tied the enable pin to the input voltage as recommended in the datasheet. The input voltage gets applied to pin 2 of the device, the datasheet recommends placing a 0.1uF capacitor between the input pin and ground so that is what we did. Pin three of the device is the output voltage, the output voltage feeds the resistor divider network used to set the adjustment pin (pin 4). The datasheet for the device highlights one of the MIC5209YU features and that is “Ultra low noise mode” and states that voltage ripple output is 300nVpp, much smaller than our 120mVpp ripple noise on our AC to DC converter. To put the device in “ultra low noise mode” the datasheet recommends adding an additional 470pF capacitor between the adjustment pin and ground, we chose to use this option and designed in the 470pF capacitor. The adjustment pin also connects to the common node on the resistor divider setting the output voltage. The adjust pin works by inputting the signal on that pin to the non inverting pin of an internal operational amplifier, the inverting pin of that amplifier is connected to the Vout line. A The figure below shows the internal workings of the regulator.

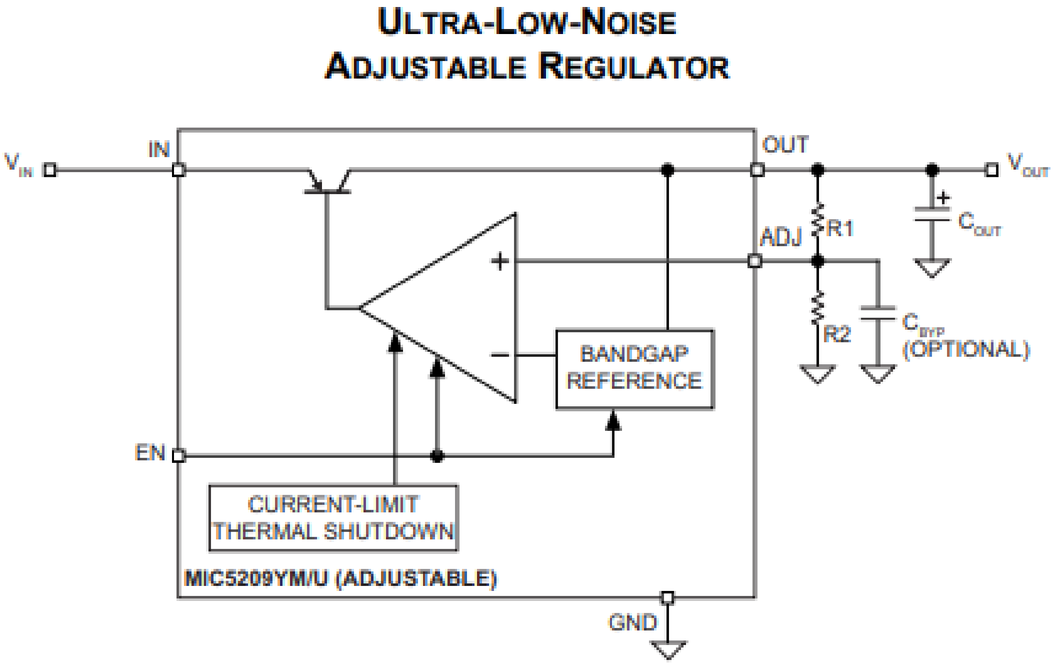


Figure 30 – Adjustable Regulator

As mentioned before the MIC5209YU is an adjustable output regulator and requires two external resistors to set the output voltage. The datasheet for the MIC5209YU gives a formula for setting the output voltage in the Adjustable Regulator Applications section. The formula provided by the data sheet is Vout = 1.2421+R2R1, we wish to output 3.3 volts so we began by rearranging the formula and solving for R2. Initially choosing a value of 1K Ohm for R1 and solving for R2 resulted in a value of 1.65K Ohm for R2, resulting in a calculated output voltage of 3.29 volts. Similarly to the AC to DC converters this linear regulator is very simple and requires only the output adjustment resistors and input and output filter capacitors to operate. The figure below shows our schematic of this regulator used to regulate 5 volts to 3.3 volts in “Ultra low noise mode”.

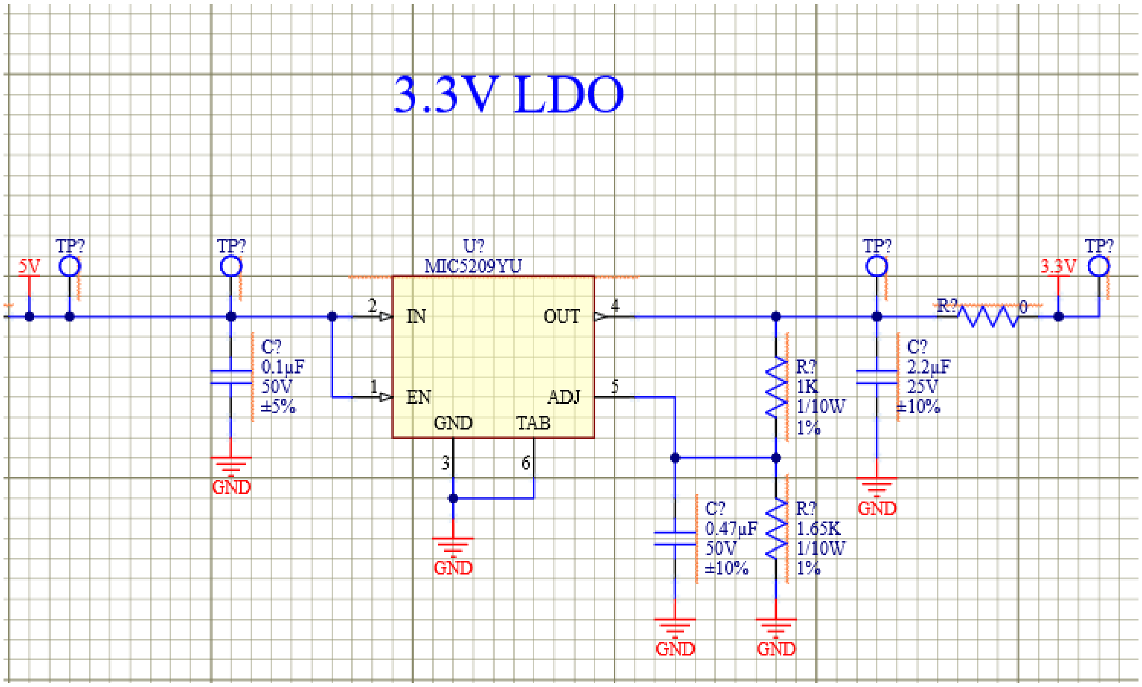


Figure 31 – 3.3V LDO

5.2 Magnetometer Circuit Design

Magnetometers are sensor devices that can measure the magnetic field present around the sensor. There are different methods used in magnetic sensing such as using the Hall Effect or using a Wheatstone Bridge. The data output of the sensor is an analog signal and must be processed. Many sensors are sophisticated integrated circuits that have the magnetometer sensor and a digital signal processor located all on one chip. This next section explains our process in designing in a magnetometer into our design.

In our design one requirement is to measure the induced magnetic field of a watch. In order to measure this we need a device that is commonly referred to as a magnetometer or gaussmeter. A magnetometer is a type of sensor that measures a magnetic field and outputs a signal that represents the measured field. Because of the nature of the device the magnetic field that wishes to be measured must be close enough to the sensor for the sensor to measure it, this requirement means we must physically locate our sensor close to the device we want to measure. For flexibility in the mechanical aspect of our design it is desired that we move our magnetometer offboard from our custom PCB so that way we can place the sensor near the watch we wish to measure. Additionally these sensors typically output an analog voltage waveform that represents the measured data. The output of the sensor must then be scaled and input into an Analog Digital Converter. Because of these sensitive analog voltages the magnetic sensor evaluation circuit could be susceptible to noise coupling. We chose to use the Gaussmeter Click module manufactured by Mikroe to overcome these design limitations.

The Gaussmeter Click is a module that uses the Melexis Technologies MLX90393 hall effect sensor to read magnetic fields and routes all of the connections to a standardized MIKROBUS device connector. The module includes all the passive components needed to run the MLK90393. The MLK90393 has numerous features that aid in the design of the device and helped us choose this part above others. One feature of the MLX90393 that we liked is that it can communicate over I2C or SPI interface protocols, this give us flexibility with interfacing to our microcontroller. Another great feature is the wide dynamic range of the sensor (5-50mT) and its incorporated on the fly programmable gain. The MLX90393 has onboard filtering, and onboard temperature sensor, and an onboard analog to digital converter adding ease to the design and eliminating the need for an additional analog to digital converter and signal conditioning circuit. The MLX90393 can be programmed to different settings to change the performance and power consumption of the sensor. Using Melexis Triaxis technology the output signal of the sensor is a 16 bit digital signal that is proportional to the magnetic flux density sensed by the sensor. The 16 bit output values are available to read over both the i2C and SPI busses adding further ease to the design. A block diagram of the MLX90393 is shown in the figure below. The device functions by using the hall effect and measuring the current produced by the hall effect. The onboard analog to digital converter samples this current and outputs truncated 16 bits by applying bit shift operations. By setting the RES_XYZ bit the resolution of the sensor can be adjusted using software. The gain of the internal amplifier can also be set by setting the GAIN bit using software. The MLX90393 also incorporates a wakeup on change function that will alert the microcontroller when a change has occurred in the magnetic field flux density.

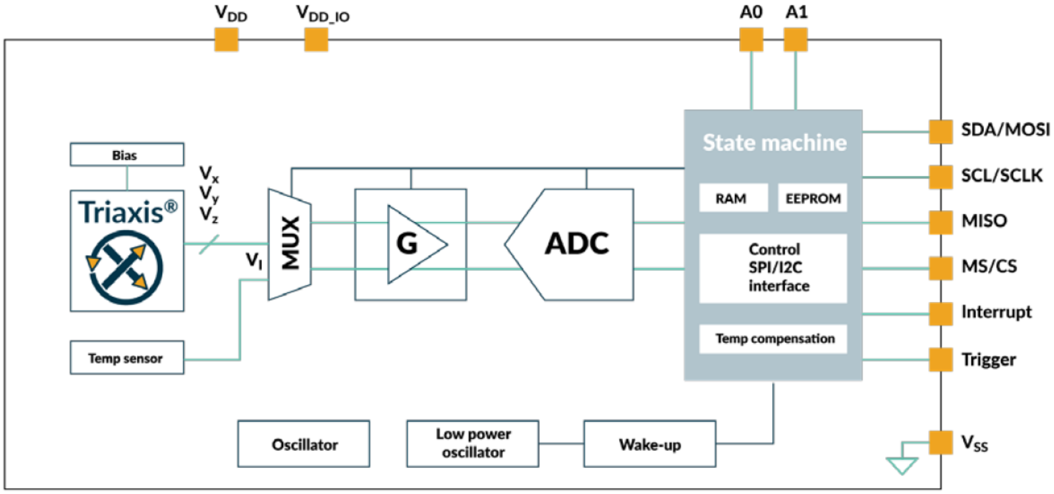


Figure 32 -- Magnetometer

The Gaussmeter Click incorporates the MLX90393 and the necessary passive components such as the pull up resistors on the SCL and SDA lines of the i2c interface and VCC filter capacitor. The signals of the MLX90393 are routed to a standardized MIKROBUS connector that we will either mate with on our PCB or attach wires to that will ultimately attach to our pcb. Onboard of the gaussmeter click they make it easy to set the i2c address bit by moving a jumper on a header from location to location. Similarly the communication protocol can be selected from either SPI or i2C by moving another jumper located onboard. The image below shows the gaussmeter click and highlights some of the key features located on the gaussmeter click. The gaussmeter click only needs 3.3 volt power to operate and it will be supplied off of pin 7. The SPI interface uses pins 3,4,5, and 6 if we choose that interface and the i2C interface uses pins 11 and 12. The interrupt pin is broken out to pin 15 and the trigger pin is broken out to pin 16. The module has 2 ground pins located on pins 8 and 9. If we choose to use SPI interface we and both the interrupt and trigger functions we will need 9 signals interfacing to the module. If we choose to use the i2C interface and both the interrupt and trigger function we will only need 7 signals going to the module with two of those being ground and one of those signals being 3.3 volt power. This makes the gaussmeter click ideal and simple to use in our application.

5.3 Design of Relay

There are four main parts in a relay.

- Electromagnet
- Movable Armature
- Switch point contacts
- Spring

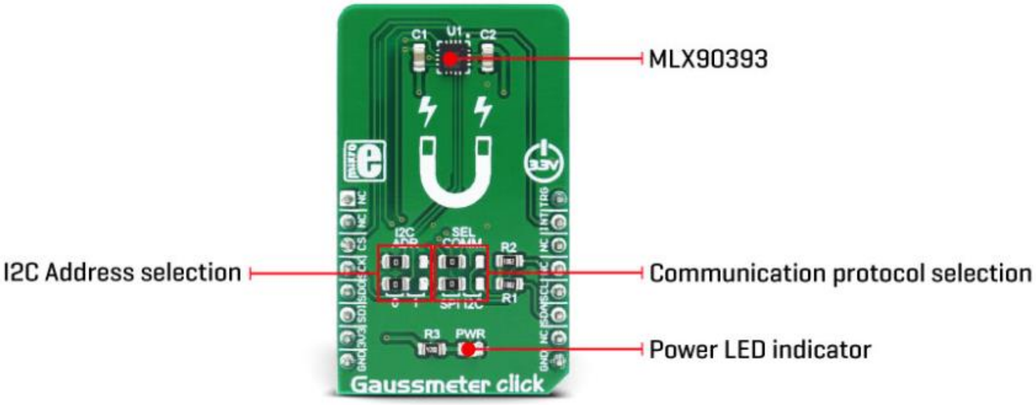


Figure 33 -- Relay

A simple electromagnetic relay consists of a coil of wire wrapped around an iron core which provides a low reluctance path for magnetic flux, a movable iron armature, and one or more sets of contacts. We are going to use a 12v dc power supply for the relay that can control the degausser circuit. This 12 v power supply will come from the microcontroller.

In addition,0 to 3.3 volt logic signals are going to be used through the NPN transistor base from the microcontroller. Our choice was to go for a PNP transistor but, having 0 to 5 volt control signals and a current flowing from 12v supply voltage coming from the controller, we couldn't easily control how much current was going to flow out of the base of the transistor in order to turn it on and off. However, in the case of NPN transistor, there is a resistor so,when this resistor is at 3.3v then current is going to flow from the base to the emitter and that is going to turn the transistor on and if the base voltage is 0v, no current is going to flow and the transistor will be off. Because of this reason,we are building the circuit using the NPN transistor as shown in the figure below.

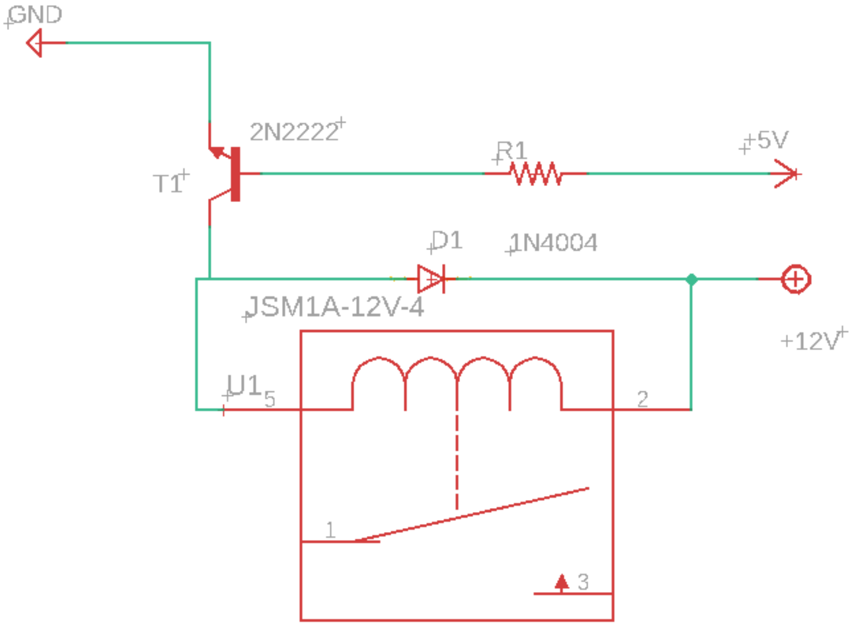


Figure 34 – Electromechanical Relay

For this particular circuit since we are switching a coil it is actually very important we add a clamp diode in parallel to the relay. The diode is pointing into the voltage source and when the transistor is turned off, all of that current that was flowing through this coil has created a magnetic field in the coil and when the transistor turns off that magnetic field collapses and the voltage goes up. If the coil has a lot of inductance, the voltage could get high enough that could blow out the circuit, so it is extremely important for safety issues to put diodes in it.

Transistor: PN2222A
Ic = collector current
Ib = base current
Ie = emitter current = GND
B = beta = 100

SPST: G5LE-1A4 DC12 from datasheet:

Coil resistance = 360Ω
Coil current = 33.3 mA
Power(P) = I^2 *R = 0.4 watt
voltage = P/I = 0.4/33.3mA = 12v
From this calculation, the transistor should handle 33.3 mA
therefore, Ib = (3.3v-0.7v)/Rb suppose we have 1mA base current, so we can calculate
the base resistor as Rb = 3.3-0.7/1mA = 2.6kΩ

As we said, a transistor is a current control switch. So, when we pour some current into the base, current will flow from base to the emitter that can turn the transistor on and allow a large amount of current to flow from the collector to the emitter. The amount of the amplification is the transistor gain so that the transistor with high gain allows large collector current to flow whereas a small base current and a transistor with no much gain will not have as much amplification. We are going to design the relay using the PN2222A NPN transistor which is a really great, medium power, very easy to use transistor and it has a current gain(beta) of 100 for this particular transistor.

5.4 Design of The Degausser

Finding a suitable coil was a bit hard. The choices were to build from a scratch or to use a half transformer from other devices. Therefore, to make a coil that generates an alternating magnetic field, we decided to use a half transformer E laminated chinese product. The core cross sectional area is x*y of 1.5cm by 1.3cm. The core permeability is 2.5*10^-7 H/m but, the number of turns of the coil is not known which is our task to figure it out. Designing the degausser circuit will follow three phases.

First Phase Design of The Degausser

As shown in the schematic below, the circuit is at the first stage and the components are a power source, and the coil with a core. The main objective is to figure out the alternating current required to produce the required alternating magnetic field. This will be accomplished in the lab varying the current and recording the magnetic field produced with the help of a degauss metter. Since we are using a half transformer for the coil, at this time we don’t have data on the number of turns of wire in the transformer. However, first we are going to measure the current and the magnetic field in tesla using degauss meter then we are going to calculate the reluctance of the E lamination core using the given dimensions and permeability by:

Reluctance = l/μA
where: l is the length
A is area
μ permeability constant

finally, we are going to calculate N(number of turns) using the formula:

$$N = (B*\text{Reluctance}*\text{Area})/I$$

With the help of the degausser meter, we are able to record the magnetic field and current is known with the help of an ammeter. Therefore, the number of turns of the transformer is calculated and recorded below.

Required	Value (Approximately)
Current	0.5A
Turns per unit length	200/0.025
Magnetic field	0.5T

Table 19

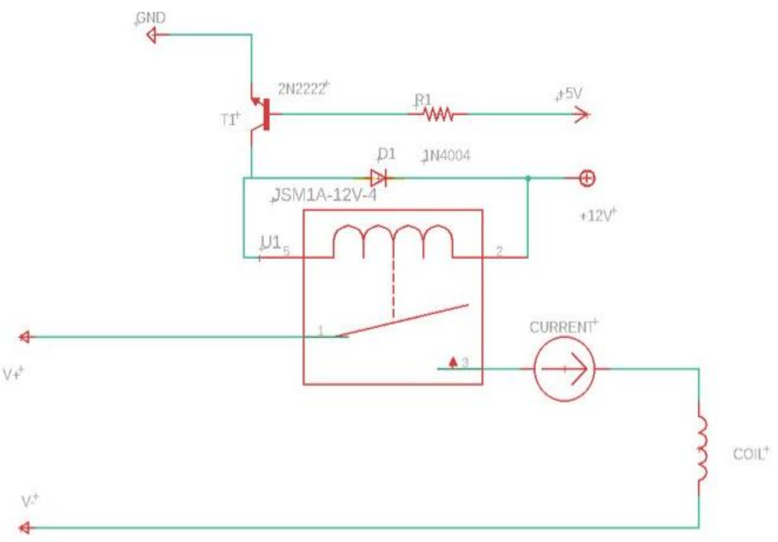


Figure 35 – Degausser First Pahse

Second Phase Design of The Degausser

From the previous design, we knew the amount of current that should be drawn from the source. In this second stage of the design, we continue working on selecting the necessary components like thermistor, diode, resistor and capacitor. We are trying to make the device that demagnetizes a watch by creating a decaying alternating magnetic field. So, we have to pick the right thermister that can draw the required amount of current that can operate the degausser. Also, we have to connect a light emmitting diode with a resistor parallel to the coil to help as an indecator. Moreover, capacitors are important to store the residual current when power is off for safety reasons

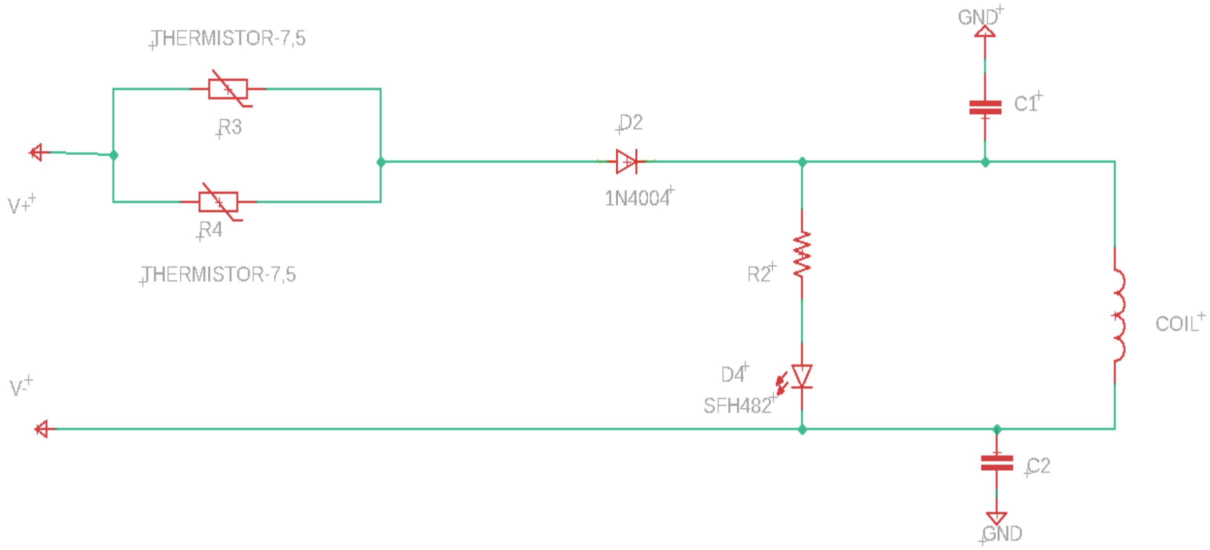


Figure 36 – Degausser Second Phase

Third Phase Design of The Degausser

After compilation of the second stage of the degausser circuit, on this final design we are going to add a control circuit which is an SPST electromagnetic relay. This relay will play a great role in controlling the power delivered to the degausser from the ac source. The SPST relay is going to get 12v DC voltage and the control signal from 0 to 3.3 volt from the microcontroller.

The circuit as shown in figure is employed 110- 240V AC power mains as a source of alternating current. Two thermistors are placed in parallel in order to boost the current carrying capacity of the circuit during the charging of the coil. When the switch is on, current starts to flow causing the thermistor to warm up and this results in an increase in magnitude of the resistance of the thermistors. As a result, within a short period of time the current starts to decay due to the increase of the resistance of the thermistor. In practice we employed SPST electromechanical relay switches. A diode is added in series with resistor and in parallel to the coil to insure back spick that comes out of the coil. When a magnetic field in the coil collapses, it produces an outrush of power that goes back into the battery. This outrush of power is reversed in polarity opposite to the alternating current that energizes the coil from a power source.

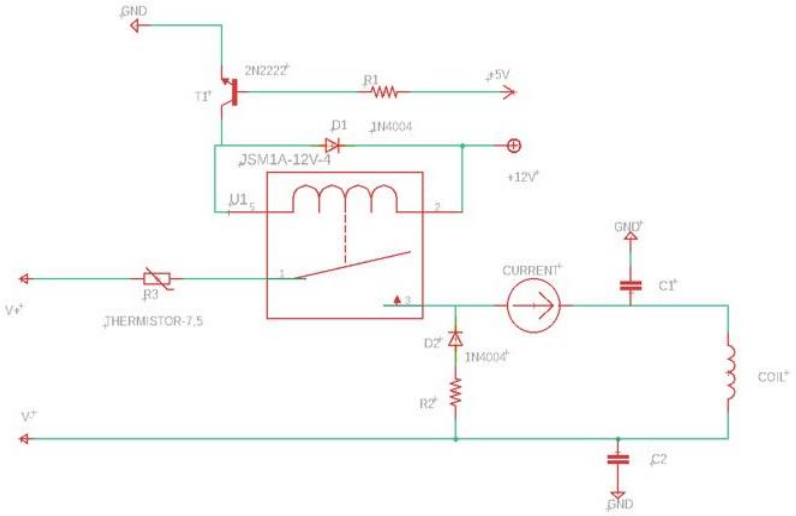


Figure 37 – Degausser Third Phase

This outrush of power is reversed in polarity opposite to the alternating current that energizes the coil from a power source. This back spike that occurs when the power is off, can blow up or ruin the circuit because the voltage is very high in magnitude. The way to solve this back spick is to connect a reverse biase diode acrose the power inputs.

Eagle Bill of Materials (BOM)

In this Bill of materials, I used an online library to search our utilized components. First, I import the necessary components into the working space and I make sure the component I chose is the right package and created footprint. All the main actors of the circuit were imported as shown below

.

Order list for C:/Users/ysengal/Documents/EAGLE/projects/transistor.sch
Exported from EAGLE with DesignLink

Quantity	2	4	3	4	4	4
Value			1N4004			
Package	C2.5-2	0204/5	DO41-10	PIS2816	SOT89	SOT23
Order code	24M1011	62W7358	08N7669	58K2483	10P4366	70R5516
Manufacturer	MULTICOMP PRO	PANASONIC	MULTICOMP PRO	VISHAY	SOLID STATE	NXP
Manuf. Code	CFR0W4JE006KIL	EEHZA1E560P	MPSA14	TLHR4405	1N270	KTY81/110, 112
Availability	135	889	12646	12713	3812	172
Price (from)	19.31	1.26	0.034	0.209	1.05	1.36
Description	Resistor Kit, 100-Pieces each, 43 Values, 10ohm to 1Mohm Carbon Film Axial Leaded Resistors	PANASONIC - EEHZA1E560P - CAP, 56µF, 25V, 20%, RADIAL	Bipolar (BJT) Single Transistor, NPN, 30 V, 500 mA, 625 mW	VISHAY - TLHR4405 - LED, Red, Through Hole, T-1 (3mm), 20 mA, 2 V, 625 nm	SOLID STATE - 1N270 - RF / Pin Diode, Single, 100 V, DO-7, 2 Pin, 0.8 pF	PTC Thermistor, KTY81 Series, 1.01kohm Zero Power Resistance 25°C, -55

Table 20

Order list for C:/Users/ysengal/Documents/EAGLE/projects/transistor.sch
Exported from EAGLE with DesignLink

Quantity	2	1	2	2	4
Value			THERMISTOR-7,5	CT10-XXXX-G4	2N2222
Package	0922/22	0204/7	R-7,5	CT10-XXXX-G4	TO18
Order code	26M7677	92T1062	06X6331	65AC5408	87K2254
Manufacturer	FINDER	PANASONIC	BOURNS	MILL MAX	MULTICOMP PRO
Manuf. Code	65.31.8.230.0300	DE1A1B-L2-3V	MF-RG600-0	816-22-005-10-005101	2N2222
Availability	81	2	258	13	39056
Price (from)	25.25	10.67	0.403	2.26	0.252
Description	FINDER - 65.31.8.230.0300 - Power Relay, SPST-NO, 230 VAC, 30 A, 65 Series, Panel Mount, AC	General Purpose Relay, DE(ADE) Series, Power, SPST-NO, SPST-NC, 3 VDC, 8 A	BOURNS - MF-RG600-0 - FUSE, RESETTABLE PTC	Spring Loaded Connector, Pogo Pin Header, 2.54 mm, 1 Row, 5 Contacts, Through Hole Mount	MULTICOMP PRO - 2N2222 - Bipolar (BJT) Single Transistor, NPN, 30 V, 500 mW, 800 mA

Table 21

Breadboard Test

We performed a breadboard test for the relay design and the three degausser design stages. On the relay circuit, to make sure the functionality of the relay and microcontroller is as desired. Also, we cared out test to confirm:

- if the degausser coil is getting enough flow of alternating current that can generate the required amount of alternating magnetic field to demagnetize a mechanical watch.
- If the thermistor is drawing the required amount of current for the degausser circuit that creates a decaying magnetic field.

- If the overall degausser circuit is working properly, safely and meets the expected standards and requirements.

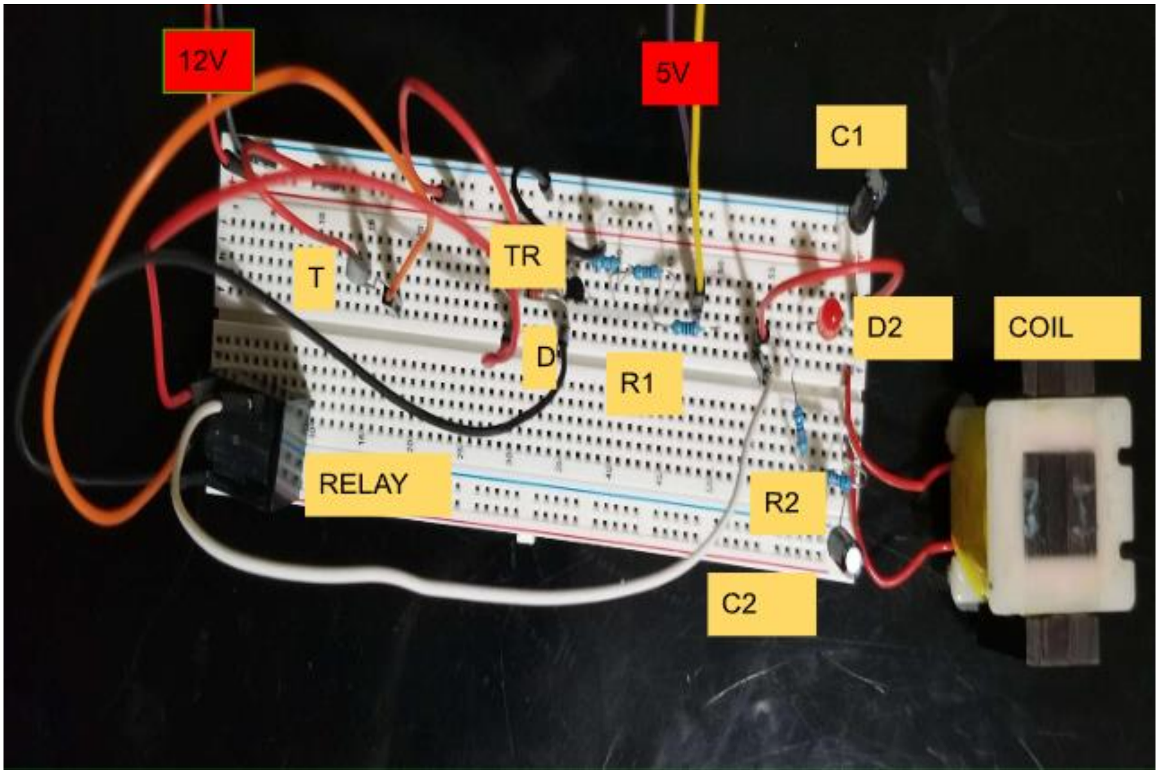


Figure 38 – Degausser Circuit

5.5 Software Design

The program will be composed in the C language, utilizing Microchip Studio to create the project files, create builds, and flash the program to the chip. The program will utilize an interrupt named **nextMenu,** the purpose of this interrupt is to allow the user to switch between different screens on the display to access different features of the project; these features likely being Rotation Speed, Rotation Direction, Stepper Motor Activation, Gauss Reading, and Degausser Activation. The **nextMenu** interrupt will trigger when a specific button is pressed on the keypad, and this will cause the display to cycle to a new menu, it will also likely serve a dual-purpose of saving any input registered from the user. The menus planned for this project are as follows:

- **Rotation speed -** This menu will allow the user to input the number of rotations desired per day and communicate this information to the motor driver circuit in order to generate a pulsing signal that will correctly implement the desired behavior.
- **Rotation Direction -** This menu will allow the user to select what direction they want the watch to spin while it rotates, since not all watches have the ability to wind up bi-directionally.

- **Stepper Motor Activation -** This menu allows the user to activate/deactivate the stepper motor circuit
- **Gauss reading** - This menu will allow the user to activate the magnetic sensor to determine how magnetized the watch is, since there is no universal threshold for what constitutes over-magnetization, the use of the degausser is left to the discretion of the user.
- **Degausser Activation -** this menu will allow the user to activate the degausser in order to demagnetize their watch, there will likely be a preset time for how long the degausser runs, as the user can just activate it again if need be.

The program will utilize the SPI communication protocol to interface with the mag sensor, motor driver circuit, and the OLED display; the keypad and relay are rudimentary enough to where GPIO pins are sufficient for their operation.

Coming to the end of the project, the lack of a user interface made the software design much simpler.The program utilizes interrupts to implement the various functionalities desired in the project.

- Bidirectional rotation - When the ‘A’ button is pressed on the 4x4 keypad, an interrupt is called that toggles the state of the GPIO pin connected to the DIR port on the motor driver circuit, which in turn allows the user to change the direction in which motor spins the watch.
- Motor power state - When the ‘B’ button is pressed, the GPIO pin connected to the motor driver EN port is toggled, thus either enabling or disabling the power stage of the motor driver.
- Degausser activation - When the ‘C’ button is pressed on the keypad, the GPIO pin connected to the gate of a transistor which eventually engages the degausser is driven high for 15 seconds to ensure the degausser can achieve its entire operation cycle.

The interrupts are triggered by the GPIO pins connected to the keypad, within the software they are programmed to register interrupts for the rising edge of a logic high signal. The chip uses multiple GPIO controllers to manage a group of pins, so the software must verify which specific pin triggered the interrupt in order for the correct behavior to trigger. Once the interrupt code for that specific input has been executed, the flag is cleared for that specific GPIO pin and the code returns to the event loop of the main function.

The motor driver circuit necessitates a clock signal on the STCK port in order to establish the timing of the steps for the motor. The ATUC256L3U-AUT features a built-in 32Khz RC clock that allows for a configurable divider and is mapped in the software to output through a GPIO pin that is multiplexed to accept a generic clock input. The divider input is an 8-bit value, and is configured to its maximum value of 255. The motor possesses a resolution of 1.8°/step.

$$rotation\ speed(\frac{degrees}{sec}) = \mathrm{RS}$$

$$RS = \frac{clock\ frequency(hz)}{divider} \times resolution(\frac{degrees}{step})$$

Using the above equations we find the final performance characteristic of the motor to be a rotation speed of ~225°/sec.

The MCU supports both JTAG and aWire for programming the chip, we will be utilizing an ATMEL ICE programmer to interface with the MCU. The ATMEL ICE programmer will use a JTAG interface to program the MCU.

5.6 Microcontroller Design Analysis

The microcontroller is the brains of the project, interpreting the input created by the magnetic sensor and keypad, and driving the logic signals for the motor stepper, relay, and the display. The particular microcontroller we chose for this project is the **ATUC256L3U-AUT** chip from *Atmel*, now *Microchip*. The microcontroller will utilize the SPI communication protocol to interact with the sensor, motor driver circuit, and display, in the same fashion as the diagram **Figure 21-2** found in the ATUC256L3U-AUT datasheet.

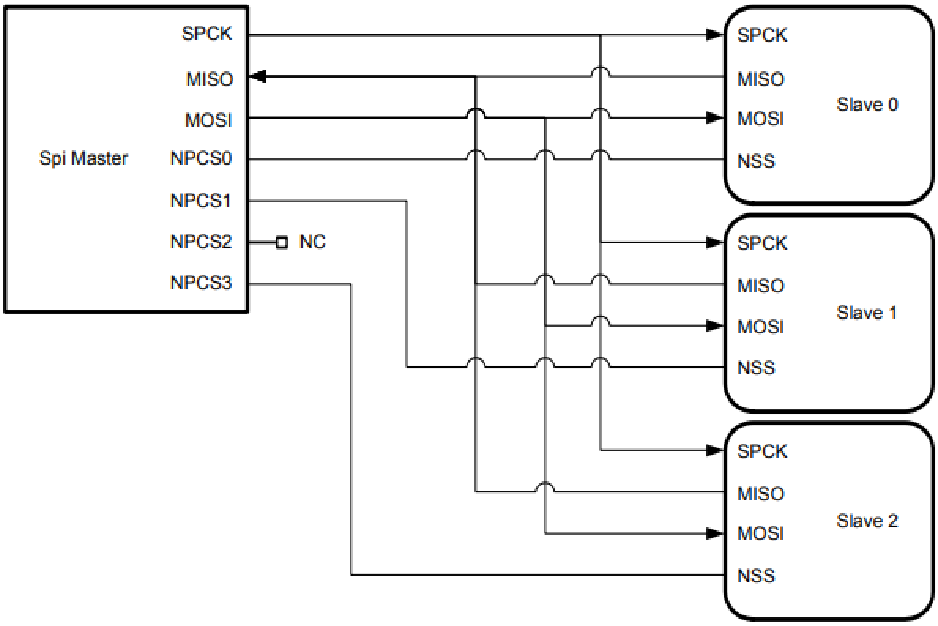


Figure 39: Single Master/Multiple Slave Implementation

The SPI system is composed of 2 control lines and 2 data lines: SPCK, NSS, MISO, and MOSI.

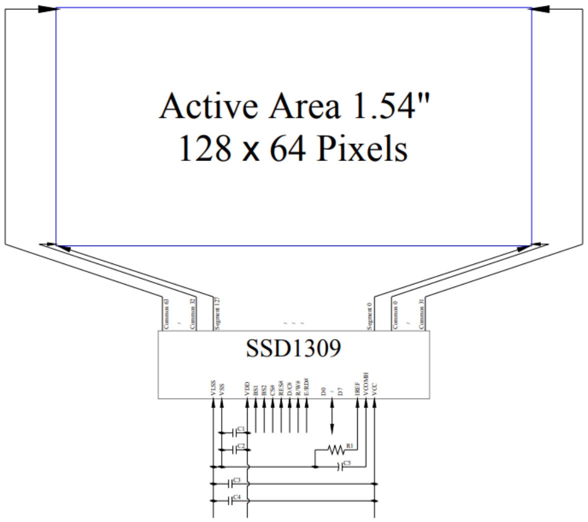
- SPCK(Serial Clock) is a control line that dictates the flow of data bit, every bit transmitted is one cycle on the SPCK line.
- NSS(Slave Select) is a control line that controls whether a slave device is on or off.

- MISO(Master In Slave Out) is the data line that recieves output from a slave device to the master, since this line is shared by multiple slave devices it is important that only one slave device be transmitting at any given time.
- MOSI(Master Out Slave In) is the data line that distributes output from the master device to the various inputs for the slave devices.

The keypad input and control signal for the relay will be handled with GPIO(General Purpose Input/Output) and without the use of any communication protocols, given the simple nature of how the device will operate.
The lack of time available for development towards the end made the entirety of the user interface pointless as no actual SPI was used in the final project.

5.6.1 OLED Display Design

The display will communicate the data relevant to the user regarding their watch, as well as provide a menu by which the user can modify certain settings such as rotation speed and direction of spin. The display we chose for the project was the **AOM12864A0-1.54WW** offered by *Orient Display*, while the display itself is important to the project, the primary area of note is the **SSD1309** controller used to dictate the state of the individual pixels, **1.6 Block Diagram** in the datasheet for the **AOM12864A0-1.54WW** further expands upon the design of the display.



MCU Interface Selection: BS1 and BS2
Pins connected to MCU interface: CS#, RES#, D/C#, R/W#, E/RD#, and D0~D7

C1, C3: 0.1μF
C2: 4.7μF
C4: 10μF
C5: 4.7μF / 25V Tantalum Capacitor
R1: 910kΩ, R1 = (Voltage at IREF - BGGND) / IREF

Figure:40 Block Diagram

- BS1 and BS2 are the pins that dictate the communication protocol the controller will utilize, referring to **1.5 Pin Definition** in the **AOM12864A0-1.54WW** datasheet, it appears that when BS1 and BS2 are zero, SPI protocol is used.

- RES# is the pin that initiates the initialization procedure for the display when the pin is pulled low, this pin is set high during normal operation.
- CS# is the chip select pin for the display, in the SPI configuration this will allow the microcontroller to turn off the display, however since the display is strictly an output device it is unlikely this will see use.
- D/C# is the data/command control pin, in the SPI configuration this pin is sampled every eighth clock cycle and dictates whether or not the byte of data is written to the command register or the Graphic Display Data RAM.
- E/RD# is the Read/Write Enable or Read pin, for SPI this pin is pulled to ground.
- R/W# is the Read/Write Select or Write pin, for SPI this PIN is pulled to ground.
- D0-D7 is the data I/O bus, for SPI the D1 pin will be the MOSI and D0 will be the SPCK, all other pins except D2 will be tied to ground.

Commands for controlling the display are done through the **SSD1309** controller, the job of which is to interpret the input from the MCU to control the display. The lack of a user interface for the final project meant the display was not actually being utilized whatsoever.

5.6.2 Display Testing

Testing for the device is relatively simple, and can be agnostic of any specific MCU platform, so long as the SPI protocol is supported and the logic voltage is 3.3V. The hardware configuration will be like that **Figure 21-2** from the **ATUC256L3U-AUT** datasheet, with the rest of the pins for the display wired as per the specifications provided **Figure: 1.6 Block Diagram**; It should be noted that $V_{DD,}$ V_{CC}, V_{SS}, V_{LSS} must be externally connected, V_{SS} and V_{LSS} must be tied to an external ground, V_{CC} must be between 12-13V, and V_{DD} must be between 1.65-3.3V. In general the process for testing the display should go as follows.

Step	Procedure
1	Utilize favorite toolkit for embedded applications (PlatformIO is preferred) and generate a new project file
2	Import all necessary libraries for project into project file
3	Compose main.c program for project, this will be the portion of code responsible for dictating the data sent to the display
4	Compile project file into a stable build file
5	Assemble hardware
6	Flash code to MCU
7	Observe the OLED display for expected behavior.

Table 22

If the display produces the expected output, then the display is functional, if not then there may be an issue with the hardware and/or software. Hardware issues are likely to manifest in the form of dead pixels on the screen, software issues tend to show up as undesired output.

5.7 Keypad Design

The keypad is an exceptionally simple design, utilizing a 4x4 matrix membrane to create 16 unique signals to output for interpretation by the MCU. **Figure: Layout for 4x4 Matrix keypad** illustrates the pinouts, essentially when a button is pressed the circuit between a particular column and row is completed, the microcontroller then polls the states of the pins and is able to determine which button was pressed. The number keys of the keypad will be reserved for inputting the number of rotations per day desired, leaving the asterisk, pound sign, A, B, C, and D buttons for rotation direction selection, degausser activation, and menu navigation.

5.7.1 Keypad Testing

Testing of the keypad is relatively straight forward, not even necessitating the use of a microcontroller whatsoever. The simplest way to test the keypad is to breadboard a circuit that pulls pins 1-4 to a high signal, and utilizing LEDs to test that each button press correctly closes the circuit. In the following circuit we used 1kΩ resistors for the supply voltages on pins 1-4.

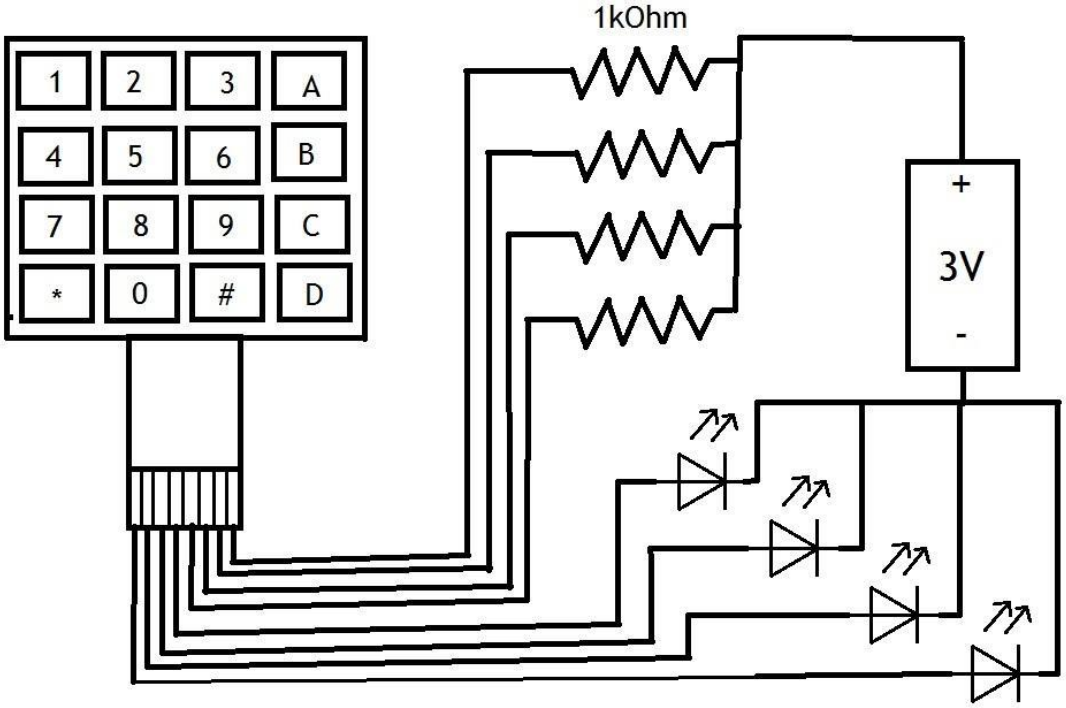


Figure 41 – Keypad Circuit

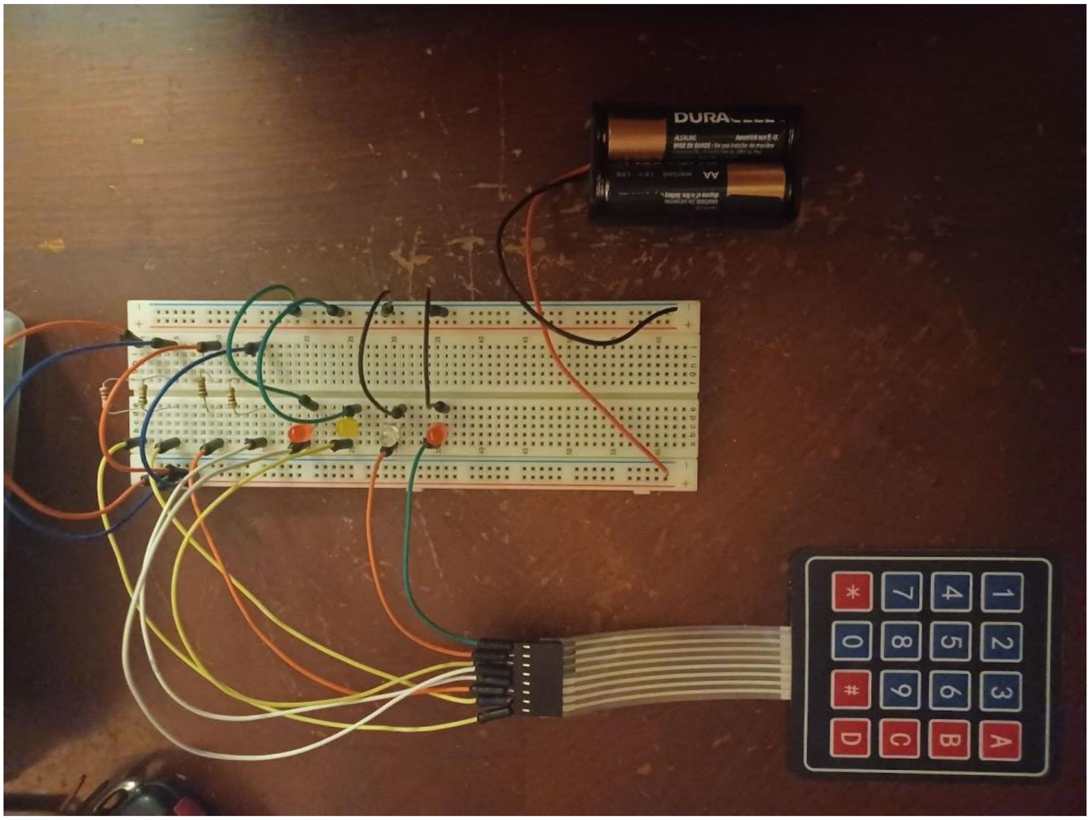


Figure 42 keypad test circuit, no actuation

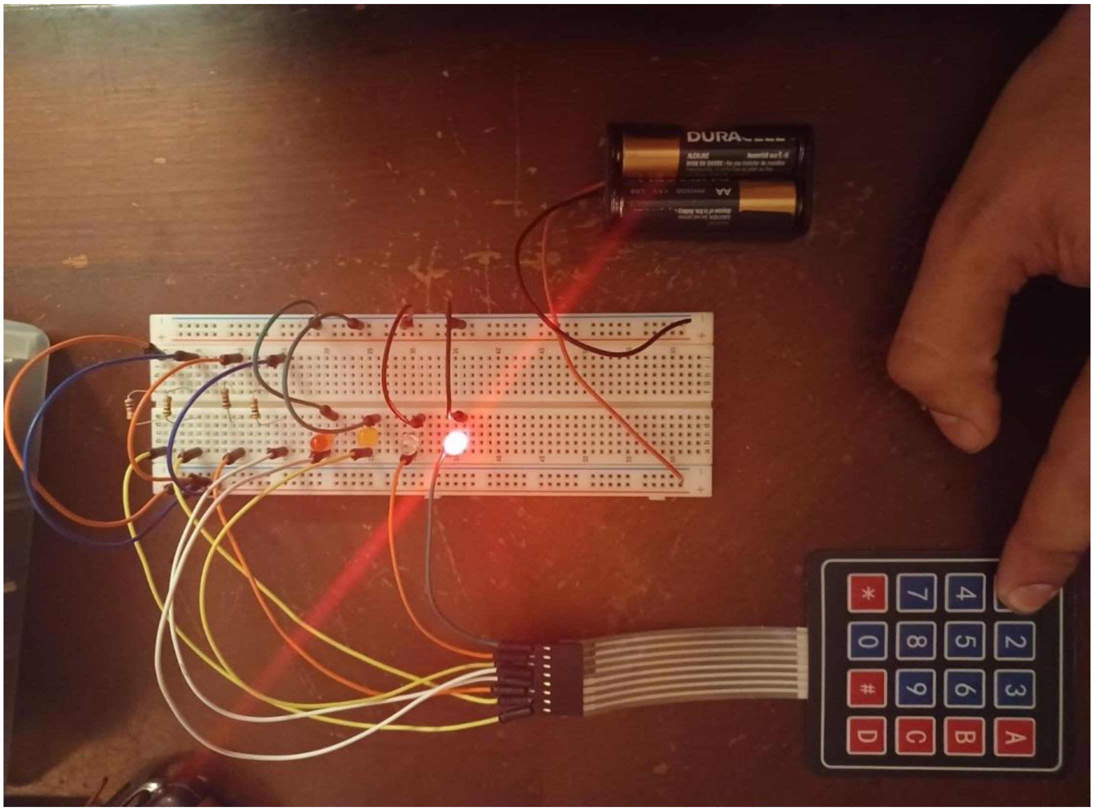


Figure:43 keypad test circuit, actuated

As we can see, if the keypad is functioning correctly, all button presses should close the circuit and power the respective row’s LED, if not the keypad is likely defective.

5.8 Stepper Motor Analysis

There are many stepper motors to consider when it comes to driving the watch winder. In this analysis, we will elaborate on a couple of stepper motors that are compatible with the project.

Adafruit 324 Stepper Motor

This particular stepper motor is our favorable option for the project as it is a hybrid bipolar stepper. Bipolar steppers are better than unipolar steppers by design. They are more efficient and offer more torque compared to unipolar steppers. Its integral design is most compatible for our project because it is compatible with our stepper motor driver, therefore the Adafruit 324 stepper is our first part selection. There are various stepping methods to drive this stepper motor. The motor driver emits out logic signals that directs the motor to step. The Adafruit 324 stepper motor is the most suitable and compatible for our projects as its phase rating is 350 mA. This phase rating permits the motor driver to easily operate the stepper. The stepper operates off of 12 V allowing more voltage and current to be feeded elsewhere if necessary. The popularity and interest in stepper motors derive from its ability to accurately stop and that they are user friendly, easy to use. The amount of rotations and the stepper motor’s speed are controlled with the same digital square wave pulse signal. The stepper motor contains four wires. Coil #1 contains a yellow and red wire pair whereas Coil #2 contains a green and gray wire pair.

Table 23: Adafruit 324 Specifications

Specification	Value
Size	NEMA 17
Steps per rev	200
Current/Phase rating	350 mA
Voltage rating	12 V
Resistance Accuracy	+/- 10%
Inductance Accuracy	+/- 20%
Shaft diameter	5 mm
Operating Temperature	-20°C – 50°C
Type	Hybrid Bipolar

5.9 Motor Driver Analysis

There are many motor driver circuits to consider when it comes to driving the watch winder. In this analysis, we will elaborate on the motor driver circuit that we are using for the project.

STSPIN820 Stepper Motor Driver

The STSPIN820 stepper motor driver includes features such as PWM current control, a wide voltage range, and selectable microstepping at a maximum of 256 microsteps. This stepper motor includes two full bridges on low resistance, control logic, and protection features. The stepper motor driver puts out a specific amount of signals to the PWM current control with a fixed off time. The STSPIN820 is compatible with a stepper motor voltage of 7V to a maximum of 45V including a current maximum of 1.5A for each bridge.

Table 24: STSPIN820 Specifications

Specification	Value
Min operating voltage	7 V
Max operating voltage	45 V
Min current per phase	0.9 A
Max current per phase	1.5 A
Min logic voltage	2 V
Max logic voltage	5.5 V
Resolutions	Full, 1/2, 1/4, 1/8, 1/16, 1/32, 1/128, 1/256

The STSPN820 contains H-Bridges that are highly effective consisting of 1ohm passing through each bridge. The motor current can be controlled using a potentiometer. Features such as these allow for the STSPIN820 to be compatible for a plethora of projects such as designing a watch winder.

In order for the bipolar stepper motor to operate, the IC contains both power MOSFETs and logic circuitry allowing the stepper motor to be controlled. Due to this advanced microstepping feature, the IC can operate smoothly and move silently.

The STSPIN820 comprises of two PWM controllers containing a specified off time per each individual H-Bridge. This design limits the maximum current passing through each phase of the stepper motor. The off times range between 13 µs to 146 µs contingent on the implemented resistors. When mixed decay mode is utilized, the decay interval is separated into slow and fast decaying sections. A fast decay section will last ⅜ of the entire off time whereas in slow decay will last ⅝ of the entire off time. When slow decay mode continues for the total off time it means that the decay pins are at a high logical level.

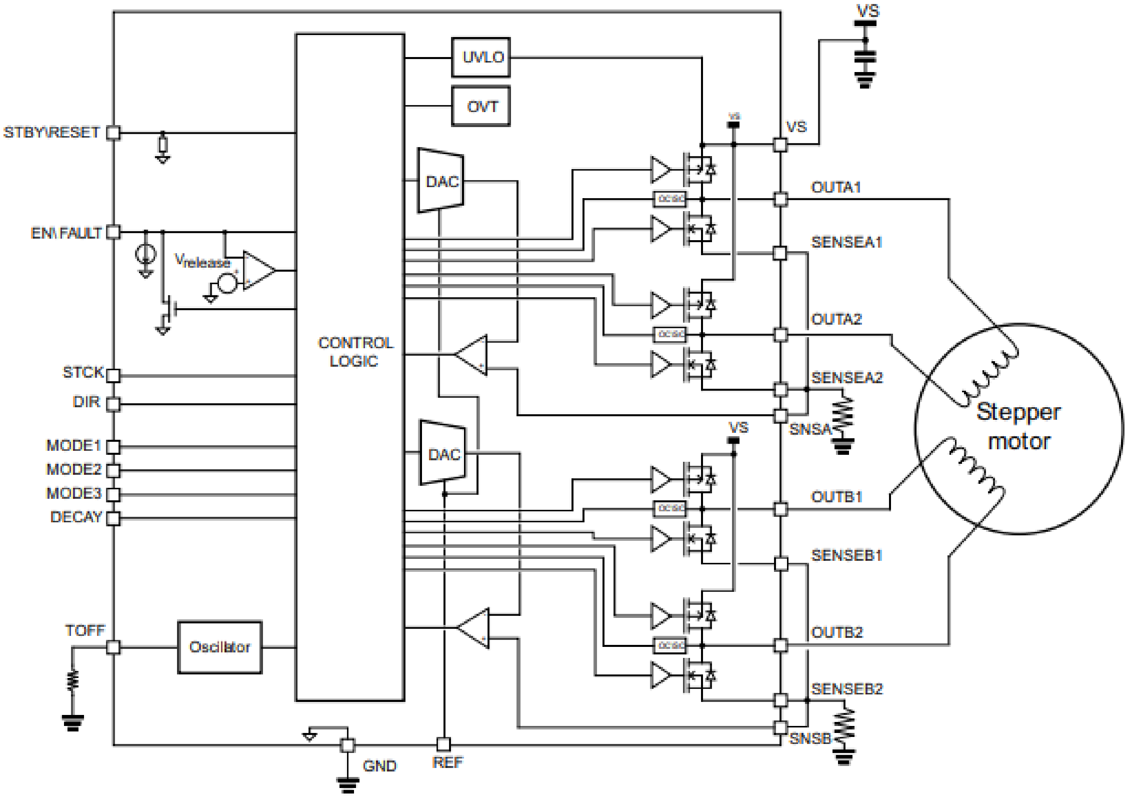


Figure 44 – STSPIN820 Block Diagram

The STSPIN820 motor driver comprises of two H-bridges that operate independently of one another. These two H-bridges independently control a single phase of the bipolar stepper motor. Pins such as DIR, STCK, RST, EN, and FAULT can control the motor. Direction of rotation is controlled by a DIR pin. Microstepping will rise producing a pulse through the STICK pin when a DIR pin is adjusted at a high logical level. However if the amount of steps is desired to decrease, it is achieved by adjusting it to a low logic level. In regards to the STCK pin, once a pulse is applied to this pin, the counter can be decreased or increased depending on the DIR pin. The RST pin is implemented to adjust both bridge outputs in high-z mode when the power is disconnected from the H-Bridges. A RST pin permits lower average power consumption due to no current ability to flow from the power supply to the motor. The EN pin in the STSPIN820 motor driver is present for two purposes. Firstly, when the EN pin is set to high logic level, the device is in operation mode. The second purpose of the EN pin is to function as an interrupt pin in a low logic level in the chance of an electrical failure.

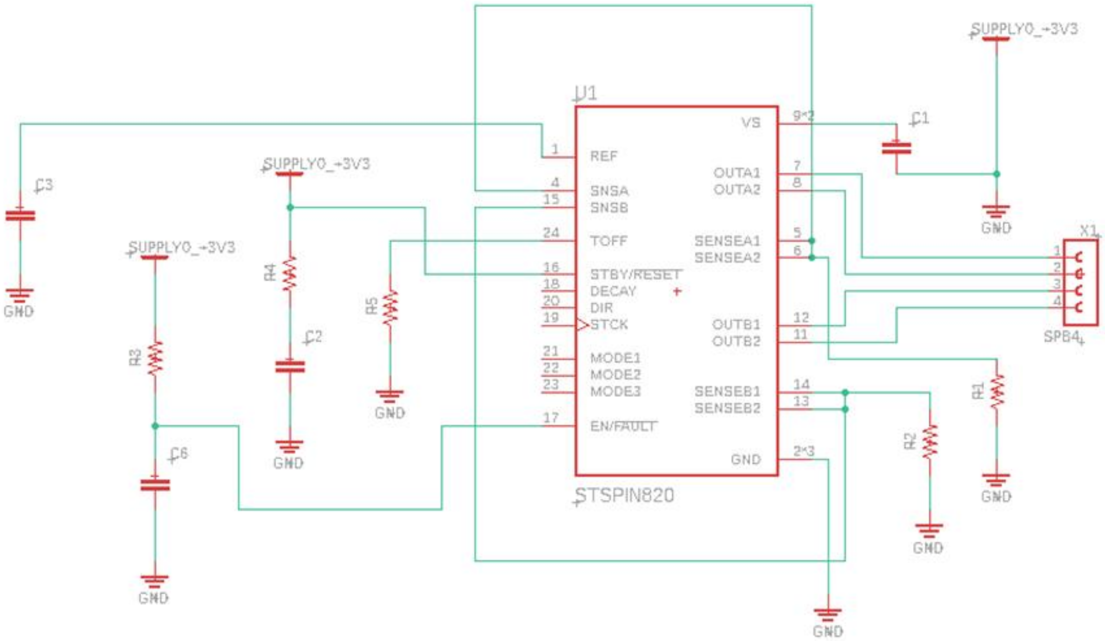


Figure – 45 – Motor Circuit

Figure 10 is a schematic of the STSPIN820 motor driver circuit connected to a 4-wire terminal block. The motor driver is not connected to the stepper motor because there was no footprint found for stepper motors. In this case, a terminal block is used to showcase how the motor driver is supposed to operate. The figure displays our connection method to connect the motor driver to the stepper motor amongst the various features associated with the motor driver.

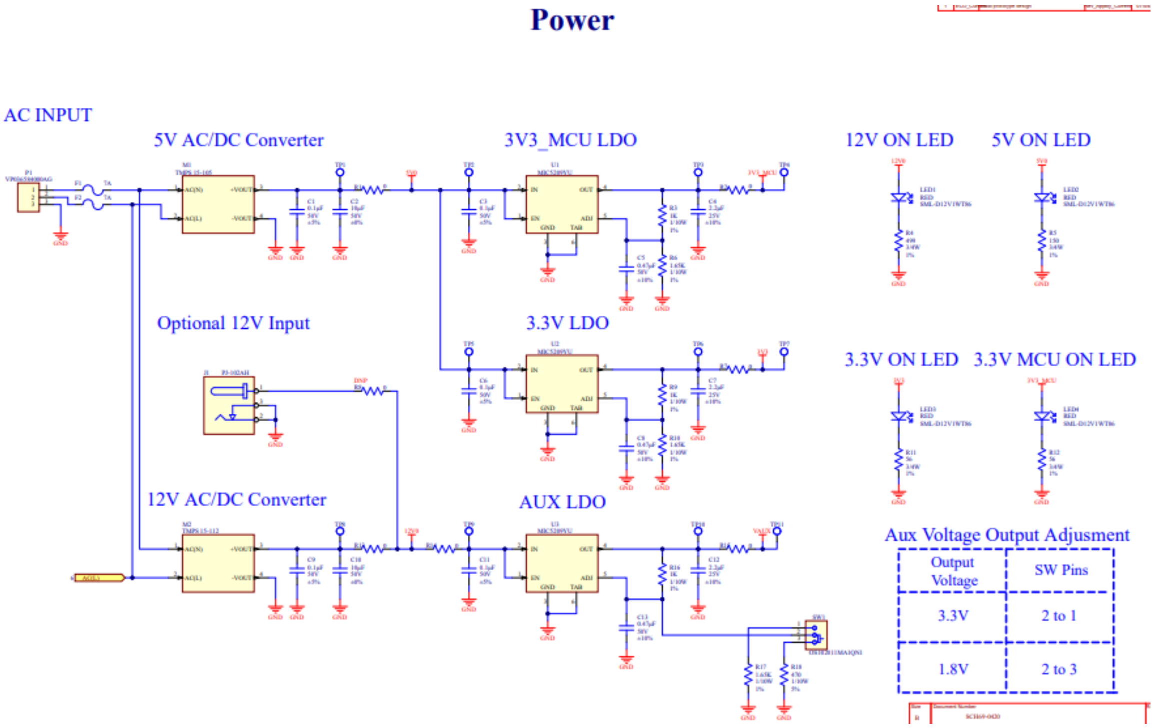
6 Testing & Prototype

Once we have established a solid systems level design of our device it is now time to start piecing the parts together into one prototype. This section will detail the development of our prototype as well as the testing we wish to perform to evaluate the performance of our device. Our team decided to take the approach of getting an early start on our first revision of the hardware in order to ease out the development process and identify any crucial bugs early on. The idea behind our philosophy is to design our circuits with many debugging options and attempt to only have to make one hardware revision but we are in fact planning on two revisions if needed. Due to many long nights of schematic design and pcb layout we are able to expedite our schematic and pcb review process enabling us to get hardware faster and into test and software development quicker. We believe this approach will give us more flexibility with testing and the time needed to fine tune our device.

To ensure a smooth design process and to stay focused we stick to a defined workflow of steps when developing our prototype. Our steps to prototyping are as follows; schematic design capture, schematic review and finalization, printed circuit board layout, printed circuit board layout review and finalization, printed circuit board fabrication, and printed circuit board assembly. If we follow the order presented and don't skip crucial steps such as the design reviews, many bugs that could be potential disasters will get caught early on in the development process before they are designed in and much harder to fix.

The first step of our prototype design process is to capture the design in schematic format. The schematic design process was done using Altium Designer Version 22.7.1 and the accompanying printed circuit board was designed using Altium Designer as well. Early into the project we split the workload into different chunks of the high level design and although each of us knew enough to be dangerous about the devices as a whole, one individual typically owned most of the low level technical information for their respective circuit creating challenges when integrating the entire design into one schematic. Altium was the preferred tool to use due to user experience and its smooth integration into the printed circuit board design but we only had one seat available for the entire group so the information on how to capture each member's circuit was taken over meetings and using this document. Our schematic design is 7 pages long and the order is as follows; page 1 is revisions, page 2 is Power, page 3 is Microcontroller, page 4 is Gaussmeter, page 5 is Motor Driver, Page 6 is Degausser, and page 7 is User Interface.

The power design was done first as we already knew a few voltage rails and power requirements that we needed and parts were already locked in. The Power section consists of two AC to DC converters and two linear regulators. The AC to DC converters produce 5 volts and 12 volts respectively and the linear regulators step down the voltages from there to produce two separate 3.3V rails. The 12 volt rail is used by the stepper motor and motor driver circuit but has power head room so we decided to feed it into an adjustable linear regulator circuit where we can easily select any voltage below 11.5 volts by adjusting the resistor divider on the adjust pin. This auxiliarily voltage regulator was outfitted with a two way switch enabling solderless adjusting between 3.3 and 1.8 volts in case of an emergency. The Auxiliarily Lienar Regulator as well as many other zero ohm resistors will be labeled Do Not Populate (DNP) on our Schematic and Bill of Materials and will be left off of the circuit card assembly unless needed. Zero ohm series resistors were strategically used at the outputs of all power supplies and the inputs of most devices allowing easy rework if for some reason we need to swap power supplies to a certain circuit. Using zero ohm resistors also helps for power bring up in the testing portion as you can isolate circuits from power by removing resistors creating an open circuit condition. An optional 2 x 5.5mm DC Barrel jack input was added as a feature as it is easy to find power brick style AC to DC converters of multiple different power and voltage outputs that interface to the standard DC Barrel jack. Finally red led's are populated on the outputs of each power rail to indicate that that power supply is running. An image of our power page of our schematic is shown below.



Output Voltage	SW Pins
3.3V	2 to 1
1.8V	2 to 3

Figure 46 – Power Circuit

For our microcontroller we are using the Atmel ATUC256L3U-AUT. We liked that the ATUC256 had enough memory for our applications, that it had multiple interface protocols available, it had multiple GPIO pins available, and the development environment was user friendly. On our microcontroller page we have placed the ATUC256. Connecting to our microcontroller we have a 16MHz crystal oscillator. The line capacitance was calculated from the datasheet for the crystal and matched to what the datasheet for the ATUC256 accepts, capacitor values of 3.9pF were calculated to be installed between Xin, Xout, and Ground. We have an additional slower 32KHz oscillator as well and the capacitance values were calculated in the same method and determined to be 12pF. The power supplies for the ATUC256 need bypass capacitors to ensure proper operation so the recommended capacitor values were obtained from the data sheet and used in our design. A 10 pin JTAG header on 100mil pitch was added to our microcontroller page to allow debugging of the device. A reset button was added for debugging and to be able to reset the ATUC256 as needed.

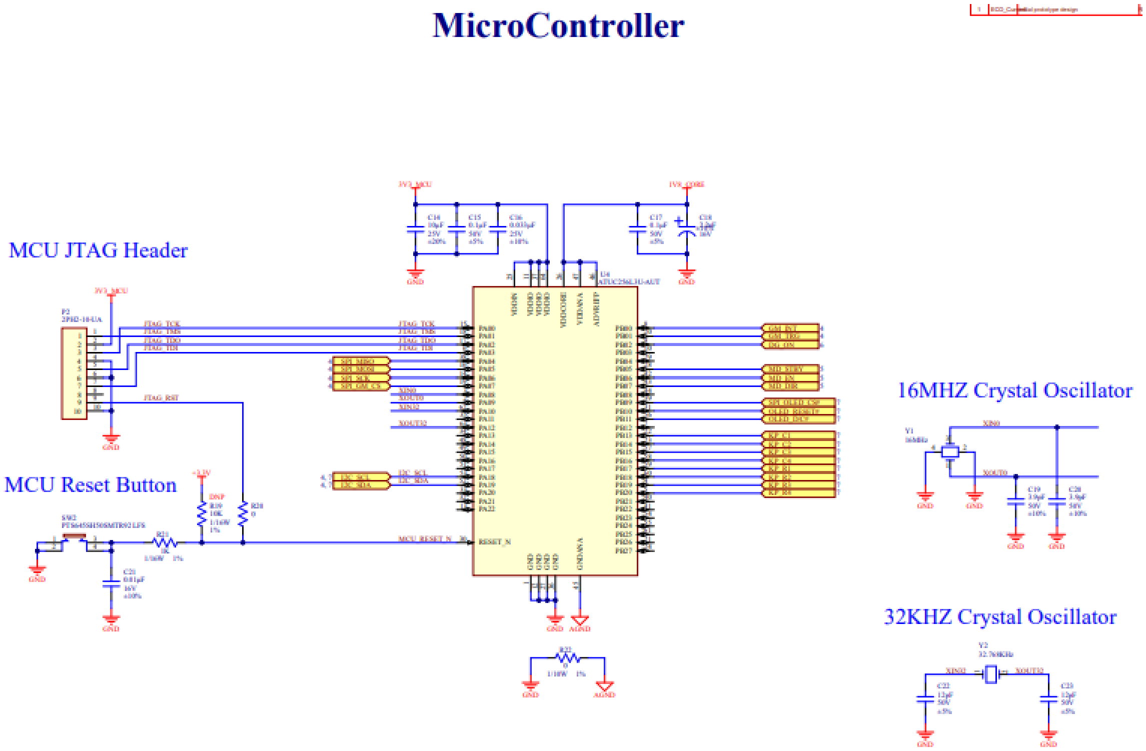


Figure 47 – Microcontroller Circuit

Page 4 of our schematic contains the magnetic sensor portion of the design. The nature of our device and the high magnetic fields it generates concerned us when it came to interference with our magnetic field sensor. We want the user experience to be natural and smooth and would like to incorporate magnetic field sensing in a user friendly location. We need our entire prototype up to fine tune the distances required for the fields we want to sense and we liked the idea of having our magnetic field sensor placement flexible in development to find the perfect home for it. We were also weary of putting a sensitive sensor on our printed circuit board with the high currents and magnetic fields of the degausser and noisy power supplies. Because of these reasons we sought after a module to do our magnetic sensing and landed on the Gaussmeter Click. The Gaussmeter click is essentially the powerful MLK9039 hall effect magnetometer mounted on a piece of FR4 and some connectors, giving us the chip down feel with placement flexibility. The MLK9039 is awesome because it comes equipped with onboard circuit conditioning and analog to digital converters and relays the data to the master over either SPI or i2C protocol. The Gaussmeter Click is also in the MIKROE BUS form factor that is becoming a pseudo standard. Using the MIKROE BUS connector we can plug the Gaussmeter Click right into our custom printed circuit board or we can wire to the two 8 pin 100mil pitch standardized pinout connectors. Because of the MIKROE BUS standard there are over 1000 different breakout IC's we can plug right into our device including hundreds of different sensors making our design robust. The Mikroe Gaussmeter click is the only thing on our Magnetic sensor schematic sheet as it really is the total package. Because we have left over GPIO and interface pins we connected both i2C and SPI to our microcontroller in case there is an issue with either.

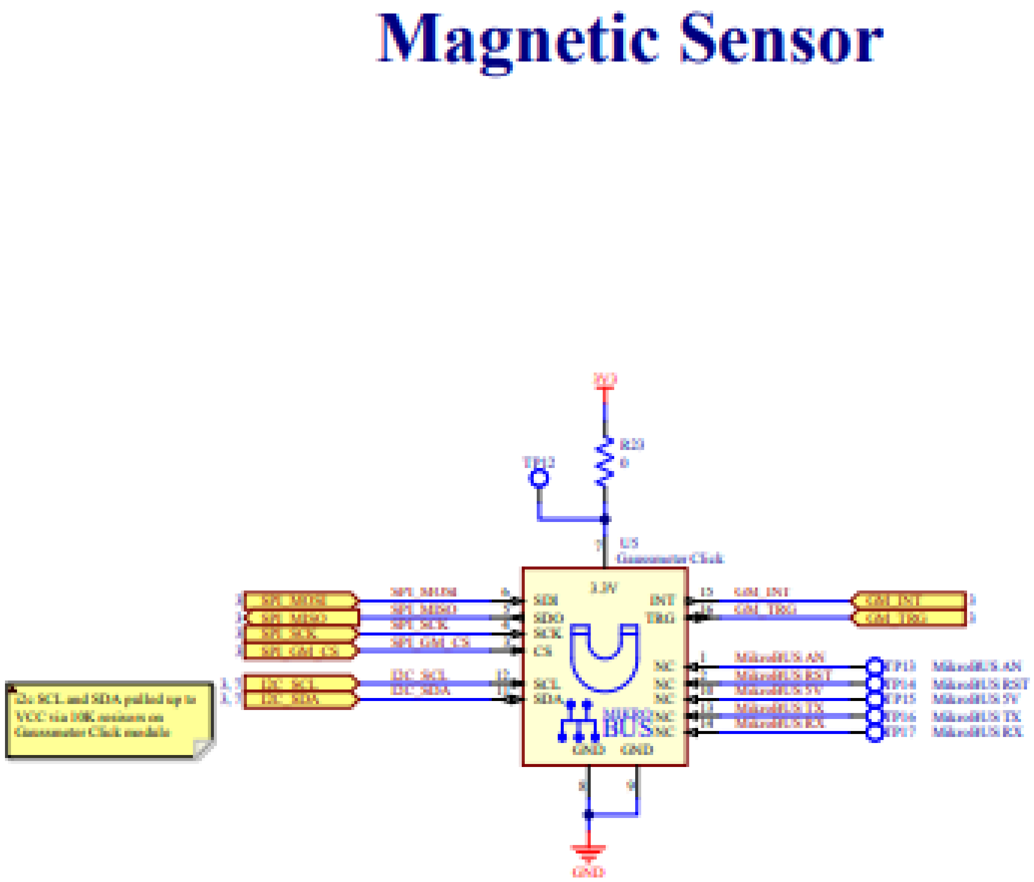
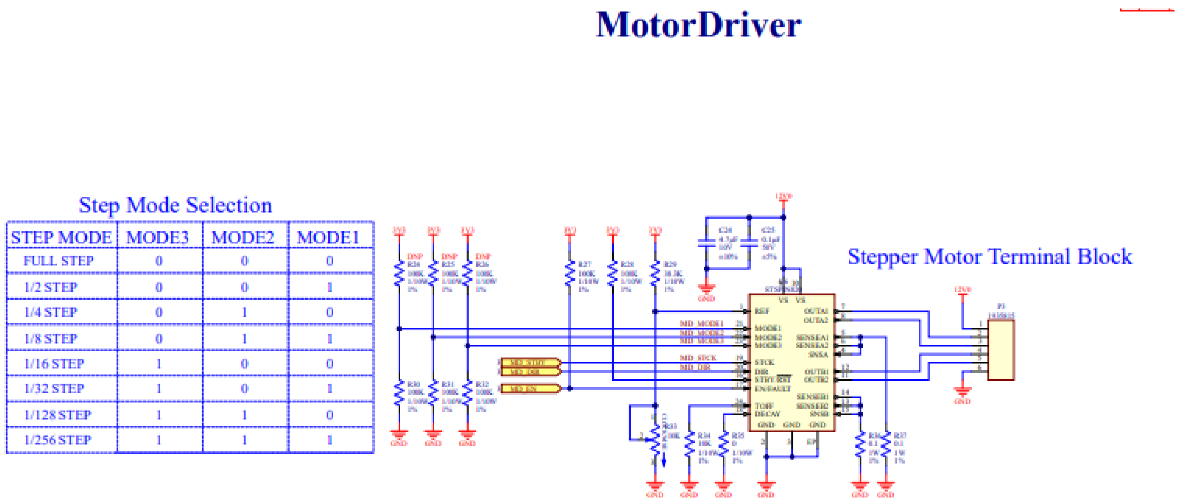


Figure 48 – Magnetic Sensor Circuit

To spin our watch and charge it we need a stepper motor. To spin the stepper motor we need a motor driver circuit. We chose to use the STSPIN820 chip down on our PCB. To set the mode of the stepper motor the 3 mode pins are either pulled high or low giving us 8 options. We intentionally pulled all three to ground putting us in full step mode but left option DNP resistors pulled up to logic high on each line giving us the possibility of adjusting in the future. To set the motor current we created a resistor divider circuit with a 10K ohm potentiometer as our bottom resistor so we can fine tune the input voltage to the REF pin. 0.1 Ohm sense resistors were calculated from the datasheet and incorporated in our design. The STSPIN interfaces to our microcontroller only using 3 pins and it alone drives the motor. The STSPIN uses 12V on the VS terminals to power the motor on the OUT terminals that run to our terminal block and out to the wires of our stepper motor. A legend is drawn in the document to aid in mode selection for the stepper motor driver. The figure below shows a snip of our motor driver schematic.



STEP MODE	MODE3	MODE2	MODE1
FULL STEP	0	0	0
1/2 STEP	0	0	1
1/4 STEP	0	1	0
1/8 STEP	0	1	1
1/16 STEP	1	0	0
1/32 STEP	1	0	1
1/128 STEP	1	1	0
1/256 STEP	1	1	1

Figure 49 – Motor Driver Circuit

To demagnetize induced magnetic fields we need a degaussing circuit. Page six of our design shows our degausser circuit. This circuit needs a lot of power to run and typically is designed using alternating voltages. Because of this issue we decided to use a mechanical relay with lots of isolation to switch our AC voltages. We can energize the relay coil by interfacing with the base of a bipolar transistor and allowing it to conduct, allowing 12V to be applied across the coil. Once the coil is energized the normally open relay contact closes and the AC voltage can be applied across our degaussing coil. NTC thermistors are used to limit the current and back off the magnetic field creating a slow field decay effect that is popular in degaussing theory these days.

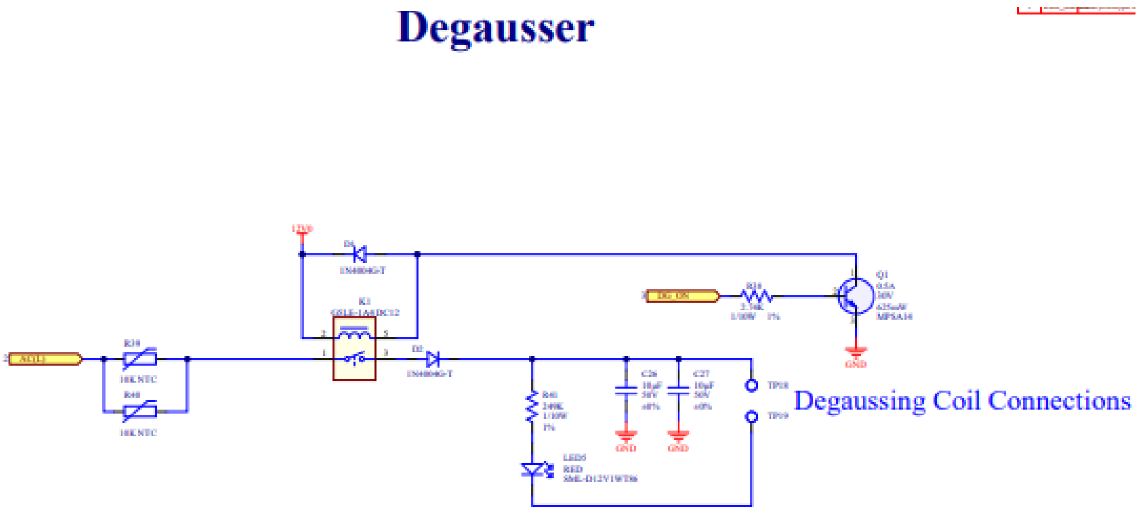
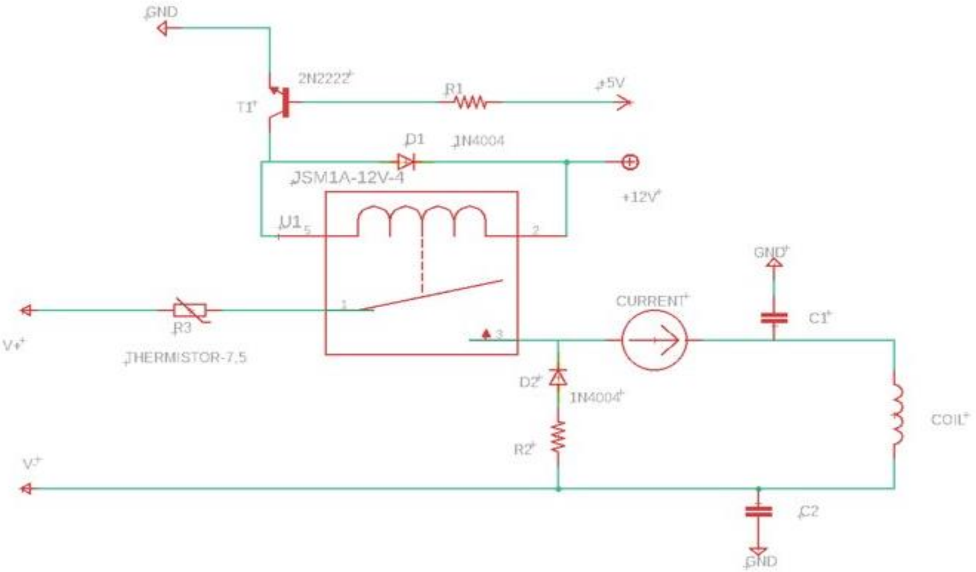


Figure 50 – Degausser Circuit

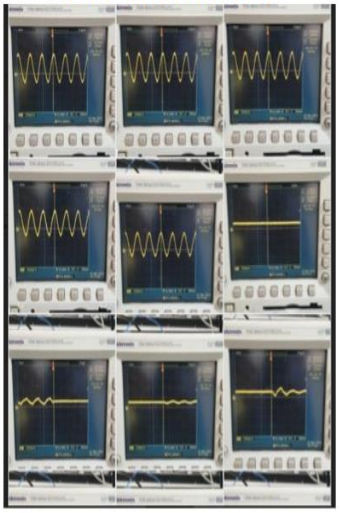
To interface with our device we have equipped an onboard OLED display that will show the user data on their watches' charge and magnetic field. The display we selected is configurable between four different interfaces including SPI and i2c and also has a built-in display driver. This display appears to be easy to use and interface with and should give the user a pleasant experience. We chose to interface to the display over SPI and followed the datasheet on the recommended pull up or pull downs on the remaining pins. We decided to break a few extra signals out to our microcontroller in case we need them in the future because we have plenty of gpio left. We added a display reset button that will drive the active low reset pin to ground when pressed, effectively resetting the OLED display. The display has a built-in flex style connector consisting of edge fingers so a mating FPC connector had to be selected. The mating connector on our board was chosen matching the pitch, thickness, Top/Bottom contact and pin count of the display's flex connector and searching until we found the Wurth Connector. To interface with the device we have a built in keypad that interfaces with GPIO pins on our microcontroller.

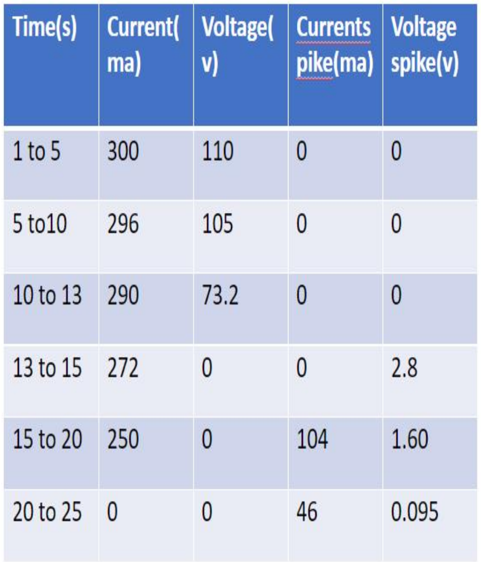
In the second stage design of the degausser, we worked on selecting the necessary components to be assembled in the circuit. One of the added components was a diode assembled in series with the thermistor and in parallel to the degausser coil. The idea was to block the back spike current that flows from the degausser coil after the power is off and the alternating magnetic field converted to current. However, the diode we connected in series to the thermistor rectified the current before it reached the degausser coil as a result the degausser couldn't work. Because, an alternating current is required to get an alternating magnetic field in the degausser coil. Therefore, we had to remove the diode from the circuit in order to solve the issue. Another problem was the wrong LED assembly. In which the polarity of the LED was reversed and finally the degausser circuit worked great. The updated schematic of the degausser circuit is as shown below.



Using Magnetometer we able to record 1000 micro Tesla alternating magnetic field and using Oscilloscope, we are able to record the alternating current and the back spik current results as shown below.

Decaying Current due to PTC Thermistor





Time(s)	Current(ma)	Voltage(v)	Currentspike(ma)	Voltage spike(v)
1 to 5	300	110	0	0
5 to10	296	105	0	0
10 to 13	290	73.2	0	0
13 to 15	272	0	0	2.8
15 to 20	250	0	104	1.60
20 to 25	0	0	46	0.095

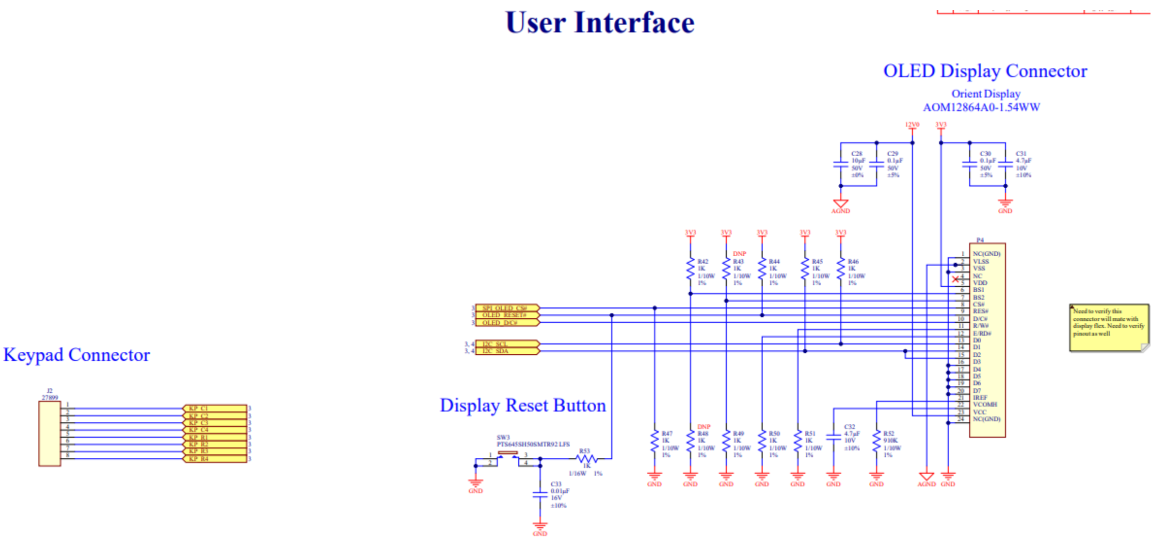


Figure 51 – User Interface Circuit

Now that the schematic is done, we can begin the printed circuit board design. We are pressing to have our design files ready in advance to enable quick prototyping but at this point we do not have our schematic fully reviewed so we only feel comfortable taking the PCB layout to a final placement. Time does not need to be invested into routing the PCB until the schematic has been finalized but an overall placement has been done. A 3D image of our PCB placement is shown below with colored boxes drawn around each sub circuit. Of course, we went with black solder mask to represent UCF's black and gold school colors, we might even etch in the school logo on the solder mask relief layer exposing the logo to copper and eventually getting flashed with gold, resulting in a gold UCF logo on a black solder mask PCB.

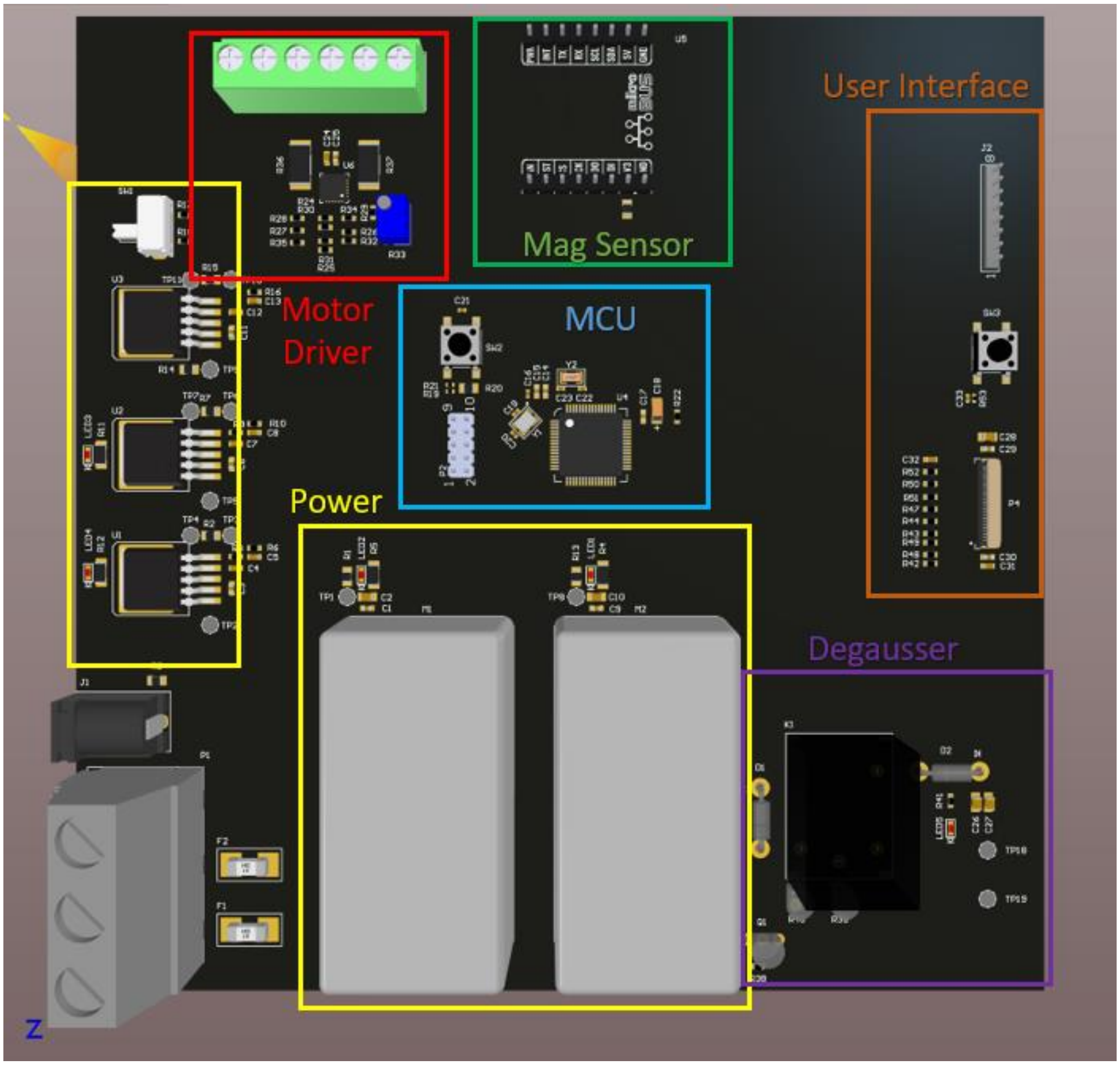


Figure 52 – Final PCB Design

7 Administrative Content

Budget

The parts cost listed below is the final tally of all costs associated with the project. The project had no sponsor, all costs were split evenly amongst group members.

PARTS	QTY	COST
Atmel ICE basic programmer	1	$129.01
ATUC256L3U-AUT MCU	3	$34.41
#27899 Parallax 4x4 keypad	1	$9.27
AOM12864A0-1.54WW Display	2	$40.92
Custom PCB	5	$216.99
STSPIN820 Stepper Motor Driver	3	$48.16
PCB parts	N/A	$302.85
Degausser Coil	1	$13.21
Adafruit Stepper Motor	1	$18.91
Gaussmeter	1	$19.00
Thermistor	10	$8.63
		Total: $841.36

Table 25

Initial Project Milestone for Both Semesters

Senior Design I

Here is a milestone breakdown of the first semester of Senior Design I. We have met all the milestone requirements we have set for ourselves. Requirements that were set by the professor have been fixed and completed.

Week	Dates	Milestone Description
1	05/17/22 to 05/20/22	Submitting project idea and forming project group Completed
2	05/21/22 to 05/27/22	Start working on Divide and Conquer document Completed
3	05/28/22 to 06/03/22	Complete and submit initial D&C Completed
4	06/04/22 to 06/10/22	Meeting with Dr. Wei and begin working on updated D&C Completed
5	06/11/22 to 06/17/22	Submit updated D&C document Completed
6	06/18/22 to 06/24/22	Start working on 60 pages draft Senior Design I Document Completed
7	06/25/22 to 07/01/22	Continue working on 60 pages draft Completed
8	07/02/22 to 07/08/22	Submit 60 pages Senior Design I Document Completed
9	07/09/22 to 07/17/22	Receive feedback on our 60 pages Senior Design I Document and start working on 100 pages report Completed
10	07/16/22 to 07/22/22	Submit updated 100 pages report Completed
11	07/23/22 to 08/02/22	Continue working and perform any modification then submit final document report Completed

Table 26

Senior Design II

Here is a milestone breakdown of the last semester of Senior Design II. These are the milestones we feel we need for the next semester going forward. The main goal is to build out the design and demo the final project.

Week	Dates	Milestone Description
1 to 2	8/22/22 to 8/28/22	Project design review
3 to 4	8/29/22 to 9/11/22	CDR Presentation
5 to 6	9/12/22 to 9/25/22	Prototyping
7 to 8	9/26/22 to 10/9/22	Conference Paper
9 to 10	10/10/22 to 10/23/22	Middle term demo
11 to 12	10/24/22 to 11/6/22	Construction and Assembly
13 to 14	11/7/22 to 11/20/22	Construction and Assembly
15 to 16	11/28/22 to 12/11/22	Demonstration and Presentation of Project Project website development

Table 27

Work Distribution

Here is a breakdown of the work that was distributed for the paper and the parts accumulated for the project. The computer engineer in our group is doing research on the microcontroller, digital display, and keypad. The other electrical engineers in the group decided to split the remaining workload equally.

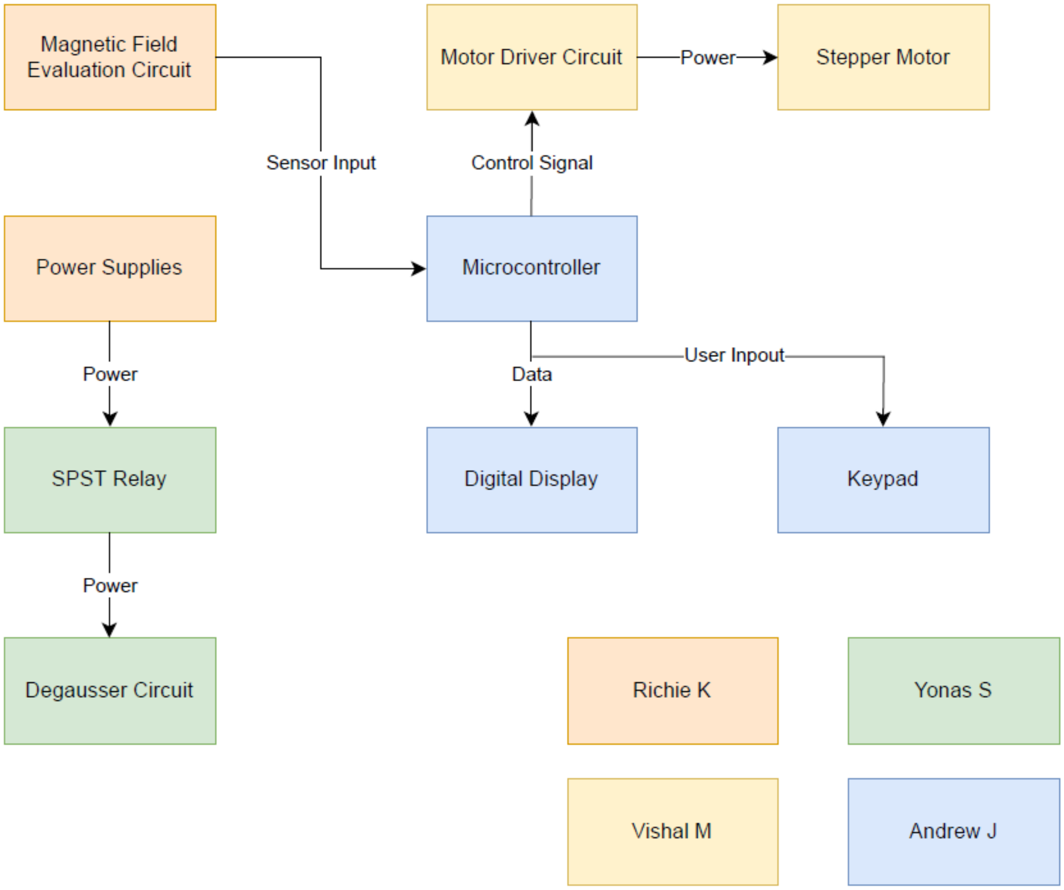


Figure 53

8 Conclusion

Having reached the end of the project, ultimately we achieved the basic goals we set out to accomplish for the project, these being the unification of the degausser and watch winder functionalities into a single unit. Afforded more time we would have been able to realize the secondary functionalities of a proper user interface, utilization of the magnetometer, and possibly even our original stretch goals of web connectivity capabilities. We are nonetheless satisfied with the work we have done so far.

Overall this project was a rewarding opportunity to apply the knowledge we obtained both in and out of the classroom, and has left us all excited to pursue such endeavors after university. Beyond the technical challenge associated with bringing the design to fruition, the project gave us the deeply fulfilling experience of coming together as a team and working towards a common goal. We all hope to be fortunate enough to replicate the experience as we advance in our own individual careers.

Resources

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