Solenoid Actuation

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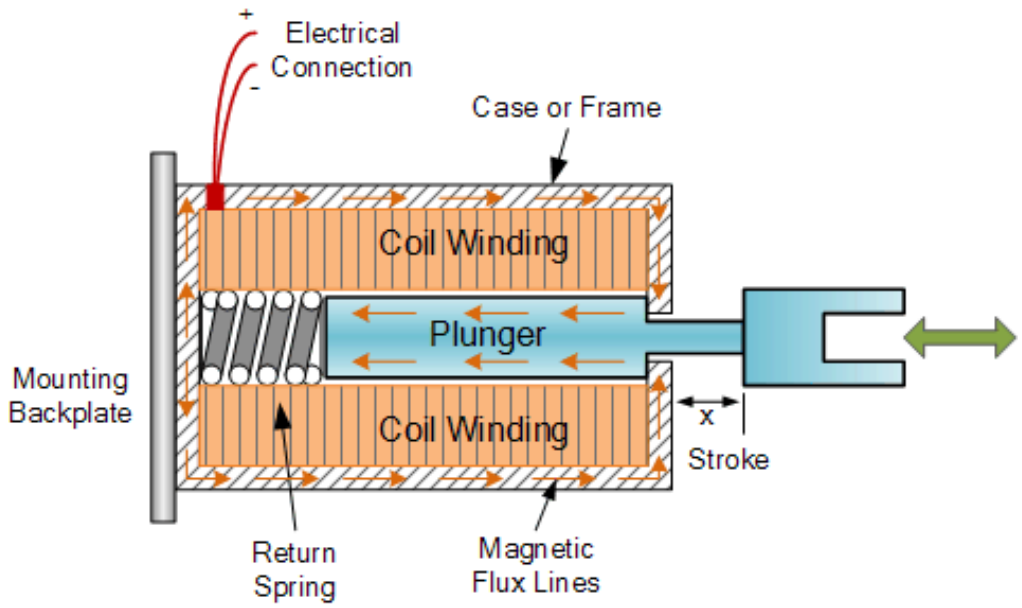
What is a solenoid actuator?

- Composed of a coil, a metal core, spring, and a case
- The core is a ferro-magnetic material
  - Ferro-magnets are very easily magnetized
- Coverts electrical energy into mechanical energy to produce a linear motion via the plunger



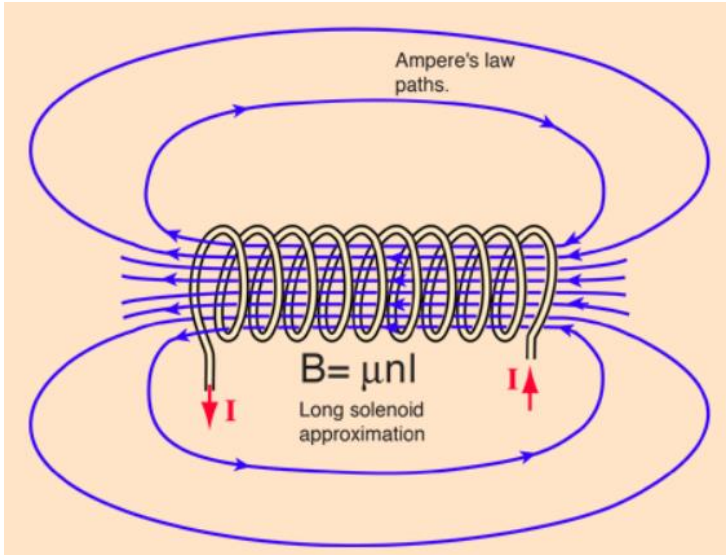
Attributes of a Solenoid Actuator

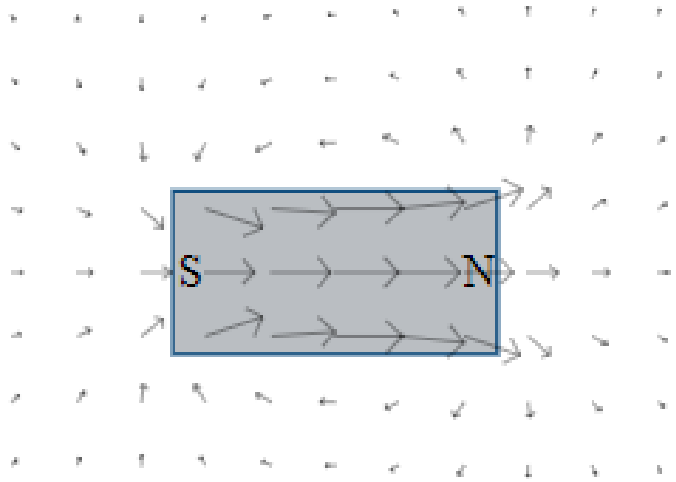
- Type of actuation – what kind of movement they're making
  - Linear – Push or Pull
  - Rotary
- Force – how "strong" the plunger is
- Stroke – maximum plunger distance
- Speed – how fast the plunger can go
- Duty Cycle – ratio of "on" vs "off"
  - Holding type
  - Latch-type

What is a Magnetic Field?

- How magnetic force is distributed
- The input current flows through the coil, producing a magnetic field around the coil
  - The magnetic field can be strengthened by increasing current or increasing number of coils
  - The direction of the north and south poles are determined by the direction of the current and the direction the coils are wound
- Follows the right-hand grip rule

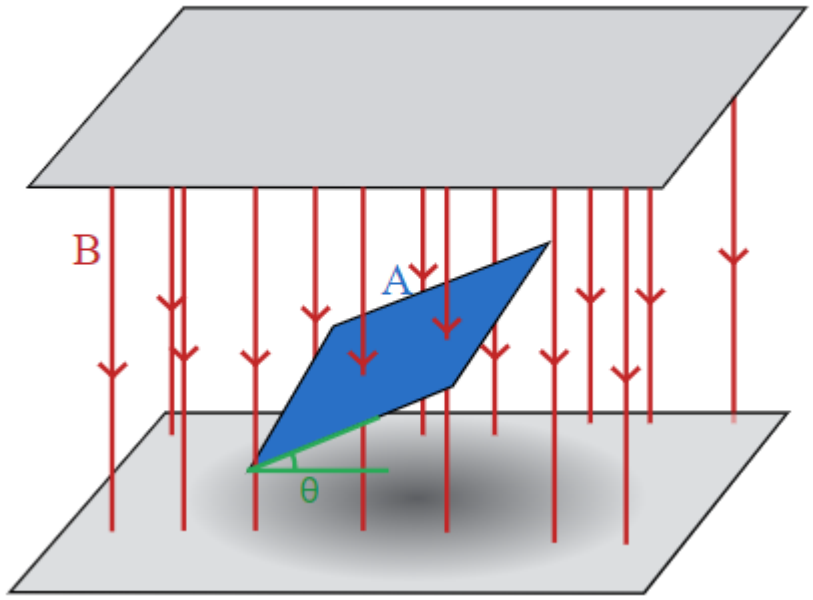
$$B = \frac{\mu_0 I}{2\pi r}$$





Magnetic Flux

- The magnetic field in a given area and describes the effects of magnetic force on a certain object
- Magnetic flux density is the amount of magnetic flux in one area
  - Magnetic flux density increases where the magnetic field is stronger
- When a magnet is passed through magnetic flux, there is a voltage generated (Faraday's Law)

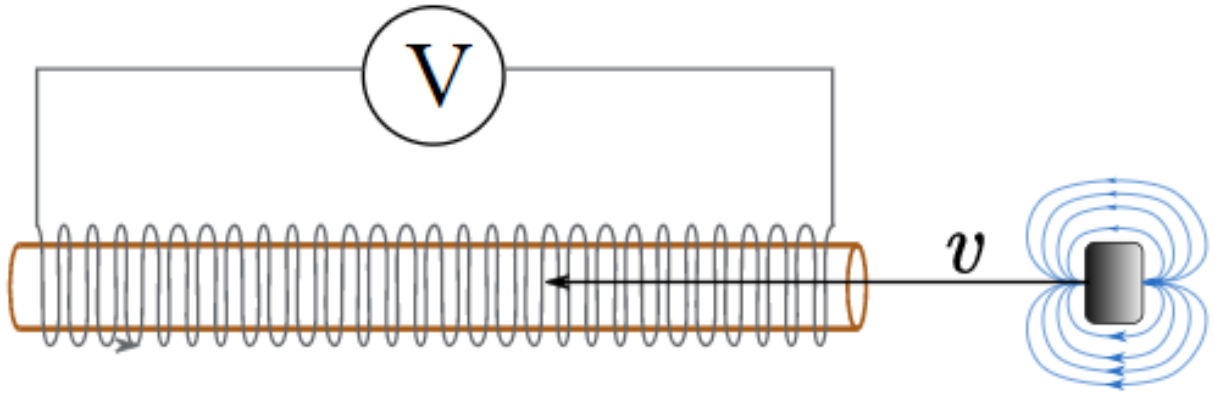


$$\Phi = BA\cos\theta$$

Faraday's Law

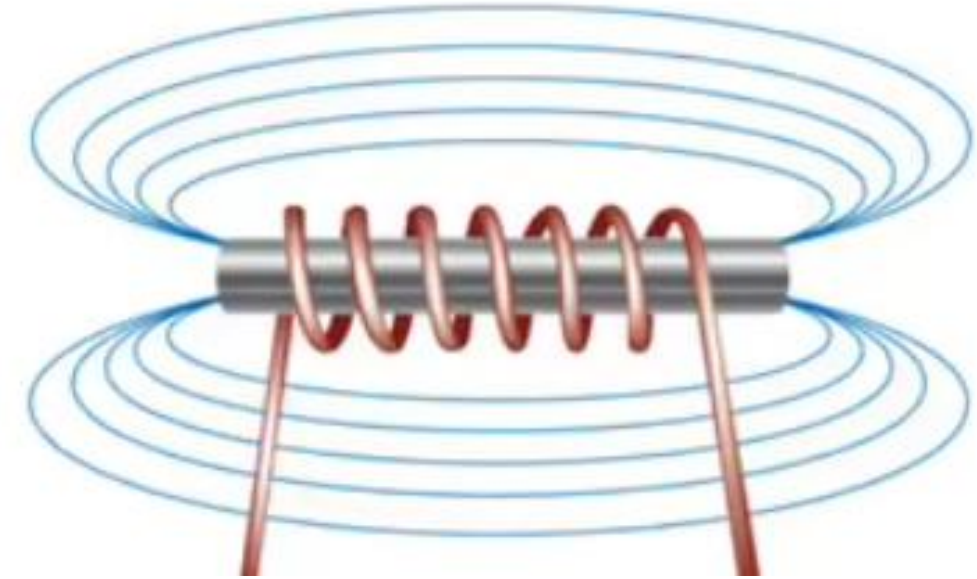
- Since the solenoid is being switched on and off, it will produce a change in magnetic flux
- Changing magnetic flux produces voltage (EMF)
  - This is why we need protection on the circuit
- Current begins to flow in the wire due to the electro-motive forces induced

$$emf = -\frac{d\Phi}{dt}.$$



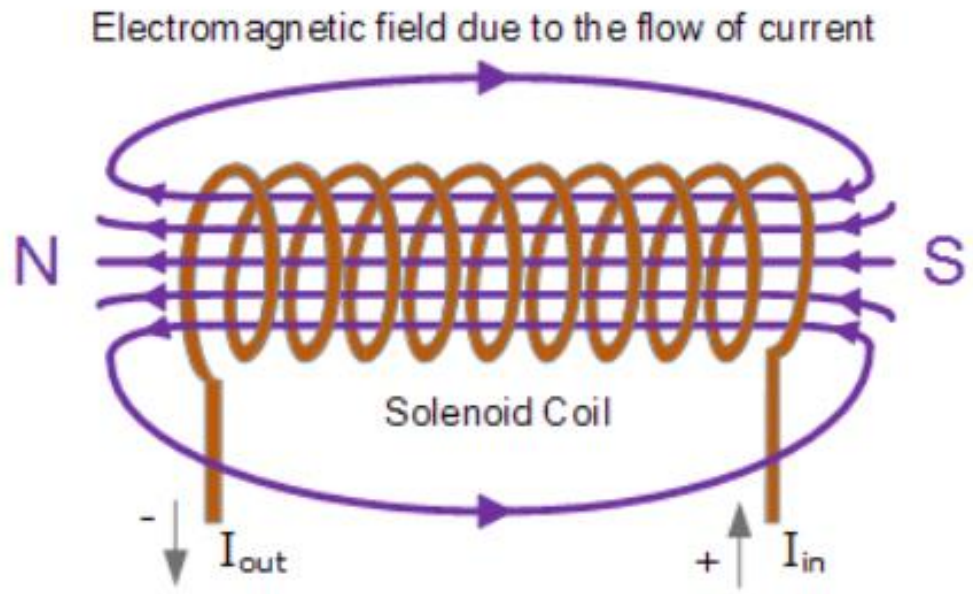
Electromagnetism

- An electromagnet is a magnet that is powered by electricity
- When current flows through the coil, a magnetic field is produced which magnetizes the ferro-magnetic material within the coil
  - Current flows North – South
- Strength can be changed by increasing the current in the coil or adding more turns to the coil



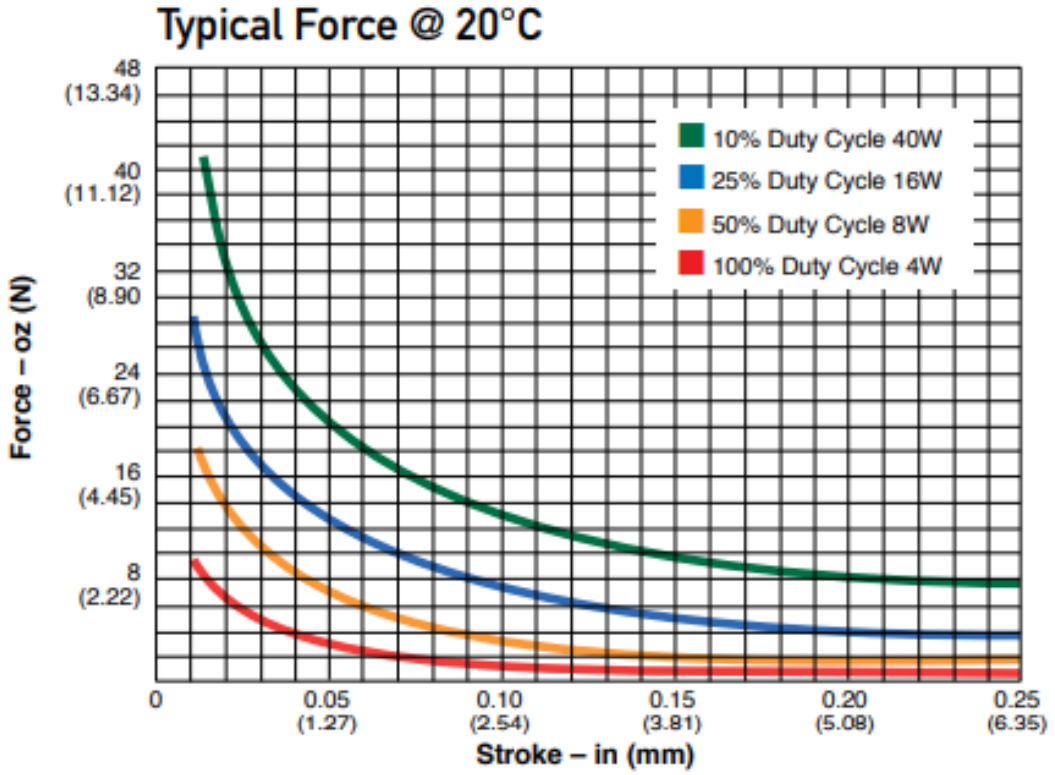
How do solenoids work?

- Solenoid actuators use electromagnetic fields to convert electrical energy to mechanical energy
- The solenoid produces a magnetic field when current is passed through it
- This electromagnet creates a magnetic flux that pulls the plunger forward and through the coil



Force

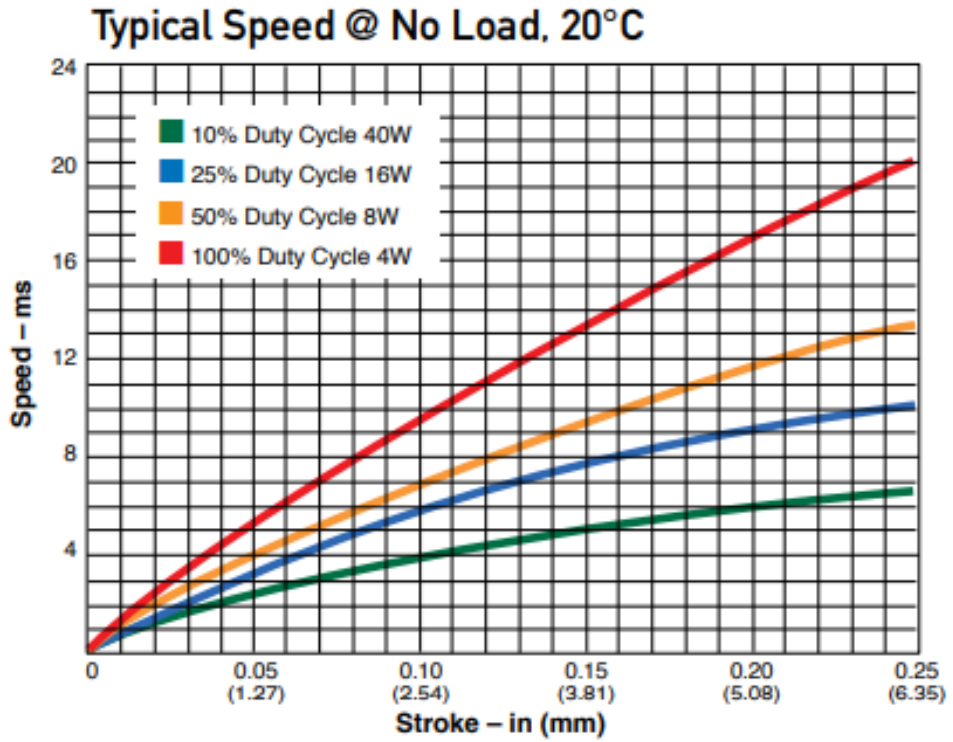
- There are two types of force in a solenoid actuator
  - Static force is the weight the actuator can hold when stationary
  - Dynamic force is the force needed to move an object
- The force of the solenoid is determined by the strength of the magnetic flux
  - The more coils and the more current provided, the more force



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

Speed

- Speed is also determined by the current, number of turns in the coil, and the mass of whatever object the plunger is pushing/pulling
- Force = Mass * Acceleration
  - The speed seems to increase with time, so that aligns with the force equation



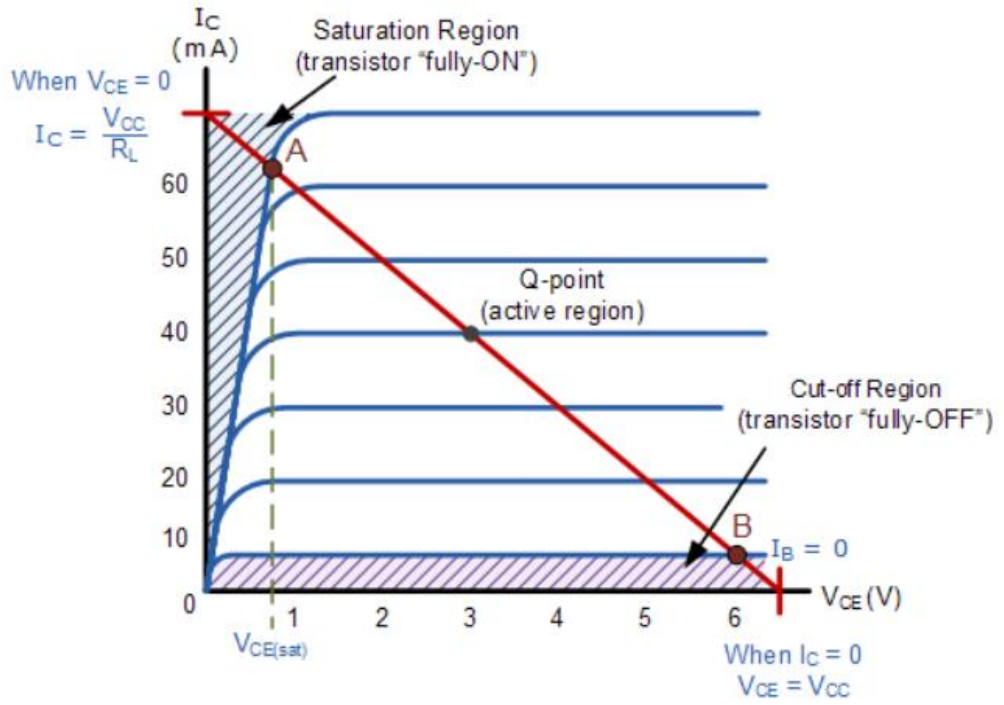
Duty Cycle

- Ratio between the time the solenoid is “on” and when it is “off ”
- For latch-type solenoid actuators, the duty cycle is very low because it only activates intermittently for very short periods of time
  - This also reduces the power consumption of the solenoid

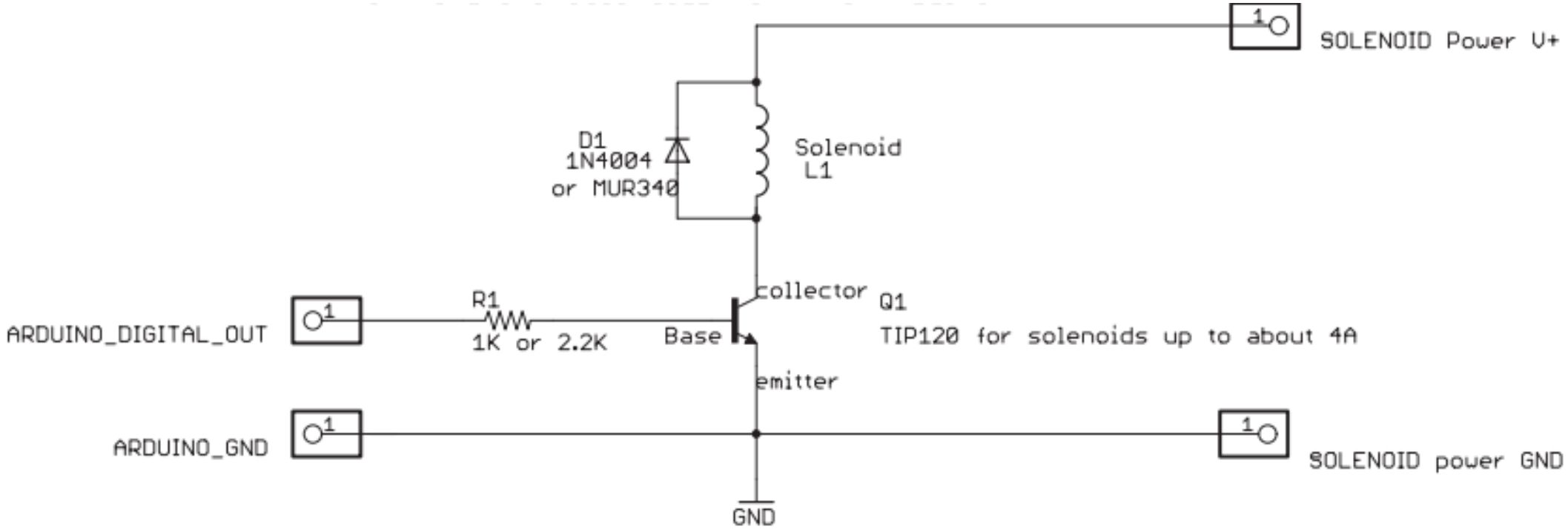
Duty Cycle = On Time / (On Time + Off Time)

Switching

- Need to be able to turn them on or off with a button, switch, or other electrical signal
- Since the solenoids operate with DC Voltage, they can be controlled using transistor (or MOSFET) switches
  - Transistor in saturation it is a closed switch, and in cut off it is an open switch

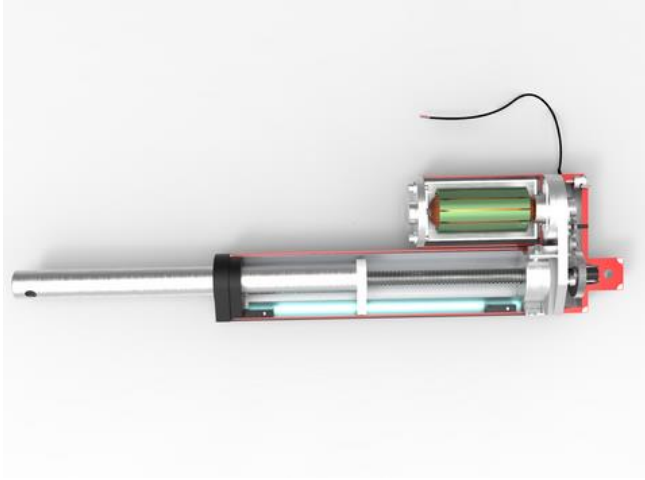


Circuit Layout



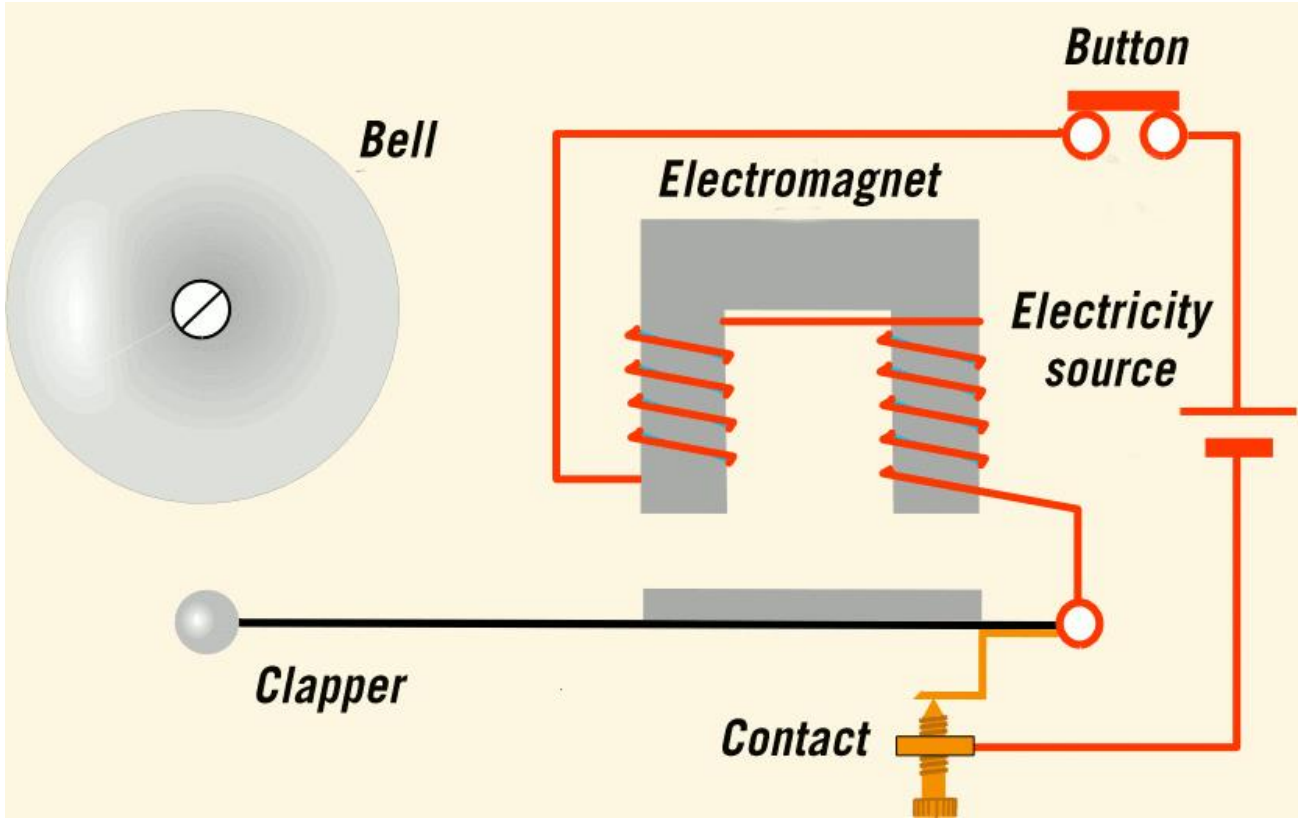
Why solenoid actuation?

- Solenoid actuators have a short stroke length, but they are fast and can deliver a lot of force
- They are cheap, simple to use, and have fast switching times
- They only have two positions
  - "high" or "low"
- They are more compact than other types of linear actuators
- In many applications, they do not consume much power due to their intermittent duty cycle



What are its applications?

- Typical uses include door latches, valve control, robotics, etc
  - In some cases, it could be used to flip a switch
- Used in everyday items, such as washing machines, doorbells, or cars



How did SECON Team use it?

- Using a latch-type pull solenoid actuator
- Using this device to “lock” the duck trailer in place

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