VOICE COIL ACTUATOR

INTRODUCTION

- Voice coils were originally developed for loud speakers for the conversion of electrical energy into sound wave through the use of a diaphragm.
- The coil were used for vibrating the paper cone of a loudspeaker.
- Loud speakers were used to amplify or create a louder voice, thus the name “voice coil” stuck.
- Voice coil actuators (VCAs) use similar technology to speakers, but they are designed to produce higher forces over a larger distances or “strokes”.

INTRODUCTION

- But, the voice coils designed to move larger masses in other applications are called “voice coils.”
- Voice coils are also commonly used in the read/write heads of computer hard drives.
- VC Actuators are direct-drive, hysteresis-free devices used for providing highly accurate linear or rotary motion.

INTRODUCTION

- Since their inception, VCAs have found wider use in applications where proportional or tight servo control is necessary.

- By virtue of their high acceleration and the absence of commutation, voice coil actuators offer numerous advantages in such applications as medical valve actuators, Z axis applications and instruments used in spectroscopy, and chromatography.

- They offer virtually unlimited resolution, limited only by the encoder used for feedback.

- And they come to stop points with amazing speed and accuracy.

INTRODUCTION

- A voice coil is a linear actuator, that moves a mass along a line.
- To be precise, it pushes and pulls a mass wherever it is along a line.
- But a voice coil doesn’t primarily move things, it is a consequence of the force it applies.
- It is sometimes said that voice coils are intended for fast motion but they work just as well for slow motion.

INTRODUCTION

- VCA are the simplest type of electric motors.
- These motors consist of two separate parts; the magnetic housing and the coil.
- Applying a voltage across the terminals of the motor causes the motor to move to one direction.
- Reversing the polarity of the applied voltage will move the motor to the opposite direction.
- The generated force is proportional to the current that flows through the motor coil.

INTRODUCTION

- Voice coil motors do not have commutator, but uses a position sensor.
- The positioning accuracies of less than one micron are achievable.
- The direct coupling of the motor to the load allows for fast acceleration / deceleration and high speed operation.
- Very high speeds and accelerations can be easily achieved.
- The moving part needs to be supported by a mechanism for which the motor is used.
- Force and pressure control are also some applications of the voice coil motors.

PRINCIPLE OF OPERATION

- Voice coils typically consist of :
  - a non-magnetic center pole,
  - a cylindrical coil connected to the power supply,
  - and an outer cylindrical permanent magnet.

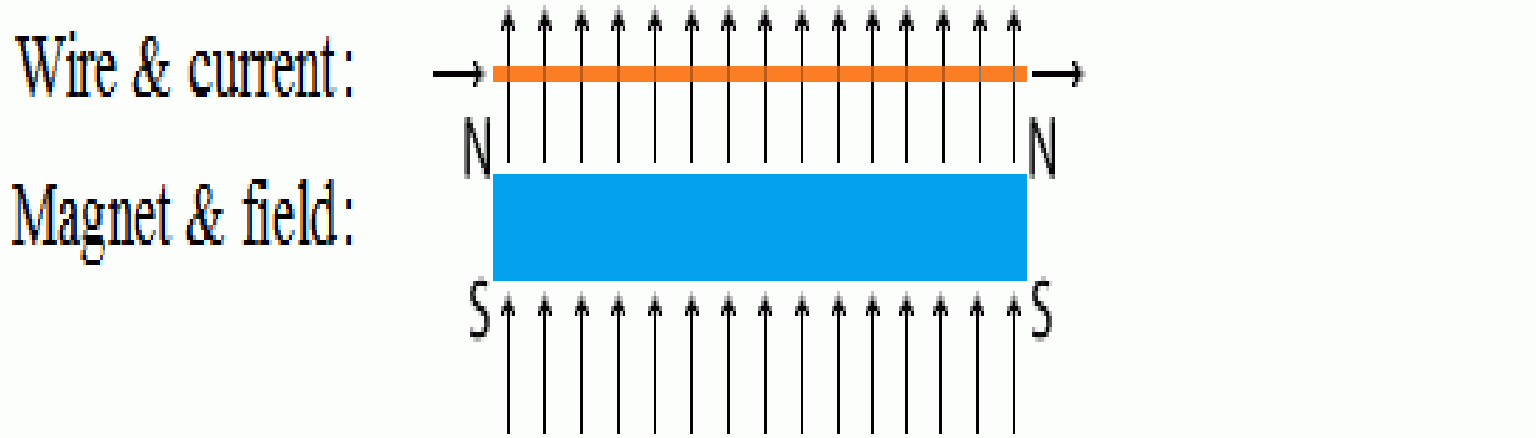
- The current running through the coil creates a magnetic field, which interacts with the field established by the permanent magnet.

- The voice coil works because of the force between a static magnetic field and an electric current perpendicular to the field.

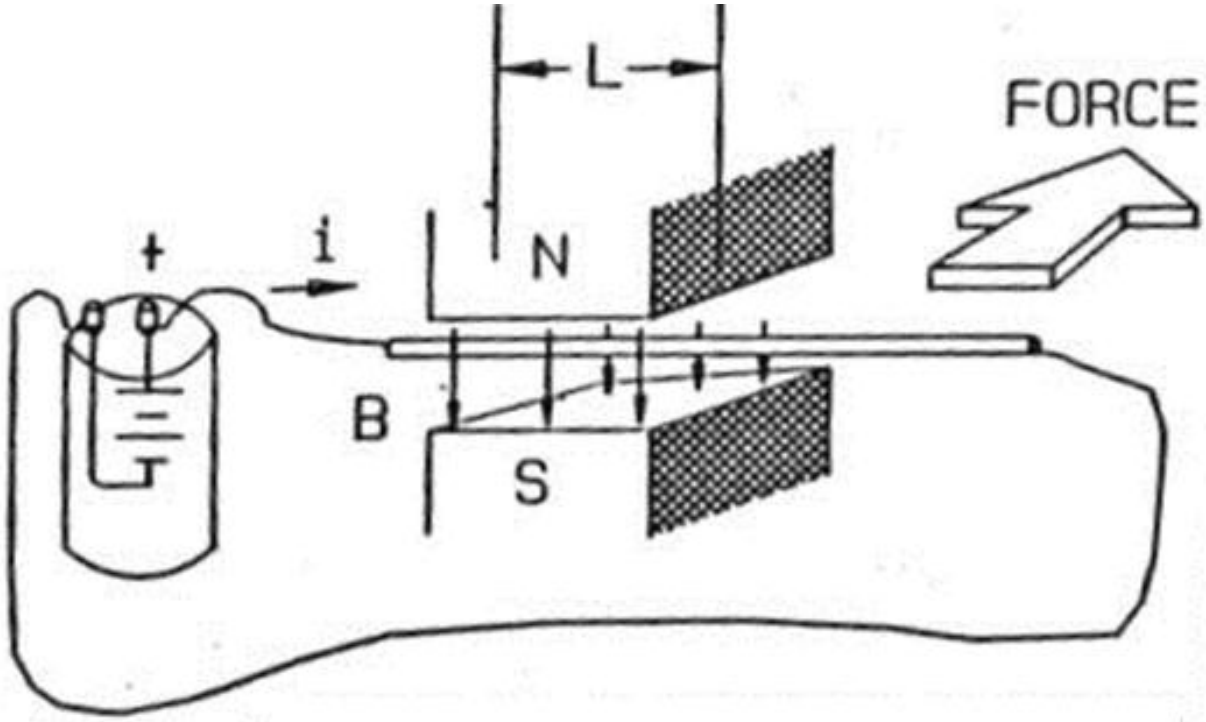
PRINCIPLE OF OPERATION

- Below is a schematic diagram of a current carrying wire and a magnet.

- Arrows indicate the direction of the electric current (to the right) and of the magnetic field (up):



PRINCIPLE OF OPERATION



FORCE ON A CURRENT-CARRYING WIRE IN A MAGNETIC FIELD

- If a conductor (wire) carrying electric current is placed in a magnetic field.
- A force is generated on the wire at right angles to both the direction of current and magnetic flux.

PRINCIPLE OF OPERATION

- The Lorentz force is proportional to the product of the magnetic field and the current, in a direction perpendicular to both of them.

- In the diagram this direction would be directly toward us. If the current were reversed it would be directly away from us.

- If the wire were free to move it would accelerate toward us all along its length.

- Since the permanent magnet flux density field is fixed, the direction of the linear displacement depends on the polarity of input current.

PRINCIPLE OF OPERATION

Lorentz Force Equation

$$\text{Force} = B \times I$$

where: B = Flux density (Tesla)
I = Current (Amps)

- If the magnetic field and conductor length are constant, then the generated force is directly proportional to the magnitude of the current applied to it.

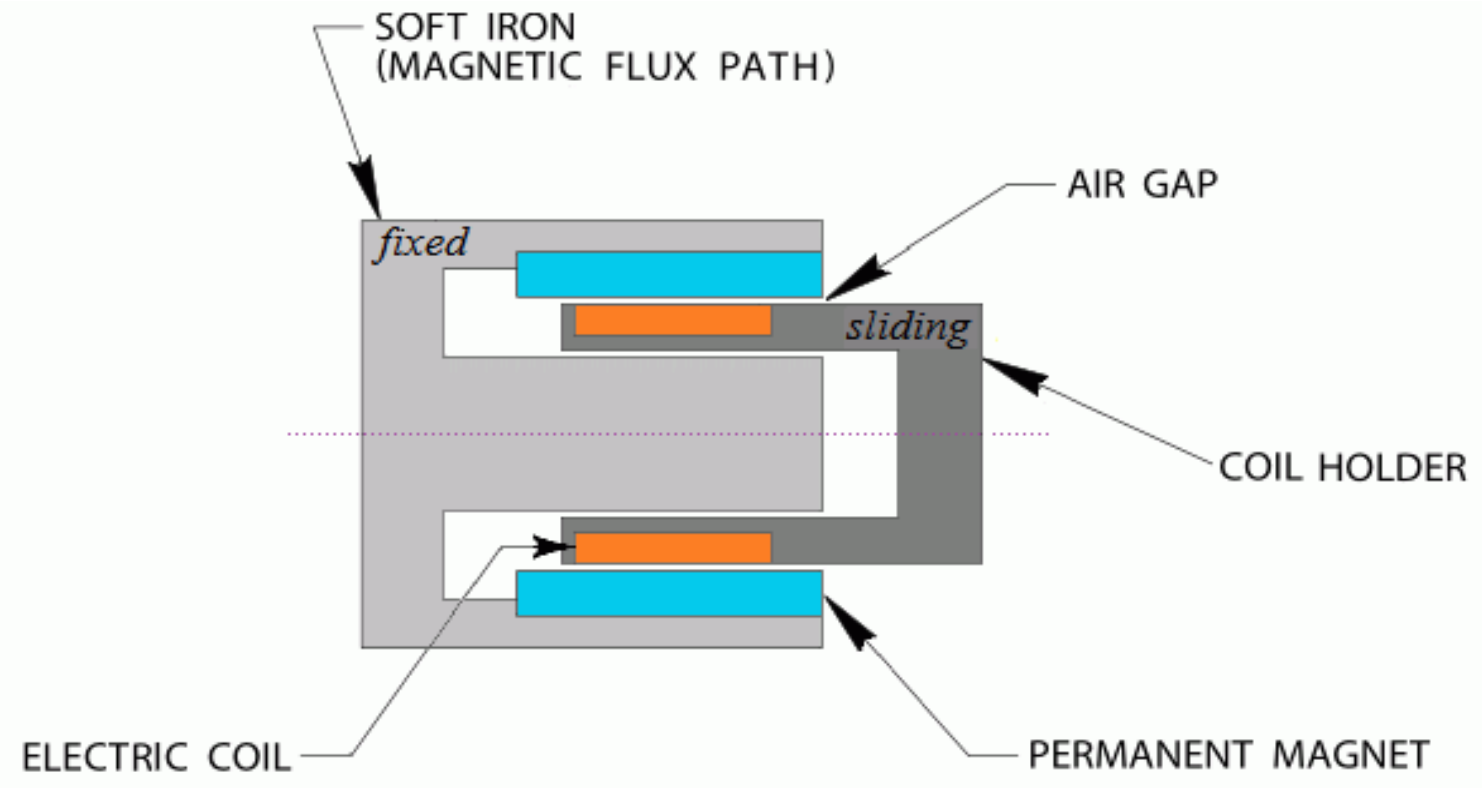
CONSTRUCTION

Linear voice coil actuator with the copper coil wound around a ferromagnetic cylinder. Two wires connect to the coil leads, shown above the coil winding.

CONSTRUCTION

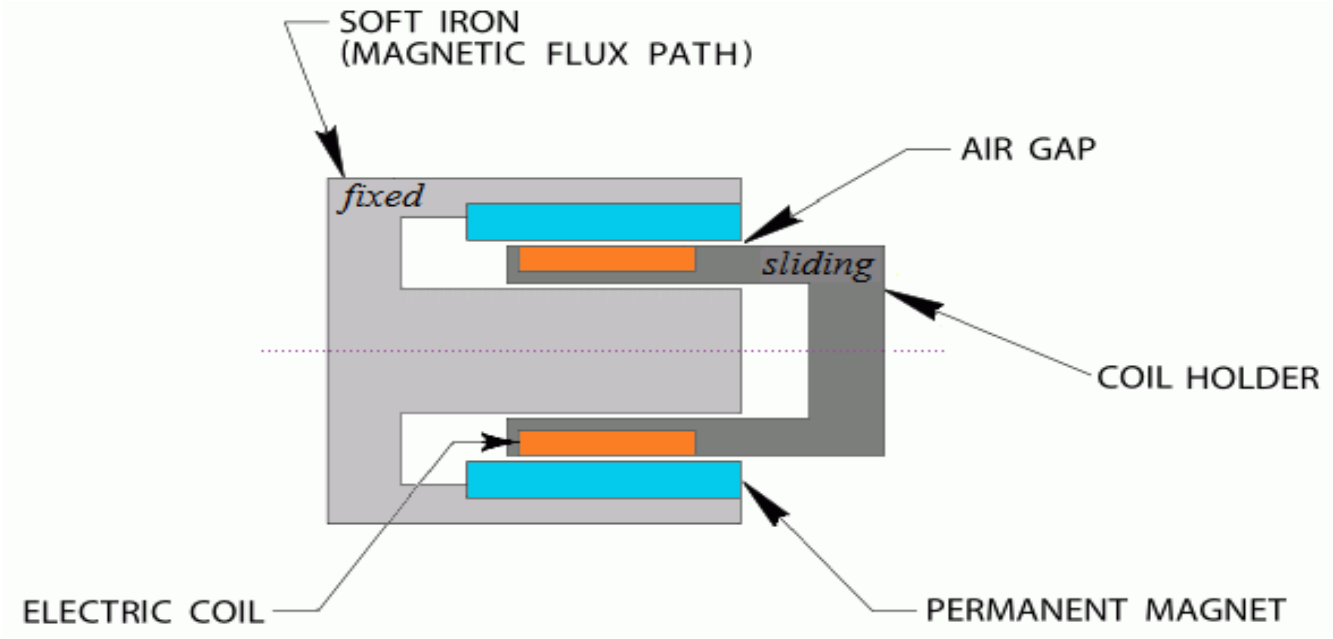
- A simple linear voice coil actuator consists of a tubular coil of wire. The wire is situated within a magnetic field.

- The magnetic field is produced by permanent magnets embedded on the inside diameter of a ferromagnetic cylinder.



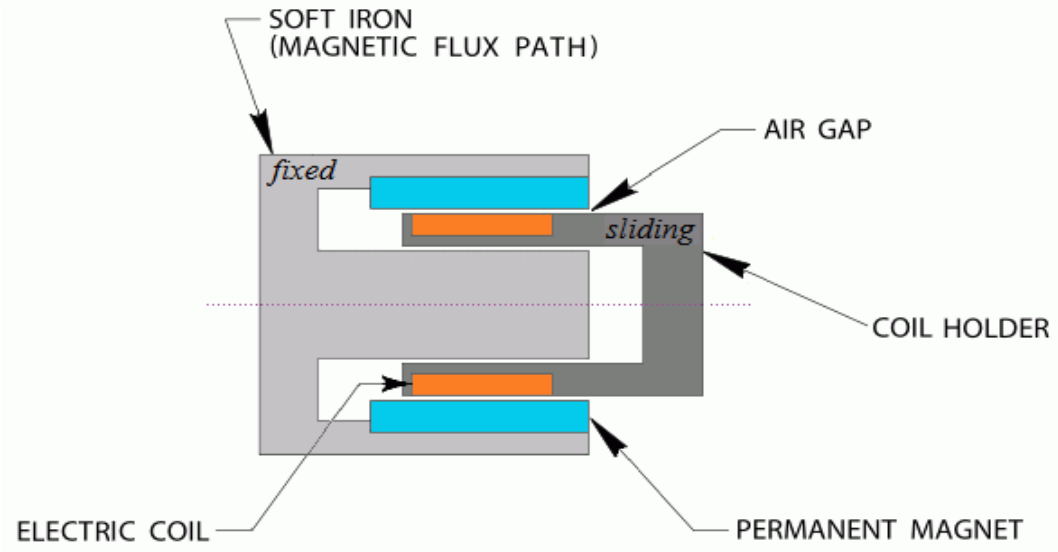
CONSTRUCTION

- The cylinder is arranged such that the side of the magnets that faces the ferromagnetic cylinder has the same polarity as the cylinder.
- The opposite side of the magnets facing the coil has the opposite polarity.
- An inner core of ferromagnetic material set along the axial centreline of the coil, joined at one end to the permanent magnet assembly, is used to complete the magnetic circuit



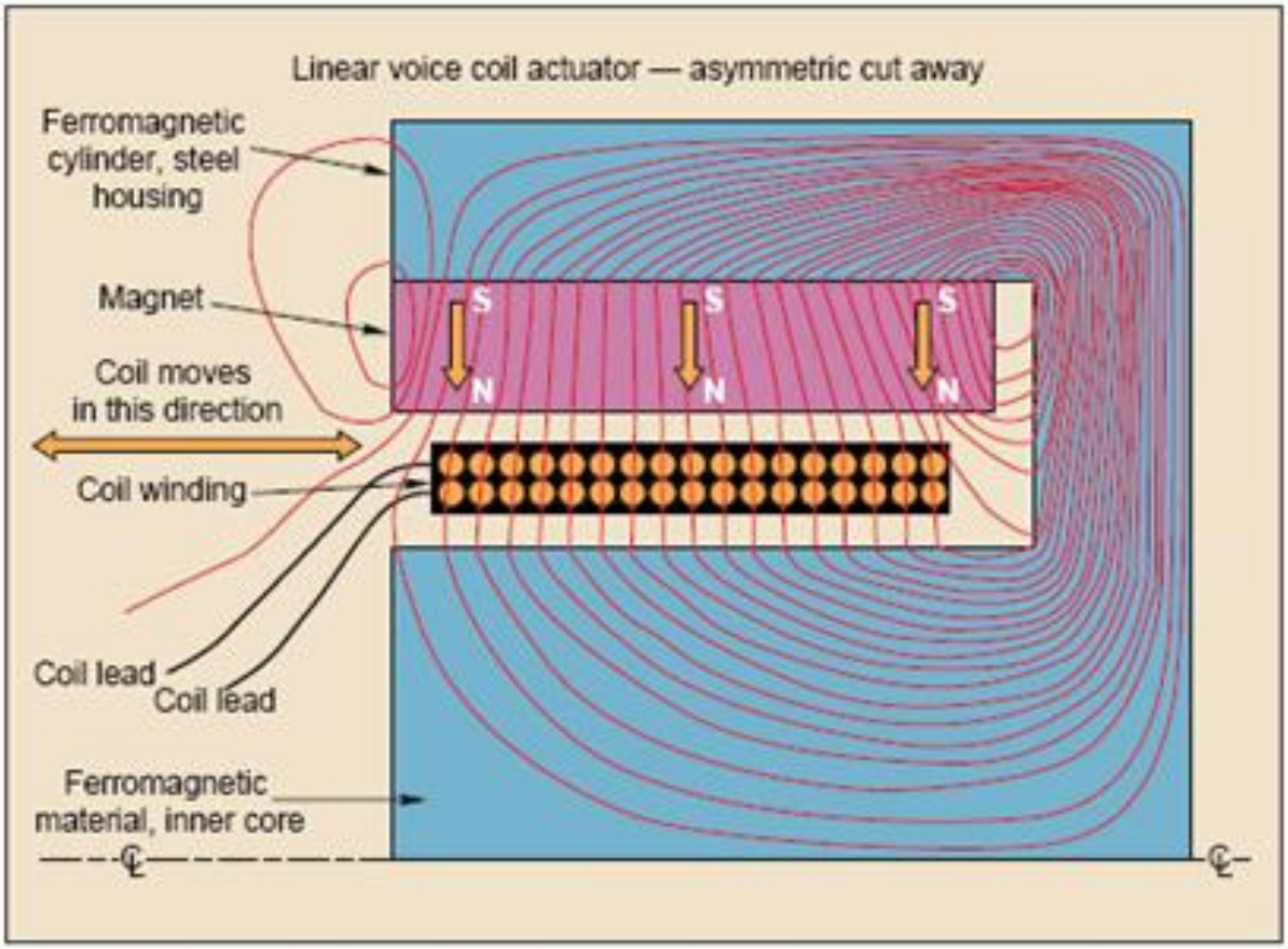
CONSTRUCTION

- When coil current flows, force is generated.
- The axial force generated along the coil will produce relative motion between the field assembly and the coil.
- But the force should be large enough to overcome friction, inertia and any other loads attached to the coil.

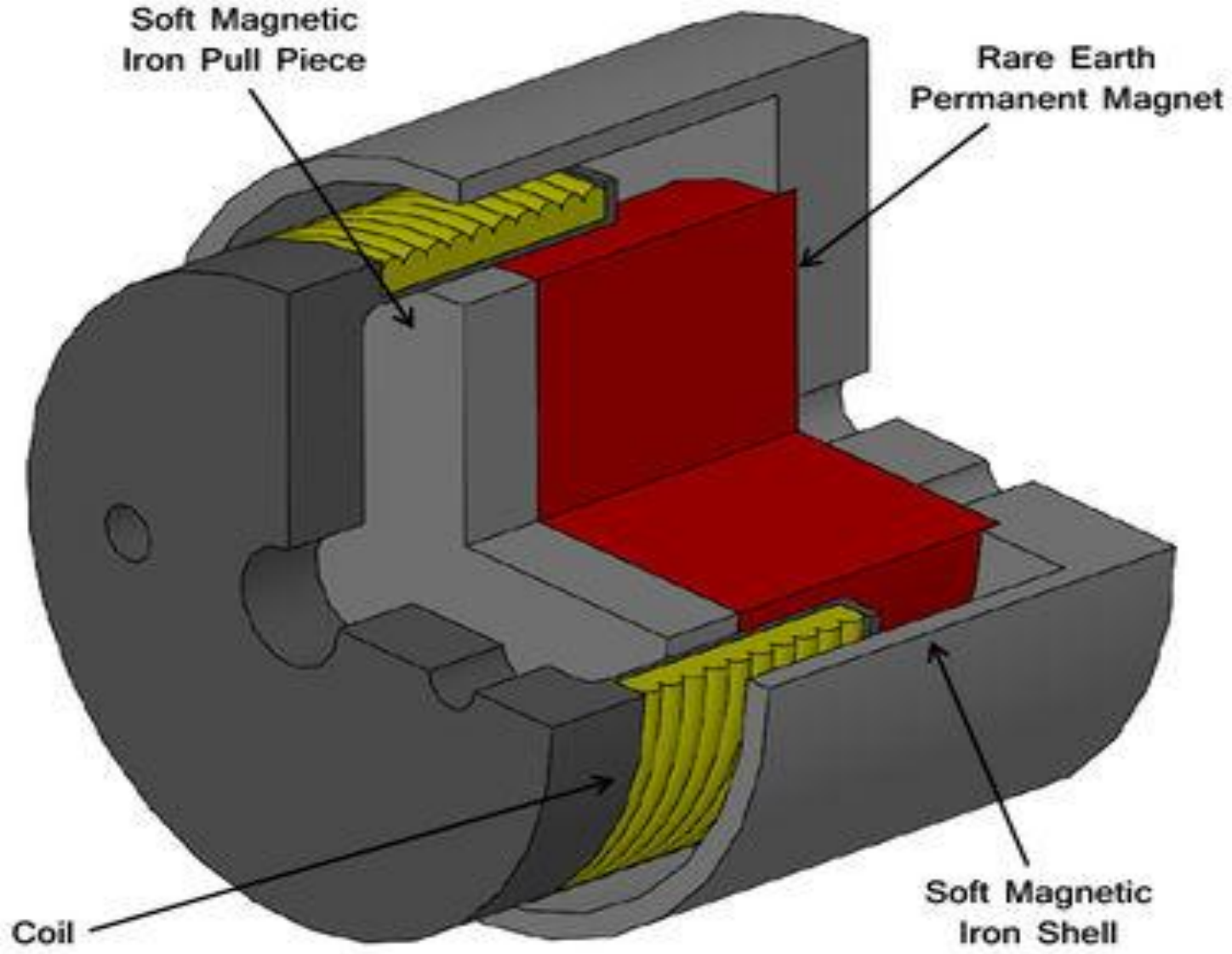


CONSTRUCTION

- The speed of actuation depends on the magnitude of the current flowing through and the voltage applied to the coil.



Side view cutaway of the flux plot of a linear voice coil actuator


Soft Magnetic
Iron Pull Piece
Rare Earth
Permanent Magnet
Coil
Soft Magnetic
Iron Shell

TYPES OF VOICE COIL ACTUATORS

- **Moving Coil, Voice Coil Actuators**
  - It consists of the usually stationary field (magnet) assembly and the moving coil assembly.

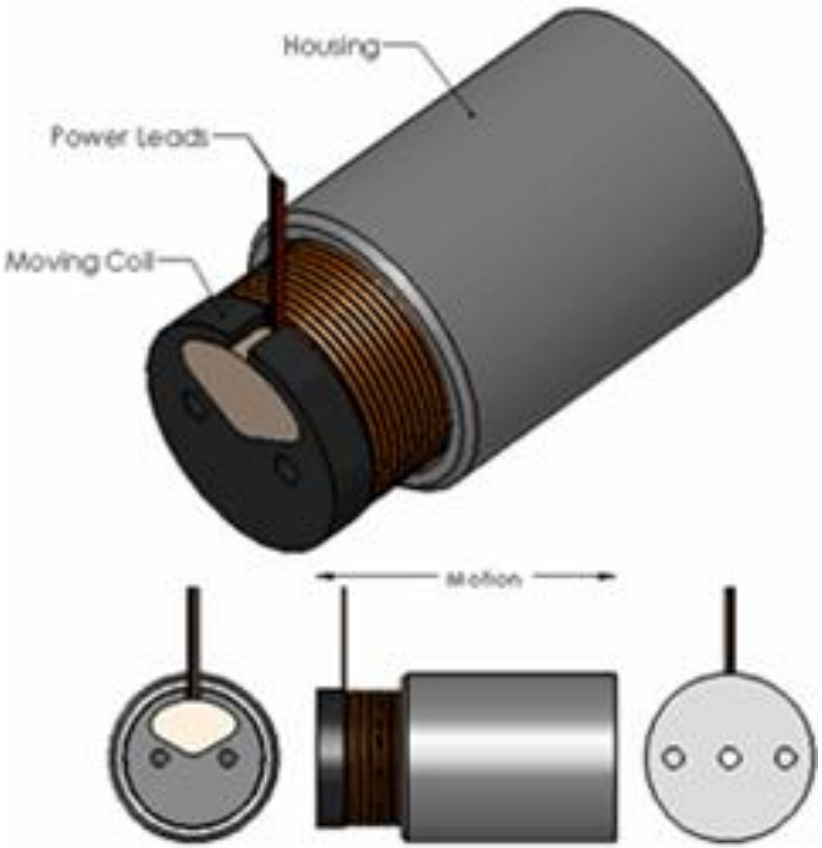
- **Moving Magnet Voice Coil Actuators**

  - It have the coil attached to a stationary soft magnetic housing, which also serves as a conductor of the magnetic flux.

Moving Coil, Voice Coil Actuators

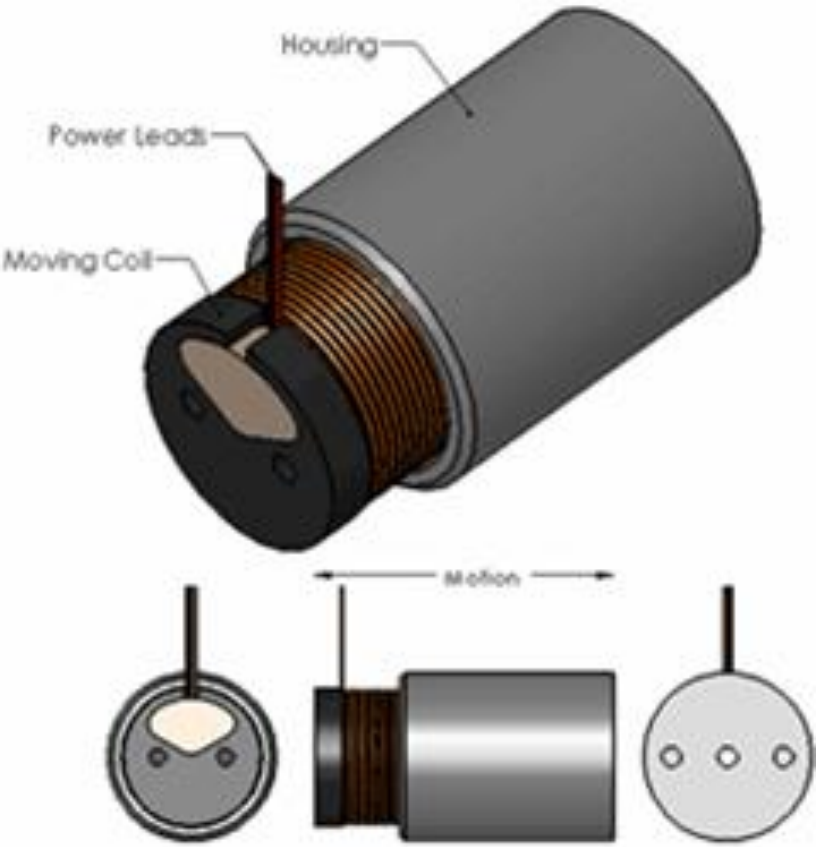
- It consist of a stationary field (magnet) and a moving coil winding (conductor) that produce a force proportional to the applied current.

- In moving coil actuators the permanent magnet field assembly is attached to the outer soft magnetic return path. This is called the field housing.



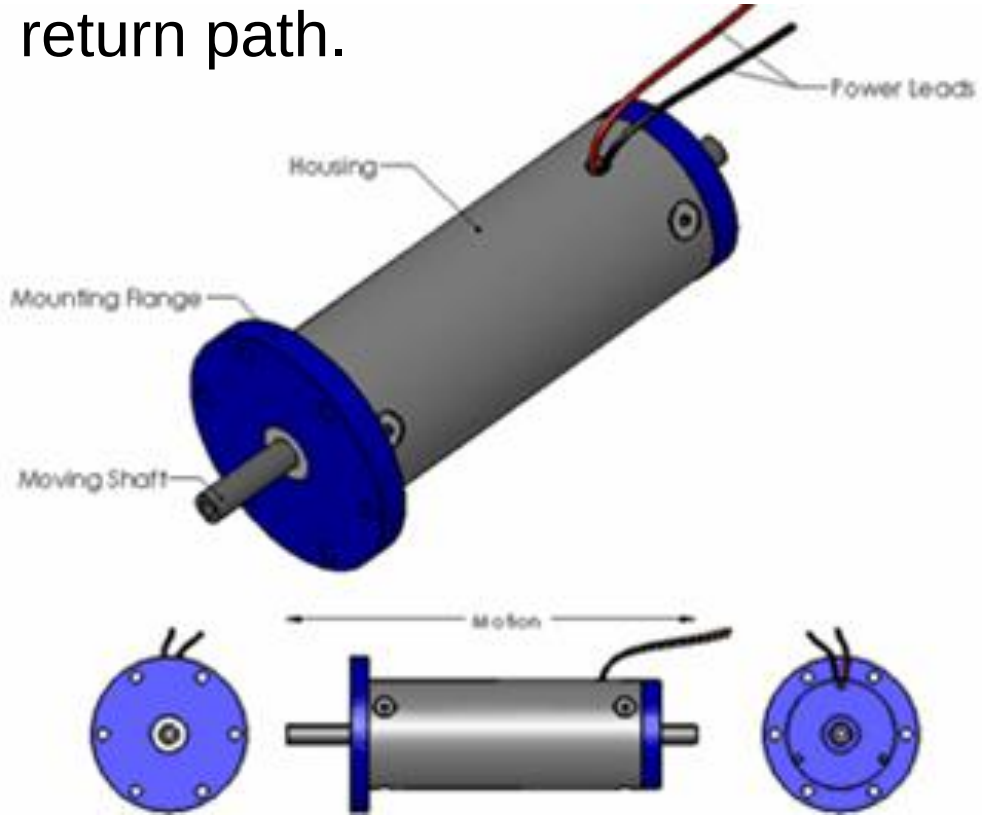
Moving Coil, Voice Coil Actuators

- Compared to other electric linear actuators such as motors with gearboxes and motorized lead screws, a voice coil actuator's key advantage is its ability to accelerate quickly because of its low moving mass.



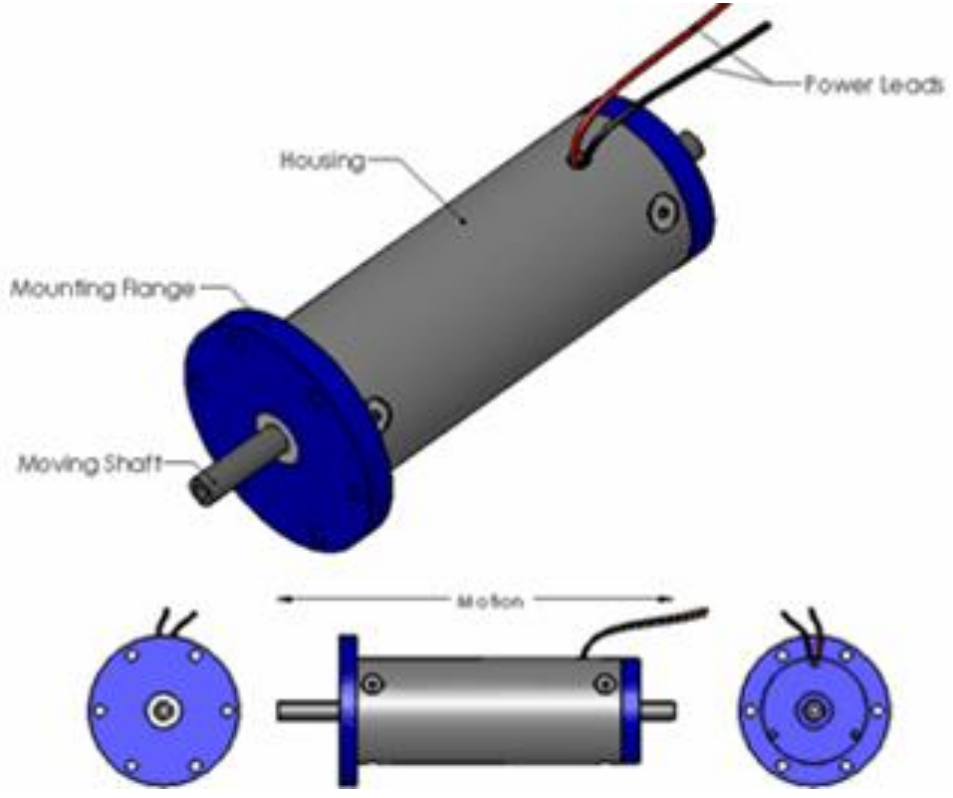
Moving Magnet Voice Coil Actuators

- Similar to moving coil VCAs
- Because they have a permanent magnet field in the middle surrounded by a coil with soft magnetic return path at the outer most diameter.
- Main difference is what gets attached to the outer soft magnetic return path.



Moving Magnet Voice Coil Actuators

- In moving magnet VCAs the coil is attached to the outer soft magnetic return path, so now it is in the stationary portion of the actuator and the permanent magnet field assembly is free to move axially.



Material composition

- Typically, the coil is wound with copper or aluminum-magnet wire coated with a thin polymer film for electrical insulation.
- The most common permanent magnet materials are hard-magnetic ferrites, Neodymium Iron Boron, and Samarium Cobalt.
- The steel flux return, or “backiron” steel, can be any high permeability ferromagnetic material, and need not be laminated.
- The fasteners and bonding agents must be able to survive the required operating environment.

Control

- In precise servo control applications, voice coil actuators require feedback for closed-loop control.
- Many position, velocity, and force transducers can function as feedback devices.
- Most common are optical encoders, contact and magneto-resistive potentiometers, LVDT's, and load cells.
- The actuator's power supply must have sufficient current to meet an application's force requirements.
- It must have a high enough voltage rating to overcome the back EMF at maximum coil velocity and the resistive and inductive voltage drops across the winding.

Mechanical systems

- Voice coil actuators are available as a set consisting of the magnet and coil assemblies.
- The minimum air gap clearance between these assemblies is 0.010- 0.015 inches.
- It needs a guidance system for full range of motion and to prevent the coil winding from rubbing against or crashing into the magnet assembly.
- In most cases, the load is connected to the coil assembly because the coil has a lower mass than the field assembly.
- In cases where the load is sensitive to applied heat, it can be connected to the magnet assembly.

Advantages of Voice Coils

- Voice coils have two advantages over other kinds of actuators.
- Simplicity of construction.
- No gears. They are completely silent and there is no backlash when direction is reversed.
- They are “hysteresis free”.

Voice Coil Parameters

•Several parameters describe a particular voice coil.

Mechanical parameters:

•Size of housing (diameter and length, or height and width and length).

•Length of stroke, measured either starting from full retraction or mid-stroke.

•Protruding length of shaft at either full retraction or mid-stroke.

Electrical parameters:

•The force exerted per amp of current.

•Coil resistance.

•Coil inductance.

•Back EMF (volts per unit velocity)

Voice Coil Parameters

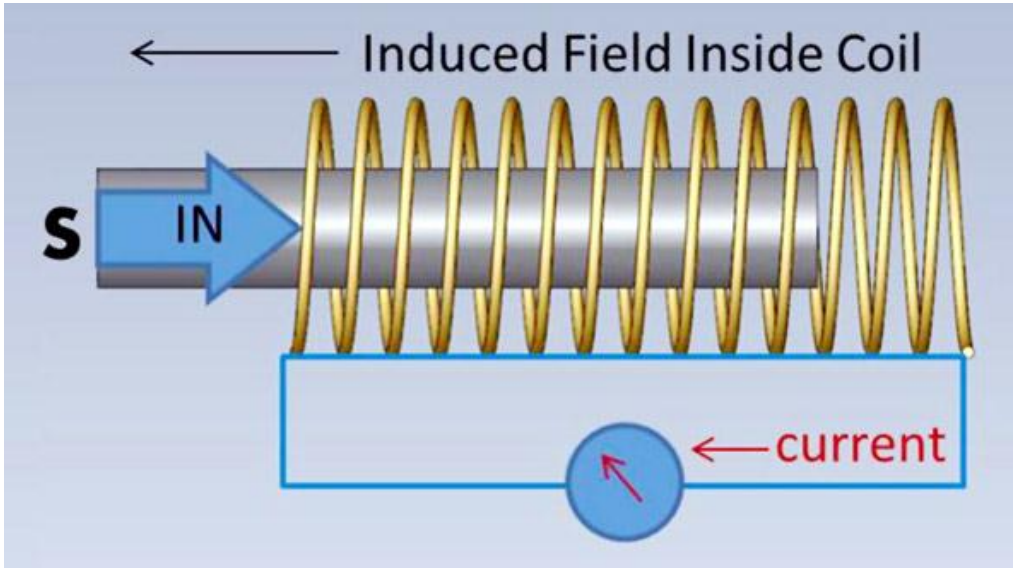
Electrical extremes and ratings:

- Allowed peak current.
- Allowed steady current.
- Force at peak current.

Difference Between Voice Coil Actuators And Solenoids

Solenoids

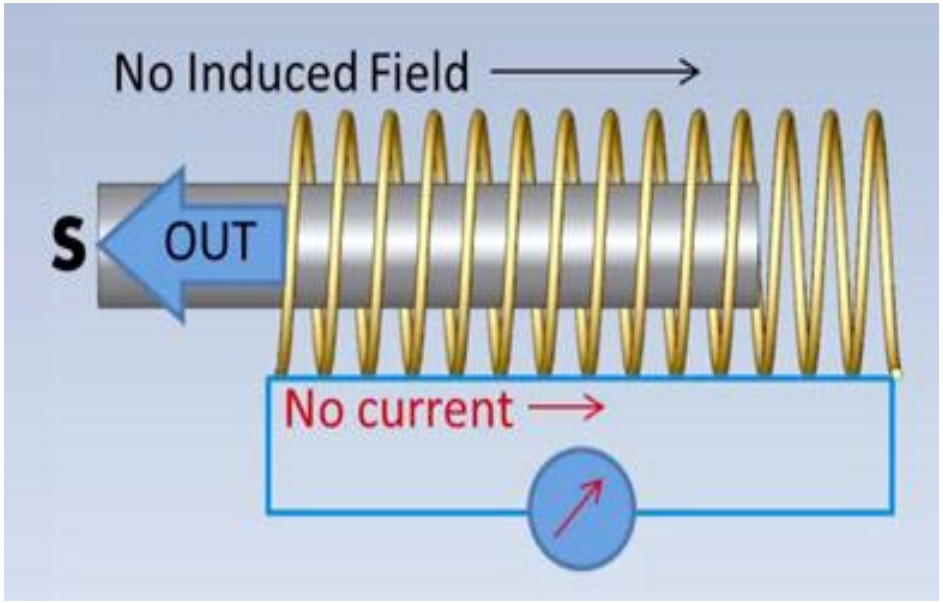
- Solenoids normally consist of a coil with no magnet attached to a soft magnetic housing, an iron or steel core, and, often, a spring.
- These on/off components are controllable via simple switches.
- When current flows through the coil, the electromagnetic field created by the coil attracts the iron core.



Difference Between Voice Coil Actuators And Solenoids

Solenoids

- When the coil is de-energized, the spring pushes the iron core back to its original position.



Difference Between Voice Coil Actuators And Solenoids

VCAs

- VCAs come in many shapes and sizes and in two types:
- VCAs with a moving coil and VCAs with a moving magnet.

- The first type consists of the usually stationary field (magnet) assembly and the moving coil assembly.

- In contrast, moving magnet VCAs have the coil attached to a stationary soft magnetic housing, which also serves as a conductor of the magnetic flux.

- The field assembly typically consists of an axially magnetized, permanent cylindrical magnet and two soft magnetic pole pieces attached to both ends of the magnet.

Difference Between Voice Coil Actuators And Solenoids

VCAs

- Applying a voltage across the terminals causes the VCAs' moving part, magnet or coil, to travel in a given direction.

- Reversing the polarity of the applied voltage will change the direction of the moving magnet or coil.

- The generated force is proportional to the flux crossing the coil and the current that flows through this coil.

VCAs

- VCAs has applications where more precise control is necessary, primarily because they are available with position feedback devices.

- VCAs can typically create more force than solenoids for a specific size, stroke, and input power.

(Because moving magnet VCAs consist of a stationary coil and a moving permanent magnet assembly, as opposed to a coil assembly and a piece of steel in a solenoid)

- VCAs with moving coils are ideal for many limited-angle rotary applications that require high acceleration.

VCAs

- The fast acceleration capability is achievable by minimizing the moving mass, in this case, the moving coil.

- Since it is separate from the magnet, it is customizable to be more lightweight than the heavy permanent magnet field assembly, allowing extremely fast speeds.

- Rotary VCAs are common to gimbal applications where fast yet controllable moves are necessary .

- Some examples include antennas, pan-and-tilt security cameras, target acquisition, laser pointing etc.

Difference Between Voice Coil Actuators And Solenoids

- Reversing the current flow in the coil causes a reversal in the interaction with the field of the permanent magnet. This allows for the voice coil to move in both directions.
- The displacement of the voice coil is proportional to the current in the coil.
- These two properties allow for the production of positive and negative air pressure variations of varying amplitude, as in a loudspeaker.
- The proportionality of the movement of the voice coil allows its use for the accurate positioning necessary for computer hard drives.
- Although solenoids are suitable for on/off linear movement and intermittent duty, VCAs are the obvious choice to control force, speed, travel, and acceleration/deceleration for continuous performance and accurate positioning .