Non-Contact Magnetic Sensing

Presented By:
Penton Publications
&
Honeywell Sensing and Control

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Our Goal for Today

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Provide you with a background on the magnetic technology to:

- Enhance your understanding of how the magnetic sensing technologies have evolved and generally how they are used.
- Provide you with a new perspective on the potential for next generation non-contact sensing.
- Distribute valuable information that may spark an idea regarding magnetic non-contact sensing and how your organization might utilize the technology.

Conventional vs. Magnetic Sensing

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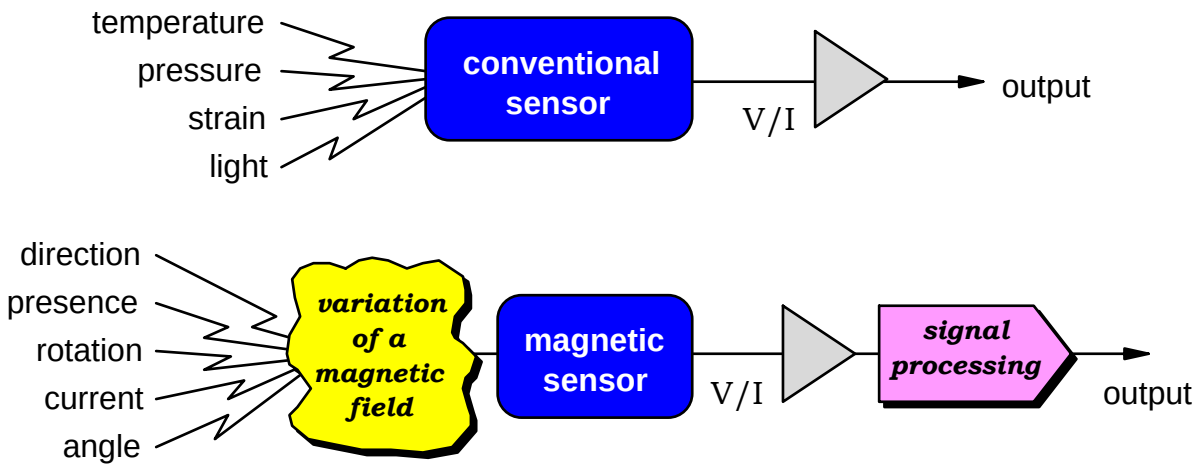

- **Conventional sensors** *(usually)* **directly sense the desired parameter**
- **Magnetic sensors** *(usually)* **do not directly sense the desired parameter**
  - They measure the variation of a field cased by the parameter
  - The sensor output often requires post signal processing
- **Magnetic sensing requires an understanding of magnetic fields and sensor characteristics to determine the parameter being measured**

Very Brief History

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- First magnet was a loadstone (or lodestone).
  - Comprised of an iron oxide ore
- One of the first records of the particle level of magnetization concept dates back to 1734.
  - from Emanuel Swedenborg
- In 1907, Weiss suggested that the observed magnetic phenomenon could be explained by an interaction on the molecular level, called the molecular field, which was later shown to be similar to Swedenborg's suggestion.
  - The molecular field is a good intuitive explanation of the situation, but is not completely correct; magnetism is a quantum mechanical effect.
- William Thomson (or Lord Kelvin, of Kelvin temperature scale fame)in 1857 found that the resistance of iron changes when it is magnetized. This property, where the electrical resistance of a metal changes with an applied magnetic field is known as magnetoresistance.
- Hall Effect was discovered in 1879 by Edwin Hall.

Magnetic Non-Contact Sensing

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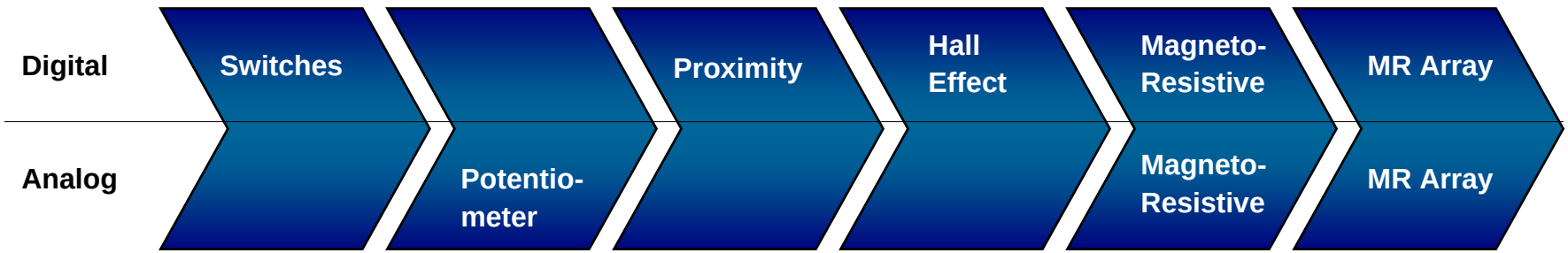
How the technology has evolved …

- In the past the options for detecting position were limited and to contacting technologies such as potentiometers and limit switches.
- These sensors do provide certain positional information but sometimes have wear issues.



Hall Effect

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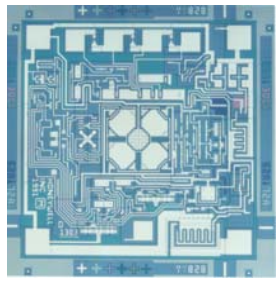
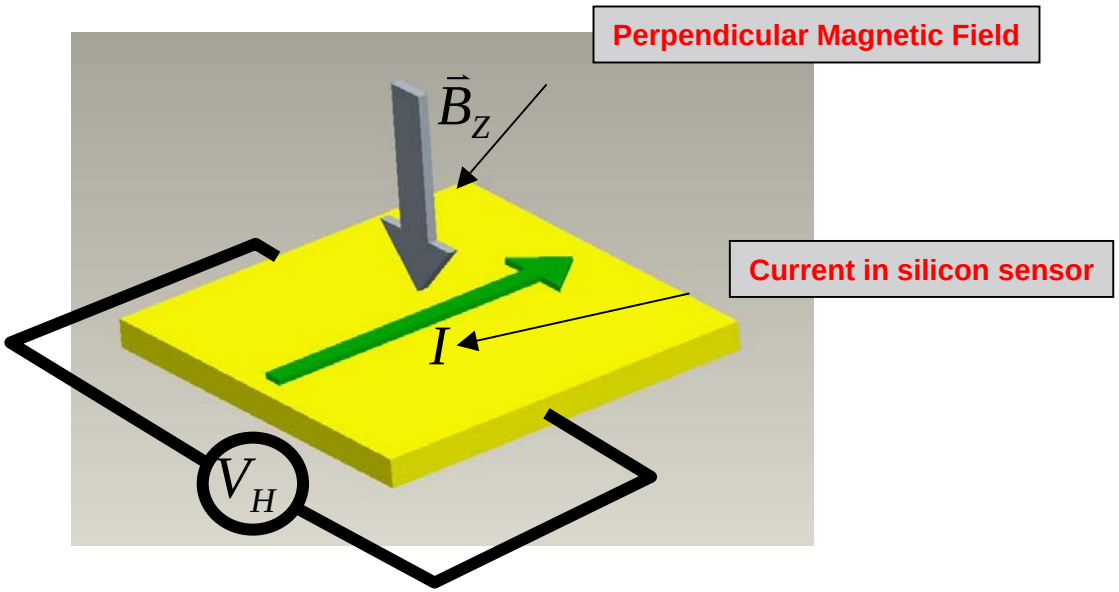
How it Works:

- Transverse electric field is developed when current in a conductor is subjected to a perpendicular magnetic field.





Magnetic Technology Today

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- **More Position Detection Options. This includes:**
  - Magnetostrictive
  - LVDT
  - Hall Effect
  - Proximity
  - Other

- **Sweet Spot for Potential Applications may include:**
  - Hydraulic position
  - Heavy duty vehicle (trucks/farm equipment and construction)
  - Plastic molding equipment
  - Tooling & tool handling
  - Presses
  - Woodworking machinery
  - Conveying, Packaging machines
  - Etc.

Next Generation: Non-Contact Sensing

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- **Position detection will continue to migrate towards completely non contacting measurement.**
  - Primary issue facing older technologies is unreliability caused by wear – due to the need to physically touch the actuator being measured – this is a major driver to develop non-contacting solutions.

- **There are many applications where it's virtually impossible to measure using "contacting methods" due to the temperature, the pressure or some other physical barrier to directly measure the actuator where it's located.**

Next Generation
Magnetic Non-Contact Sensing

Real Life Example

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What is it?

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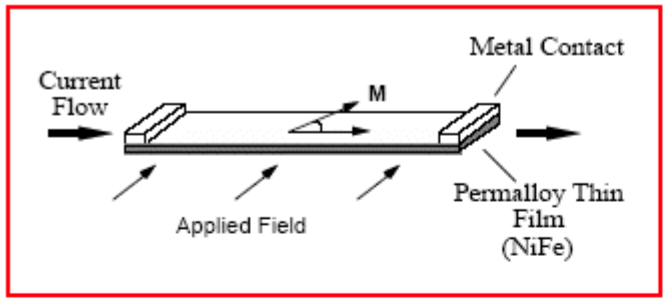

Figure 1. Principle of operation for MR sensors.

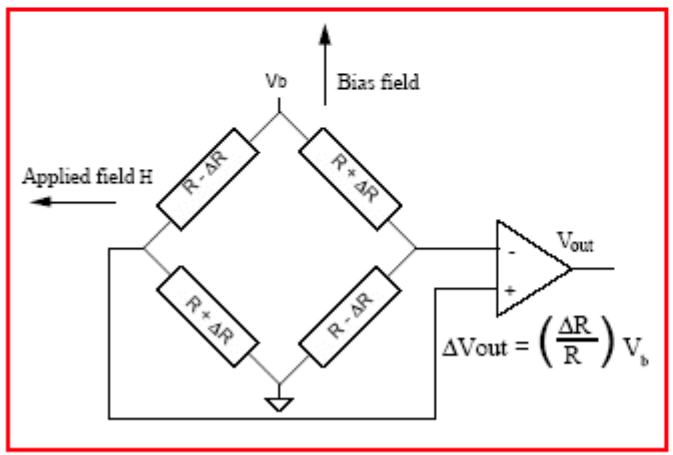

Figure 2. Magnetoresistive transducers.

What is a Magnetoresistive Sensor?

Anisotropic magnetoresistance (AMR) occurs in ferrous materials. It is a change in resistance when a magnetic field is applied perpendicular to the current flow in a thin strip of ferrous material (Figure 1). The transducer is in the form of a Wheatstone bridge (Figure 2). The resistance, R, of all four magnetoresistors is the same. The bridge supply, V_b, causes current to flow through the resistors. A crossed applied field, H, causes the magnetization in two of the oppositely placed resistors to rotate towards the current, resulting in an increase in the resistance, R. In the remaining two oppositely-placed resistors magnetization rotates away from the current resulting in a decrease in the resistance, R. In the linear range the output becomes proportional to applied field $\Delta V=S\ H\ Vb$. The range of linearity of the transfer function is inversely proportional to the sensitivity. For Honeywell's MR sensors the sensitivity is typically 3 mV/(V/Oe) and the range of linearity is within 2 Oe.

…up Close

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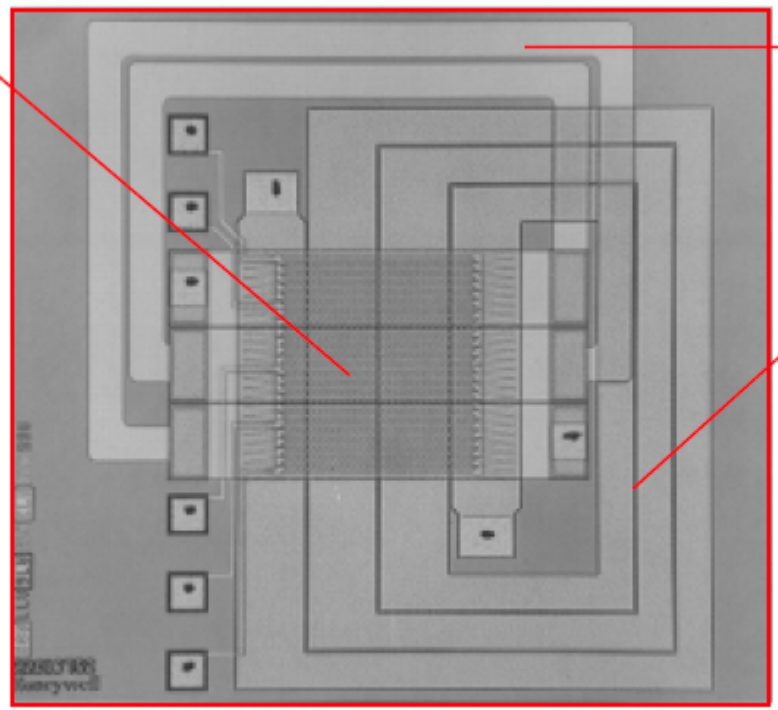
Magnetic field sensing bridge

- Magnetic thin film nickel-iron (permalloy)
- 4-legged Wheatstone bridge
- Self-biasing (barber pole pattern)



Aluminum offsetting field strap

- Compensation for ambient magnetic fields
- Calibration
- Closed loop operation

Aluminum set/reset strap

- Reset after upset field
- Polarity set

Figure 3. Magnetoresistive sensing element.

How does it work?

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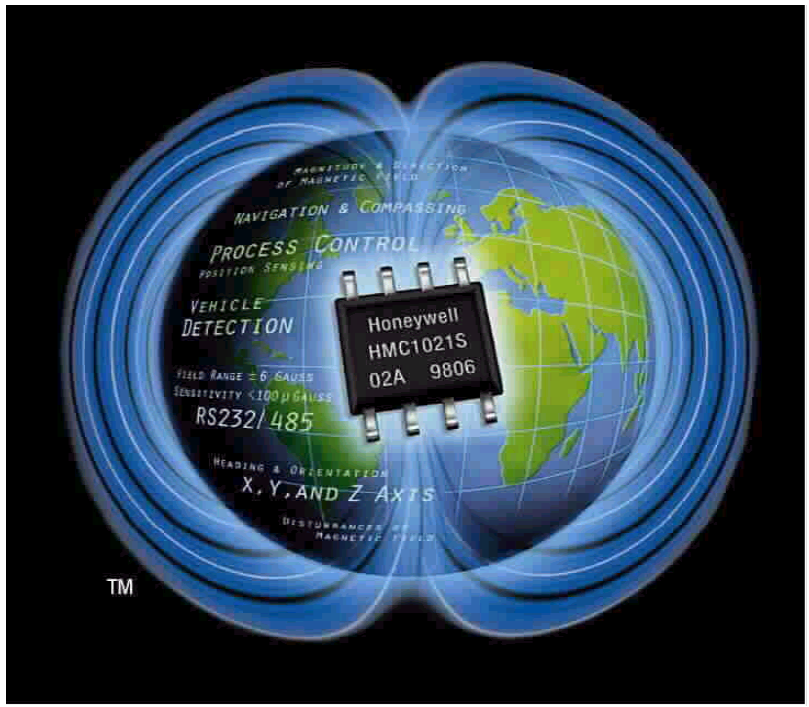
How it Works:

- MR sensors are arranged in an array.
- They monitor the position of the magnetic flux lines emanating from a magnet positioned in the elevator shaft.
- Sophisticated algorithms analyse these signals to accurately determine the position of the magnet.



Background to MR Array

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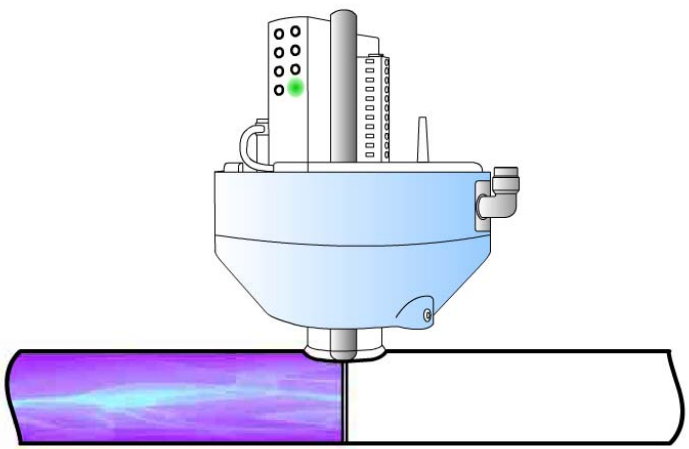
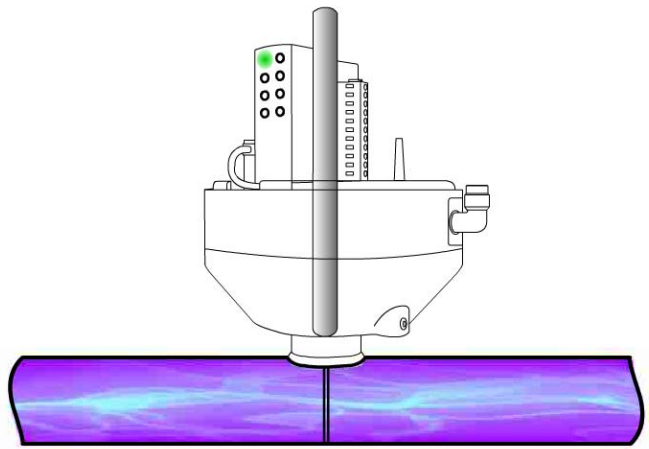
How it Works:

- The Array concept was commercialized as a result of our work in Valve Actuation Control – measuring valve stem position to 0.1mm accuracy.
- The Valve application environment is a hot and cold, humid and dry.
  - In other words the solution is tested and typically robust in these conditions.





How does it work?

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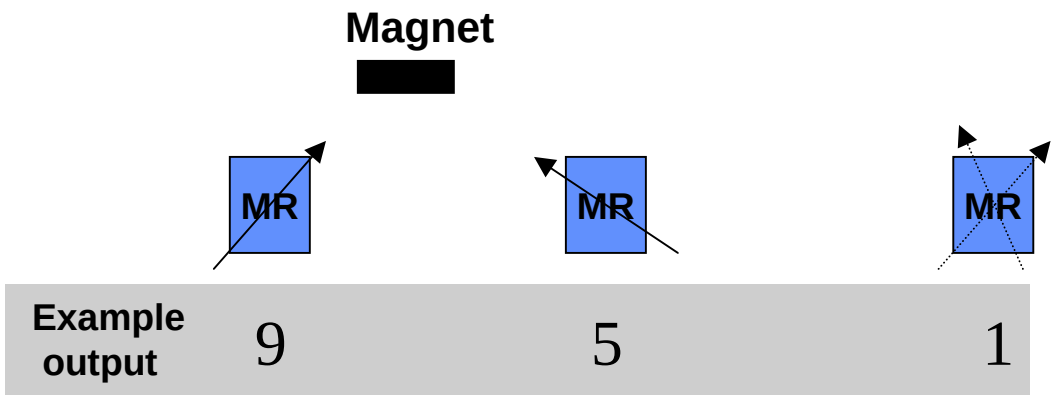
How it Works:

- Magneto Resistive (MR) chips give an output which points to the magnetic source.



MR Array

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More Info on How it Works:

- This illustrates how one single chip sees the magnet as it passes by

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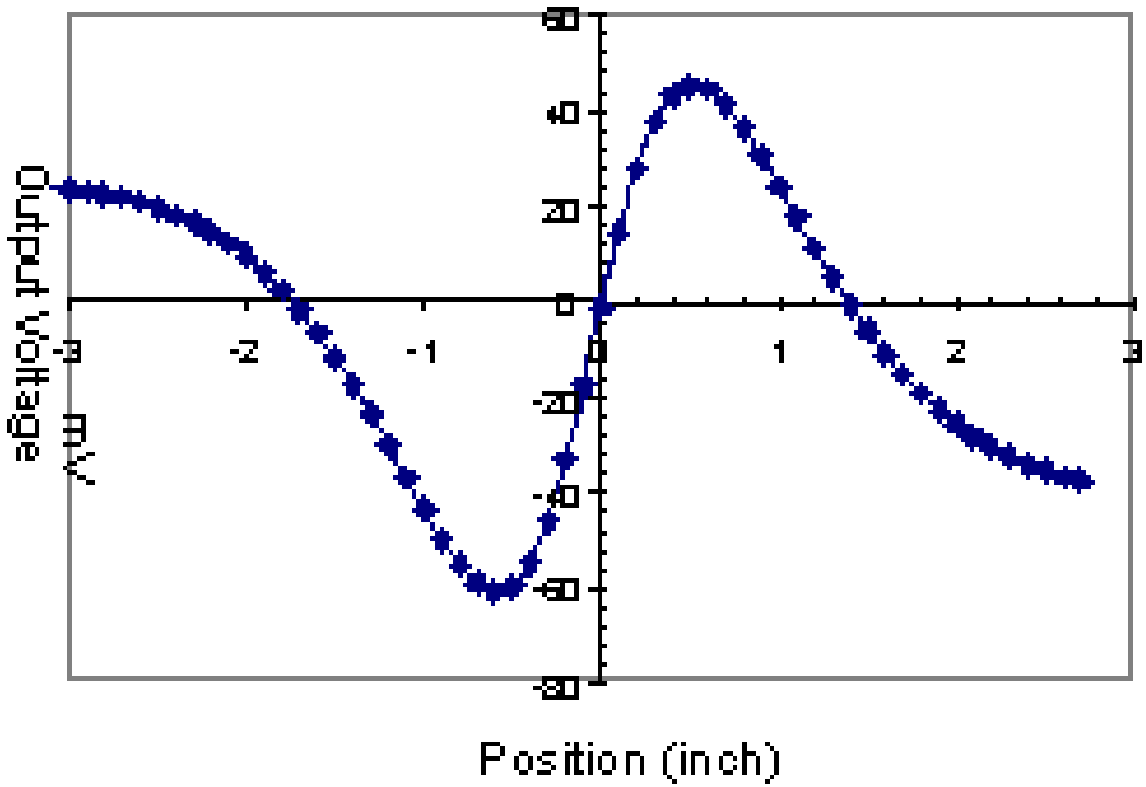

The Technology Explained

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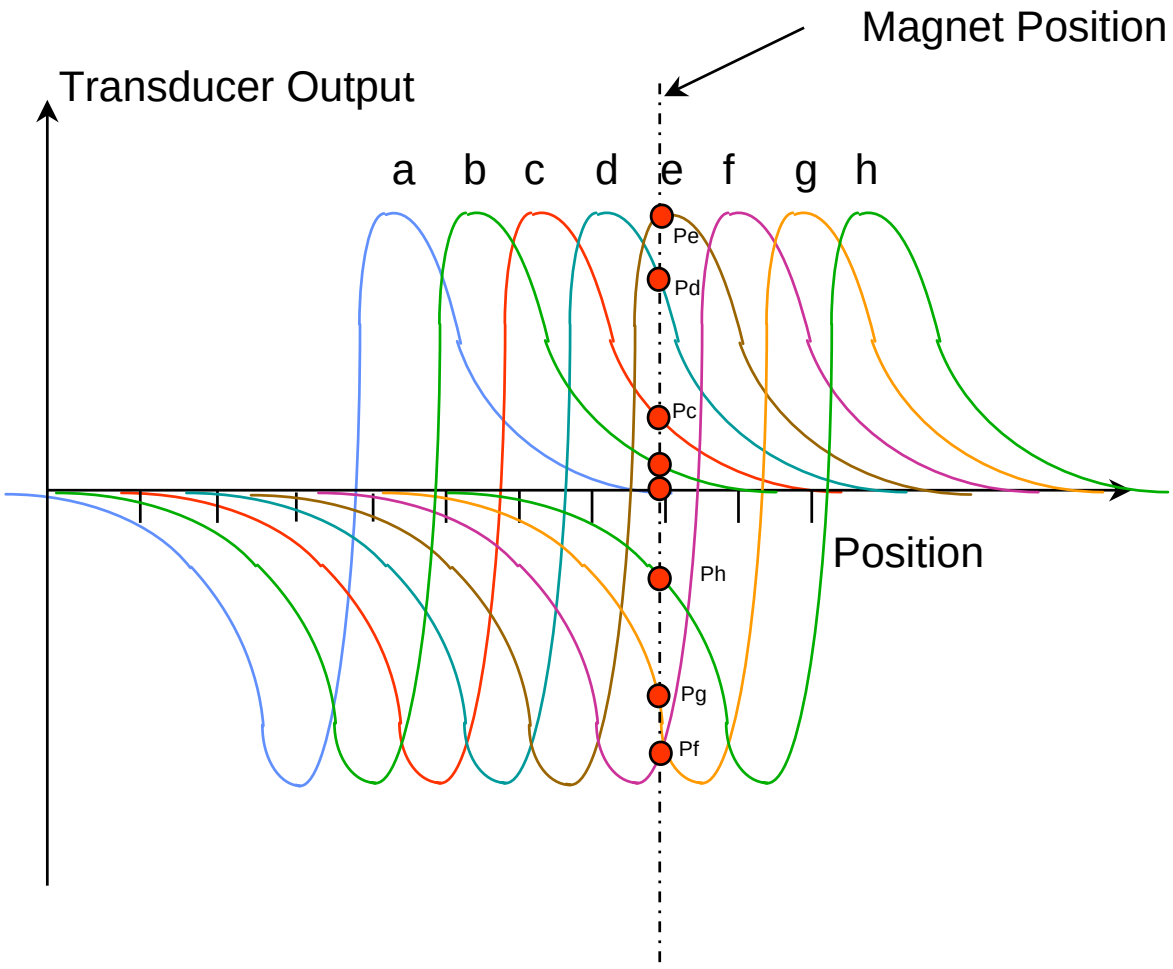
Magnetic Sensing - Background



- Varying output signal from each sensor as the magnet moves past.
- Unique combination of signals for any given position.

The Technology Explained

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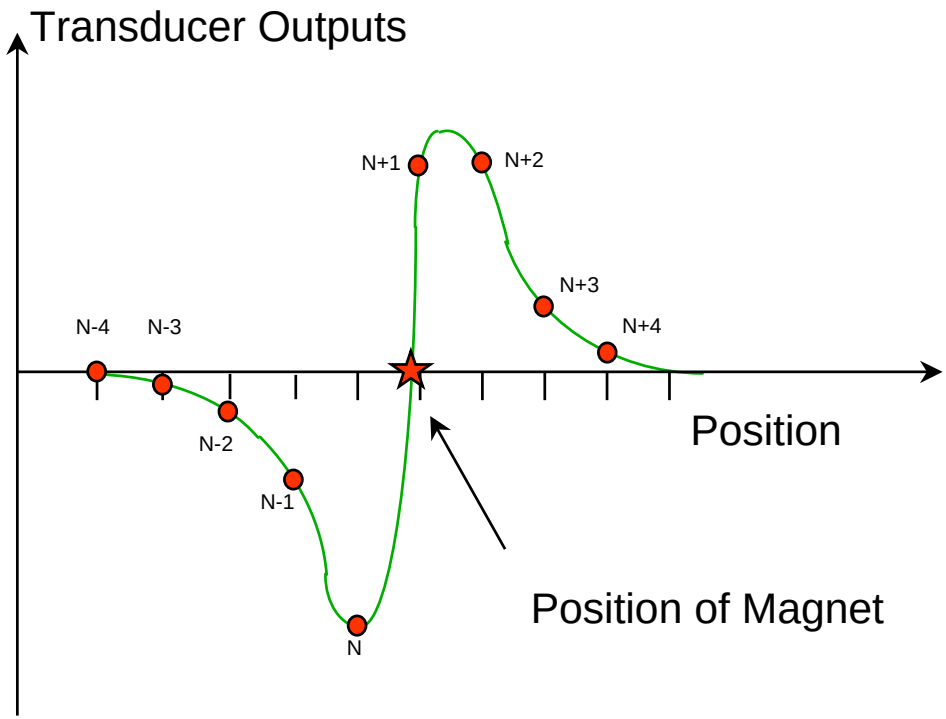
Magnetic Sensing - Background



- Sensor outputs are analysed and compared to a known curve.
- Position of the magnet, and actuator “magnet attached to wall” are obtained from where the curve crosses the position axis.

The Technology Explained

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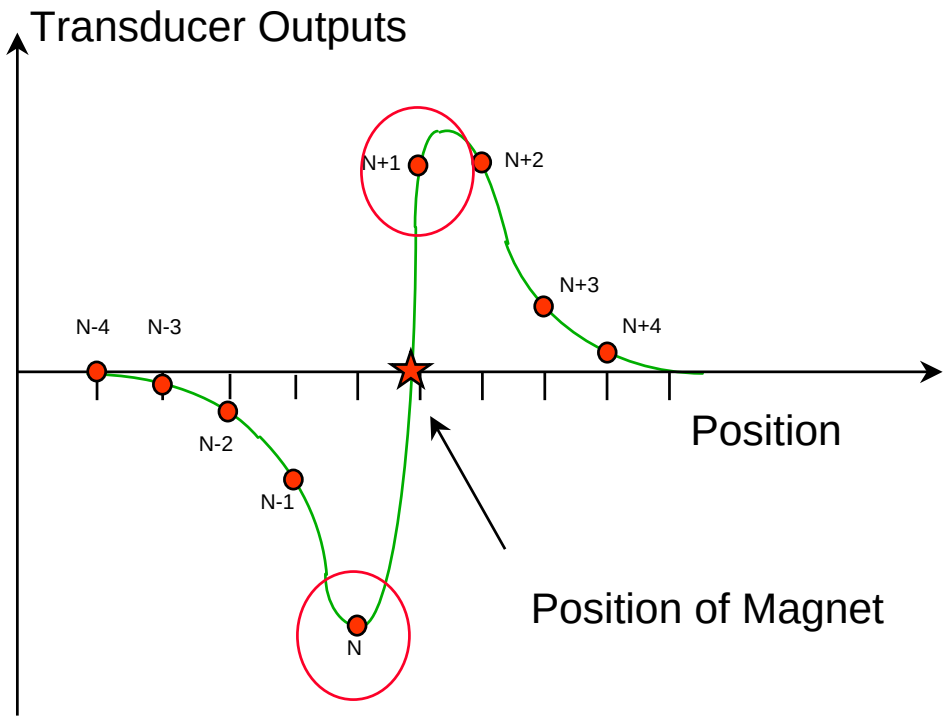
Magnetic Sensing - Background



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The Technology Explained

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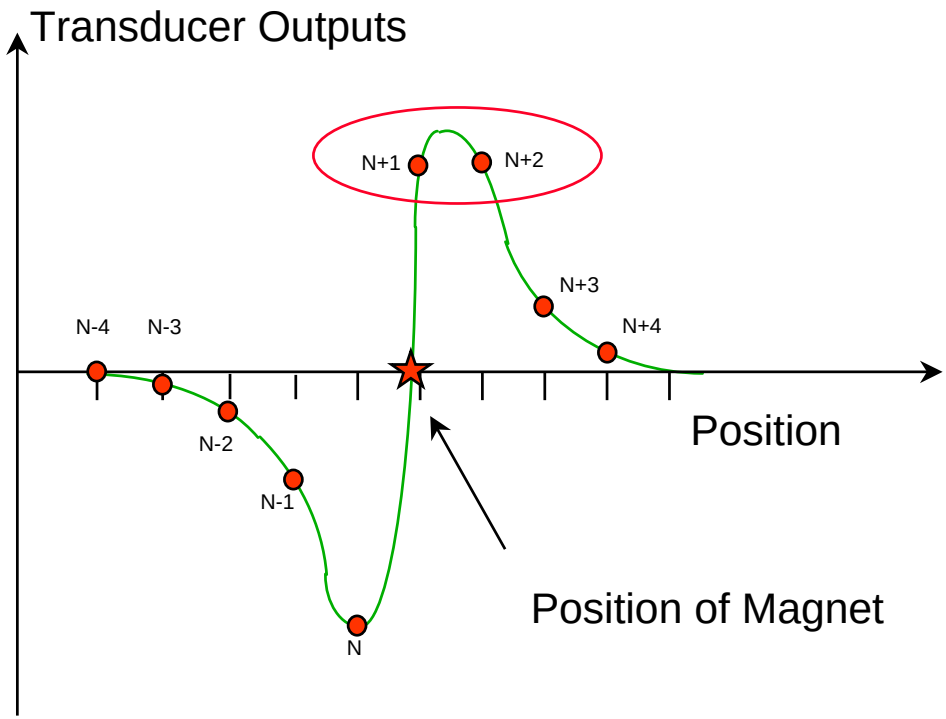

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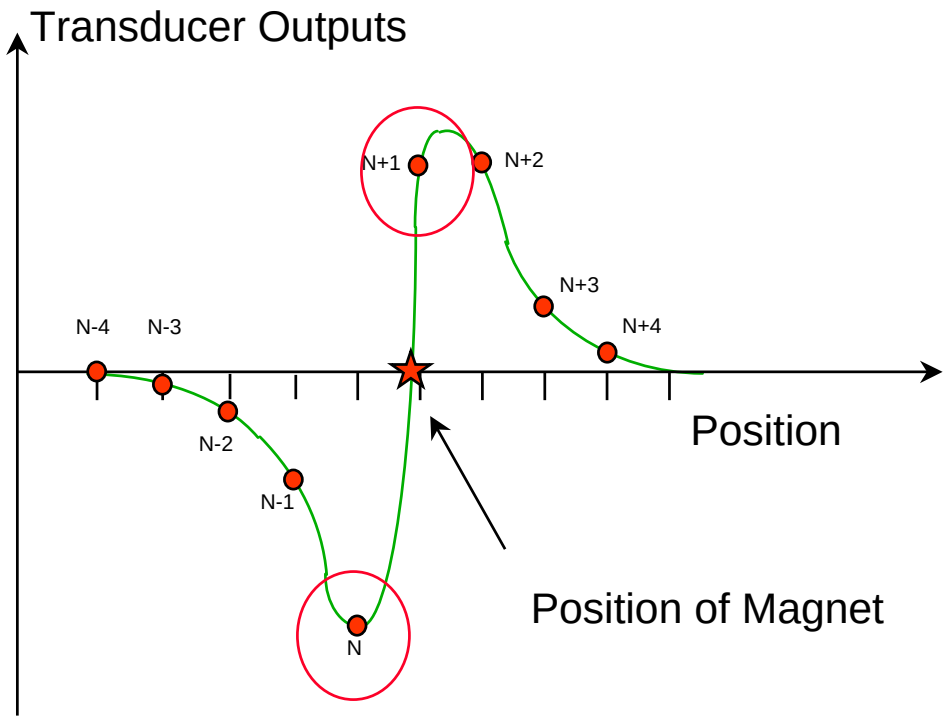

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The Technology Explained

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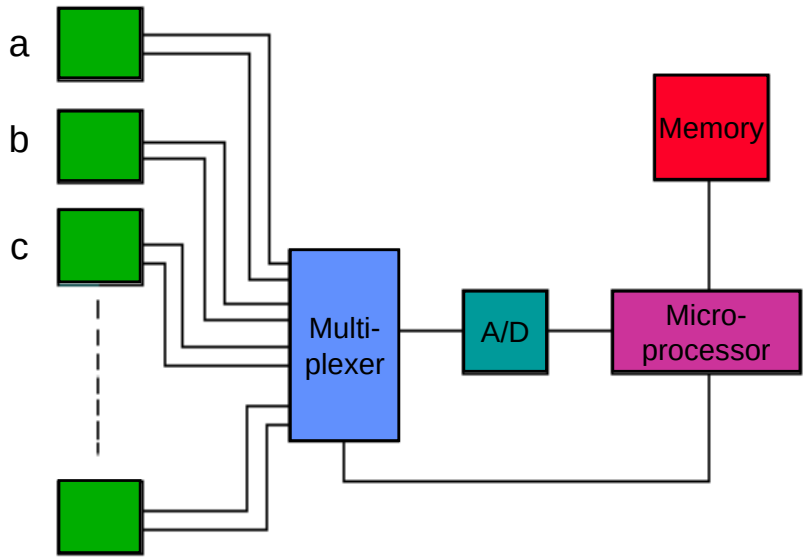
Electronics - Overview

Magnetic sensors



- To reduce power consumption the sensors can be wired to a Multiplexer which obtains data serially.
- Algorithm embedded in the Microprocessor compares measured outputs to known curve.

Example of Use

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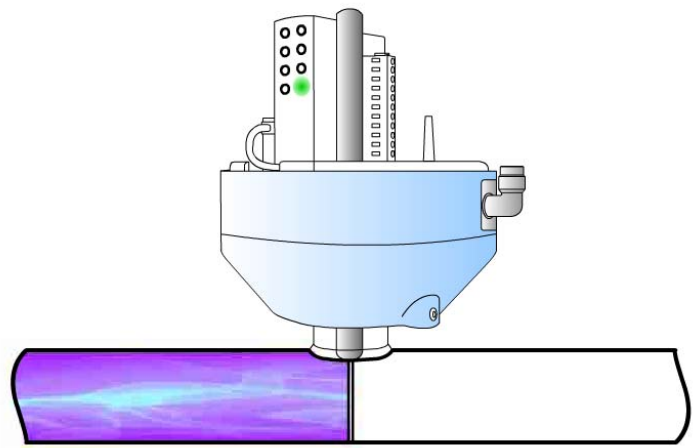
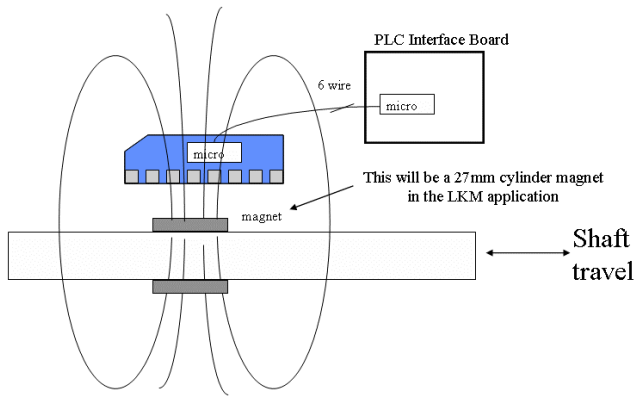
- **Potential Technology Need:**
  - Reduce the set-up of valves
  - Provide continuous analog position data

- **Solution:**
  - Simplified set-up and measurement technology
    - An implemented MR Array is then able to see all valve stroke lengths. meaning that the open and closed position can easily be programmed using a single sensor for all valve types.





Potential Configurations

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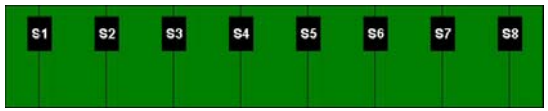
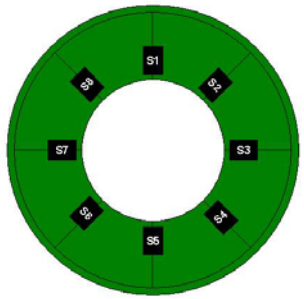


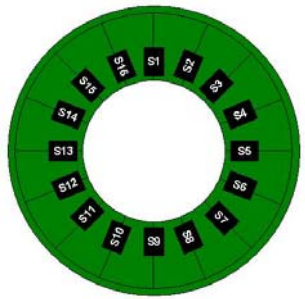
Segment

Semi-Circle

Circle
Low Resolution



Circle
High Resolution



Potential Configuration

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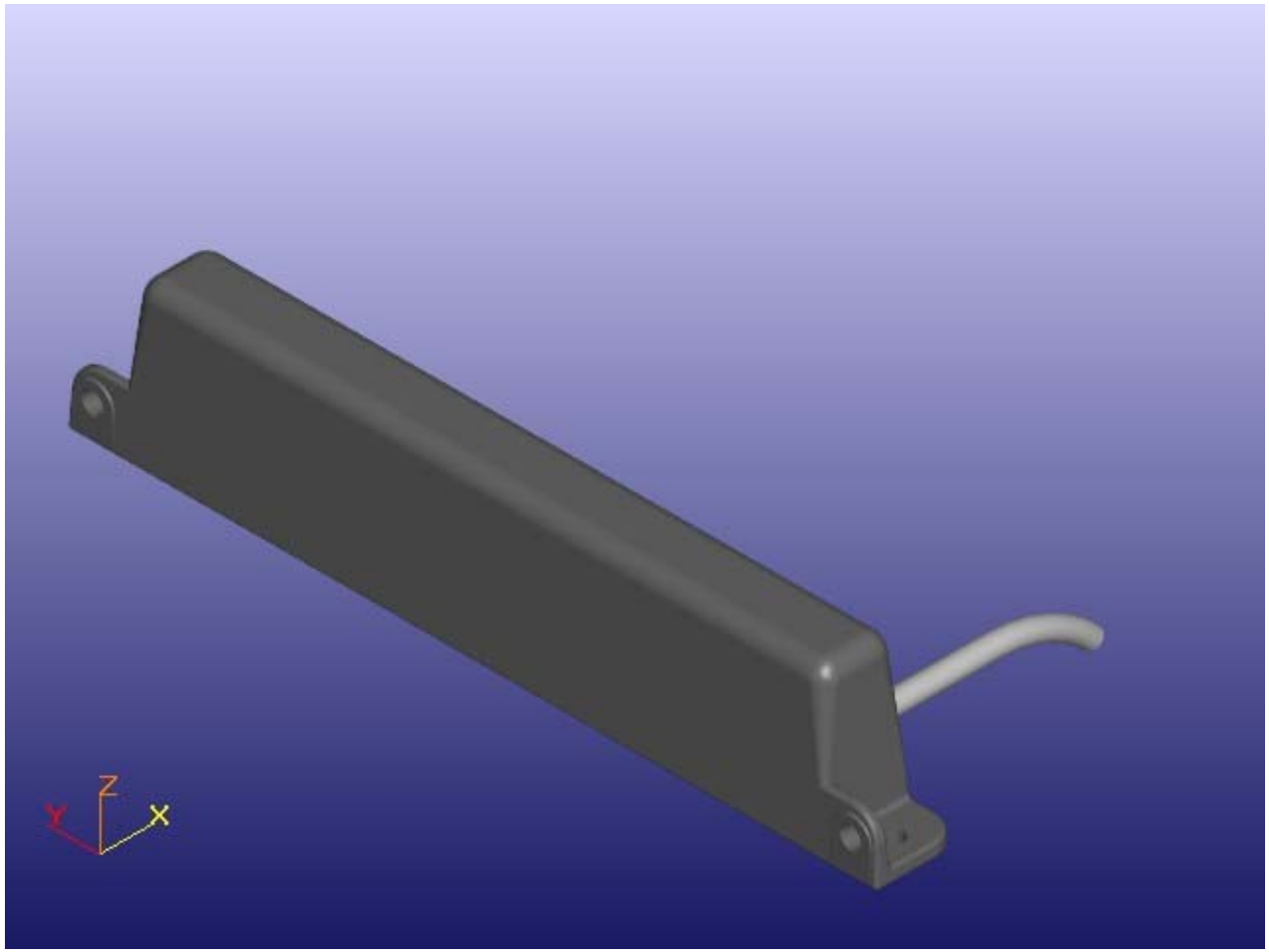

MR Array Review

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- **This technology example can provide:**
  - Ease of set-up or installation
  - Removal of wear issues and maintenance impact of this
  - Greater distance required between the sensor and the actuator due to housing, pressure or temp.
  - High immunity to light, dust and wear effects – can detect through non ferrous materials
  - Can often replace discrete sensors via simple programming

Next Generation Technology

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- **Tomorrow's sensors will be:**
  - Smarter
  - Smaller
  - Money saving
- **Tomorrow's sensors may feature:**
  - Self-configuring wireless communication
  - New measurement physics
  - Mobile robots doing intelligent sensor-based processing
  - New methods of actuation based on integrated microstructures
  - Smart materials capable of healing, self-repair and self-calibration

Next Generation Technology

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- **High STEP solutions address applications (especially automotive) that require high degrees of:**
  - Sealing
  - Temperature
  - Electromagnetic interference
  - Pressure
- **Medical sensor applications:**
  - Compact, accurate sensors for monitoring and diagnostics
  - Microfluidic devices for nanoliter and sub-nanoliter levels of fluids
- **Increasing variety of sensor applications:**
  - Home comfort
  - process monitoring
  - Low Health care
  - Industrial power sensors configured in vast wireless networks

Thank You!