

Motion – Position - Speed

Coverage

● Rotary Motion

- Position
- Velocity

● Linear Motion

- Position
- Velocity

● Special

Strobotach

- One of the oldest methods
- Still used frequently
- Advantages:
 - Can use it regardless of shaft design
 - If you can see it, you can measure it!
- Requires a touch of finesse
- Can be more accurate than other methods if done correctly.

Strobotach

- Mark shaft
 - Preferably in two or more places
- Turn on the tach
- Look for the “Pattern”
- Read the speed on the tach’s digital readout.



DC Tachometers

- Similar to a DC motor
- Generate a DC voltage
- VERY linear once above minimum velocity
- Low current output
 - Usually a few milliamps



DC Tach Characteristics

- Slope varies greatly
 - 1 Volts / 1000 RPM
 - 100 Volts / 1000 RPM
- Low V/RPM
 - Good for high RPM
- High V/RPM
 - Good for Low RPM
 - Limited RPM

DC Tach Characteristics

- 200:1 or greater turndown
- Accuracy from 1% to 4% typical
- Ripple Voltage 1.5% to 10%
- Linearity depends on load
 - Higher current load > Lower linearity
- Higher V/RPM > Lower Min RPM

Ripple Voltage

● There is a small amount of ripple on all DC Tachs

- Inherent in the method of generation.
- Armature spinning in a magnetic field
- More poles = less ripple

● 2% Ripple

- $10\text{V} / 1000 \text{ RPM} > .2 \text{ V AC ripple} / 1000 \text{ RPM}$
- At 4000 RPM = 0.8 Volts AC on 40V signal

Brushless DC Tach

- No brushes
- Uses a magnetic core rotating inside a set of coils
- Output is a trapezoidal waveform
- Requires a conditioning circuit
- Typically 1.5 to 5 Volts P-P per 1000 RPM
- Closer to an AC tach than a DC tach

AC Tachometers

● Two types

- P-P voltage WRT velocity
- Freq WRT to Velocity

● Both type work similar

- BOTH frequency and P-P voltage change with RPM.
- Difference is which the unit is optimized for

AC Voltage Type

- Typical rates of 1.5 to 90 VAC / 1000 RPM
- AC Sine wave
- $\pm 5\%$ Accuracy typical
- 4 to 10 cycles per Rev typical
- Typically 150:1 Turndown

AC Frequency Type

- Typical rates of 4 to 10 cycles / Rev
- AC Sine wave
- $\pm 0.1\%$ Accuracy typical
- Typically 300:1 Turndown
 - Highly dependant on the measurement circuit.
- Circuits look for 0 voltage crossing

Magnetic proximity detector

- Uses a variety of magnetic transducers to detect the passing of either a mechanical portion of the system, or teeth on a gear.



- Two types

- Internal Magnetic

- Passing ferrous metal disrupts magnetic field creating switching

- External Magnet

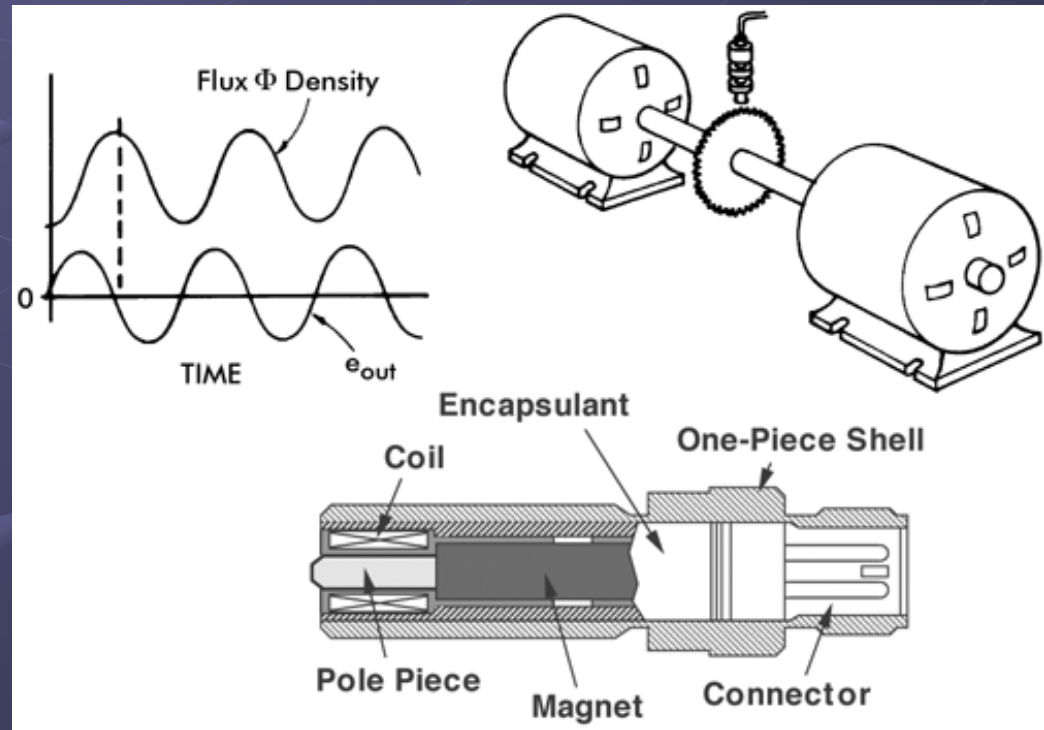
- Requires a passing magnet to trigger the device

Magnetic

- Output is a pseudo sine wave for a 50% Mechanical duty cycle gear
- Typically 30 or 60 teeth per gear

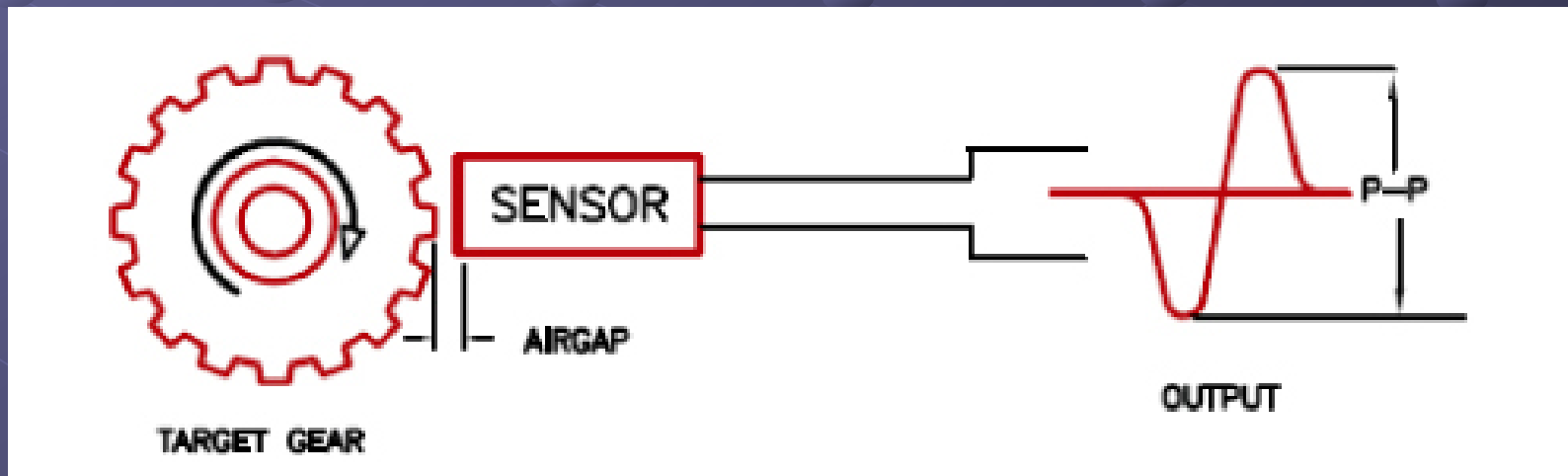
Switching rate
(Bandwidth)

Varies Greatly!!!



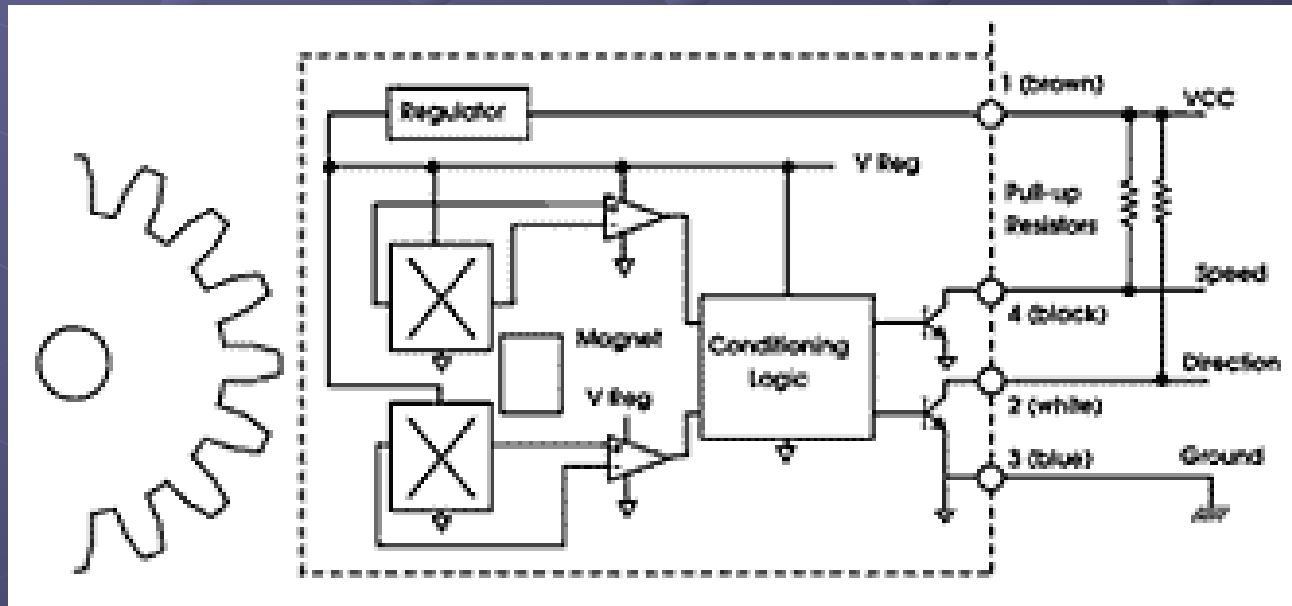
Magnetic (gear design)

- Tooth gap at least equal to tooth width
- Optimum operation
 - Tooth width $\geq$ Sensing diameter
 - Air gap $< 1/2$ Sensing diameter



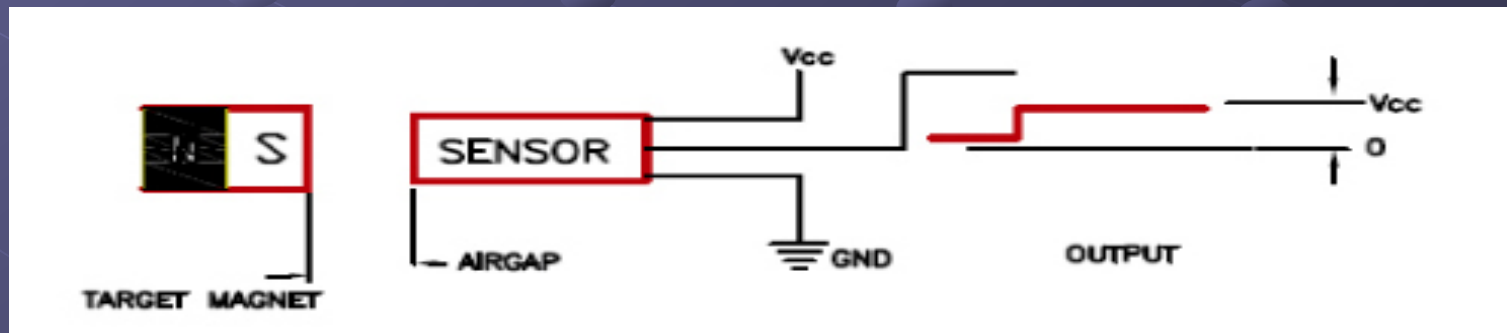
Internally conditioned

- Digital output
- Capable of lower linear rates and higher bandwidth



External Magnetic (Hall effect)

- Require power for their internal circuitry
- Require an external magnet
- Rates from 0 to several thousand pole passing per second
 - Effectively an on/off digital switch, changing state with the rate of the passing pole.



External Magnetic (Reed switch)

- Mechanical switch that detects the presence of a certain level of magnetic field
- Low speed... 0 to 100 Hz typically
- Limited to a few million “actuations”
- Good for intermittent or low speed applications

Capacitive pickup

- Requires power to operate
- Targets as small as 130% sensor area
- Range / Diameter ratio 1:8
- Limited temp range (0-50°C)
- Clean / Dry environment
- Work with non-ferrous materials and liquids (paper, cardboard, powders etc)
- Up to 50mm range
- Good for “are you there” detection

Eddy Current

- Generates a magnetic field
- Feedback is based on the disruption of that field (or coupling to sensor)
- Not that good for speed
- Excellent for close position measurement
 - Material thickness
 - Approach position measurement “clearance”

Eddy Current

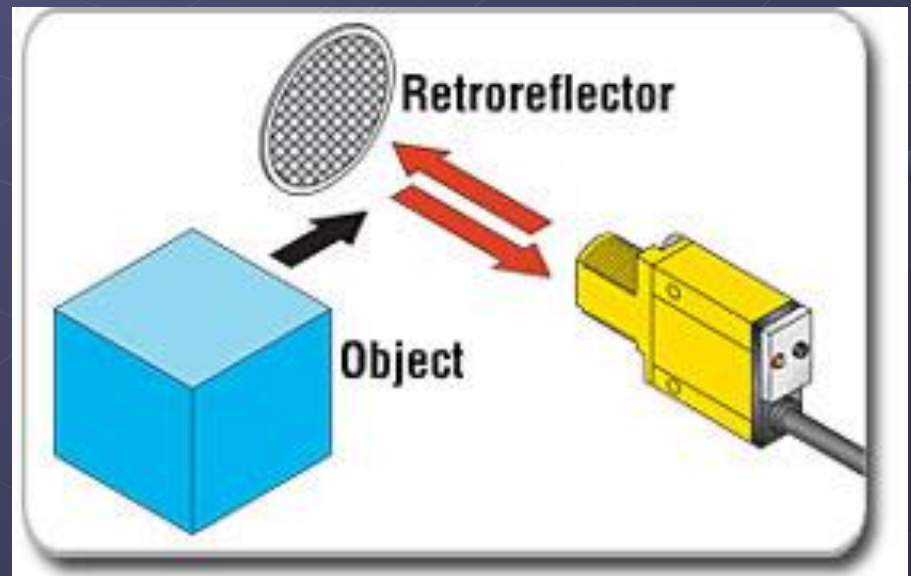
- Requires power to operate
- Targets as small as 300% sensor area
- Range / Diameter ratio 1:3
- Wide temp range (-40 to +200°C)
- Hostile environment friendly
- 64Hz to 80 KHz max bandwidth
- Only works with ferrous materials

Optical

- “Looks” for optical reflection that exceeds a specific level.
- Reflective and “look through” types
- Optical, IR and laser units
- Ranges up to several feet (Longer for laser type)
- All of these are “are you there” detectors

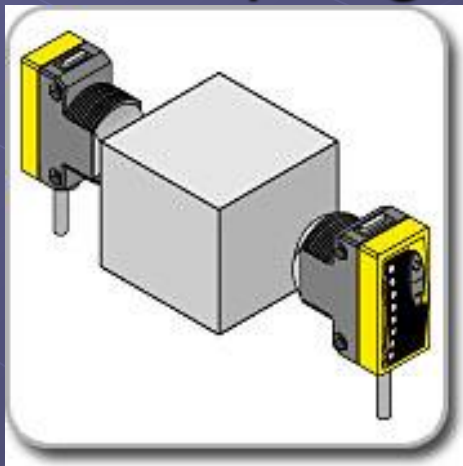
Reflective / Retro-reflective

- Generates a light beam
- Looks for the reflection
- Light beam can be IR or Visible (usually red)



Look through

- Generates a light beam
- Detector “sees” light.
- Requires on part of on each side of the interrupting area



Speed sensing with Opto's

- Don't work well in dirty environments
- Limited in speed
 - 1ms switching times typical (Faster available)
 - Low speed, or low # lobes per revolution
- Look through (Opposed) better than reflective

Photo tach

- Specialized form of photo detector system
- Hand held
- Bounces beam off a piece of reflective tape
- Speeds up to 100,000 RPM
- Accuracies of .02% and resolution .01 RPM fairly typical.
- Why so much better than other opto?

Photo tach

- Most opto's have to average and take into account ambient light changes
- Photo-tachs, don't do that.
 - faster response time
(Higher frequencies)
 - More susceptible to stray light



Laser sensor

● On / Off detectors

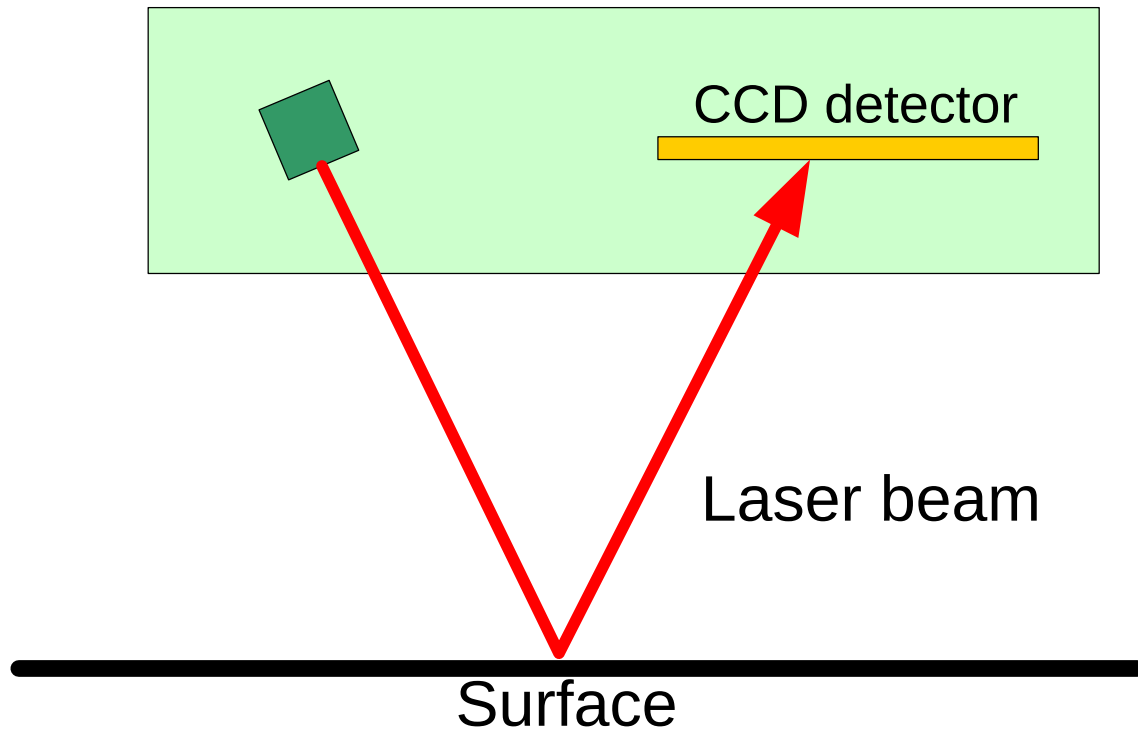
- Work the same as other photo electrics, but use a laser to extend the range.

● Distance detectors

- Work by bouncing a beam off a surface.



Laser Displacement



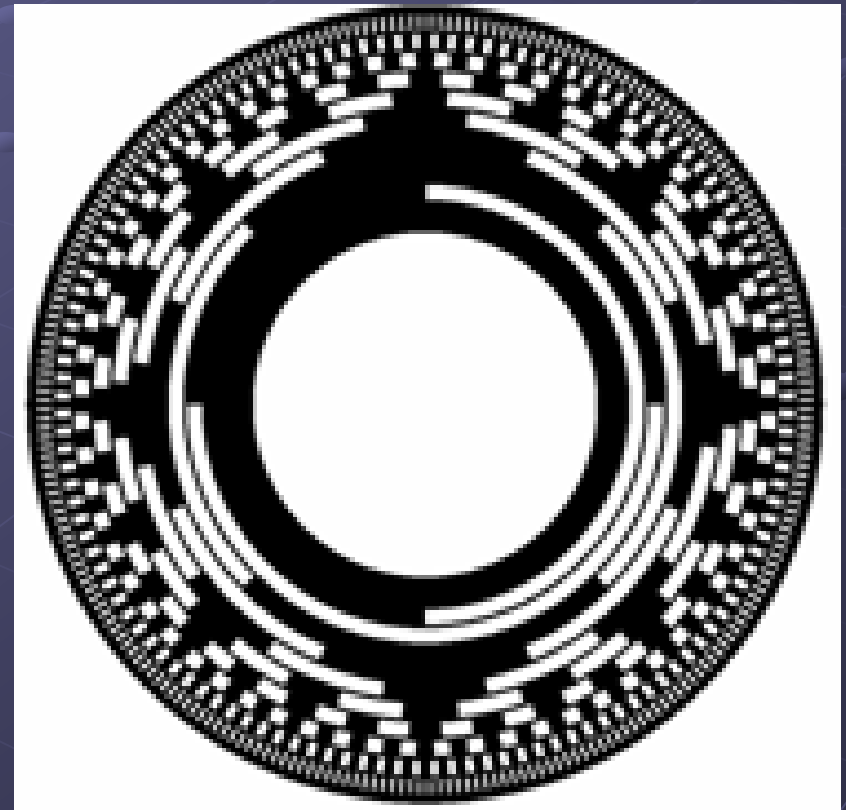
Optical encoders

- Two types.
 - Absolute
 - Parallel channels
 - Incremental
 - Count increments
- Both types use a grating between a set of emitters and detectors
- Output a digital signal



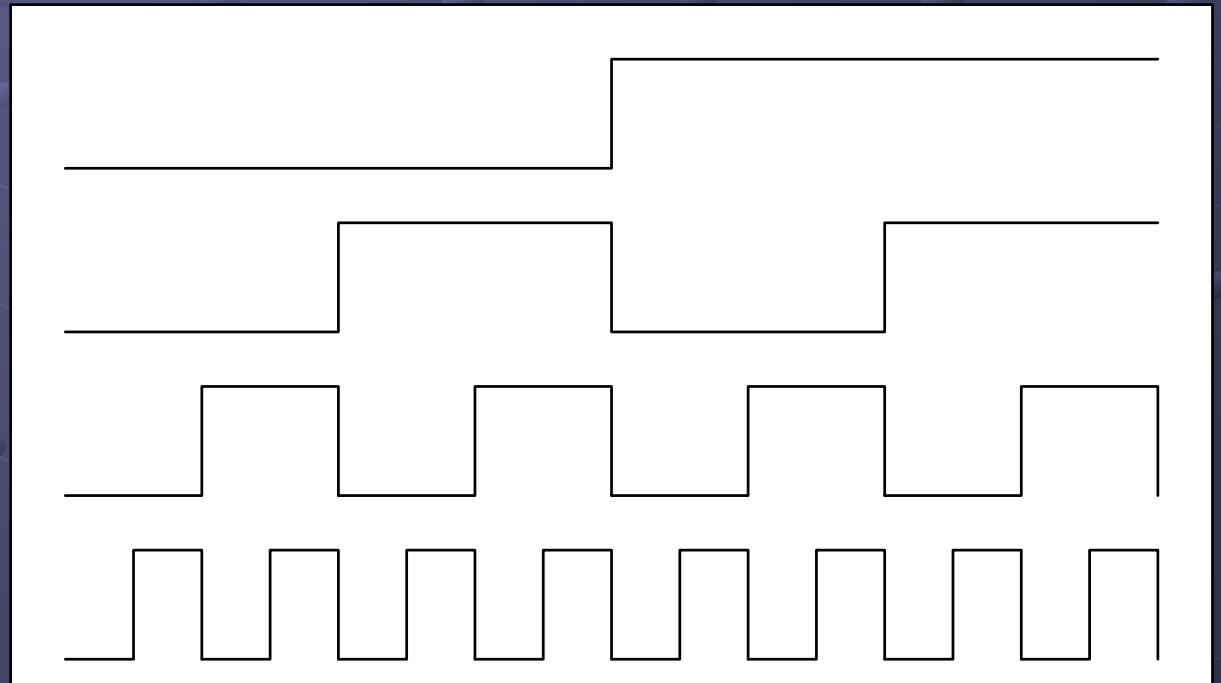
Absolute

- Each channel is one digital bit
- Outputs a digital word based on the “code”
- Can use for speed by measuring the rate a single bit changes.
- Designed for real position control



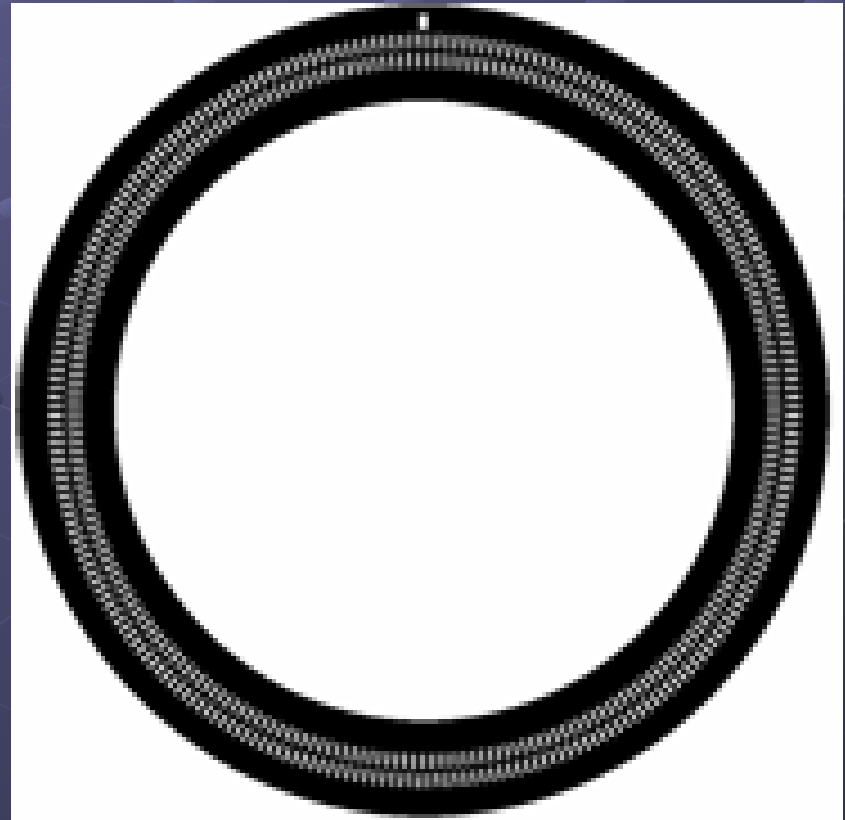
Absolute encoder

- Resolution limited to the number of channels that can be put on the disk
- Good for absolute position
- Binary output



Incremental

- Consist of two or more channels that are related
- Can be used for position control by counting pulses
- Resolutions from 100 to 4096 pulses per revolution
- Limited only to how small they can etch them in the disk



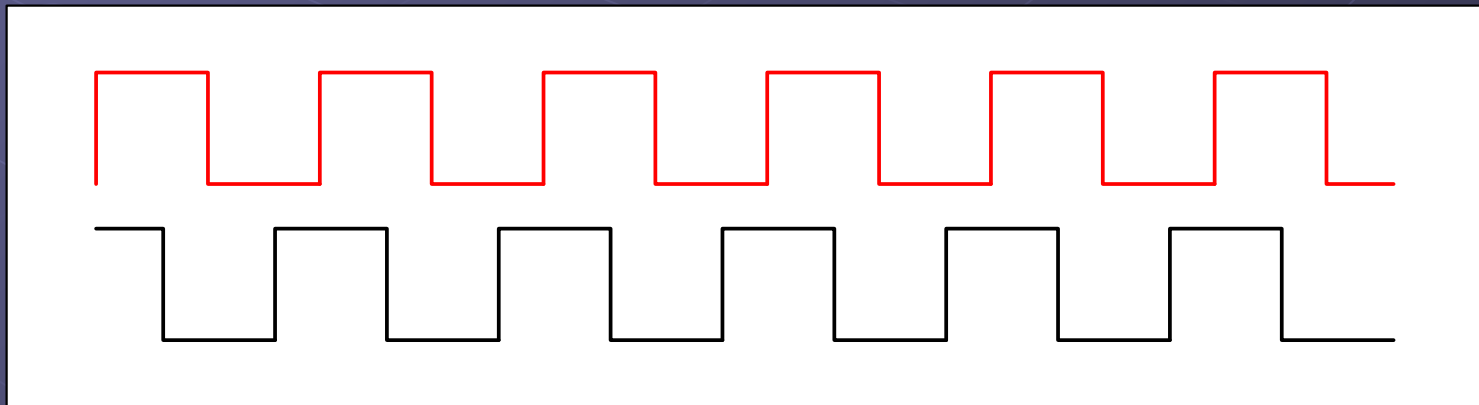
Linear incremental

- Similar to rotary incremental encoder.
- Consists of a glass scale and reader head.
- Linear resolution down to $0.25\text{ }\mu\text{m}$



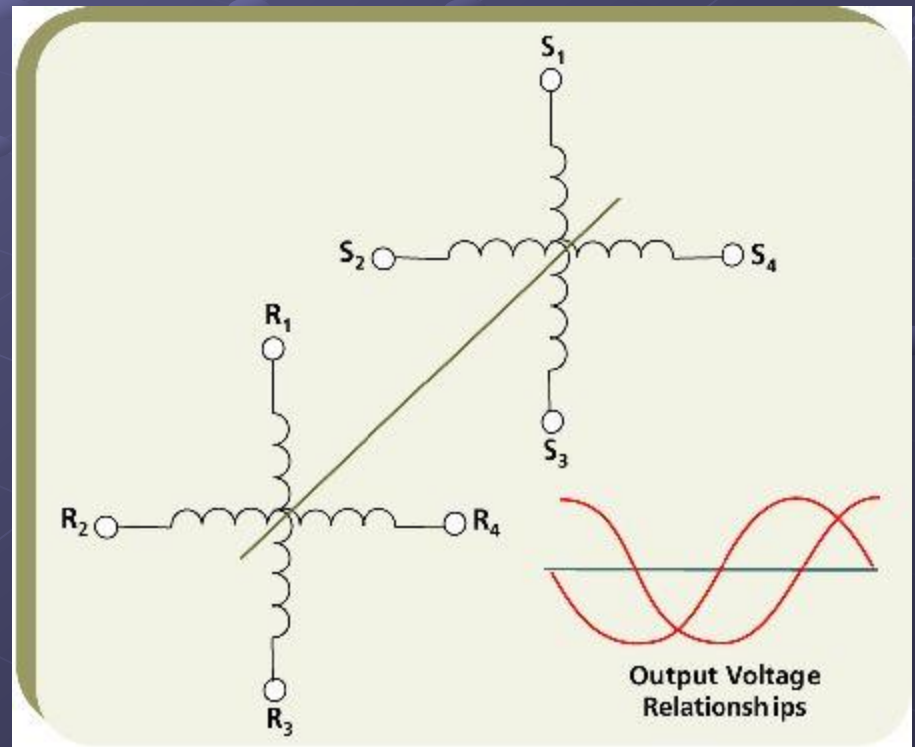
Quadrature output

- Two channels offset by 90°
- Detecting which pulse is leading allows direction detection
- Very good for both velocity and direction



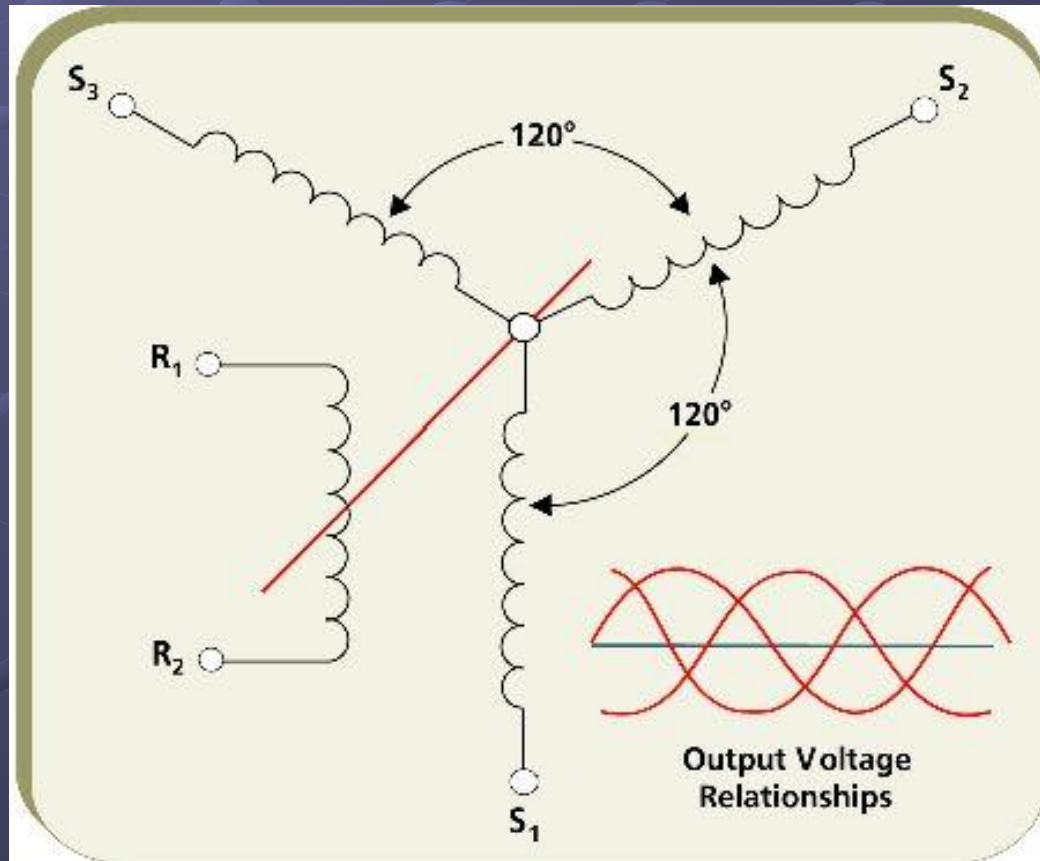
Resolver

- Rotary transformer with $N \times 2$ poles
- Two coils excited at 90° phase shift
- Two output coils measured
- Measurement is NOT absolute. It's only a fraction of rotation.
 - $360 / (\text{\#poles} \times 2)$



Synchro

- Rotary transformer
- Three outputs are compared to determine real position.
- True absolute position
- Infinitely variable



Linear Resistance

- Potentiometer
- Limited number of “strokes” (100×10^6)
- True analog, so its resolution is the resolution of your reading instrument.
- Linearity and accuracy around 1%
- Lengths from 2 to 36” travel

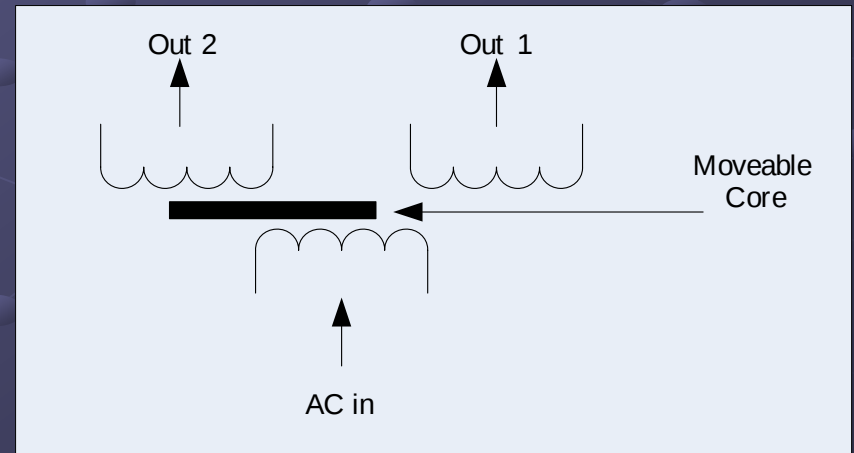


Rotary Resistance

- Rotary potentiometer with no stops
- Linearity around 1%
- Always has a dead spot at the rollover point (apx 5 to 10°)
- LOW SPEED
- Very limited number of revolutions before the pot wears out ($10 - 100 \times 10^6$)
 - Less for high speed oscillatory motion

LVDT

- Linear Variable Differential Transformer
- Linearity $\leq \pm 0.25\%$ of FSO
- Repeatability / Hysteresis $\leq \pm 0.01\%$ of FSO

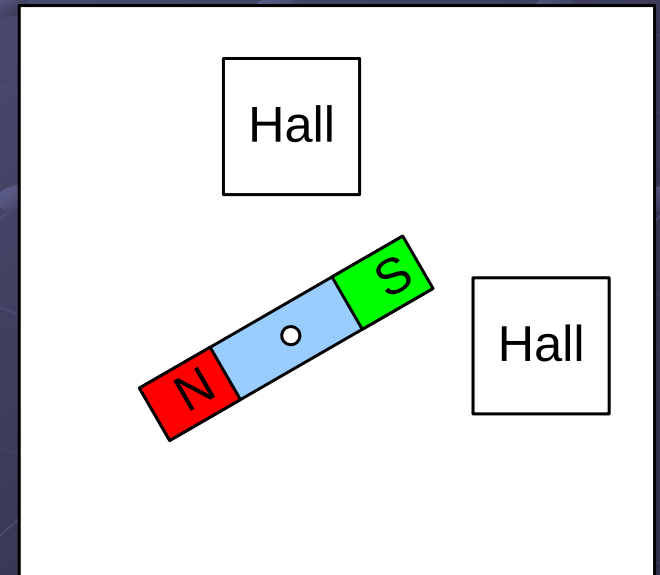


RVDT

- Rotary Variable Differential Transformer
- Similar to LVDT except rotary motion instead of linear.
- Usually good for $\pm 30^\circ$
- Frequently have internal signal conditioning so the output is in mv instead of differential AC

Magnetic

- Uses hall sensors and a rotary magnet to detect position
- Analog output (Infinitely variable)



Dial Indicator

- Good for very small displacements ($< 1''$)
- Resolution to $.00005''$ (0.0001mm)
- Very accurate ($.00012''$)
- Mechanical and electronic types
- Electronic types typically use a rotary encoder



Ultrasonic

- Output is a cone (NOT a spot)
- Resolution typically based on its internal digital processor
- Ranges up to 40'
- 75:1 turndown typical

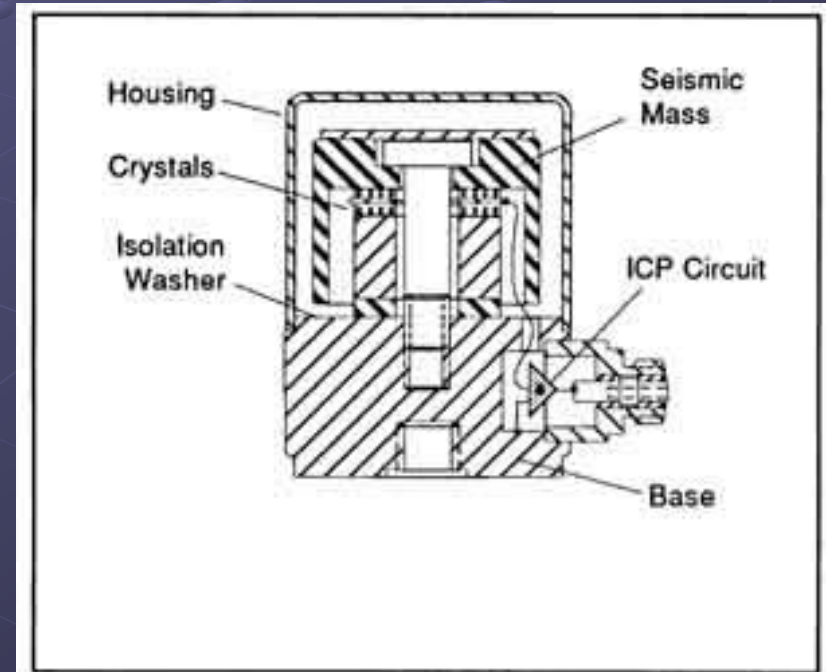
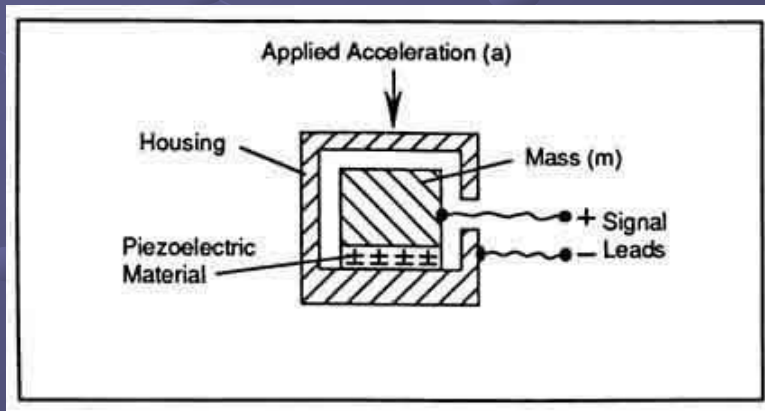


Accelerometer

- Used to measure change in motion
- Dynamic only (Charge based)
- Static (Semiconductor)

Charge Based Accelerometer

- Mass causes force on crystal.
- Can only read dynamic changes
- Larger masses required for lower frequencies



Charge based pre-conditioned

- quartz and polycrystalline ceramics.

- 5mv/g $\pm 1000\text{g}$ 20 to 10KHz



- 10v/g $\pm 0.5\text{g}$.03 to 500Hz



Charge output

● 0.4 pC/g 1 - 26000 Hz 5000 g max
Weight: .14 g



● 1000 pC/g
1 - 3000 Hz 500 g max
Weight: 120 g

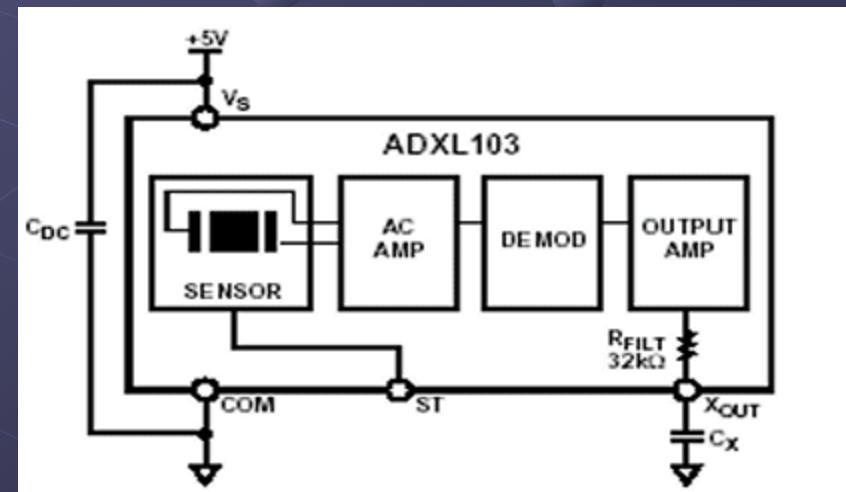


Special Purpose



Static Accelerometer

- Semiconductor based
- Micro-machined into silicon substrate
- Mass moves on beams. Position is measured
- Can read continuous G load
- Makes all kinds of new applications Possible!



Static Accelerometers

- Accurate to about 4%
- 1 mg resolution at 60Hz typical
- 1000mv to 150mv per g
- Single, double and triple axis units.
- Tilt indicators
- Inertial motion systems

Position from Acceleration

- First integral – velocity
- Second integral - Position



Analog integration

- Works only with
 - repetitive semi-sinusoidal signals.
 - Dynamic transducers
- Typical units:

g's

m/s²

ft/s

m/s

Mils p-p

mm

Numeric integration

- Sample data
- Mathematically integrate
- Complex and time consuming.
 - A lot more common today with higher power computing available.

Others

- Magnetostrictive
- Extensometer
- “Pull string”
 - Analog
 - Digital
- Differential laser / optical

The background features a 3D perspective of a grid of small, light blue spheres. These spheres are arranged in a regular pattern, receding into the distance to create a sense of depth. The spheres are connected by thin, light blue lines, forming a mesh-like structure. The overall color scheme is a gradient of dark blue, with the spheres providing a subtle contrast.

The End!