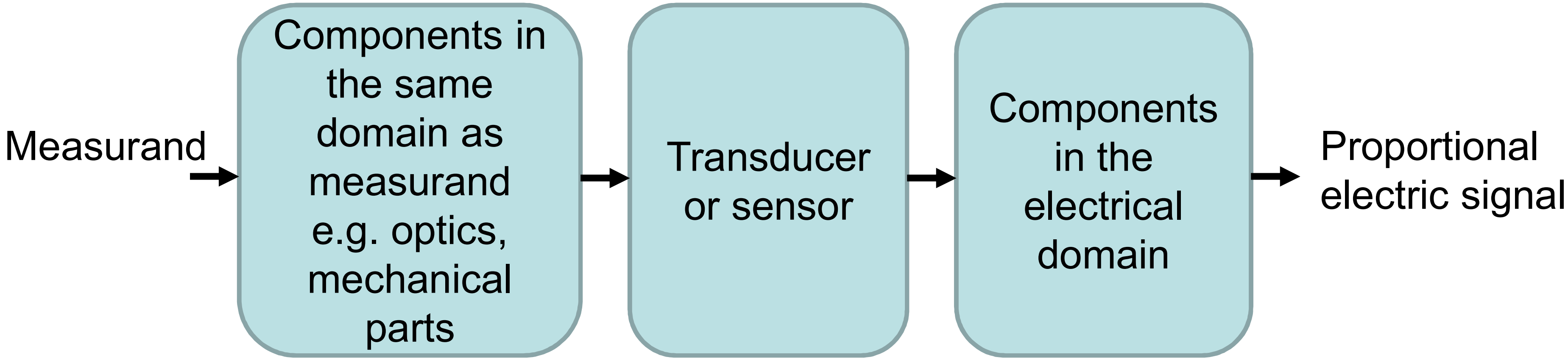
Measurand to Signal:
Acceleration, pressure, position

We are going to look at….

- Acceleration
  - *Navigation*
- Pressure
  - *Air data*
- Position (linear and Rotary)
  - *feedback i.e. flight surface position*

Scope



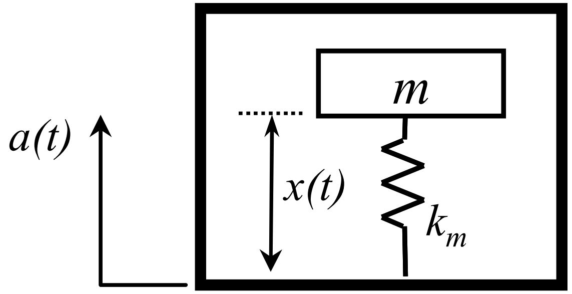
- In these lectures we want to consider how we get from an input *measurand* to an electrical output (normally a voltage) proportional to the value of the measurand.
- This might include some mechanical components, a sensor or transducer, and some electrical circuits

Questions?

- So why do we want the output to be in the electrical domain?
- Why is it most often a voltage?
- Why do we want the output to be proportional to the measurand?

Acceleration

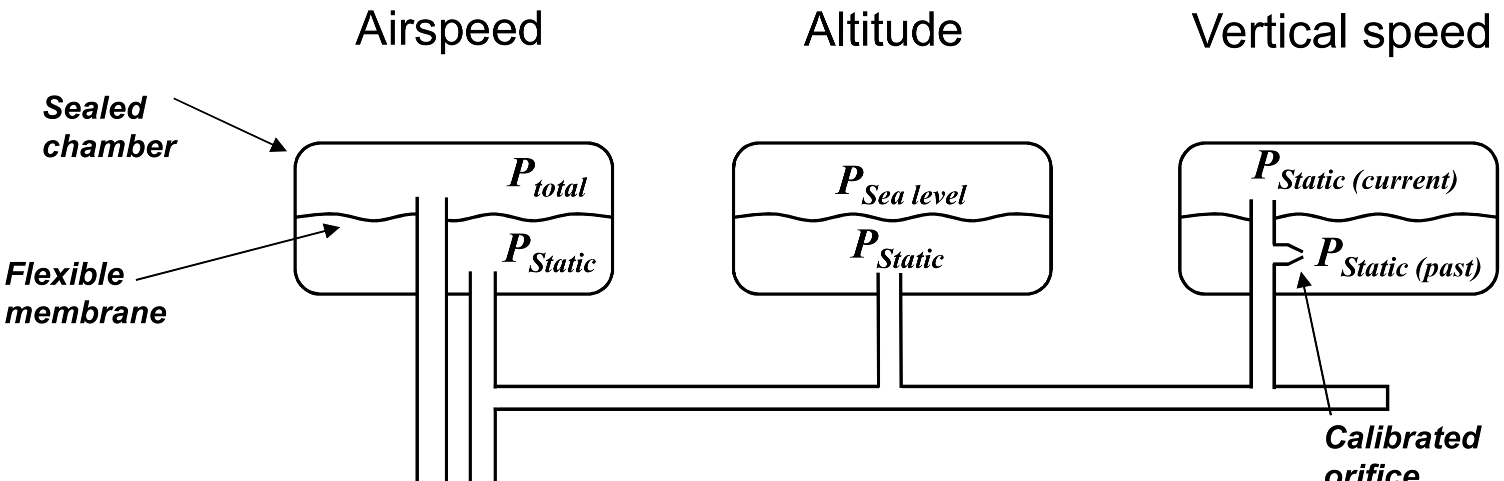
- Accelerometers typically measure the force exerted on a known mass.
- Most commonly this force is turned into a displacement via a compliant element and it is the displacement that is measured.



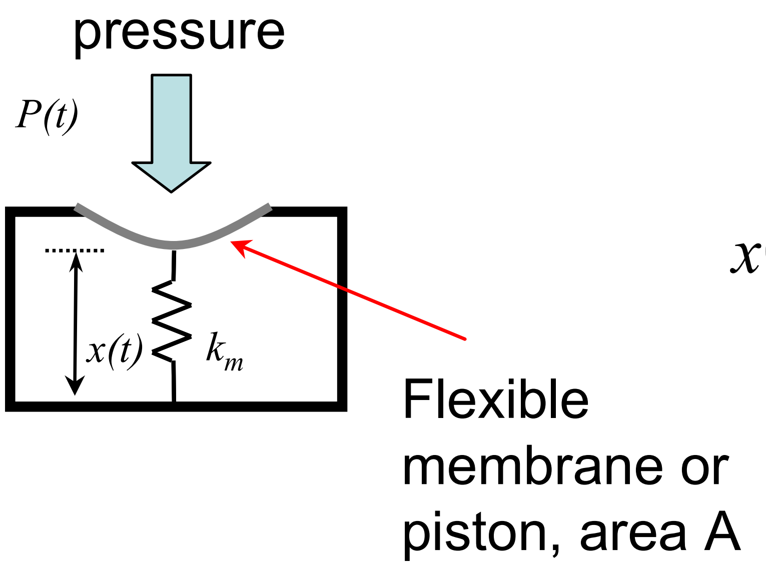
$$a(t) = x(t)\frac{k_m}{m}$$

Displacement is then converted into an electrical signal by strain gauges, piezoelectric transduction etc.

Air Data Instruments



Pressure sensors



$$x(t) = \frac{P(t)A}{k_m}$$

- Pressure sensors measure the force exerted on a membrane or piston of known area.
- This force is turned into a displacement via a known compliance and measured or the strain in the membrane can be measured.
- The measured pressure can be relative or absolute

Pressure to displacement…..

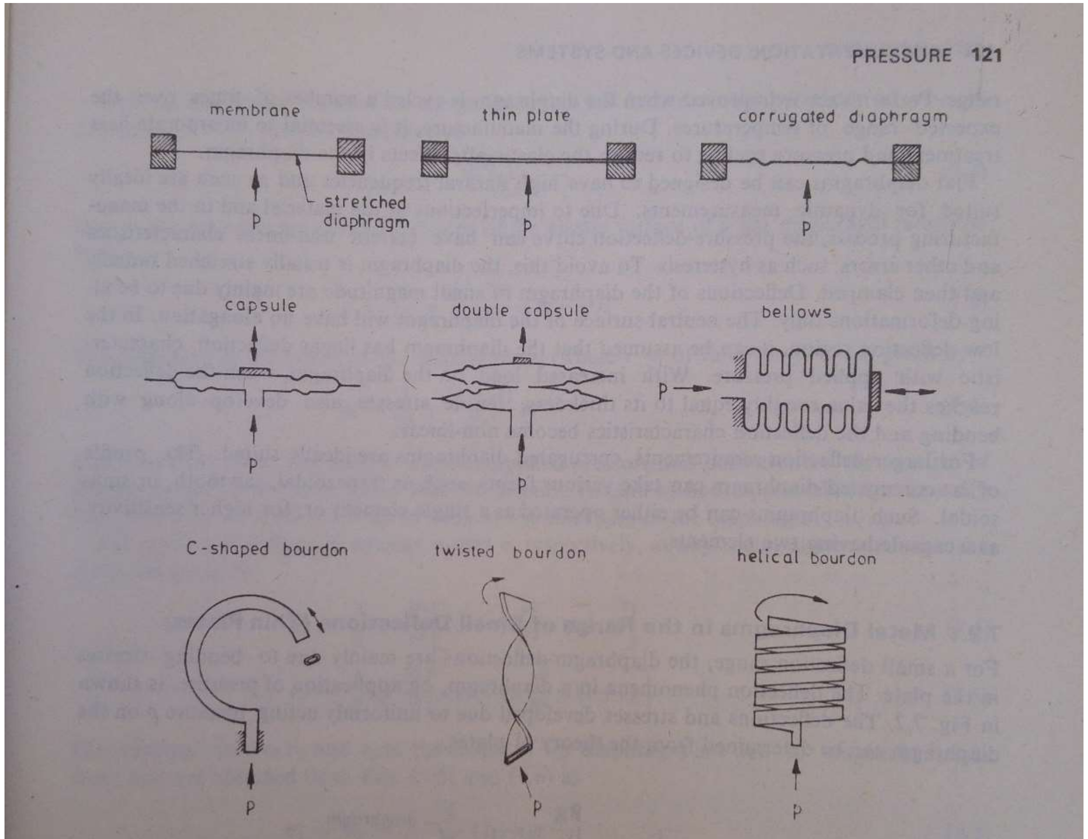


Fig. 7.1 Various elastic elements for pressure measurements

- Rangan (p121) shows various ways to convert pressure to displacement

Absolute and relative quantities?

- Absolute: defined without reference to anything else.
- Relative: defined by reference to another value.

- Some quantities are fundamentally one or the other e.g.
  - ***Absolute – Current, Force,***
  - ***Relative – Velocity, Voltage.***

- ***In practical usage:*** Sometimes it is more subtle – many relative systems measure change and integrate to give the desired output. In such cases the measurement is lost when power to the system is cut.

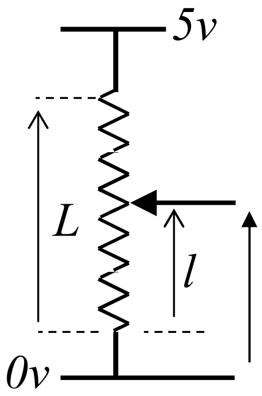
Position detection

- In both the acceleration and pressure sensors we manipulated the measurand into displacement.

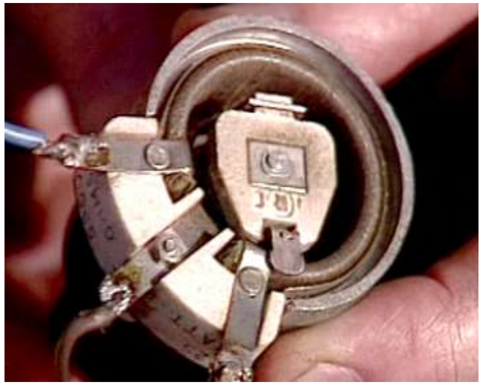
- Also in many aerospace applications position, either linear or rotary, is itself the measurand:

  - Flight control surface position
  - Landing gear position etc.

Potentiometers



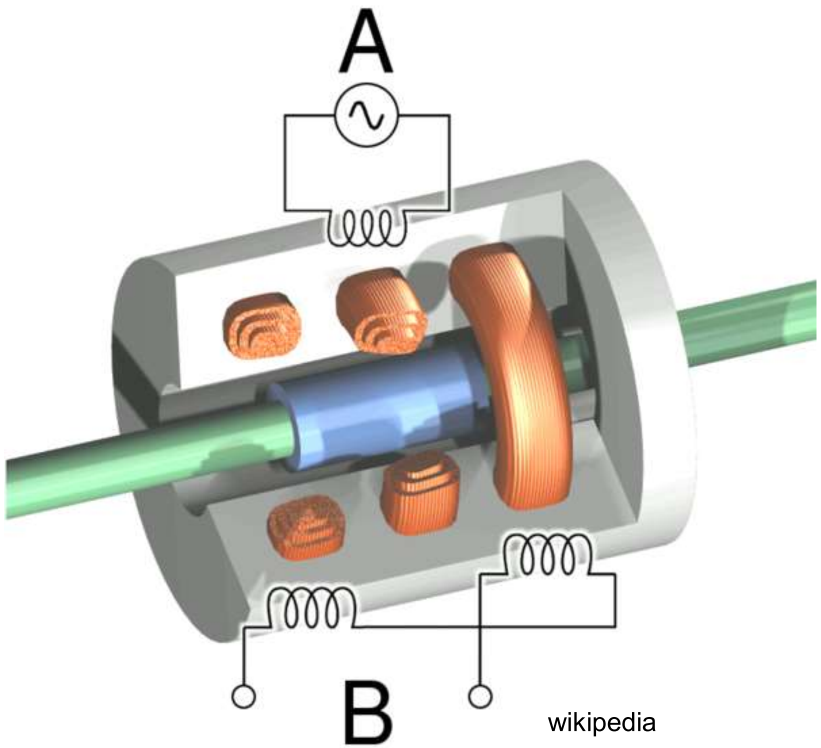
$$V_{out} = \frac{5l}{L}$$



- A potentiometer can be used as a rotary or linear position sensor.
- High accuracy is achievable and some are m's long. Outputs absolute position.
- Contacts can wear and limit maximum velocity, also they can cause sparking/electrical noise, especially with age.

LVDT – Linear Variable Displacement Transformer

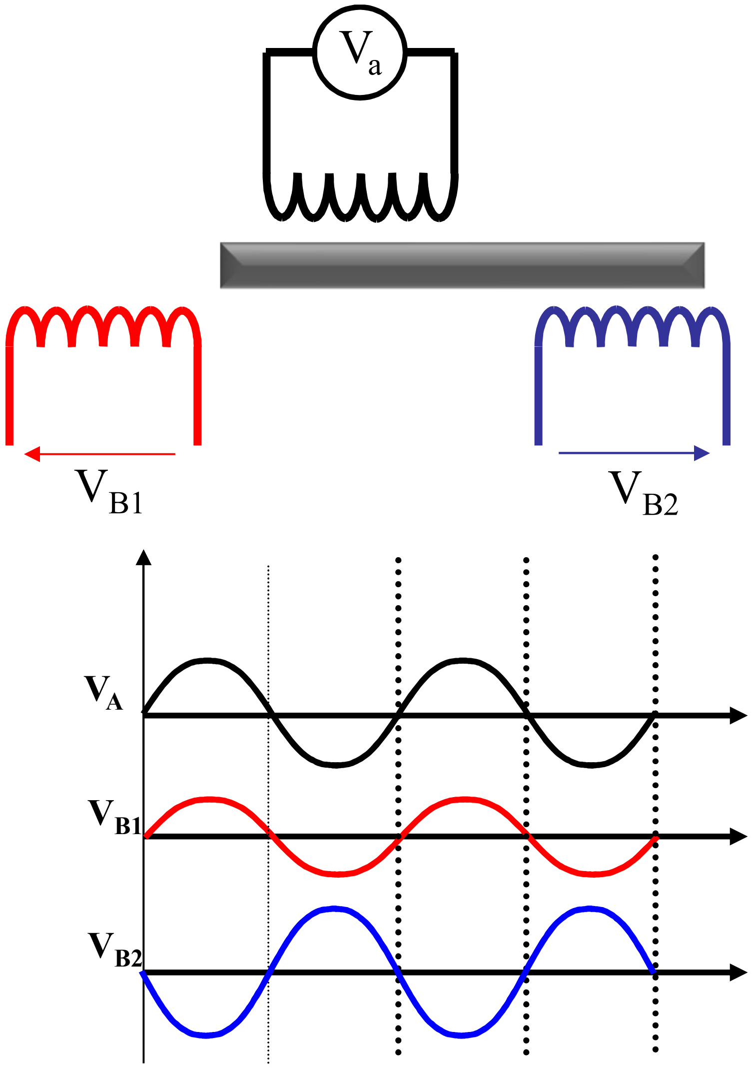
- The LVDT is a common displacement sensor for aerospace applications.
- Uses electromagnetic induction to link the flux of an exciting coil (A) to two secondary coils (B).
- Moving the plunger changes the magnetic flux linkage between coils and thus voltage output.



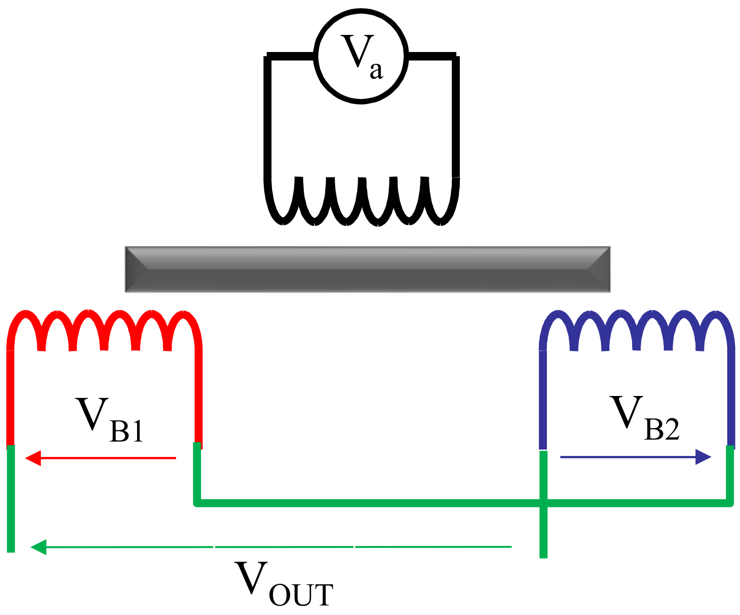
wikipedia

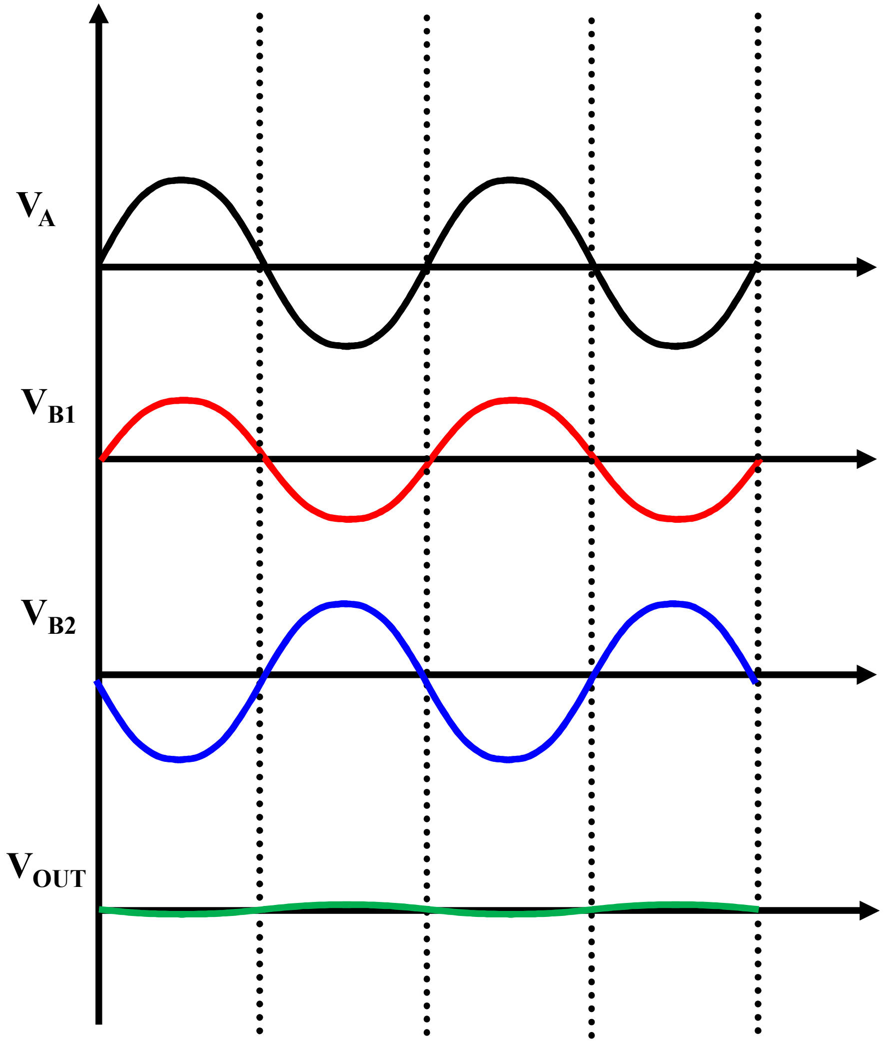
LVDT

As the plunger moves relative to the static coils, the flux linkage to the secondary coils changes in a reciprocal manner. The secondary coil with greater flux linkage has a higher output.



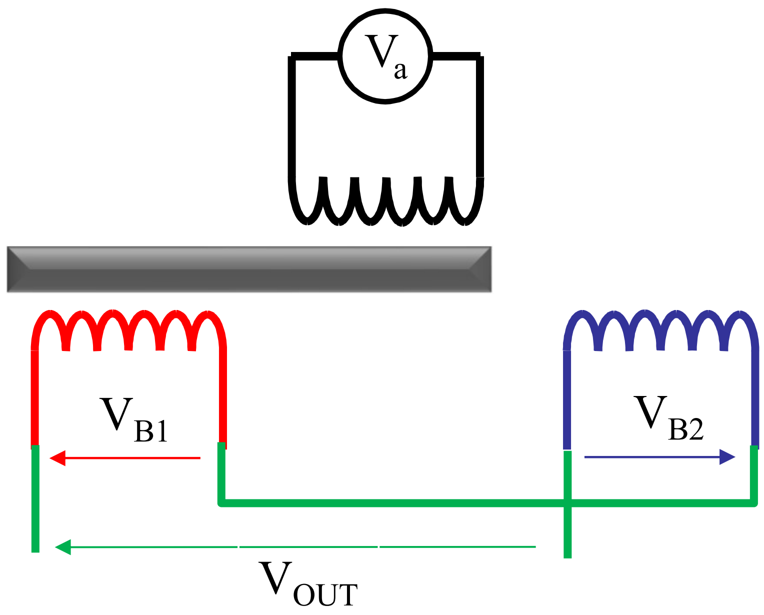
LVDT

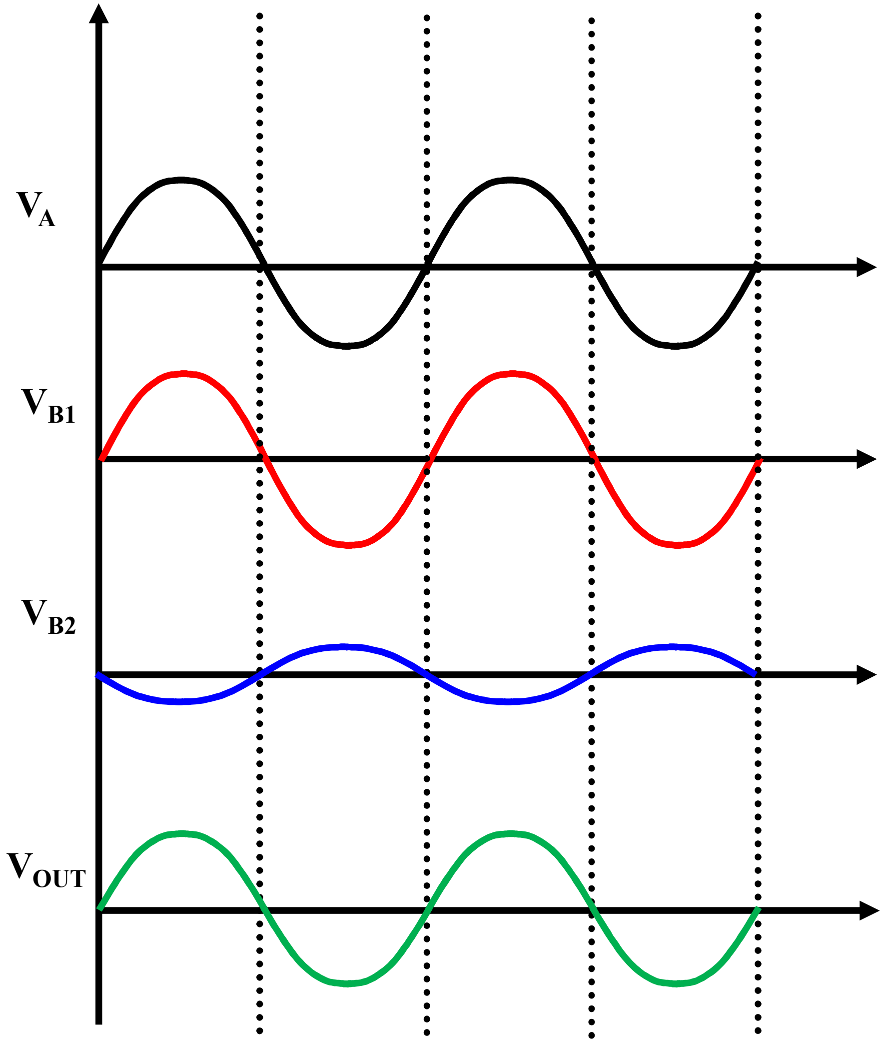




The phasing of the secondary windings is arranged such that if both have equal magnitude (plunger at mid point) the output is zero

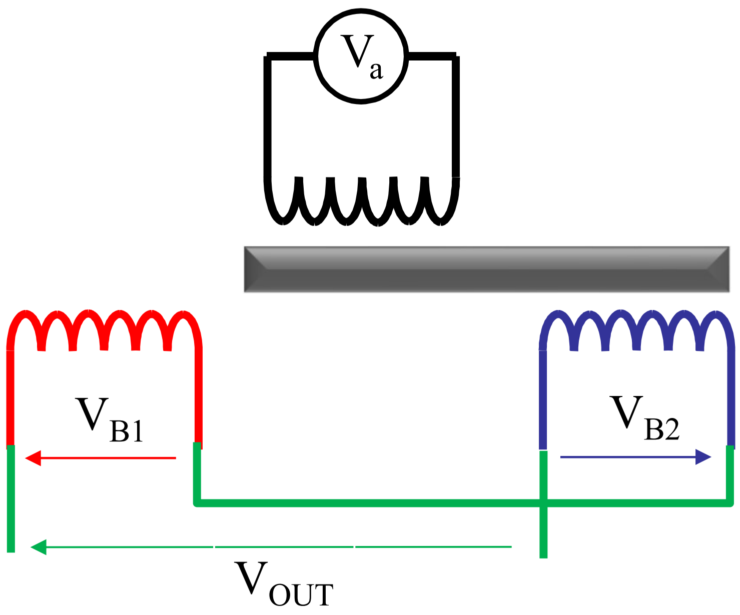
LVDT

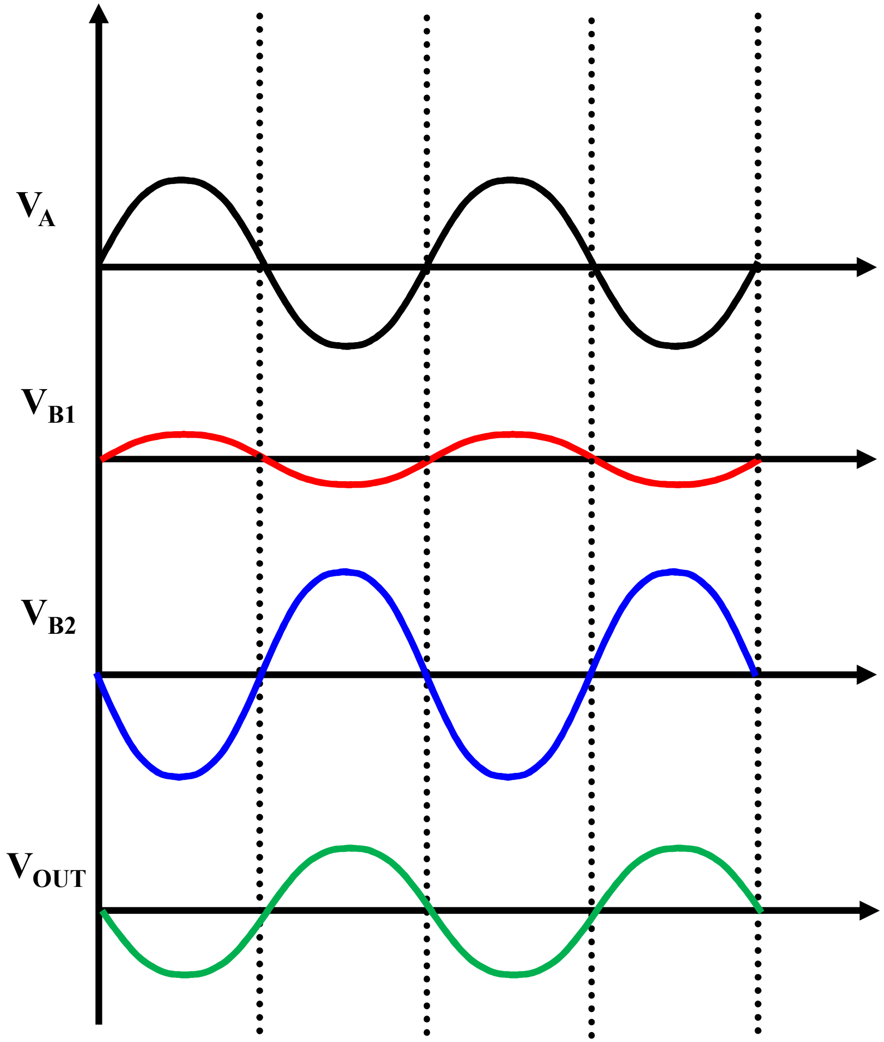




When the plunger is offset towards phase B1, the output has greater magnitude and is in phase with the excitation.

LVDT





With the plunger displaced towards B2, the output has greater magnitude but is now out of phase with the excitation.

LVDT

- The magnitude of the displacement of the plunger from the mid point is proportional to the magnitude of the output.

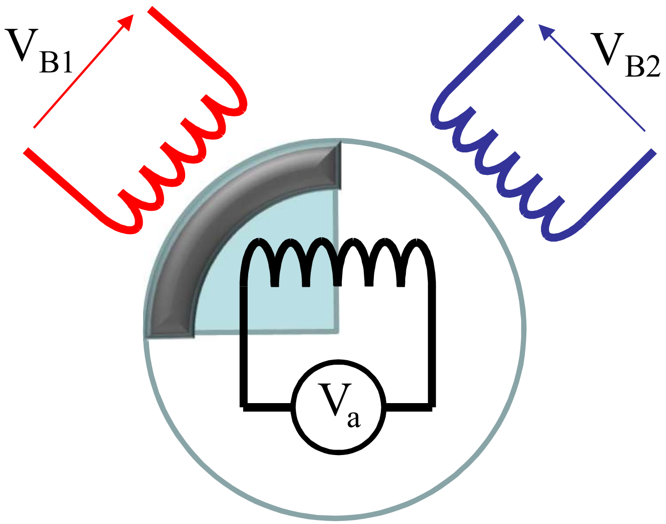
- The phase of the output relative to the excitation gives us the direction.

- The frequency of excitation (the ‘carrier frequency’) is typically several kHz – this is much higher then the frequency at which the plunger can move.

- The big advantage of the LVDT is that it is non-contact.
  - Nothing to wear; suitable for high velocities
  - Can be completely sealed

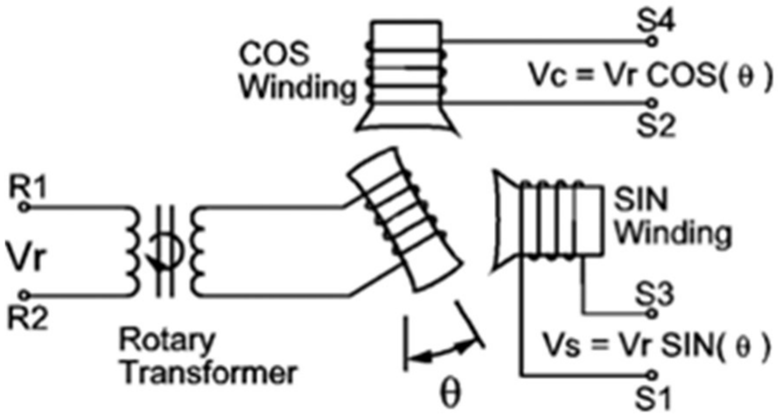
- The LVDT outputs absolute position.

Rotary Variable Displacement Transformer RTVP



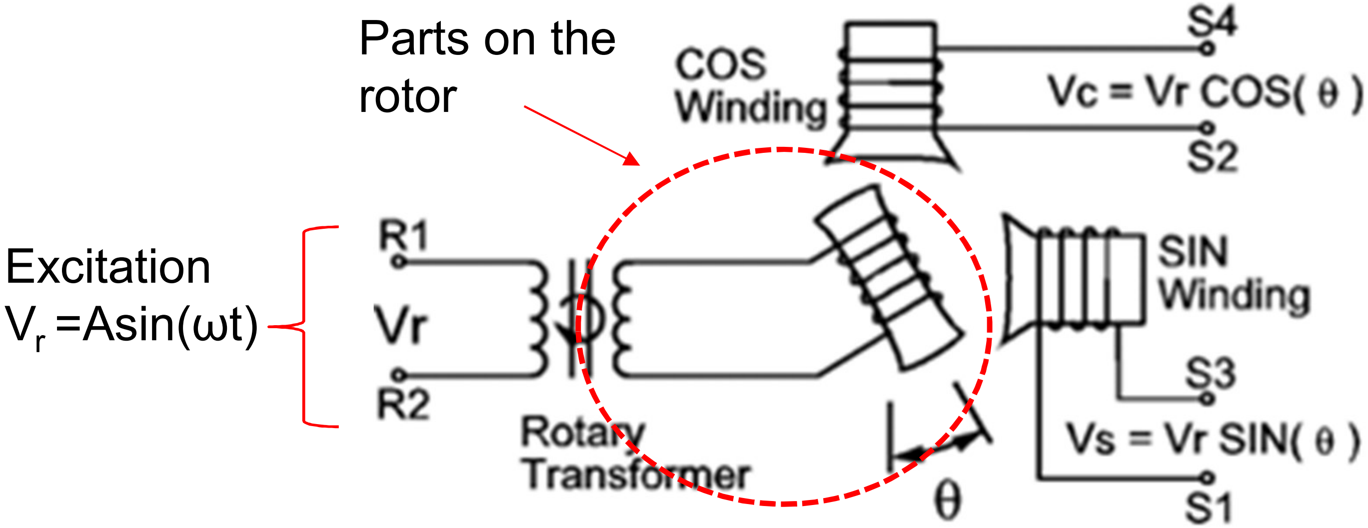
- The LVDT can be morphed into an arc to measure angular displacement, it is then called RVDT. *Note: all coils are still stationary, only the magnetic 'plunger' rotates.*
- The RVDT has limitations over wider angles so cannot be used to measure full rotations.

Resolver



- The resolver is used to overcome the angular limitations of the RVDT.
- An electromagnet on the rotor excites two static windings displaced 90° from each other.
- The outputs of the resolver form sine and cosine components from which angular position is derived – we will come across this idea of representing rotation with two components again
- The downside is the increased complexity on the rotor making the device less durable

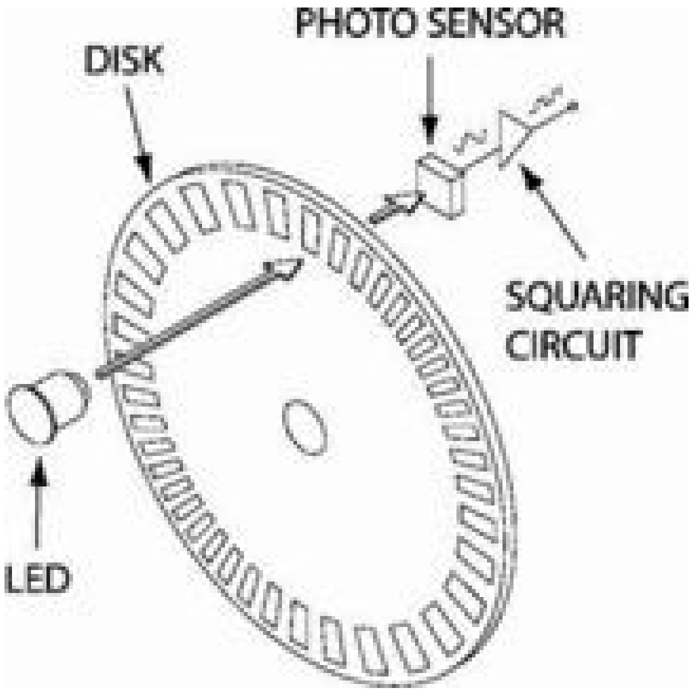
Resolver



$V_c = A\cos(\theta)\sin(\omega t)$ and $V_s = A\sin(\theta)\sin(\omega t)$

$$\theta = tan^{-1}\left(\frac{|V_s|}{|V_c|}\right)$$

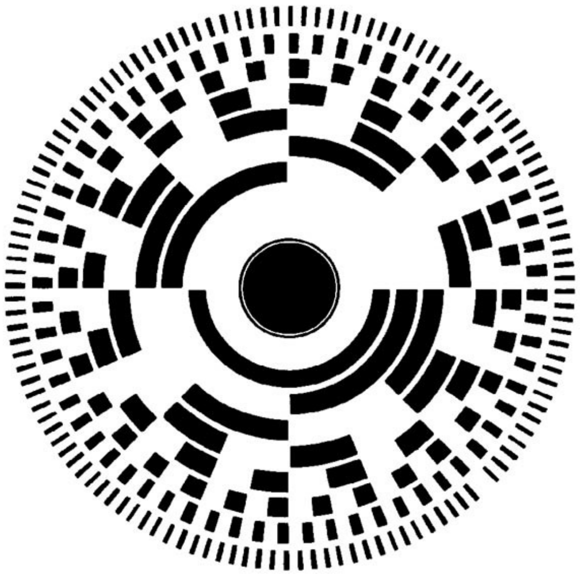
Encoders



Optical relative encoder

- The digital equivalent of the analogue family of position sensors are the encoders.
- Often seen as rotary encoders, linear versions are also available.
- Simple encoders may be relative – that is the absolute position is not known just the displacement from some previous point, often by counting ‘pulses’

Absolute Encoders

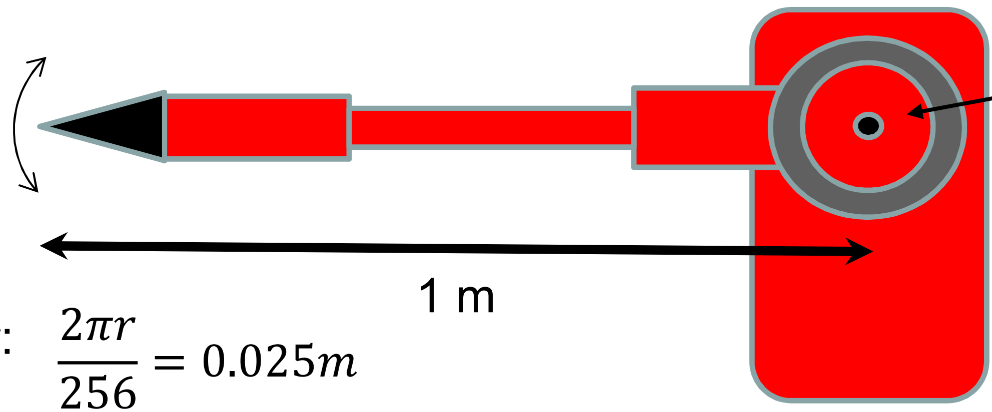


Absolute encoder disc with 8 channels, giving resolution of 1/256th of a full rotation

- Absolute encoders give absolute position at the expense of a greater number of ‘channels’, thus complexity.
- Optical or magnetic technologies can be used to read the encoder disc or linear track.

How good is 8 bit angular precision?

- Imagine a robot arm 1 m long
- If the rotation is measured with an 8 bit encoder, what resolution in angular position can be achieved at the end?



Answer: $\frac{2\pi r}{256} = 0.025m$

Encoders

Optical encoder from Renishaw. Accurate to better than 10,000th of a degree. (>20 bit)

Typical industrial rotary encoder packaging

Digital callipers often utilise a linear magnetic encoder

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