ELEC 207
Instrumentation and Control

8 – Displacement Transducers (2)

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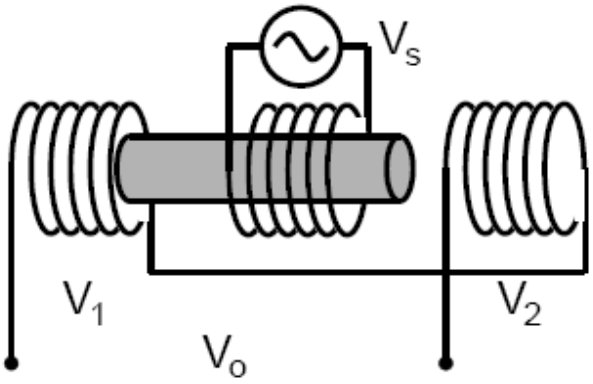
Inductive transducers

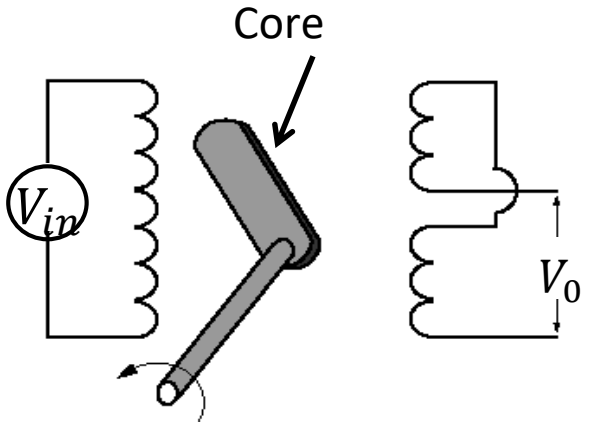
Principle of operation

The principle of operation of inductive transducers relies on variable magnetic coupling between coils:

- There are two main types of inductive transducers:
  - **Linear Variable Differential Transformer (LVDT)**;
  - **Rotary Variable Differential Transformer (RVDT)**.



LVDT



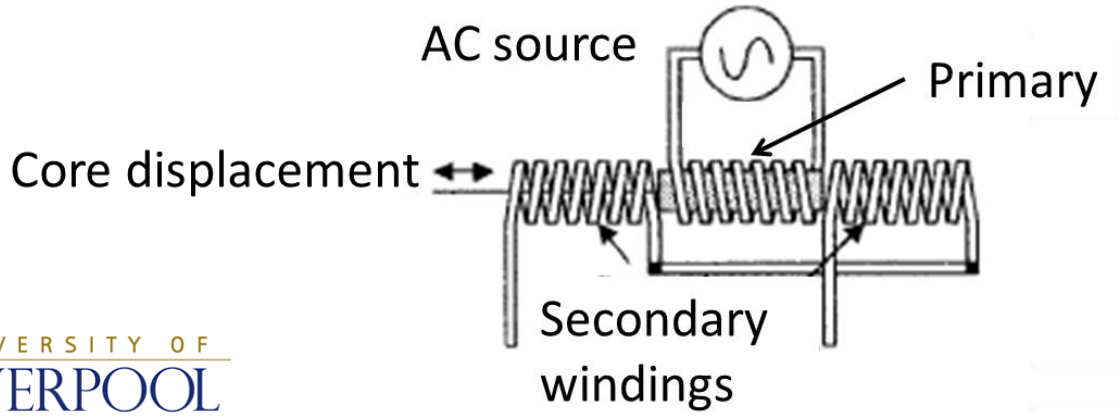
RVDT

Linear variable differential transformer

Physical structure

The LVDT consists of:

- **Three coils**:
  - One central coil acting as the primary circuit of a transformer;
  - Two outer coils acting as the secondary circuit;
- **A movable core**, used to sense displacement;
- AC voltage source applied to the primary coil.

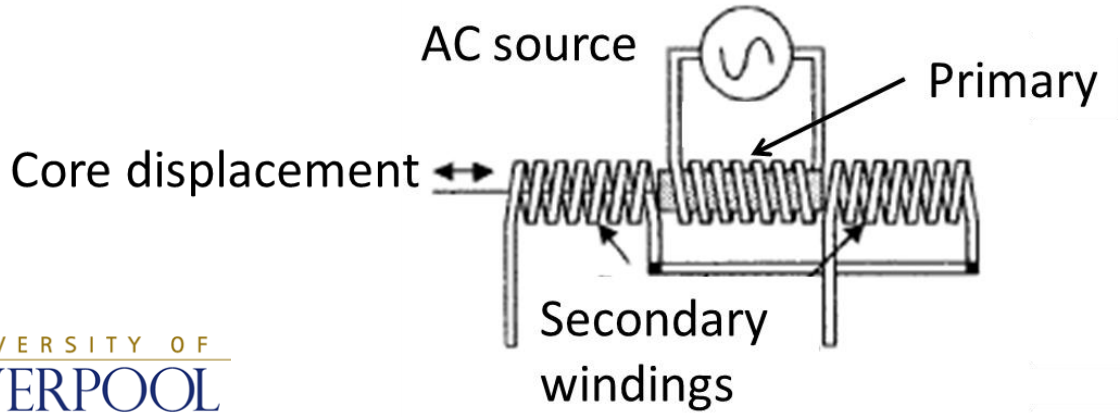


Linear variable differential transformer

Principle of operation (1)

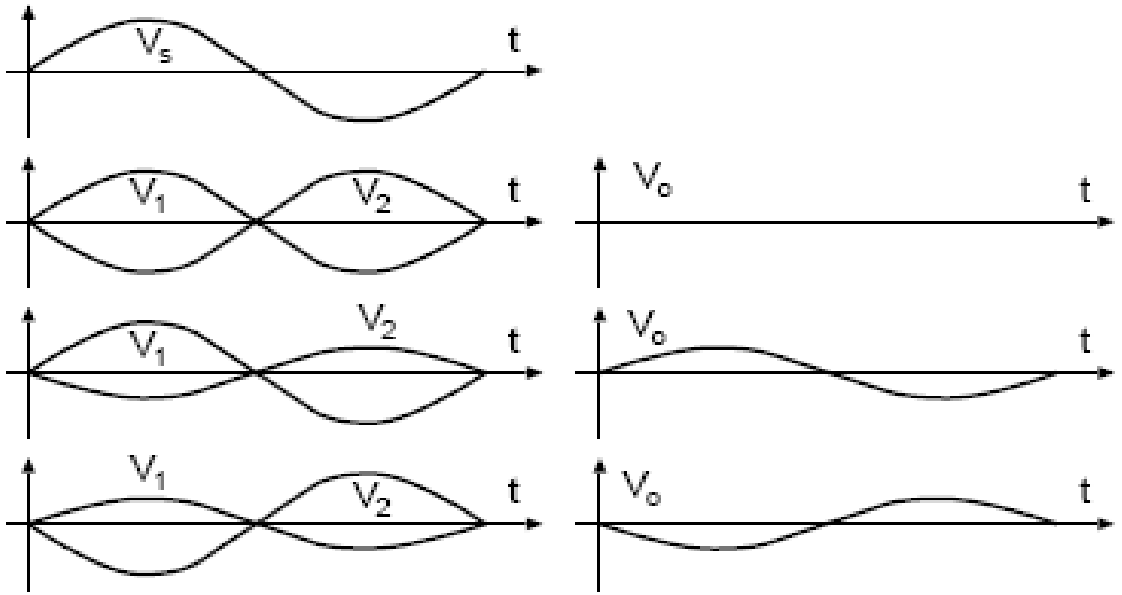
The two secondary circuits are in series, but with **opposite directions**:

- When the core is in the **central position**, the magnetic coupling with the two secondary circuits is the same and it induces opposite voltages:
  - The overall voltage measured on the secondary circuits is zero;
- When the core is moved, an **unbalance** appears:
  - An AC voltage is detected on the secondary circuit.



Linear variable differential transformer

Principle of operation (2)



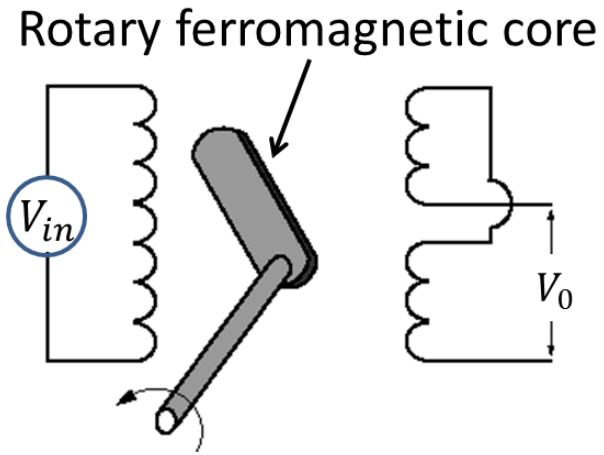
- The **magnitude** of the output voltage V_o is proportional to the displacement;
- The **phase** of the output voltage V_o provides the direction of displacement.

Rotary variable differential transformer

Principle of operation

The principle of operation of the RVDT is similar to the LVDT:

- The main difference is that in the RVDT the core rotates within the coils instead of moving longitudinally:
  - A voltage is induced on the secondary circuit depending on the **angular position of the core**.



Optical transducers

Application to rotation measurements

Optical transducers are often employed to measure **rotation angles**, e.g. in a motor:

- A typical transducer consists of a light source, a light detector and one or two circular disks placed between the source and the detector;
- This type of transducer allows a **digital output**, without requiring an analog-to-digital converter:
  - No light = 0, light = 1;
- There are two types of transducers:
  - **Incremental**: it measures only a change in the rotation angle;
  - **Absolute**: it measures an absolute angle.

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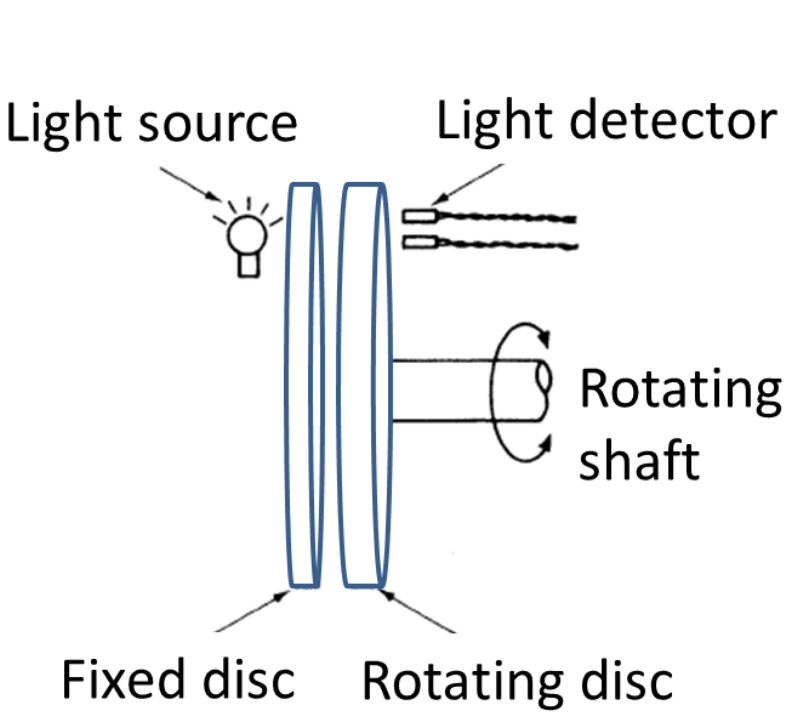
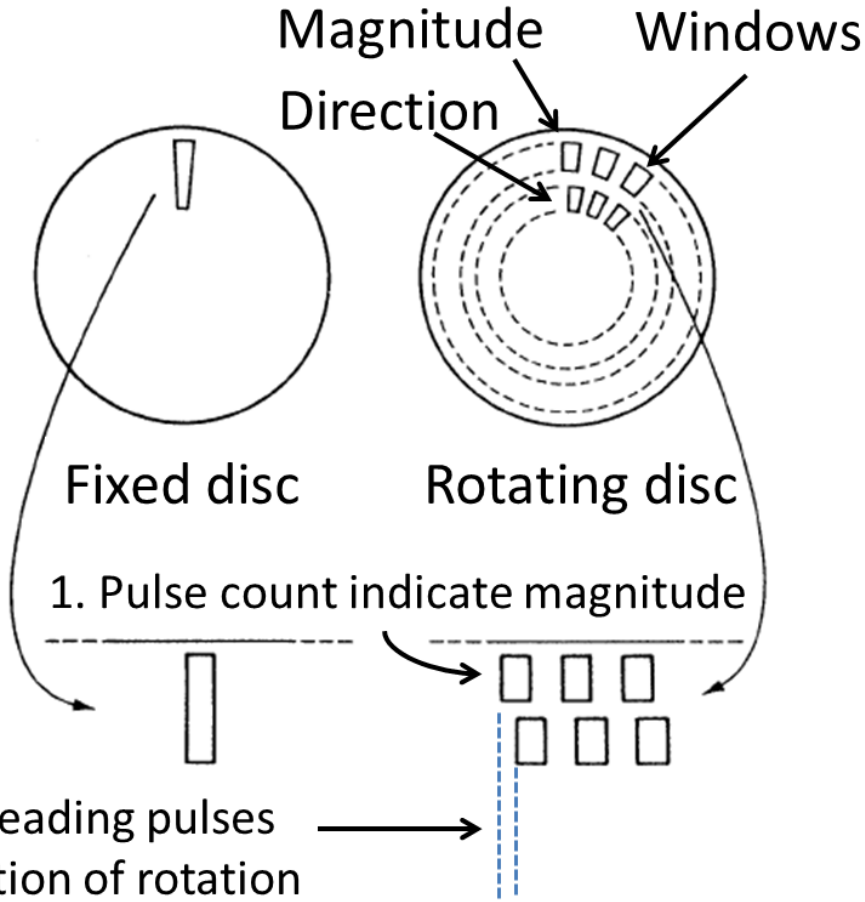
Incremental encoder

Principle of operation (1)





Incremental encoder

Principle of operation (2)

An incremental encoder is usually composed of two disks:

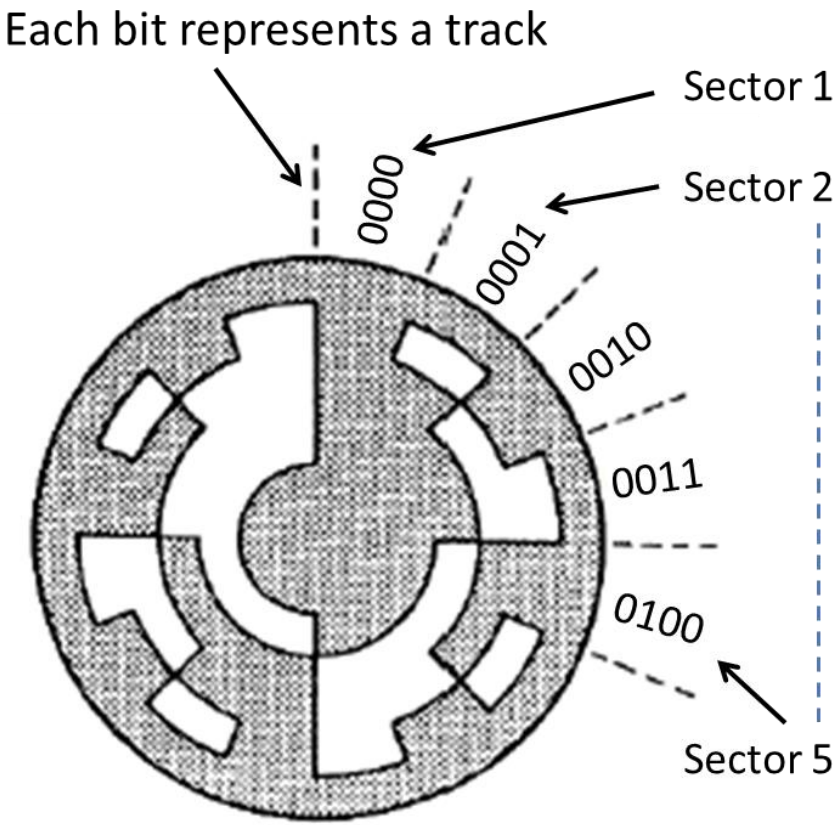
- **A fixed disk** has one window, which is aligned to the light source;
- **A rotating disk** has two tracks of windows cut into it, and light detectors are aligned to each track:
  - When the disk rotates, light pulses are recorded through the two windows;
  - Pulses from the **outer track** are counted by a counter to determine the magnitude of the angular displacement from the starting position;
  - Pulses from the **inner track** are used to determine the direction of rotation.

Absolute encoder

Principle of operation

In an absolute encoder, the digital output is encoded in the rotating disk, by using **several tracks** (and several light detectors):

- The measurement is absolute because there is a **unique binary code** associated with each angle;
- The standard binary code could cause large errors in case of tracks misalignment:
  - This problem is solved by using the **gray code**.



Rotating disc with four tracks (binary code)

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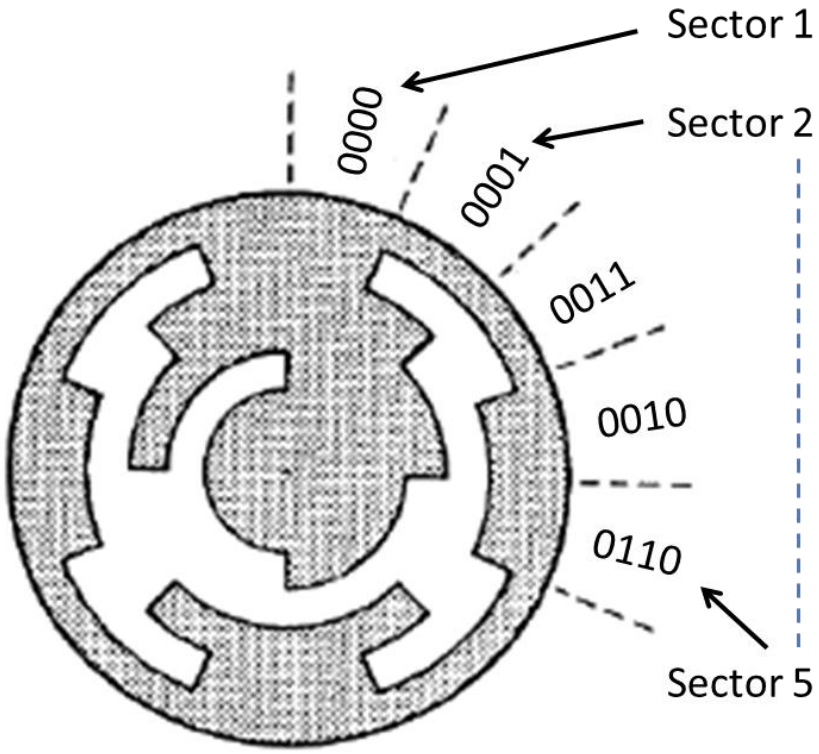
Absolute encoder

Gray code

With the gray code, only one binary digit changes from one sector to the following one:

Decimal	Binary	Gray
0	0000	0000
1	0001	0001
2	0010	0011
3	0011	0010
4	0100	0110
5	0101	0111
6	0110	0101
7	0111	0100
8	1000	1100



Rotating disc with four tracks (Gray code)

Incremental and absolute encoders

Advantages and disadvantages

Incremental encoders:

- Are simpler and less expensive;
- Have a resolution which depends on the number of windows in the tracks;
- Do not provide an absolute measurement, so are subject to errors in case of missed pulses;
- They are therefore more suitable for speed measurements than for angular position measurements.

Absolute encoders:

- Are more complex and more expensive;
- Have a resolution which depends on the number of tracks (and detectors);
- Provide an absolute measurement, so are potentially more accurate for angular position measurements.

References

Textbook: Principles of Measurement Systems, 4th ed.

For further explanation about the points covered in this lecture, please refer to the following chapters and sections in the **Bentley** textbook:

- Chapter 8, Sec. 8.3: **Inductive sensing elements**;
- Chapter 15, Sec. 15.6.2: **Modulation of intensity by transmission medium [in optical measurement systems]**.

NOTE: Topics not covered in the lecture are not required for the exam.

References

Textbook: Measurement and Instrumentation, 2nd ed.

For further explanation about the points covered in this lecture, please refer to the following chapters and sections in the **Morris-Langari** textbook:

- Chapter 19, Sec. 19.2.2: **Linear variable differential transformer**;
- Chapter 20, Sec. 20.2.2: **Rotational differential transformer**;
- Chapter 20, Sec. 20.2.3: **Incremental shaft encoders**;
- Chapter 20, Sec. 20.2.4: **Coded-disk shaft encoders**.

NOTE: Topics not covered in the lecture are not required for the exam.

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