Pearson BTEC Level 4 Higher Nationals in Engineering (RQF)

Unit 21: Electrical Machines

Unit Workbook 3

in a series of 3 for this unit

Learning Outcomes 4

Electromagnetic Transducers and Actuators

Contents

INTRODUCTION

GUIDANCE

This document is prepared to break the unit material down into bite size chunks. You will see the learning outcomes above treated in their own sections. Therein you will encounter the following structures;

Purpose

Explains *why* you need to study the current section of material. Quite often learners are put off by material which does not initially seem to be relevant to a topic or profession. Once you understand the importance of new learning or theory you will embrace the concepts more readily.

Theory

Conveys new material to you in a straightforward fashion. To support the treatments in this section you are strongly advised to follow the given hyperlinks, which may be useful documents or applications on the web.

Example

The examples/worked examples are presented in a knowledge-building order. Make sure you follow them all through. If you are feeling confident then you might like to treat an example as a question, in which case cover it up and have a go yourself. Many of the examples given resemble assignment questions which will come your way, so follow them through diligently.

Question

Questions should not be avoided if you are determined to learn. Please do take the time to tackle each of the given questions, in the order in which they are presented. The order is important, as further knowledge and confidence is built upon previous knowledge and confidence. As an Online Learner it is important that the answers to questions are immediately available to you. Contact your Unit Tutor if you need help.

Challenge

You can really cement your new knowledge by undertaking the challenges. A challenge could be to download software and perform an exercise. An alternative challenge might involve a practical activity or other form of research.

Video

Videos on the web can be very useful supplements to your distance learning efforts. Wherever an online video(s) will help you then it will be hyperlinked at the appropriate point.

- **Stability** - A measure of how the accuracy and precision of the measurement system perform over time. In other words, it is a measure of how much the output drifts in the face of a constant input. Stability will determine the required interval between calibration of the measurement system.
- **Noise** – There are many sources of noise in electronic systems, but all electronic systems are subject to it and exhibit random fluctuations of output for no discernible input.
- **Signal to Noise Ratio (SNR)** – Simply the ratio between the wanted signal and the unwanted background noise. Obviously, it is desirable that the SNR is as high as possible.
- **Dynamic Range** – Dynamic range is a term used to describe the ratio between the smallest and largest signals that can be measured by a system. The dynamic range of a data acquisition system is defined as the ratio between the minimum and maximum amplitudes that a data acquisition system can capture.
- **Linearity** - Describes how accurate measurements are across the complete expected range of the measurements. It answers the question about how accurate the system is across the dynamic range of the system.

Types of Transducer

There are a large number of different types of transducer available, the idea behind most of them are to convert the physical attributes they detect into an electrical signal which is then processed by the controller.

- **Temperature Sensors** – Used to measure variations with transfer with temperature, following well-characterised transfer functions. This should be no surprise since nearly all electronic components have properties that vary with temperature. Many of these components could potentially be used as temperature transducers if their transfer functions were well behaved and insensitive to other variables. Examples include; Thermocouples, Thermistors, Resistance Temperature Detectors, and Monolithic Temperature Transducers.
- **Optical Sensors** – Used for detecting light intensity. Typically, they respond only to particular wavelengths or spectral bands. Examples include; Vacuum Tube Photo Sensors, Photoconductive Cells, Photovoltaic (Solar) Cells, Semiconductor Light Sensors, and Thermoelectric Optical Sensors.
- **Position Displacement Sensors** – Used to measure mechanical displacement or position of an object. Some require physical connection to the object, others do not. Examples include; Potentiometers, Capacitive and Inductive Sensors, Linear Voltage Differential Transformers (LVDT), Optical Encoders, and Ultrasonic Range Finders.
- **Force and Pressure Transducers** – Used for measuring force and pressure. Most pressure transducers rely on the movement of a diaphragm mounted across a pressure differential and the transducer measures minute movements in the diaphragm. Capacitive and inductive pressure sensors operate in a similar way to capacitive and inductive displacement sensors. Examples include; Strain Gauges, and Piezoelectric Transducers.
- **Magnetic Field Sensors** – Measure either varying or fixed magnetic fields.
- **Ionising Radiation Sensors** – Ionizing radiation can be particle produced by radioactive decay, such as alpha or beta rays, or high-energy electromagnetic radiation, such as gamma rays or X-rays. In many of these detectors, a radiation particle or photon collides with an active surface material which as a result produces charged particles which are measured as an electric current. Examples include Geiger Counters, Semiconductor Radiation Detectors, and Scintillation Counters.

person had a go at taking the same measurement on different days using different measuring equipment, a wider range of answers would be much less surprising. This is known as 'reproducibility' and describes the agreement within a set of measurements where different people, equipment, methods, locations or conditions are involved.

- **Repeatability** is the closeness of agreement between repeated measurements of the same thing, carried out in the same place, by the same person, on the same equipment, in the same way, at similar times.
- **Reproducibility** is the closeness of agreement between measurements of the same thing carried out in different circumstances, e.g. by a different person, or a different method, or at a different time.

Tolerance

Theory

Tolerance, also known as 'acceptance criteria'. It is the maximum acceptable difference bet ween the actual value of a quantity and the value specified for it. For example, if an electrical resistor has a specification of 10Ω and there is a tolerance of $\pm 10\%$ on that specification, the minimum acceptable resistance would be 9Ω and the maximum would be 11Ω. Many factors can reduce accuracy or precision and increase the uncertainty of your measurement result. Some of the most common are:

- **Environmental conditions** – changes in temperature or humidity can expand or contract materials as well as affect the performance of measurement equipment.
- **Inferior measuring equipment** – equipment which is poorly maintained, damaged or not calibrated will give less reliable results.
- **Poor measuring techniques** – having consistent procedures for your measurements is vital.
- **Inadequate staff training** – not knowing how to make the right measurement, not having the confidence to challenge the results and not being willing to seek advice can all have a negative impact.

Error Analysis and Significant Figures

Errors using inadequate data are much less than those using no data at all. (C. Babbage)

Theory

No measurement of a physical quantity can be entirely accurate. It is important to know, therefore, just how much the measured value is likely to deviate from the unknown, true, value of the quantity. The art of estimating these deviations should probably be called uncertainty analysis, but for historical reasons is referred to as error analysis.

Significant Figures

Whenever you make a measurement, the number of meaningful digits that you write down implies the error in the measurement. For example, if you say that the length of an object is $0.428m$, you imply an uncertainty of about $0.001m$. To record this measurement as either 0.4 or 0.42819667 would imply that you only know it to $0.1m$ in the first case or to $0.00000001m$ in the second. You should only report as many significant figures (S.F) as are consistent with the estimated error. The quantity $0.428m$ is said to have three S.F that is, three digits that make sense in terms of the measurement. Notice that this has nothing to do with the "number of decimal places". The same measurement in centimetres would be $42.8cm$ and still be a three S.F number. The accepted convention is that only one uncertain digit is to be reported for a measurement. In the example if the estimated error is $0.02m$ you would report a result of $0.43 \pm 0.02\ m$, not $0.428 \pm 0.02\ m$.

Sensor Types

Proximity Sensor

A proximity sensor can detect the presence of a nearby object without actually touching it. There are several types of proximity detector; capacitive, photoelectric and inductive. Here we shall look at the inductive type of proximity sensor.

An inductive proximity sensor detects the presence of a metallic target. Ferrous metals, such as steel or iron, are more easily detected, but aluminium and copper may also be detected with reduced sensitivity. Figure 1 shows an inductive proximity detector.

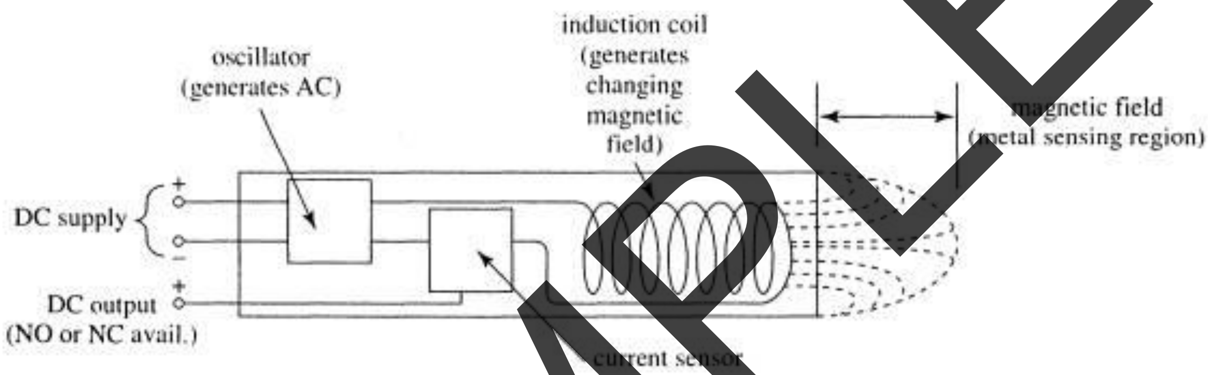

Figure 1 *Principle of an inductive proximity detector*

In figure 1 we see that a DC supply powers an AC oscillator. This oscillator provides a varying sinusoidal current to a coil. The coil can be wound on a ferrite or iron core. The electromagnetic field produced by the coil in this state emanates magnetic flux (shown dotted) from the side of the coil.

When a metallic object locates itself inside the flux emanating from the coil here will be a change in the overall inductance of the coil, changing the level of current flow. This change in current is detected by the current sensor, which then outputs a signal which can be in the form of a DC level, or either activating normally-open or normally-closed contacts. A typical inductive proximity detector is shown in figure 2.

Figure 2 *A tubular inductive proximity detector*

Clamp Meter

A clamp meter is a sensor which detects the flow of current through a coil (in the clamp). This is a useful tool when it is not possible to disconnect a cable from its current supply, so opening the clamp and allowing it to surround the cable will provide an indication on an LDC display of the current flowing in the cable. A typical clamp meter is shown in figure 5.

Figure 5 *A clamp meter used for measuring current in a cable*

Microphone

A moving-coil microphone has a coil glued to a membrane (diaphragm). A strong magnetic field produced by a permanent magnet is formed to surround the coil. When a pressure wave (sound) hits the microphone, the membrane moves in sympathy with the varying level of the sound wave. Since the membrane moves, so does the coil, and, as we know, relative movement between a coil and a magnetic field produces a current in the coil. This current is then amplified and sent to a further stage, perhaps a loudspeaker. The principle of operation of a moving coil microphone is depicted in figure 6.

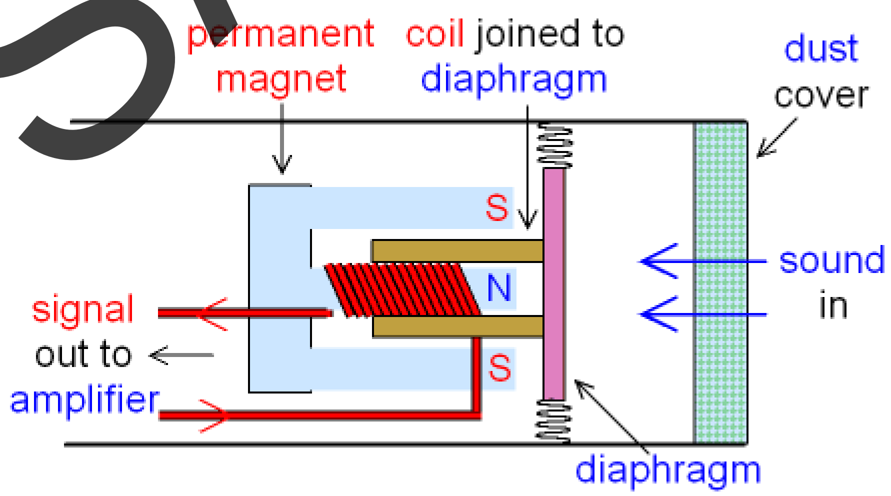

Figure 6 *Principle of operation of a moving coil microphone*

Solenoid

A solenoid is a coil of wire wrapped around a piston. The piston is usually made from iron. When current passes through the coil a magnetic field is set up which tends to pull the piston into the space occupied by the coil.

Solenoids form many parts of automated factory equipment, control starter motors for vehicles, and activate the ringer in an electric doorbell. The principle of how a solenoid works is depicted in figure 10.

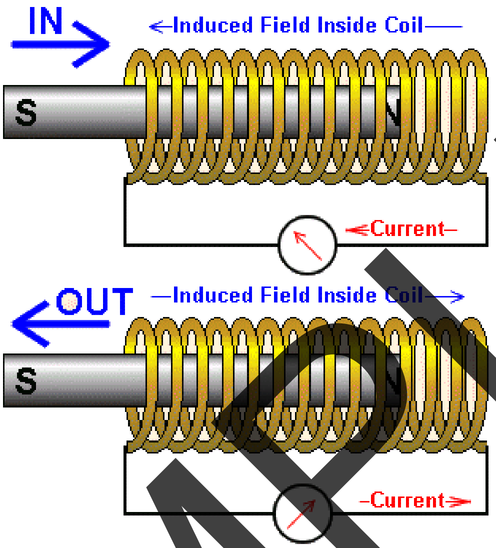

Figure 10 *Principle of operation of an electromagnetic solenoid*

Linear

A linear actuator converts electrical energy into linear displacement. The displacement is commonly provided by a screw drive, as shown in figure 11.

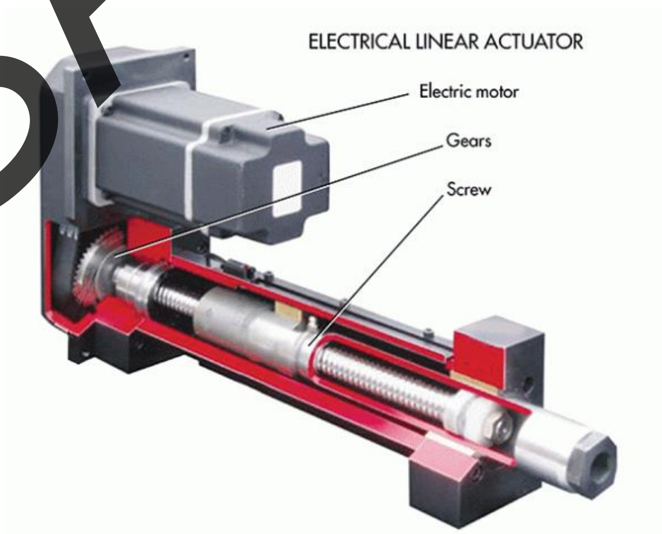

Figure 11 *Principle of operation of an electromagnetic linear actuator*