BFF3302 SENSOR AND INSTRUMENTATION SYSTEM

Signal Conditioning

By

Ahmad Shahrizan Abdul Ghani (*shahrizan@ump.edu.my*)
Nafrizuan Bin Mat Yahya (*nafrizuanmy@ump.edu.my*)

Faculty of Manufacturing Engineering (FKP)

Chapter Description

- Aims
  - Obtain basic knowledge about electronic, measurement, sensors, and instrumentation
  - Able to analyse particular sensor, instrument, and measurement situation.

- Expected Outcomes
  - Determine general treatment of instrument elements and their characteristic
  - Analyse transducer elements, intermediate elements, and data acquisition system (DAQ)
  - Determine principles of the work and derive mathematical model of sensors for measuring motion and vibration, dimensional metrology, force, torque and power, pressure, temperature, flow and acoustics

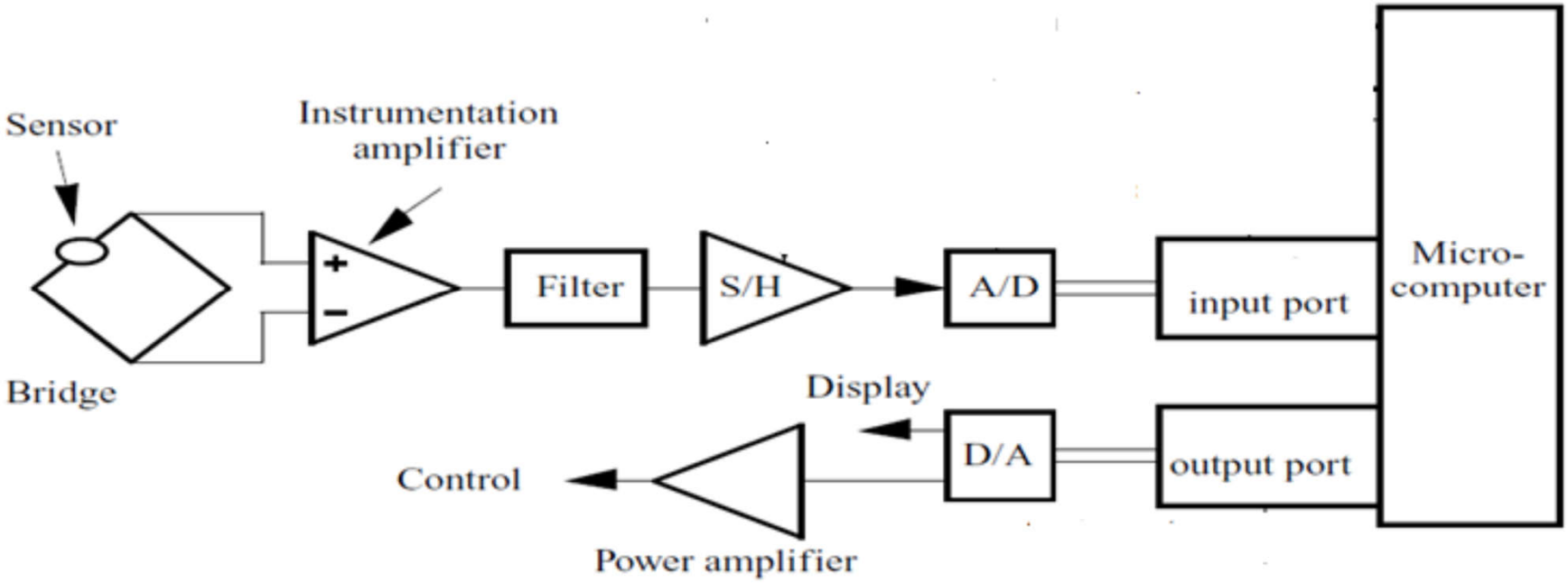
- References

  - B.C.Nakra and K.K. Chaudhry, 2012. Instrumentation measurement and analysis, 3rd ed., Tata-McGraw-Hill.
  - Introduction to signal processing, instrumentation, and control : an integrative approach / Joseph Bentsman Hackensack, NJ : World Scientific Pub., 2016
  - Transducers for instrumentation / M. G. Joshi, New Delhi, India : Infinity, 2017
  - Instrumentation and measurement in electrical engineering / editor : Harinirina Randrianarisoa, New York : Arcler Press, 2017

Signal conditioning

Signal conditioning → used to process output signal from sensor of a measurement system to make it suitable for the next stage operation.

- Most sensors → **weak output signals**.
- The magnitudes signals → the order of **microvolts** (μV) or **pico-amperes** (pA).
- The output signal of any transducer usually needs to be modified by elements known as **intermediate elements**.
- Standard electronic data processors (e.g. A/D converters, frequency modulators, data recorders, etc.) → require input signals of **sizable magnitudes on the order of volts** (V) and milliAmperes (mA).



Introduction

1. **Amplifier**= for amplifying the transducer output, which may be small.
   - An element that increase the magnitude of the signal from a transducer so that it can be conveniently displayed or recorded.
   - Can be identified as an electronic devices / group of devices, which **increase the magnitude of voltage / current signal**, without altering the signal basic characteristic.
   - It has a **power supply separate** from the signal that it is acting on.

2. Attenuators= to reduce the magnitude of the signals from the transducers.

- If for some reasons we need to supply internal components inside data acquisition system with low voltage, we should use so called attenuator.
  - Attenuator → electronic device that reduces the (magnitude) power of a signal without distorting its waveform.

Introduction

3. Compensating devices= to improve characteristics like frequency response, impedance loading, etc.

4. Differentiating or integrating elements= to proportionate the output to the desired input which may be, for example, displacement, velocity or acceleration, in any given situation.

5. Filters= for filtering out unwanted portions of the signal.

6. A-D/D-A converter= convert analog type signal to digital form or vice versa.

7. Data transmission elements= transmit the transducer output to certain distance as desired.

Mechanical Amplifying Element

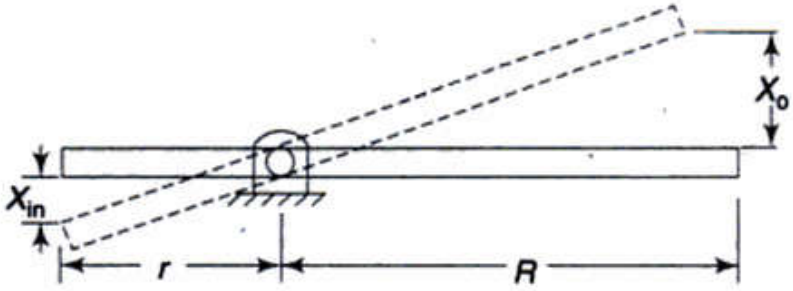


Fig. 5.1 *A typical mechanical amplifier (a lever type device)*

$$X_0 = \left(\frac{R}{r}\right) X_{in}$$

B.C.Nakra and K.K. Chaudhry, 2012. Instrumentation measurement and analysis, 3rd ed., Tata-McGraw-Hill.

Hydraulic Amplifying Element

- Is find a wide range of applications in form of hydraulic actuators in the control elements used in the **automobile hydraulic brakes** and **hydraulic steering systems**.
- Pro= **compactness** for a specified force.
- Cons= possible **leakages** and problems in dusty environments.

Hydraulic Amplifying Element

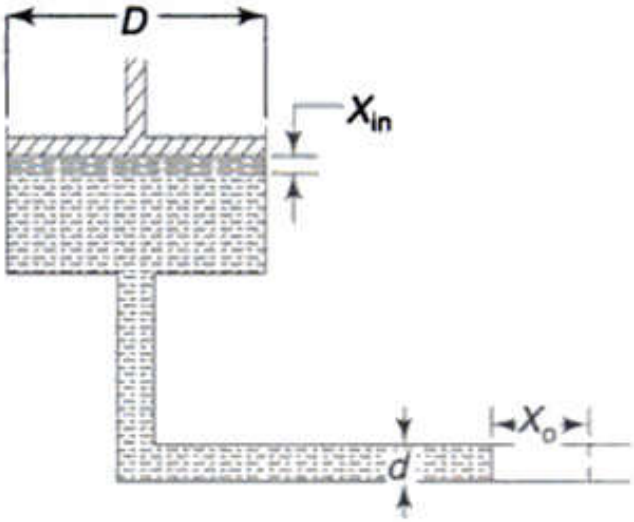


Fig. 5.2 *A typical hydraulic type of amplifier*

$$X_0 = \left(\frac{D}{d}\right)^2 X_{in}$$

B.C.Nakra and K.K. Chaudhry, 2012. Instrumentation measurement and analysis, 3rd ed., Tata-McGraw-Hill.

Pneumatic Amplifying Element

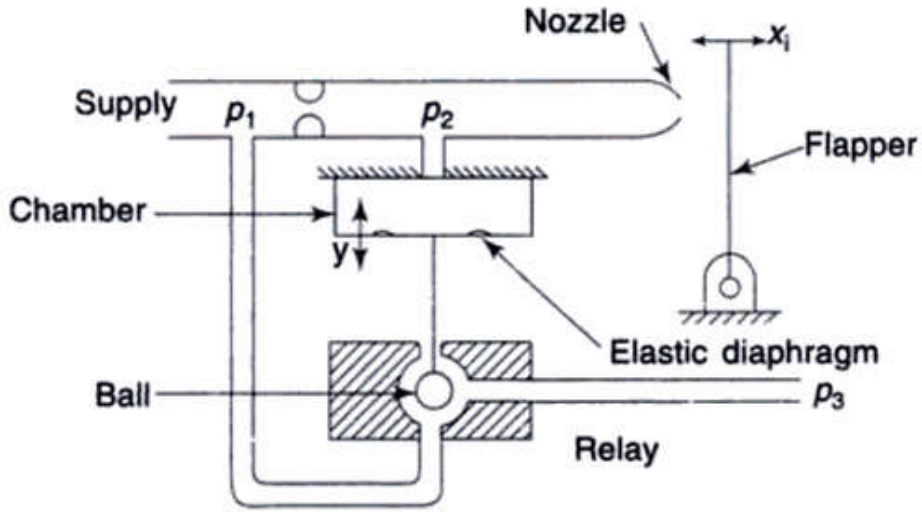


Fig. 5.3 *Pneumatic relay as amplifier*

B.C.Nakra and K.K. Chaudhry, 2012. Instrumentation measurement and analysis, 3rd ed., Tata-McGraw-Hill.

Pneumatic Amplifying Element

- In order to amplify pressure signal p_2 , a ball type relay is shown which is operated by the motion of an elastic diaphragm which get deflected due to p_2 .
- If the ball is at the lowest position, pressure p_3 is atmospheric while at the topmost position, p_3 equals air supply pressure p_1 .
- Thus, p_3 changes from zero gauge pressure to p_1 due to a small pressure change in p_2 and so the relay can be treated as a pneumatic amplifier.
- These are used in industrial environment where compressed air is easily available.

Optical Amplifying Element

- Most common used in the taut suspension type of the optical type of galvanometer which is a very sensitive type of instrument.
- **Pro**= inexpensive but provides a large amount of amplification to the input signals.
- **Cons**= due to inertia effects of because of mirror mass cannot be employed in the dynamic type of measurements.

Optical Amplifying Element

$$X_0 = 2R\theta_i$$

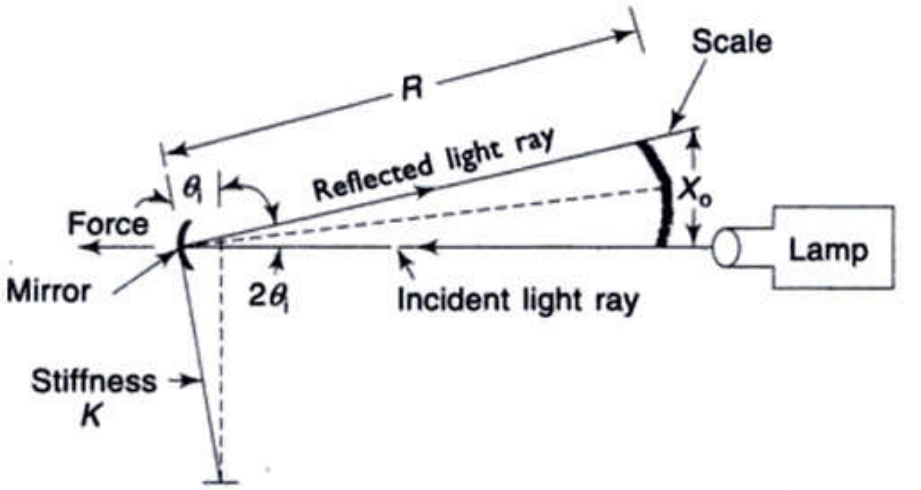


Fig. 5.4 *A typical lamp and scale arrangement*

B.C.Nakra and K.K. Chaudhry, 2012. Instrumentation measurement and analysis, 3rd ed., Tata-McGraw-Hill.

Electrical Amplifying Element

- Most of the electrical amplifiers are either **transistor** based or employ suitable **integrated circuits** (ICs) or both.
- Nowadays, a wide variety of amplifiers are available to meet the specific requirements in the signal conditioning element of the instrument systems.
- In amplifiers, an **external power source** is invariably required.

Electrical Amplifying Element

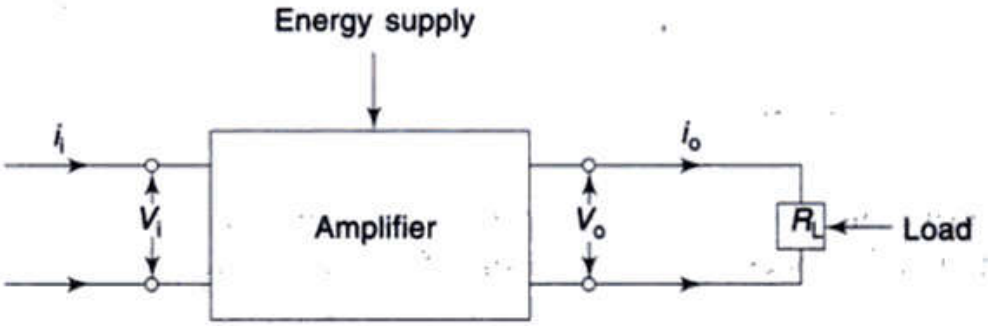


Fig. 5.5 *A typical electrical amplifying element*

Voltage gain?

Current gain?

Power gain – decibels?

B.C.Nakra and K.K. Chaudhry, 2012. Instrumentation measurement and analysis, 3rd ed., Tata-McGraw-Hill.

Electrical Amplifying Element

- Type of amplifiers:
  - AC and DC amplifiers
  - Carrier amplifiers
  - Chopper amplifiers