Elements of an Instrument

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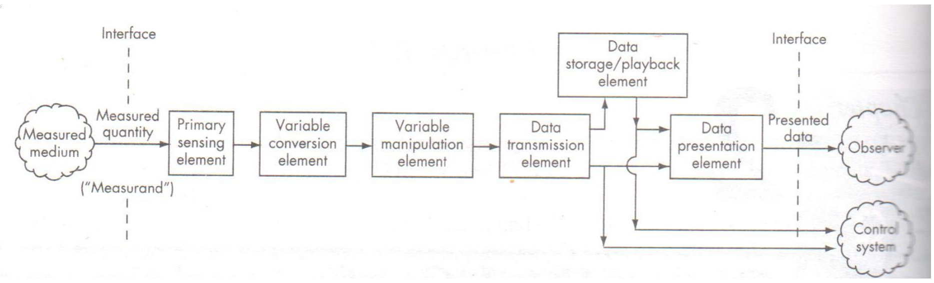
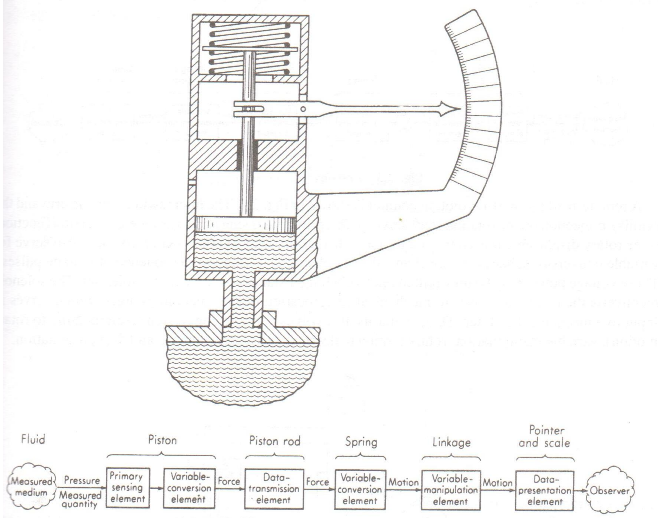
Functional Elements of an Instrument

- Operation characteristics of an instrument can be described by its static and dynamic performance characteristics
- If one tries to generalize the functional elements of an instrument or measurement system, we have



Pressure Gauge



Functional Elements of an Instrument
(contd.)

- Primary Sensing Element: First element which receives energy from the measured medium and produces an output (in some manner)
- Variable Conversion Element: Convert the output of the primary sensing element to a more suitable variable (eg. Motion converted to voltage)
- Variable Manipulation Element: May involve amplification or some other manipulation of the signal
- Data Transmission Element: It is usually necessary to transmit the data from one to the next block

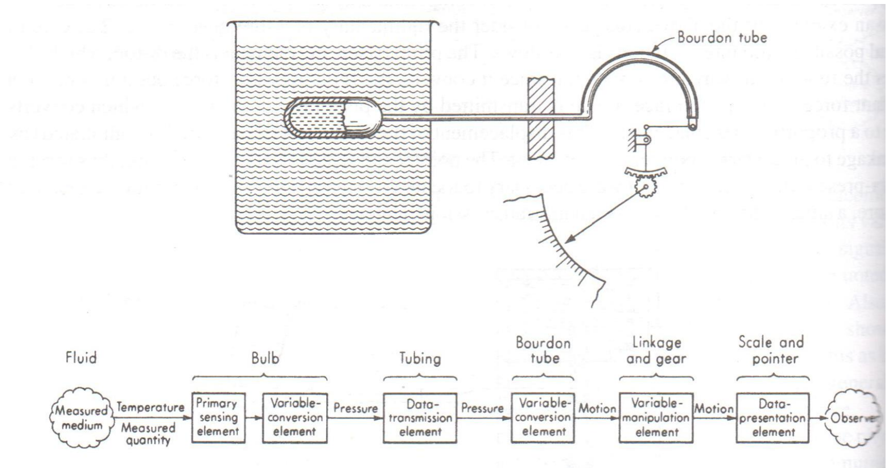
Functional Elements of an Instrument
(contd.)

- Data Presentation Element: Information put in form understood by humans (eg. Pointer on a scale; Pen moving on a chart)

Notes:

1) Concept of various *functional* elements (and **not** *physical* elements) is presented above
2) A *physical* element may perform tasks of more than one *functional* element
3) The order in which blocks are arranged may change between instruments

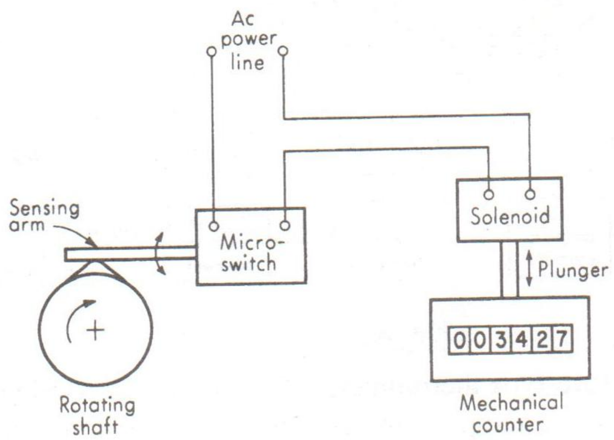
Pressure Thermometer



Active and Passive Transducers

- Transducer: Input and output of *different energy types*. So transducer is a device involving energy conversion (mechanical to electrical, for example)
- Passive Transducer: A component whose *output energy is supplied entirely* (or almost entirely) *by its input signal* is called a passive transducer
- Active Transducer: *Has an auxiliary source of power* supplying a major part of the output power (input signal supplies only an insignificant portion of power)
  (Digital revolution counter is an active device)

Digital Revolution Counter



Analog and Digital Modes of Operation

- Analog signal: The *precise value* of the quantity (voltage, rotation angle, etc) carrying the information is significant

- Digital signal: Basically *binary* (ON/OFF) type

  Typically, +2 to +5 V : ON state

  0 to +0.8 V : OFF state

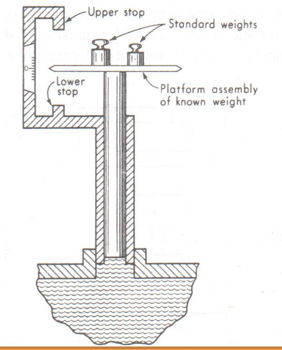
  Note: Both 2.5 and 3 V have the same meaning in digital signal (ON state) but different meaning if signal is analog. So digital signals more tolerant to "noise".

Analog and Digital Modes of Operation
(contd.)

- A measurement system may have combined analog/digit systems
- Majority of primary sensing elements are of analog type
- Digital revolution counter is however of digital type
- Importance of digital instruments is increasing because digital computers are used in data-reduction and automatic control systems
- Most measurement systems have "analog-to-digital convertors" (input to computer) and/or "digital-to-analog convertors" (output from computer)

Null and Deflection Methods

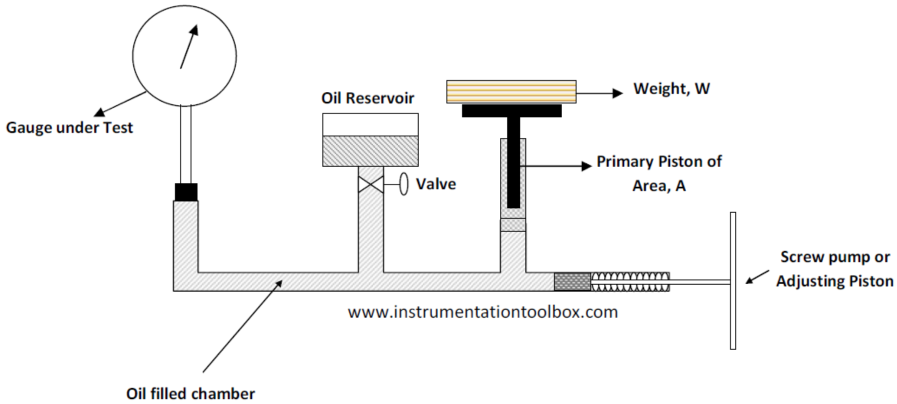
- In a *deflection type* device, the measured quantity produces an effect
- In contrast, in a *null type* device, deflection is maintained zero (by application of a suitable opposing effect)



Comparison of Null and Deflection Methods

- Comparing pressure gauges, note that accuracy of pressure gauge with spring (deflection type gauge) depends on calibration of spring; for deadweight pressure gauge (null type gauge), accuracy depends on standard weights. So accuracy higher in the latter case.
- In general, higher accuracy attained with null-type gauges. (Spring has to be calibrated against some standard. Whereas, in null type, direct comparison against standard is possible.)
- Also, high sensitivity to any deflection around zero can be achieved (since smaller range is to be covered)
- The detector need not be calibrated (since it has to detect only presence or direction of unbalance)

Calibration of pressure gauge with deadweight pressure gauge



From internet

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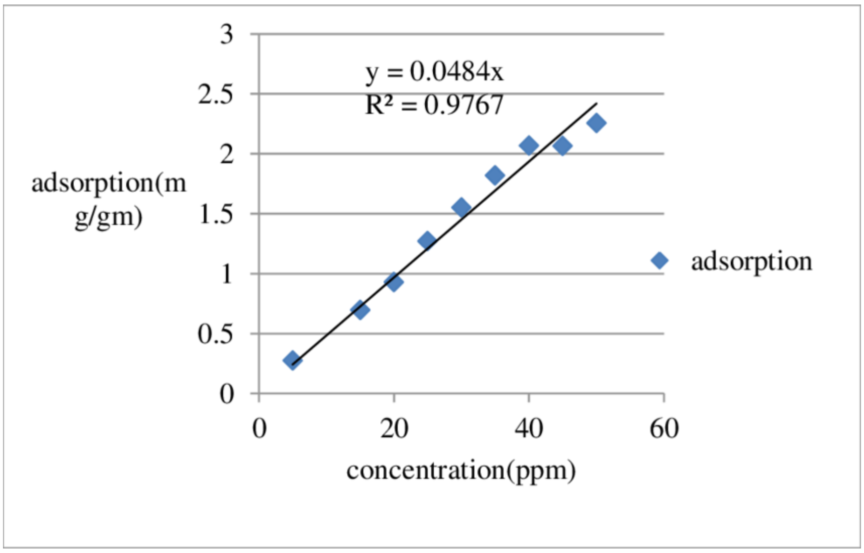
Example

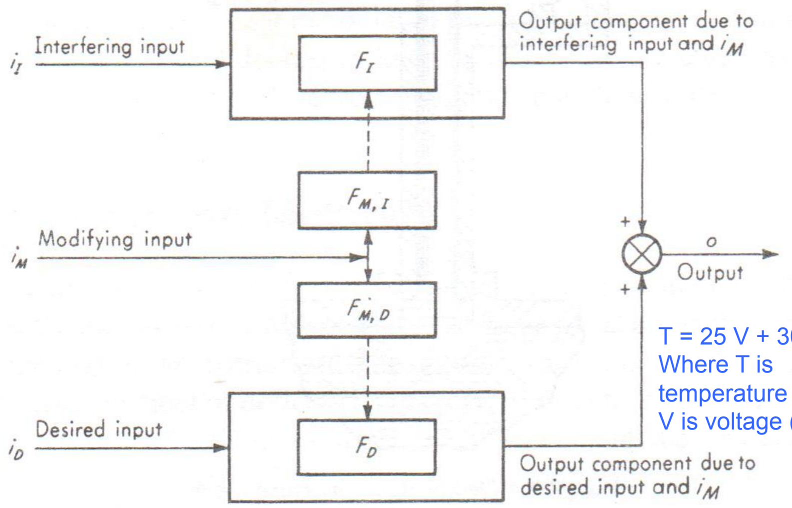


Input-Output Configuration of Instruments

Input quantities can be: desired, interfering or modified inputs

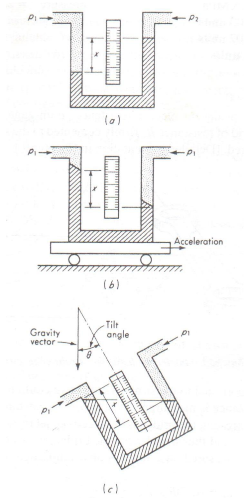
- Desired inputs: Quantities that the instrument is designed to measure
- Interfering inputs: Quantities to which the instrument is unintentionally sensitive
- Modifying inputs: Quantities that cause change in the input-output relations for the desired and interfering inputs. (Note: may affect both desired and interfering inputs.)

Generalized Input-Output Configuration



T = 25 V + 30
Where T is temperature (°C); V is voltage (V)

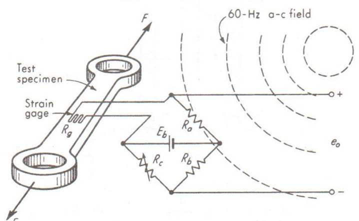
Spurious Inputs for Manometer



- <u>Interfering input</u> for manometer: acceleration
- <u>Modifying inputs</u> for manometer include ambient temperature (changes length of the calibration scale; density of mercury) and gravitational force (due to change in latitude/ altitude of the manometer) – these factors change the proportionality factor

Methods of Correction for Interfering and Modifying Inputs

- <u>Method of inherent insensitivity</u>: Make the instrument inherently sensitive only to the desired inputs. That is, make F_I and $F_{M,D}$ (see **Generalized Input-Output Configuration** slide) as close to zero as possible. Thus, even when i_I and/or i_M exist, they do not affect the output.
- <u>Eg.</u> Strain gauge with very low temperature coefficient of resistance, but very high sensitive to strain (metal alloy Invar and glass/ceramic Zerodur meet these requirements)



Methods of Correction for Interfering and Modifying Inputs (contd.)

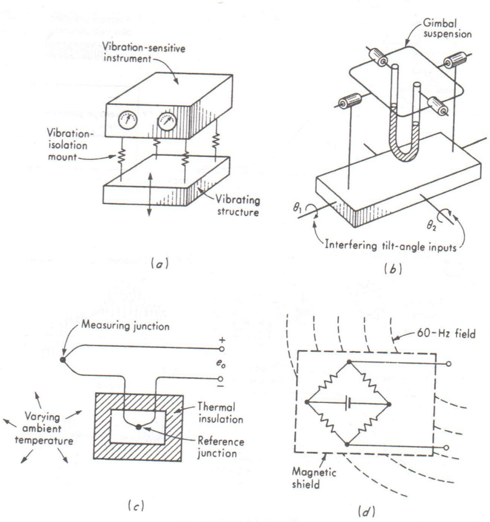
- Method of calculated output corrections: requires measurement/ estimation of the magnitudes of interfering and/or modifying inputs and to know quantitatively how they affect the output
- That is, estimate the amount of correction and subtract from the indicated output

- Eg. For manometer, effect of temperature on scale's length and density of mercury is known and can be corrected
- Similarly, change in value of 'g' with location can be accounted for

- Some of these corrections can be done on-board using smart sensors

Methods of Correction for Interfering and Modifying Inputs (contd.)

- Method of signal filtering (examples)



Methods of Correction for Interfering and Modifying Inputs
(contd.)

- Method of signal filtering (examples)

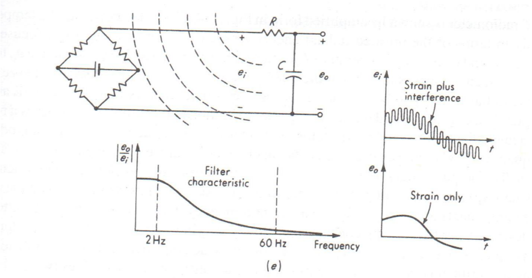


Fig. 2.14 (a)-(e) Examples of filtering.

Methods of Correction for Interfering and Modifying Inputs
(contd.)

- Method of signal filtering (examples)