Characteristics and Choice of Transducers

When choosing a transducer for any application the input, transfer and output characteristics have to be into account.

Input Characteristics

1. ***Type of input and operating range :*** The foremost consideration for the choice of a transducer input quantity it is going to measure and its operating range. The type of input, which can b physical quantity, is generally determined in advance.

2. ***Loading Effects :*** Ideally a transducer should have no loading effect on the input quantity measure

Transfer Characteristics

The transfer characteristics of transducers required attention of three separate element, viz, (i) transfer function (ii) error, and (iii) response of transducer to environmental influences.

1. ***Transfer Function :*** The transfer function of a transducer defines a relationship between the quantity and the output.

2. ***Error :*** The errors in transducers occur because they do not follow, in many situations the input-o relationship given by $q_0 = f(q_i)$. Any departure from the above relationship results in errors.

3. ***Transducer Response:*** The response of the transducer to environment influences is of a g importance. This is often given insufficient attention when choosing the best transducer for a partic measurement.

Output Characteristics

The three conditions in the output characteristics which should be consider are.

1. ***Type of Electrical output:*** The type of output which may be available from the transducers may be a voltage, current, impedance or a time function of these amplitudes. These output quantities may or may not be acceptable to the latter stages of the instrumentation system.

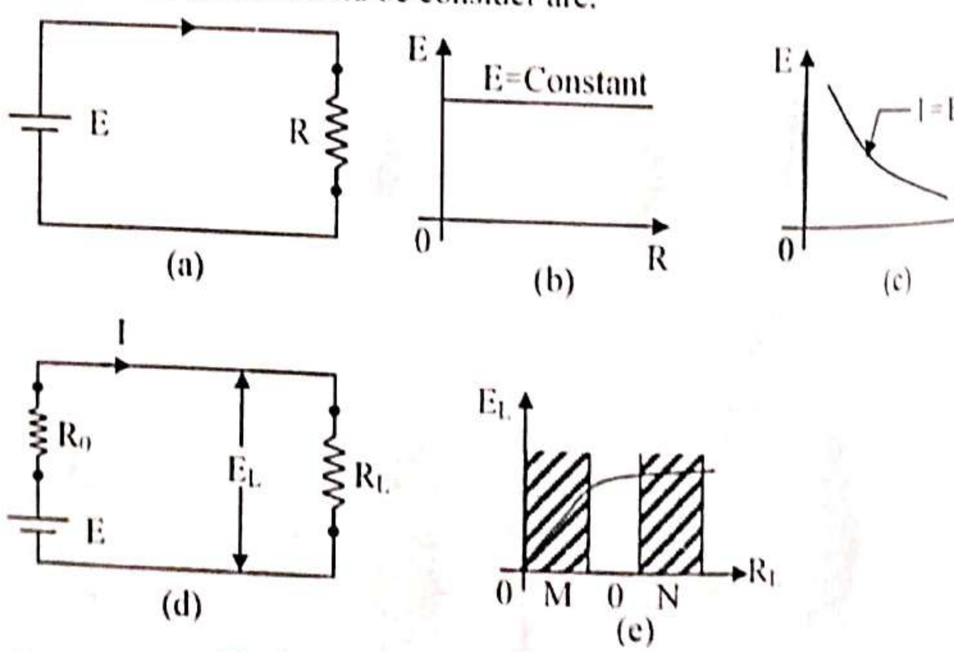


Fig. Depiction of a constant voltage source

2. ***Output Impedance:*** The output impedance, Z_0, of a transducer determines to the extent the subsequent stages of instrumentation is loaded.

3. ***Useful Output Range:*** The output range of a transducer is limited at the lower end by noise signals which may surround the desired input signal.

Summary of Factors influencing the choice of Transducers

In the following parts of this chapter, an attempt has been made to give the details and applications of the transducers for measurement of different physical quantities.

1. ***Operating principle:*** The transducers are many a times selected on the basis of operating principle used by them. The operating principles used may be resistive, inductive, capacitive, optoelectronic, piezoelectric etc.

2. ***Sensitivity:*** The transducer must be sensitive enough to produce detectable output.

3. ***Operating Range:*** The transducer should maintain the range requirements and have a good resolution over its entire range. The rating of the transducer should be sufficient so that it does not breakdown while working in its specified operating range.

4. ***Accuracy:*** High degree of accuracy is assured if the transducer does not require frequent calibration and has a small value for repeatability. It may be emphasized that in most industrial applications, repeatability is of considerably more importance than absolute accuracy.

5. ***Cross sensitivity:*** Cross sensitivity is a further factor to be taken into account when measuring mechanical quantities. There are situations where the actual quantity is being measured is in one plane and the transducer is subjected to variations in another plane.

6. ***Errors:*** The transducer should maintain the expected input–output relationship as described by its transfer function so as to avoid errors.

7. ***Transient and Frequency Response:*** The transducer should meet the desired time domain specification line peak overshoot, rise time, setting time and small dynamic error. It should ideally have a flat frequency response curve. In practice, however, there will be cutoff frequencies and higher cut off frequency should be high in order to have a wide bandwidth.

8. ***Loading Effects:*** The transducer should have a high input impedance and a low output impedance to avoid loading effects.

9. ***Environmental Compatibility.*** It should be assured that the transducer selected to work under specified environmental conditions maintains its input–output relationship and does not break down.

10. ***Insensitivity to Unwanted Signals:*** The transducer should be minimally sensitivity to unwanted signals and highly sensitive to desired signals.

11. *Usage and Ruggedness:* The ruggedness both o mechanical and electrical intensities of tra versus its size and weight must be considered while selecting a suitable transducer.

12. *Electrical aspects:* The electrical aspects that need consideration while selecting a transducer the length and type of cable required.

13. *Stability and Reliability*. The transducer should exhibit a high degree of stability to be operative its operation and storage life.

14. *Static Characteristics:* Apart from low static error, the transducers should have a low non-linear hysteresis, high resolution and a high degree of repeatability.

Static Performance Parameter

The definitions and brief descriptions of the various static performance parameters of the instruments are follows.

Accuracy

Accuracy of a measuring system is defined as the closeness of the instrument output to the true value measured quantity (as per standards).

For Example, if a chemical balance reads 1 g with an error of 10^{-2}g, the accuracy of the measurement would specified as 1%.

The accuracy of the instruments (which represents really is inaccuracy) can be specified in either following forms:

1. Percentage of true value (Accuracy)

$$= \frac{\text{measured value - true value}}{\text{true value}} \times 100$$

2. Percentage of full–scale deflection (Guaranteed Accuracy Error)

$$= \frac{\text{measured value - true value}}{\text{maximum scale value}} \times 100$$

NOTE – it is noted that accuracy specification of the instrument as a percentage of full scale deflection (% of fsd) is less accurate than the percentage of true value (% of TV). For example, an error ±1% of full-scale deflection of a voltmeter having a range of 1000 V means that a true voltage of 100V could be read from 90 110V

Precision

Precision is defined as the ability of the instrument to reproduce a certain set of readings within a given accuracy.

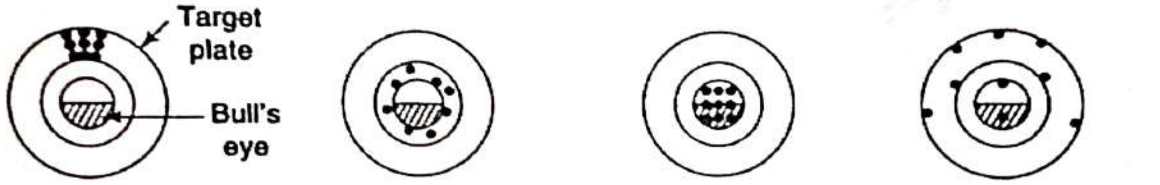
Precious of an instrument is in fact, dependent on the repeatability. The term repeatability can be defined as the ability of the instrument to reproduce a group of measurements of the same measured quantity, made by the same observer, using the same instrument, under the same conditions.

Accuracy versus Precision

It may be noted that accuracy represents the degree of the measured value with respect to the true value. On the other hand, precision represents degree of repeatability of several independent measurements of the desired input at the same reference conditions. As mentioned before, accuracy and precision involved in a measurement are dependent on the systematic and random errors, respectively. Therefore, in any experiment both the quantities have to be evaluated. The former is determined by proper calibration of the instrument and the latter by statistical analysis. However, it is instructive to note that a precise measurement may not necessarily be accurate and vice versa. To illustrate this statement we take the example of a person doing shooting practice on a target. He can hit the target with the following possibilities as shown in Fig.

1. One possibility is that the person hits all the bullets on the target plate on the outer circle and misses the bull's eye [Fig. (a)]. This is a case of high precision but poor accuracy.
2. Second possibility is that the bullets are placed as shown in Fig. (b). In this case, the bullet hits are placed symmetrically with respect to the bull's eye but are not spaced closely. Therefore, this is case of good average accuracy but poor precision.
3. A third possibility is that all the bullets hit the bull's eye and are also spaced closely [Fig. (c)]. As is clear from the diagram, this is a case of high accuracy and high precision.
4. Lastly, if the bullets hit the target plate in a random manner as shown in Fig. (d), then this is a case of poor precision as well as poor accuracy.

Based on the above discussion, it may be stated that in any experiment, the accuracy of the observations can be improved but not beyond the precision of the apparatus.



(a) High precision with poor accuracy **(b) Good average accuracy with poor precision** **(c) High accuracy with high precision** **(d) Poor accuracy with poor precision**

Fig. Illustration of degree of accuracy and precision in a typical target shooting experiment

Resolution (or Discrimination)

It is defined as the smallest increment in the measured value that can be detected with certainty by the instrument. In other words, it is the degree of fineness with which a measurement can be made.