MODULE 1
Mechanical Measurements

1. Introduction to Mechanical Measurements

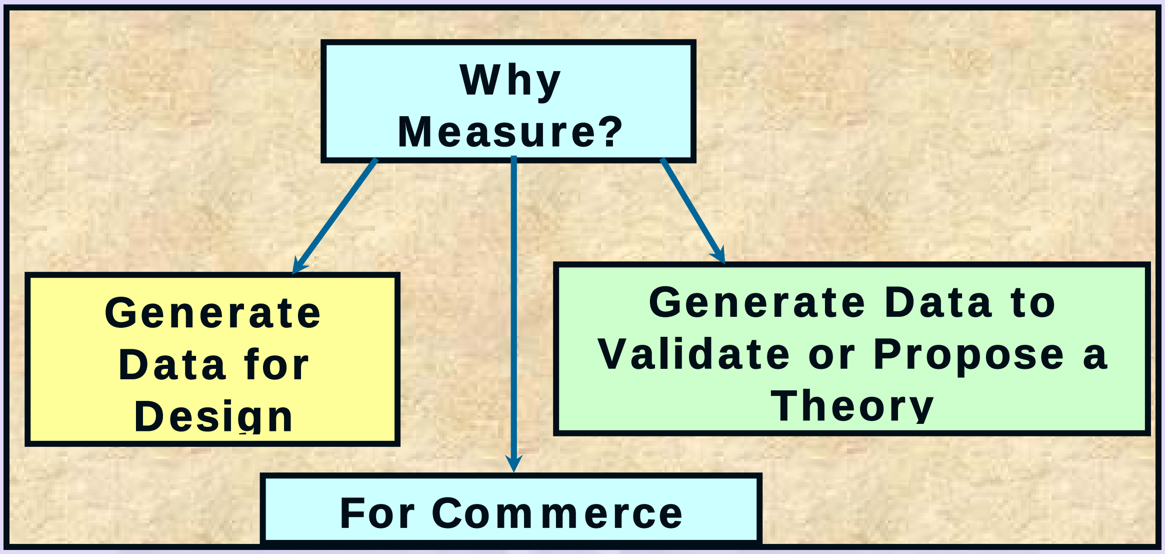

Figure 1 Why make measurements?

We recognize three reasons for making measurements as indicated in Figure 1. From the point of view of the course measurements for commerce is outside its scope.

Engineers design physical systems in the form of machines to serve some specified functions. The behavior of the parts of the machine during the operation of the machine needs to be examined or analyzed or designed such that it functions reliably. Such an activity needs data regarding the machine parts in terms of material properties. These are obtained by performing measurements in the laboratory.

The **scientific method** consists in the study of nature to understand the way it works. Science proposes hypotheses or theories based on observations and need to be validated with carefully performed experiments that use many measurements. When once a theory has been established it may be used to make predictions which may themselves be confirmed by further experiments.

Measurement categories

1. *Primary quantity*
2. *Derived quantity*
3. *Intrusive – Probe method*
4. *Non-intrusive*

Measurement categories are described in some detail now.

1. Primary quantity:

It is possible that a **single quantity** that is **directly measurable** is of interest. An example is the measurement of the diameter of a cylindrical specimen. It is directly measured using an instrument such as vernier calipers. We shall refer to such a quantity as a **primary quantity**.

2. Derived quantity:

There are occasions when a quantity of interest is not **directly measurable** by a single measurement process**.** The quantity of interest needs to be estimated by using an appropriate relation involving several measured primary quantities. The measured quantity is thus a **derived quantity**. An example of a derived quantity is the determination of acceleration due to gravity (g) by finding the period (T) of a simple pendulum of length (L). T and L are the measured primary quantities while g is the derived quantity.

3. Probe or intrusive method:

Most of the time, the measurement of a physical quantity uses a **probe** that is placed inside the system. Since a probe invariably affects the measured quantity the measurement process is referred to as an **intrusive** type of measurement.

4. Non-intrusive method:

When the measurement process does not involve insertion of a probe into the system the method is referred to as being **non-intrusive**. Methods that use some naturally occurring process like radiation emitted by a body to measure a desired quantity relating to the system the method may be considered as non-intrusive. The measurement process may be **assumed to be non-intrusive** when the probe has negligibly small interaction with the system. A typical example for such a process is the use of laser Doppler velocimeter (LDV) to measure the velocity of a flowing fluid.

General measurement scheme:

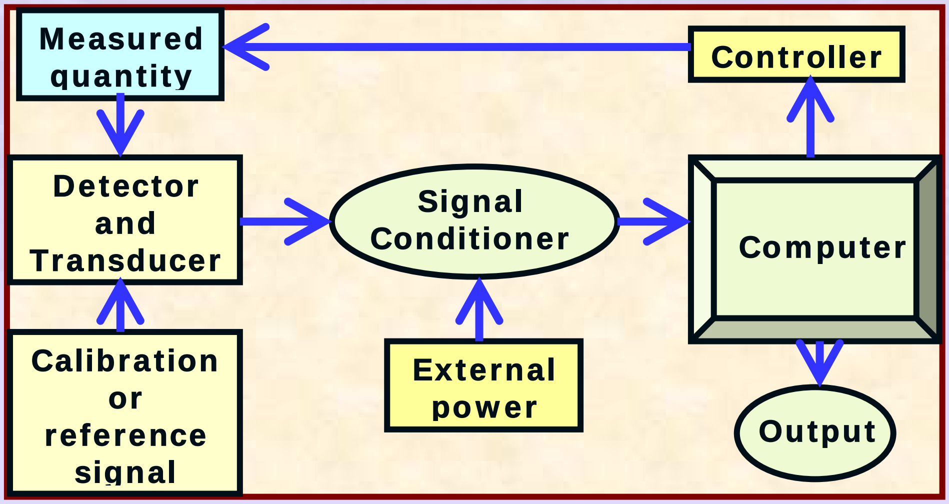

Figure 2 Schematic of a general measurement system

Figure 2 shows the schematic of a general measurement scheme. Not all the elements shown in the Figure may be present in a particular case. The measurement process requires invariably a **detector** that responds to the measured quantity by producing a measurable change in some property of the **detector**. The change in the property of the detector is converted to a measurable output that may be either mechanical movement of a pointer over a scale or an electrical output that may be measured using an appropriate electrical circuit. This action of converting the measured quantity to a different form of output is done by a **transducer.** The output may be manipulated by a signal conditioner before it is recorded or stored in a computer. If the measurement process is part of a control application the computer can use a controller to control the measured quantity. The relationship that exists between the measured quantity and the output of the transducer may be obtained by **calibration** or by **comparison** with a **reference value**. The measurement system requires external power for its operation.

Some issues:

1. *Errors – Systematic or Random*
2. *Repeatability*
3. *Calibration and Standards*
4. *Linearity or Linearization*

Any measurement, however carefully it is conducted, is subject to measurement **errors**. These errors make it difficult to ascertain the **true value** of the measured quantity. The nature of the error may be ascertained by **repeating** the measurement a number of times and looking at the spread of the values. If the spread in the data is small the measurement is **repeatable** and may be termed as being good. If we compare the measured quantity obtained by the use of **any instrument** and compare it with that obtained by a **standardized instrument** the two may show different performance as far as the **repeatability** is concerned. If we add or subtract a certain correction to make the two instruments give data with similar spread the correction is said to constitute a **systematic error**. The spread of data in each of the instruments will constitute **random** error.

The process of ascertaining the systematic error is **calibration**. The response of a detector to the variation in the measured quantity may be **linear** or **non-linear**. In the past the tendency was to look for a linear response as the desired response. Even when the response of the detector was non-linear the practice was to make the response linear by some manipulation. With the advent of automatic recording of data using computers this is not necessary since software can take care of this aspect.