Basic input circuits-Active and passive transducer-Error-types-calibration.

Basic input circuits

The output available from the sensor or transducer is often not compatible with the desired transmission system or display unit. This can be made to be so by appropriate signal conditioning and processing of data thereafter. Depending on the type and mode of the output from the sensor, the intermediate stage of conditioning of signal is decided. There may be a number of units in this conditioning stage. A very simple instrumentation system is represented in the figure.

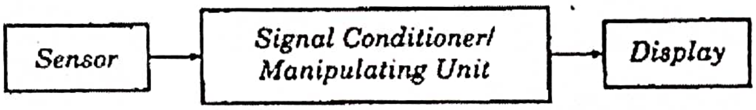


Fig A simple instrumentation system.

The manipulating unit consists mainly of a conversion circuit (a bridge circuit), an amplifier, if necessary an impedance matching circuit, for transmission a modulation circuit and a detector fro display. All units are not always necessary and sometimes some more and different units are needed.

The present day trend is to convert the sensor output into an electrical signal first whatever be the form of its original output as conditioning and data processing are much more convenient by electrical means.

1 Basic input circuits (Interfacing circuits)

Interfacing circuit or input circuit is an electrical circuit that interfaces the sensor/transducer (where electrical output is available) with the more demanding signal conditioning equipment like amplifier, modulator, processor, etc. There are a number of such circuits performing appropriate functions in the interfacing stage. One major reason of such circuits is that the transducer may be a passive type and requires an auxiliary source of energy for giving a signal in voltage or in current. As mentioned earlier, bridge circuit is a very common interfacing circuit. There are others like ballast circuits current sensitive circuits, voltage divider circuits etc.

2 Current sensitive circuit

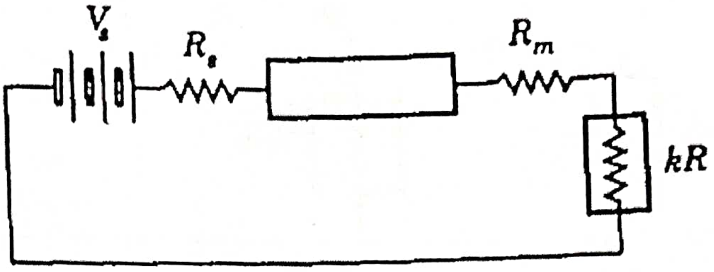


Fig. ! A current sensitive circuit.

It is basically a series circuit of the voltage supply, a current indicating/recording device and the transducer of the resistance type. The supply source has a internal resistance R_S. The meter has a resistance R_m and the transducer resistance may vary between 0 and R (say) – let it be represented by kR when 0 £ k £1. The circuit schematic is shown in Fig. 13.2. The meter current at any stage is i with a maximum of i_x.

Let $R_m + R_s = R_T$ then the circuit current is given by

$$i = \frac{V_S}{R_T + kR}$$

The maximum current occurs when k = 0, so that

$$i_x = \frac{V_S}{R_T}$$

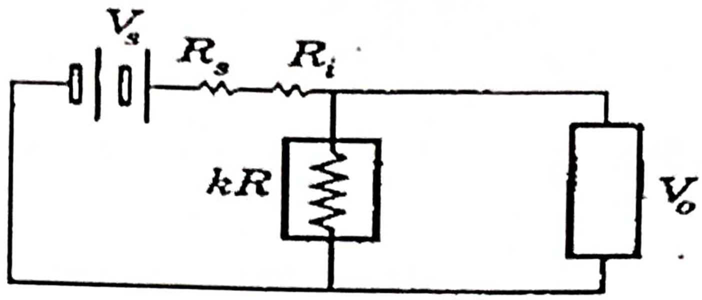
giving the ratio

$$\frac{i}{i_x} = \frac{1}{1 + k\dfrac{R}{R_T}}$$

The output, I is a function of i_x i.e. of V_S and it should be maintained constant. The sensitivity of the system increases with increasing R/R_T i.e. system is nonlinear.

Ballast circuit

3



: A ballast circuit.

It is a voltage sensing circuit instead of the current sensing type. The scheme is shown in Fig. 13.3. V_S is the supply voltage, R_V is the supply or voltage source resistance, V_0 is the supply voltage, R_V is the supply or voltage source resistance, V_o is the voltage indicated or recorded for a variation in R again given as kR, R_i is a resistance introduced in the position as shown and $R_i >> R_S$. The resistance R_i is known as the ballast resistance.

For the voltmeter having a very high resistance, current through $R_i + R_S$ is

$$\frac{V_s}{R_i + R_s + kR}$$

and the voltage across kR is also the output voltage V_0

$$V_o = ikR = \frac{V_s kR}{R_i + R_s + kR}$$

or

$$\frac{V_o}{V_s} = \frac{kR/(R_i + R_s)}{1 + kR/(R_i + R_s)} = \frac{kR/R_b}{1 + kR/R_b}$$

With change in measurand k changes so that change in V_0 with k is given by

$$\frac{dV_o}{dk} = \frac{V_s(R_i + R_s)R}{(R_i + R_s + kR)^2}$$

There is, however, an optimum choice of R_i (or, $R_i + R_S = R_b$ say) for which sensitivity can be made maximum. By differentiating V_0 with respect to R_b, this is obtained as

$R_b = kR$

Obviously, this also varies with sensor output resistance

Loading Error

If the voltmeter draws a current, there is an error in measurement called the loading error. If the meter has a resistance R_m then the total resistance seen by the source V_s is

$$R_t = R_b + \frac{kR \times R_m}{kR + R_m}$$

and the current is now

$$i = \frac{V_s}{R_t} = \frac{V_s}{\left[\frac{(kR + R_m)R_b + R_m kR}{kR + R_m}\right]}$$

so that the output voltage is now

$$V_o = V_s - iR_b$$

$$= \frac{V_s - V_s R_b / [R_b(kR + R_m) + kRR_m}{kR + R_m}$$

$$= V_s \frac{kR / R_b}{1 + kR / R_m + kR / R_b}$$

By taking the difference one can show that

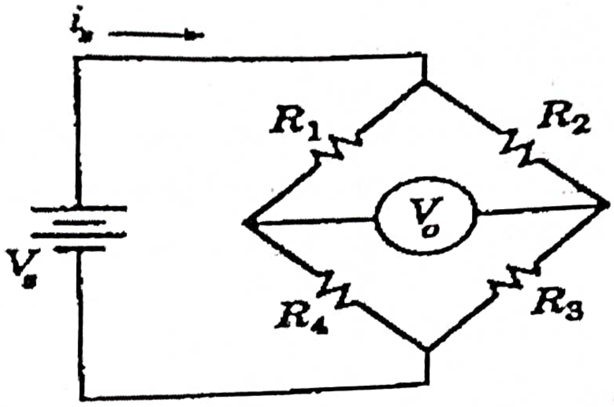
$$\Delta V_o = V_s \left[\frac{1}{1 + \frac{1 + kR / R_b}{kR / R_b}}\right]$$

so that the % error is

$$E\% = \frac{\frac{100}{1 + \frac{1 + kR / R_b}{kR / R_m}} \times \frac{1 + kR / R_b}{kR / R_b}}{}$$

It is worthwhile to note that (percentage) error also is a function of k.

Bridge Circuits



The wheatstone bridge circuit.

The most common interfacing circuit between a passive sensor and the measurement system is the bridge circuit. Wheatstone bridge is a circuit that is extensively used till today although it was devised as early as 1833. A lot of variation has since been in operation of this bridge without altering the basic structure which is shown in Figure.

The resistance bridge supply is V_s and output V_o. Solving for $V_o = 0$, the condition in terms of R_1, R_2, R_3 and R_4 is obtained as

$$\frac{R_1}{R_4} = \frac{R_2}{R_3} \quad or \quad \frac{R_1}{R_2} = \frac{R_4}{R_3}$$

This is called the null-balance bridge. It is possible to take output V_o for different values of resistance. It is initially balanced satisfying the above condition and subsequently the unbalanced voltage is measured b a voltmeter of very high impedance. However, alternative to this, a current meter may also be connected and response observed.

For voltage detector scheme with very high impedance of the detector and R_4 as the sensor resistance that changes to R_4 + DR_4 and initially with $R_1 = R_2 = R_3 = R_4 = R$ one derives.

$$\frac{\Delta V_o}{V_s} = \frac{\Delta R_s / R}{4 + 2\dfrac{\Delta R_s}{R}}$$

which changes to

$$\frac{\Delta V_o}{V_s} = \frac{\Delta R_s}{4R}$$

for $DR_s << R$.

If, instead, a galvanometer is used as a detector with its resistance R_g often chosen to be equal to R_v and, again with all R/s equal initially to R, one derives the incremental detecting current through the galvanometer for an incremental change in R_1 equal to DR_1 say, and is given as

$$\frac{\Delta i_g}{i_g} = \frac{-\Delta R_1 / R_1}{4\left(1+\frac{R_g}{R}\right)+\left(2+\frac{R_g}{R}\right)}$$

where i_g is the current supplied by the source.

Bridge circuits have been used in ac operation for resistance, capacitance as well as inductance measurement. Impedance bridges, as they are called, are listed in figure

Active and passive transducers

To perform all the general functions, a physical component may act as an active transducer or a passive transducer.

A component whose output energy is supplied entirely or almost entirely by its input signal is commonly called a passive transducer. The output and input signals may involve energy of the same from or there may be an energy conversion from one form to another farm.

An active transducer has an auxillary source of power which supplies a major part of the output while the input signal supplies only an insignificant portion.

Error Analysis

Types of Errors

a) Gross errors- largely human errors, among them misreading of instruments, incorrect adjustment and improper application of instruments and computational mistakes.

b) Random errors –those errors that cannot be directly established because of random variations in the parameter or the system of measurement.

c) Systematic errors- Shortcomings of the instruments such as defective or worn parts and effects of the environment on the equipment or the user.

Types of systemic errors

- Instrumental errors
- Environmental errors
- Static errors
- Dynamic errors

The uncertainty in the final result is due to the uncertainties in the primary measurements. This may be done by a commonsense analysis of the data which may take many forms. One rule of thumb that could be used that the error in the result is equal to the maximum error in any parameter used to calculate the result. Another commonsense analysis would combine all the errors in the most detrimental way in order to determine the maximum error in the final result. Consider the calculation of electric power from

$P=EI$

Where E and I are measured as

$E=100V\pm2V$

$I=10A\pm0.2A$

The nominal value of the power is 100*10=1000W.by taking the worst possible variations in the voltage and current, we could calculate

$P_{max}= (100+2)(10+0.2) =1040.4W$

$P_{min}= (100-2)(10-0.2) =960.4W$

Thus, using this method of calculation, the uncertainty in the power is +4.04 percent,-3.96%.it is quite unlikely that the power would be in the error by these amounts because the voltmeter variations would probably not correspond with the ammeter variations. when the voltmeters reads an extreme " high" there is no reason that the ammeter must also read an extreme "high" at that particular instant, indeed, this combination is most unlikely.

Calibration

Calibration: To check the instrument against a known standard and subsequently to reduce errors in accuracy

Calibration procedures involve a comparison of the particular instrument with either a primary standard or a known input source.

NIST-This institute defines the standard for length, mass, time, temperature and force.

Static calibration -All the static performance characteristics are obtained in one form or another by a process called static calibration. All working instruments must be calibrated against some reference instruments which have a higher accuracy.

Error calibration-Error calibration means that an instrument has been calibrated against a suitable standard.