DIGITAL INSTRUMENTATION SETUP FOR DISPLACEMENT STRAIN AND TEMPERATURE

PROJECT REPORT

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SYNOPSIS

In these days the automation of industrial process followed for which the acquisition of non electrical data is required.

In this project measurement of non electrical quantities such as displacement, strain and temperature is considered. The transducers used are LVDT for displacement measurement, strainage for strain measurement, and thermocouple for temperature measurement.

The design and testing of the subsystems comprising of transducer circuits, amplifier and output stages with display has been completed. Working of the displacement and temperature measuring setups was satisfactory. Drift problems associated with the strain gage setup are yet to overcome.

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INTRODUCTION

1.1. MEASUREMENT:

Measurement is the result of a quantitative comparison between an unknown magnitude and the predefined standard. If the result is to be meaningful two requirements must be met, namely,:-

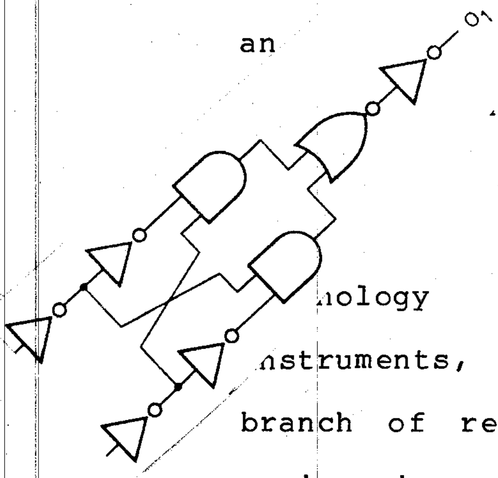
i) The standard which is used for comparison must be accurately known and commonly accepted;

ii) The procedure and equipments used for this comparison must be provable.

Need for Measurement:

Basic functions of all the branches of engineering are the design and proper operation and maintenance of equipment and systems wherein measurement plays a very important part in providing information for such purposes.

In fact all engineers activities are completely dependent on measurements, otherwise one would only be guessing and speculating. Theoretical methods cannot be used in particular applications since they requ[illegible] numerical values of universal constants which [illegible] be obtained by actual measurements during an [illegible] Hence it is only with the help of [illegible]hat engineers can produce result.



Recent advances in science and [illegible]nology and the increased applications of [illegible]nstruments, have made measurements as an important branch of research and development in every field of engineering and science. Measurements have enabled us to know more about the world we live in.

1.2 Elements of Measurement System:

It is desirable to describe the operation of a measuring instrument or a system in a generalized way without involving details of physical aspects of a specific instrument or a system. The whole operation can be described in terms of three functional elements. Each functional element is made up of a distinct component or groups of components which perform the required and definite steps in measurement. These may be taken as basic elements, whose scope is determined by their functioning rather than their construction.

Fig. 1. 1 represents the functional elements of a measuring instrument or a system.

Primary Sensing Element:

The quantity under measurement makes its first contact with primary sensing element of a measurement system. Immediately after this a transducer converts measured quantity into an analogous electrical signal. This is true in most of the cases but, in many cases the measured quantity is directly converted into an electrical quantity by a transducer.

Variable Conversion Element:

The output of the primary sensing element may be any kind of electrical signal. It may be a voltage, a frequency or some other electrical parameter. Often this output does not suit to the system. For the instrument to perform the desired function, it may be necessary to convert this output to some other suitable form while retaining the original nature of the signal.

further theoretical research. These physical quantities can be measured in form of electrical signals using transducers which convert the physical quantities into electrical signals.

An exact definition of transducer is far more general and includes devices capable of being acctuated by waves from one or more transmission systems or media and of supplying related waves to one or more other transmission systems or media. They are also called prime sensors, gages, pickups and signal generators. Transducers use almost all known electro-mechanical principles to convert the measured quantities into their electrical analogs. Most transducers contain two essential functions; an actuating device or mechanism, and the transducing element itself.

The following table 1.1 summarizes different types of transducers available and their applications in the field of instrumentation engineering.

Types of Transducers → Quantity to be measured	Capacitive	Electron tube	Inductive	Magneto electric	Magneto strictive	Photo electric	Piezo electric	Radio active	Resistive	Thermo electric
Acceleration	X	X	X	X	X		X		X	
Displacement	X	X	X	X		X	X	X	X	
Flow	X		X	X			X	X	X	
Force			X			X	X	X	X	
Humidity and moisture	X								X	
Level	X					X	X	X	X	
Light						X			X	X
Mass			X	X			X	X		
Pressure	X	X	X	X	X		X	X	X	X
Temperature						X		X	X	X
Thickness	X		X			X	X	X		
Velacity	X	X	X	X		X	X	X	X	
Viscosity	X				X		X		X	

Table I.I
Measurement versus transduction methods

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In the following chapters, schemes for the measurement of displacement, strain and temperature using linear variable differential transformer, strain gage and thermocouple transducers respectively, are discussed.

FIG. 1.1 FUNCTIONAL ELEMENTS OF A MEASUREMENT SYSTEM

CHAPTER - II

MEASUREMENT OF DISPLACEMENT

2.1. Introduction to Inductive Transducers:

For measurement of displacement inductive transducers are mainly used. The variable inductance type of transducers works generally upon one of the following principles:

Variation of self inductance
Variation of mutual inductance
Production of eddy current

2.1.1. Inductive transducers working on the principle of variation of self inductance:

In this type of transducers, the displacement to be measured is arranged to cause variation of self inductance. The variation in inductance may be caused by change in number of turns, variation in geometric configuration, change in permeability of magnetic material or magnetic circuit, or change in reluctance.

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In the case of transducers working on pricniple of change of self inductance with a number of turns, the output is caused by change in the number of turns. As is well known, the inductance of a coil is proportional to the square of the number of turns. Thus if the output is in the form of an inductance, then the inductance output is proportional to square of displacement in case the windings are uniformly wound.

Similiarly a change in geometric configuration of the coil results when one part of the coil is moved with respect to the other part. The displacement to be measured causes the movement of a part of the coil.

An inductive transducer which works on the princciple of variation of permeability to cause change of self inductance, incorporates an iron core surrounded by a winding. If the iron core is inside the winding, its inductance is high; but when the iron core is moved out of the winding, the permeability of the flux path decreases resulting in reduction of self inductance of the coil.

2.1.3 Inductive Transducers Working on the Principle of Production of Eddy Currents:

These inductive transducers work on the principle that if a conducting plate is placed near a coil carrying alternating current, eddy currents are produced in the former. The conducting plate acts as a short circuited secondary of a transformer. The eddy current flowing in the plate produces a magnetic field which acts against, the magnetic field produced by the coil. This results in a reduction of flux and thus the inductance of the coil is reduced. The nearer is the plate to the coil, the higher are the eddy currents and thus higher is the reduction in the inductance of the coil. Thus the inductance of coil varies with variation of distance between the plate and the coil.

In the present work, measurement of displacement is done using linear variable differential transformer which works on the principle of variable reluctance.

2.2. Principle of LVDT

The most widely used inductive transducer to convert the linear motion into electrical signal is the linear variable differential transformer (LVDT). Fig. 2.1 shows the schematic and circuit diagrams for translational LVDT. The two identical secondary coils have induced in them sinusoidal voltages of the same frequency as the excitation; however, the amplitude varies with the position of the iron core. When the secondaries are connected in series opposition, a null position exists at which the net output is essentially zero. Motion of the core from null then causes a larger mutual inductance (coupling) for one coil and a smaller mutual inductance for the other, and the amplitude of eo becomes a nearly linear function of core position for a considerable range either side of null. The voltage eo undergoes a 180 phase shift in going through the null. The output eo is. generally out of phase with the excitation. However, this varies wwith the frequency of excitation and for each differential transformer there exists a particular frequency at which this phase shift is zero.

Fig. 2.1 shows the core of a LVDT at three different positions. When the core is moved to the left as in (a) the voltage across one of the secondary windings is more than the other and therefore Eo is positive (By convention, this movement represents a positive value of Eo and therefore the phase angle Ø=0. When the core is moved to the right towards B as shown in (C), voltage across the winding at the side is greater than the other and hence Eo is negative. Therefore, the output voltage is 180 out of the phase with the voltage which is obtained when the core is moved to the left. Thus phase angle is equal to 180·, If the core is at 0, as in (b) which is the central zero or a null position, the voltage across both the secondaries are equal and hence output voltage Eo = 0.

The output voltage of an LVDT is a linear function of core displacement within a limited range of motion. Fig. 2.2. shows the variation of output voltage against displacement for various position of core. The curve is practically linear for small displacements. Beyond this range of displacement, the curve starts to deviate from a straight line.

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Ideally the output voltage at the null position should be equal to zero. However in actual practice there exists a small voltage at the null position. This may be on account of presence of harmonics in the input supply voltage and also due to harmonics produced in the output voltage on account of use of iron core.

2.3 Constructional Details:

Linear variable differential transformer is the most widely used inductive transducer to translate the linear motion into electrical signal. It consists of three coils wound on a single cylindrical former as shown in fig. 2.3 with centre coil acting as primary winding. The other two coils are called secondary coils and have equal number of turns and are identically placed on either side of the primary windings. The primary winding is connected to an alternatinve current source. A movable soft iron core is placed inside the former. The displacement to be measured is applied to an arm attached to the soft iron core. In practicce, the core is made of nickel iron alloy which is slotted longitudinally to reduce eddy current losses. When the core is in its normal

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(NULL) position, equal voltages are induced in the secondary windings. The frequency of a.c. applied to the primary windings maybe between 50 Hz to 20 KHz.

The transducers are generally available in two types of lead take out configurations axial and radial. In the axial type the connections are through 3 - pins co-axial connector, while in the radial type the transducer is supplied with cable integral to it. In radial lead type transducers the coil assembly has a through bore. The spring loaded transducers are supplied with a core shaft housed in a detachable spring loaded attachment housing. The core shaft is moved smoothly in bushes.

Termination:

The coil assembly consists of a primary winding and two secondary windings which are connected in series opposition. One lead of the primary winding is shorted to one lead of the composite secondary winding and is brought to the centre pin of the connector. This is known as the common lead. The other ends of the primary and composite secondary coils are also brought out to their respective pins on the connector of the transducer as shown in figure 2.4.

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2.4 Merits and Demerits of LVDTs:

Advantages of a LVDT:

* Linearity : - The output voltage is practicially linear for displacements upto 50 mm .
* It gives a high output and therefore many a times there is no need for intermediate amplification devices.
* The transducer possesses a high sensitivity as high as 40 m V / mm.
* These transducers can usually tolerate a high degree of shock and vibration without any adverse effects. They are simple and by virtue of being small and light in weight, they are stable and easy to allign and maintains:
* Infinite resolution: The change in output voltage is in discrete steps. The effective resolution depends more on test equipment than on the transducer. It is possible to build a transducer with a resolution as fine as 1×10^{-3}mm
* There are no sliding contacts and hence there is less friction and less noise.
* Repeatability is excellent under all conditions
* Low power consumption.

Disadvantages:

- Relatively large displacements are required for appreciable differential output.
- They are sensitive to stray magnetic fields but shielding is possible. This is done by providing magnetic shields with longitudinal slots.
- The receiving instrument must be selected to operate on a.c. signals or a demodulator network must be provided if d.c output is required.
- Many a time, the transducer performance is affected by vibration.
- The dynamic response is limited mechanically by the mass of the core and electrically by the frequency of applied voltage.

2.5 Block Diagram Explanation

The fig 2.5 shows the schematic diagram of a displacement measurement. The LVDT is excited using a wein bridge oscillator the secondary winding (or) winding output of LVDT is connected to a precision rectifier. Were it is rectified and then it is fed to the digital volmeter (DVM) for display in the digital form. The explanation of each block is given in the subsequent pages.

amplitude of oscillations a non-linear resistor is normally used for R1, this makes the loop gain to depend upon the amplitude of oscillations. Increase in amplitude of oscillations causes an increase in the current through R1 which results in an increase in the value of R1. An increase in the magnitude of R1 means a greater amount of negative feedback and a consequent reduction in loop gain and signal amplitude.

The impedances Z2, Z1, R2 and R1 in fact form the arms of a bridge network (a Wienbridge). It is the bridge unbalance voltage which constitutes the signal actually applied between the differential input terminals of the amplifier. Analysis of the bridge network shows that when R2 = 2R1 the bridge is balanced at a frequency

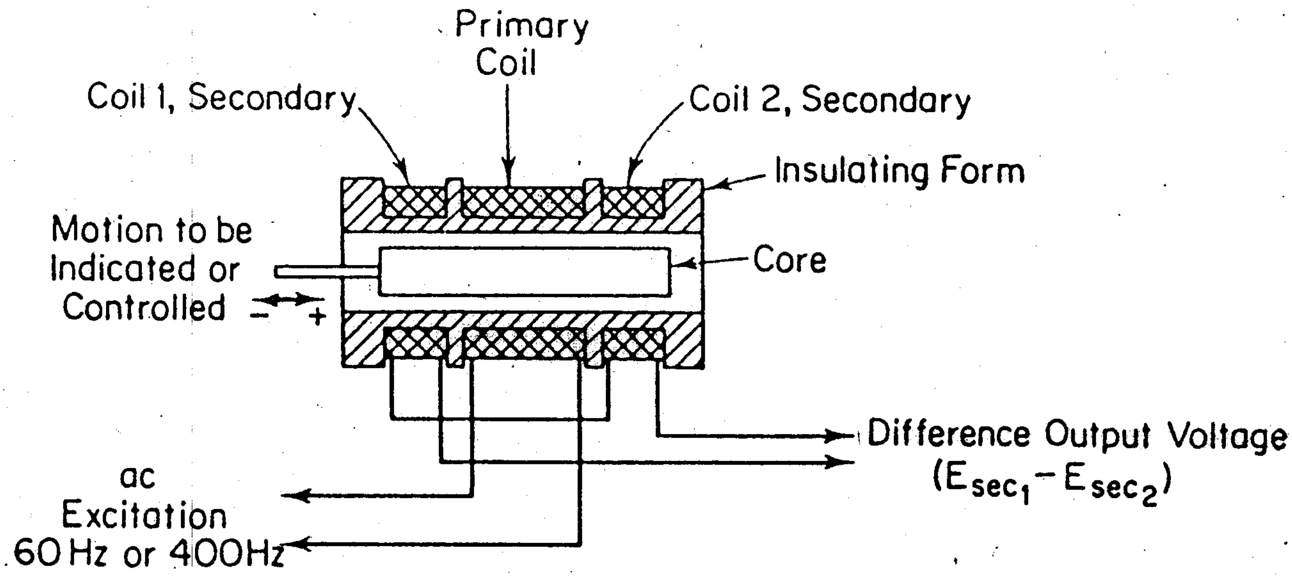
$$fo = \frac{1}{2\pi \; CR}$$

In practice a small inbalance must always exists. But greater is the open loop gain of the amplifier, the closer is the bridge to balance and greater is the frequency stability of the oscillator.

Fig 2.7 represents the wienbridge oscillator circuit used in the measurement scheme.

2.7 Precision Rectifier

The output of a linear variable differential transformer is a sine wave whose amplitude is proportional to the coremotion. If this output is applied to an a.c. voltmeter, the meter reading can be directly calibrated in motion units. This arrangement is perfectly satisfactory for measurement of static or very slowly varying displacements except that the meter will give exactly the same reading for displacements of equal amount on either side of the null position since the meter is not sensitive to the 180° phase change at null. Thus we cannot tell to which side of null the reading applies, without some independent check. Furthermore, if rapid coremotions are to be measured, the meter cannot follow or record the output, and an oscillograph or oscilloscope must be used as a readout device. These instruments record the actual wave form of the output as an amplitude modulated sinewave, which is usually undesirable. What is desired is an output voltage record that looks like the mechanical motion being measured. To achieve the desired results, demodulation and filtering must be performed; if it is necessary to detect unambiguously the motions on both sides of null, the demodulation must be phase sensitive.



(a)

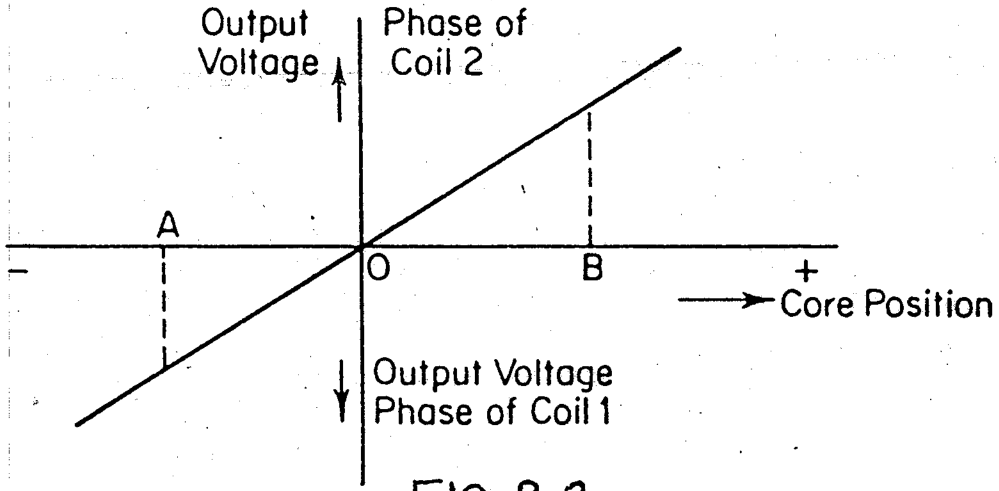
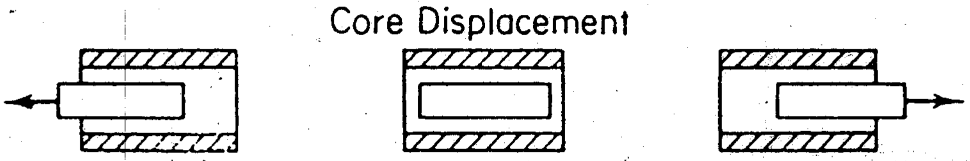


Fig 2·2



Core at A

Core at O

Core at B

Fig 2·1

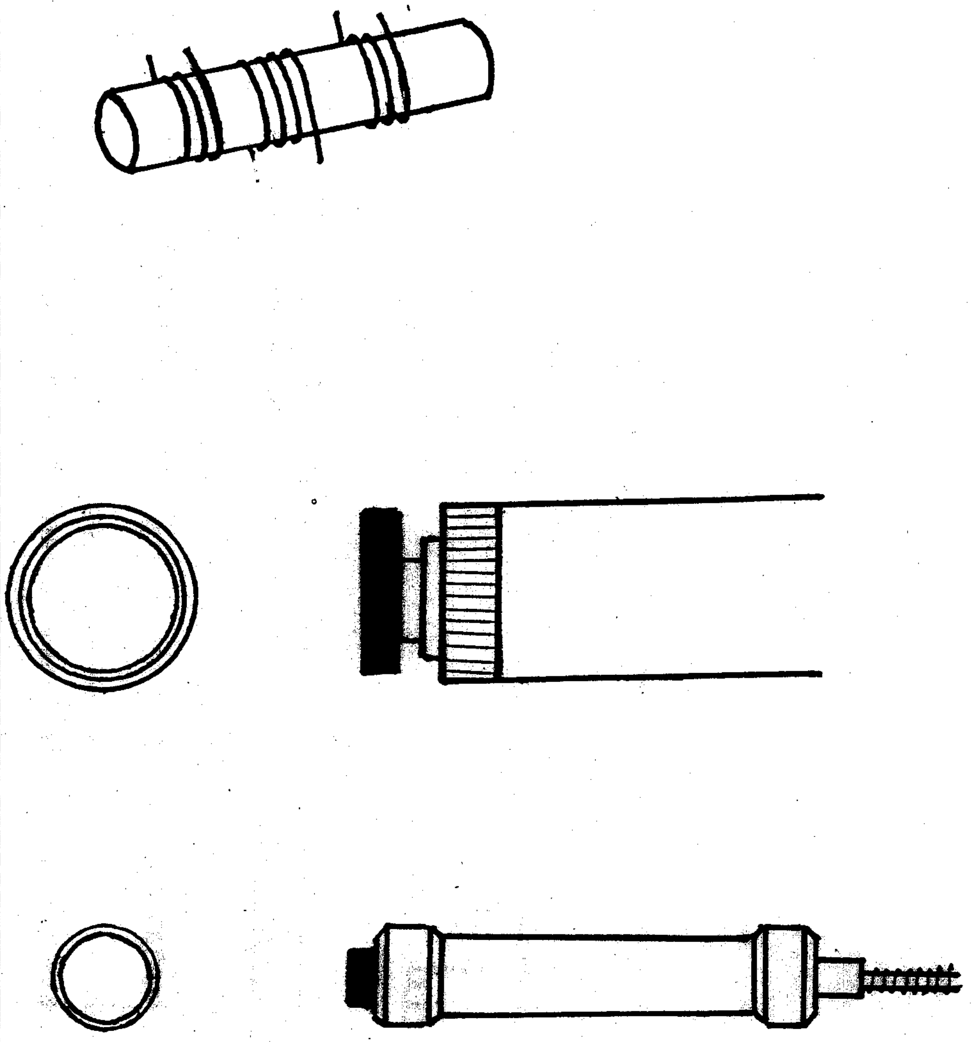


Fig. 2.3 CONSTRUCTIONAL DETAILS OF LVDT

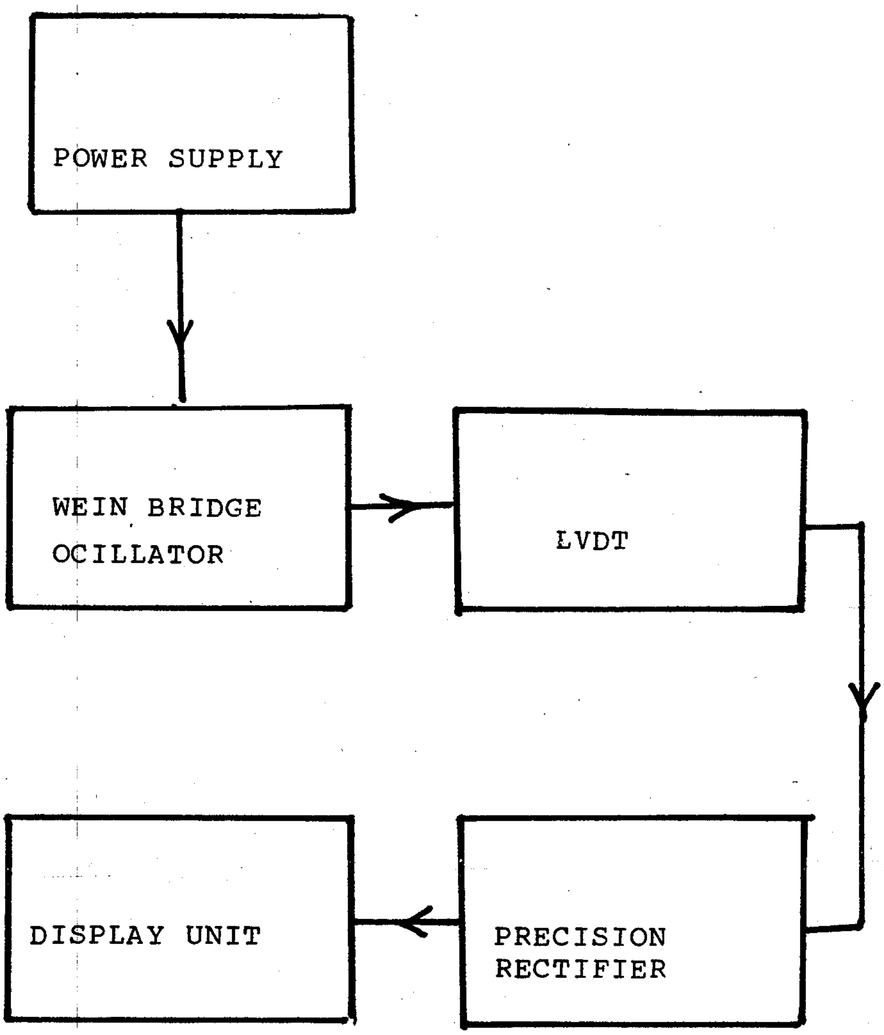


FIG. 2.5 BLOCK DIAGRAM REPRESENTATION OF DISPLACEMENT MEASUREMENT SCHEME

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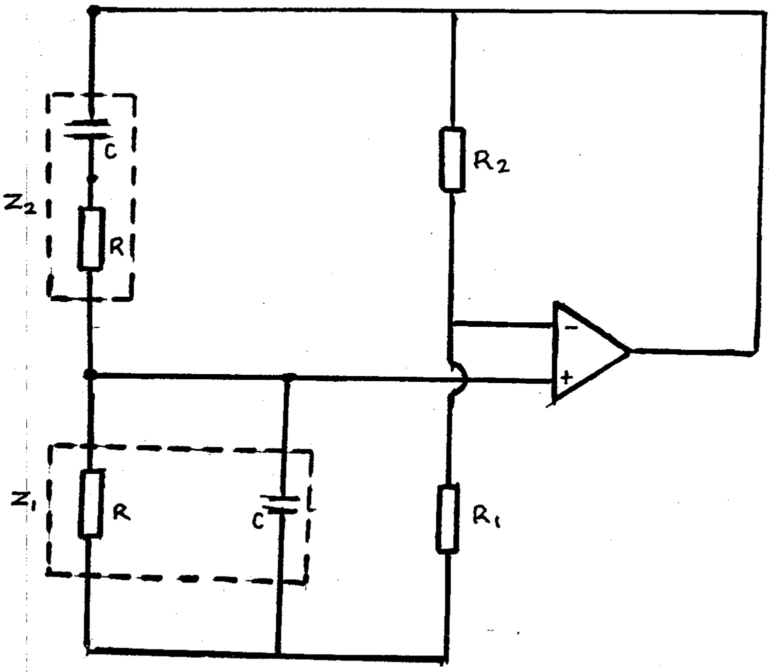


FIG. 2.6 WEIN BRIDGE OSCILLATOR CIRCUIT

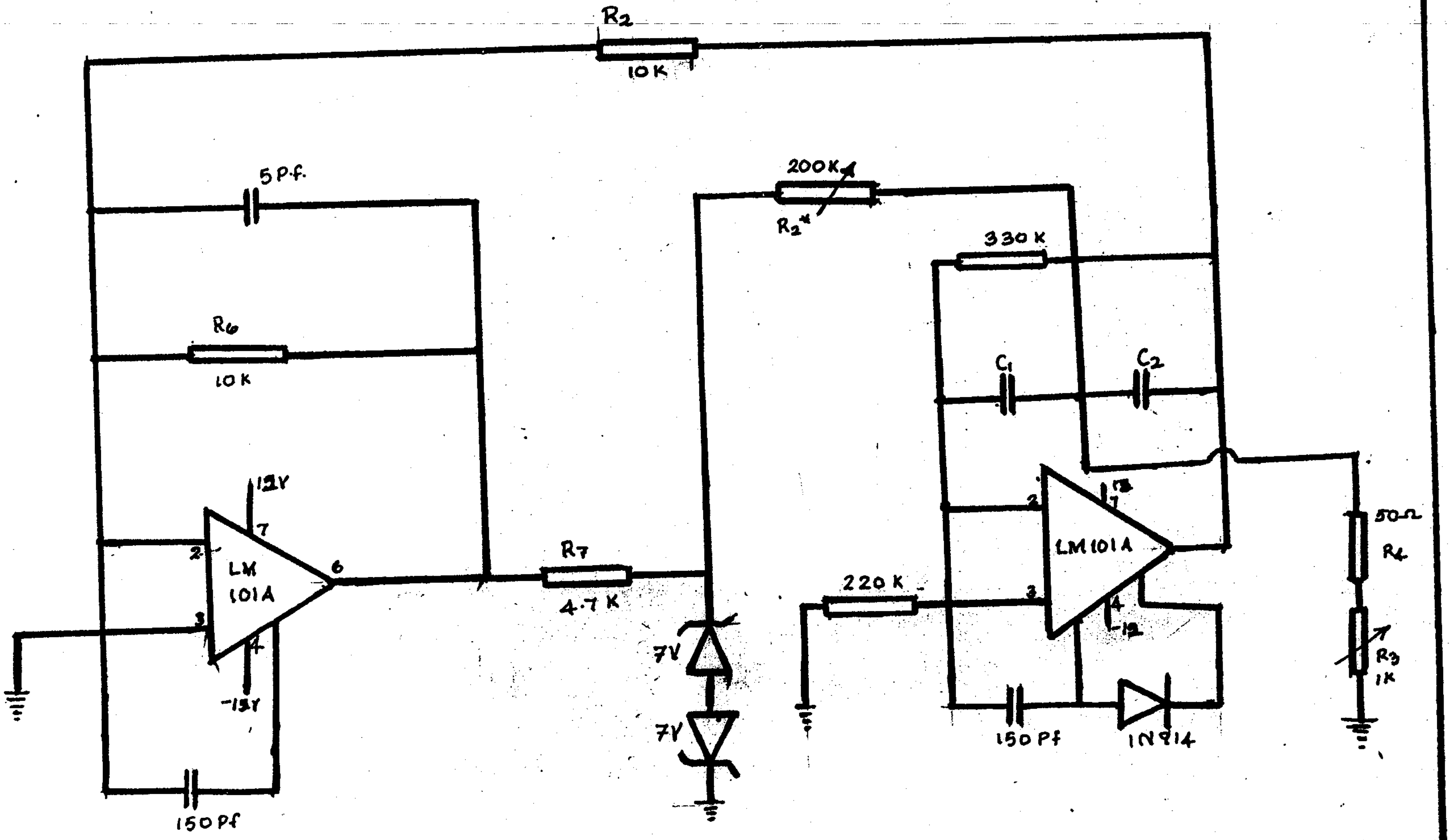


FIG. 2.7 WEIN BRIDGE OSCILLATOR CIRCUIT USED IN MEASUREMENT SCHEME

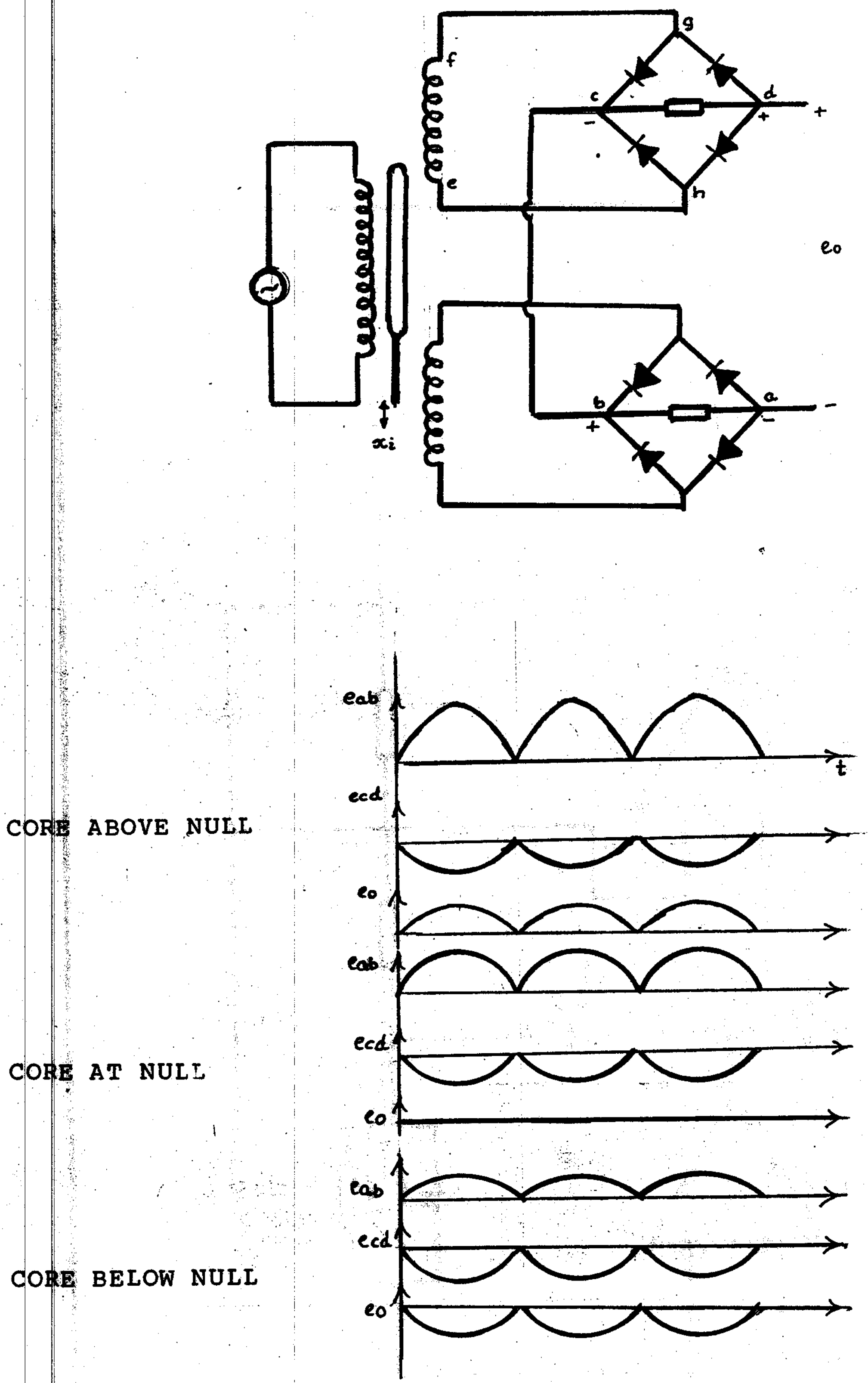


FIG. 2.8 PHASE SENSITIVE DEMODULATION CIRCUIT

CHAPTER - III

MEASUREMENT OF STRAIN

3.1 Introduction

Gages applied to the surface of structural members under test sense the elongation or strain due to applied loads. They are known as strain gages. The principle of the strain gage is also widely used in many other transducers, like pressure sensors.

The ability to determine accurately the strain, and hence the stress, caused in various objects under given conditions provides a very powerful and necessary design tool for the engineers. The need for an accurate assessment of strain is particularly important in the design off equipment where large factors of design safety are not feasible, due to serve reliiability, economic, or weight factors.

3.2. Working principle of strain gage;

If a metal conductor is stretched or compressed, its resistance changes on account of the fact that both length and diameter of the conductor change. Also there is a change in the value of resistivity of the conductor when it is strained and this property is called piezo-electric effect. Therefore resistance strain gages are also known as piezoresistive gages. The change in the value of resistance by straining the gage may be partly explained by the normal dimensional behaviour of elastic material. If a strip of elastic material is subjected to tension (ie) positively strained), its longitudinal dimension will increase while there will be a reduction in the lateral dimensioon. Since the resistance of a conductor is proportional to its length and inversely proportional to its area of cross section, the resistance of the gage increases with positive strain.

The change in the value of resistance of strained conductor is more than what can be accounted for an increase in resistance due to dimensional changes. The extra change in value of resistance is attributed to change in the value of resistivity of a conductor when strained. This is known as piezoresistive effect.

This change in resistance is proportional to the applied strain and is measured with a specially adapted wheatstone bridge.

The sensitivity of a strain gage is described in terms of a characteristic called the gage factor, K defined as the unit change in resistance per unit change in resistance per unit change in length, or

$$\text{gage factor } K = \frac{\Delta R \;/\; R}{\Delta l/l} \qquad (1)$$

Where R	nominal gage resistance
ΔR	change in gage resistance
l	normal specimen length (unstressed condition)
Δl	change in specimen length.

The term dl/l in the equation (1) is the strain

$$k = \frac{\Delta R/R}{\sigma} \quad \text{Where} \qquad (2)$$

$\sigma \rightarrow$ strain in the lateral direction.

The resistance change ΔR of a conductor with length l can be calculated by using the expression for the resistance of a conductor of uniform cross section:

$$R = \rho \frac{\text{length}}{\text{area}} = \frac{\rho \times l}{(\pi/4)\, d^2} \qquad (3)$$

where

ρ → the specific resistance of the conductor material

l → length of the conductor

d → diameter of the conductor

Tension on the conductor causes an increase Δl in its length and a simultaneous decrease ΔD in its diame4ter.

The resistance of the conductor then changes to

$$R = \frac{\rho(l + \Delta l)}{\pi/4\, (d - \Delta d)^2}$$

$$= \frac{\rho\, l\, (1 + \Delta l/l)}{\pi/4)\, d^2\, (1 - 2\Delta d/d)} \qquad (4)$$

Equation (4) is simplified further. Poisson's ratio, is, defined as the ratio of strain in lateral direction to strain in the axial direction,

$$\mu = \frac{\Delta d/d}{\Delta l/l} \qquad (5)$$

substitution of equation (5) in equation (4) yields

$$R = \frac{\rho\, l}{(\pi/4)\, d^2} \qquad \frac{(1 + \Delta l/l)}{(1-2\mu\Delta l/l)}$$

Which can be simplified to

$$R = R + \Delta R = R\,(1 + (1 + 2\mu)\ \ \Delta l/l\ )$$

The increament of resistance ΔR as compared to the increment of length Δl can then be expressed in terms of the gage factor K

where

$$K = \frac{\Delta R/R}{\Delta l/l} = 1 + 2\mu$$

Poisson's ratio for most metals lies in the range of 0.25 to 0.35 and the gage factor would then be on the order of 1.5 to 1.7.

For strain - gage applications, a high sensitivity is very desirable. A large gage factor means a relatively large resistance change which can be more easily measured.

3.3. Constructional Details:

There are three types of strain gages:

i) Wire wound strain gages,
ii) Foil type strain gages and
iii) Semiconductor strain gages.

Wire Wound Strain gages:

The wire strain gage depends on the fact that when a wire is stretched elastically, its length and diameter are altered. This results in an over-all change of resistance due to both the dimensional change and a change in resistivity.

In the usual form of the gage, a wire of about 5 inches long and approximately 0.001 inches in diameter is wound into a grid shape and securely bonded with cement to the surface of the test member to be measured as in Fig. 3.1. Gages are used in sizes smaller than a postage stamp to 6 inches long and 3/4 inches wide. Any strain at the surface is then transmitted to the wire as a corresponding change in resistance. Total resistance of 120 or 350 ohms is most

Bonded wire strain gages:

A resistance wire strain gage consists of a grid of fine resistance wire of about 0.025 mm in diameter or less. The grid of fine wire is cemented to a carrier (base). The wire is covered on top which a sheet of thin material so that it is not damaged mechanically. The spreading of the wire permits a uniform distribution of stress. The carrier is bonded with an adhesive material to the structure under study. This permits a good transfer of strain from carrier to wires.

Foil Strain gages:

This class of strain gages is only an extension of resistance wire strain gages. The strain is sensed with the help of metal foils as against metal wires as in wire strain gages. Foil gages have a much greater dissipation capacity as compared with wire wound gages on account of their greater surface area for the same volume. For this reason they can be used for higher operating temperature range. Also the surface area of foil gages leads to better bonding. The advantage of foil strain gages is that they can be fabricated economically on a mass scale.

Semi Conductor Strain gages:

These gages are used where a very high gage factor and a small envelope are required. The resistance of the semiconductors changes with change in applied strain. The semiconductor strain gages depend for their action upon piezo-resistive effect. Semiconducting materials are used as resistive materials for semiconductor strain gages.

3.4 BLOCK DIAGRAM EXPLANATION;

The fig. 3.5 shows the schematic diagram of a strain Measurement.

The bridge is supplied with a 5 V D.C, the output of the bridge is given to a differential amplifier where it is amplified. The amplified analog signal is given to a digital voltmeter for displaying in the digital form.

The explanation of each block is given in the subsequent pages.

3.5 Strainer:

In the measurement scheme employed, two similar strain gages are attached on either sides of a cantilever beam. The strain gages are attached in such a way that one gage experiences a positive strain and the other a negative strain.

Fig. 3.3 shows the two strain gages mounted on a cantilever. The gage Rg1 is on the top side of the cantilever and hence experiences tension or a positive strain. Rg3 is at the bottom surface of the cantilever and hence experiences a compression or a negative strain.

The bridge arrangement for the two gages is shown in fig. 3.4 There are two active gages in the 4 arm bridge and hence it is called Half Bridge.

The temperature effects are cancelled out by having $R_2 = R_4$ and using two identical gages in the opposite arms of the bridge.

Let Rg1 = Rg3 = R2 = R4 = R.

When no strain is applied both points b and d are at the same potential, ei/2 and the value of output voltage eo=0.

When the arrangement shown in Fig. 3.3(b) is subjected to strain, the resistance of gage Rg1, increases and that of gage Rg3 decreases.

Resistance of gage Rg1 when strained is R(1 + ΔR/R).

Resistance of guage Rg3 when strained is R(1 -ΔR/R).

Now R2 = R4 = R Therefore potential of point d is ei/2

Therefore potential of point b =

$$b = \frac{R\ (1 + \Delta R/R)\ x}{R(1 + \Delta R/R) + R\ (1 - \Delta R/R)}\ ei = 1 + R/R$$

Therefore change in output voltage when strain is applied is

$$\Delta eo = \frac{1 + \Delta R/R}{2} \quad e1 - e1/2 = \frac{\Delta R/R}{2} \quad C1 = \frac{GfE_i}{2}$$

Thus the output voltage from a half bridge is twice that from a quarter bridge and therefore the sensitivity is doubled. In addition, the temperature effects are cancelled. The gage, sensitivity of a half bridge is sg = 2K Rg Gf..

3.6 Amplifier Circuit:

The output obtained from the strainer is a differential output whose magnitude is very small. This output is amplified using a differential amplifier in which the active element is an OPAMP. The schematic of an operational amplifier used as a differentiator amplifier is shown in figure. 3.5.

In its basic form it has two inputs and two outputs. Output obtained from the differential amplifier at its two terminal is the same except that they are 180° out of phase and is proportional to the difference between the two input voltages. Operational differential amplifiers are designed to have a very high gain of the order 10

3.7 Display Unit;

The output from the differential amplifier is fed to the display unit which is a 3 1/2 digit LED display D.V.M Module. The schematic of display unnit is given in the chapter.5.

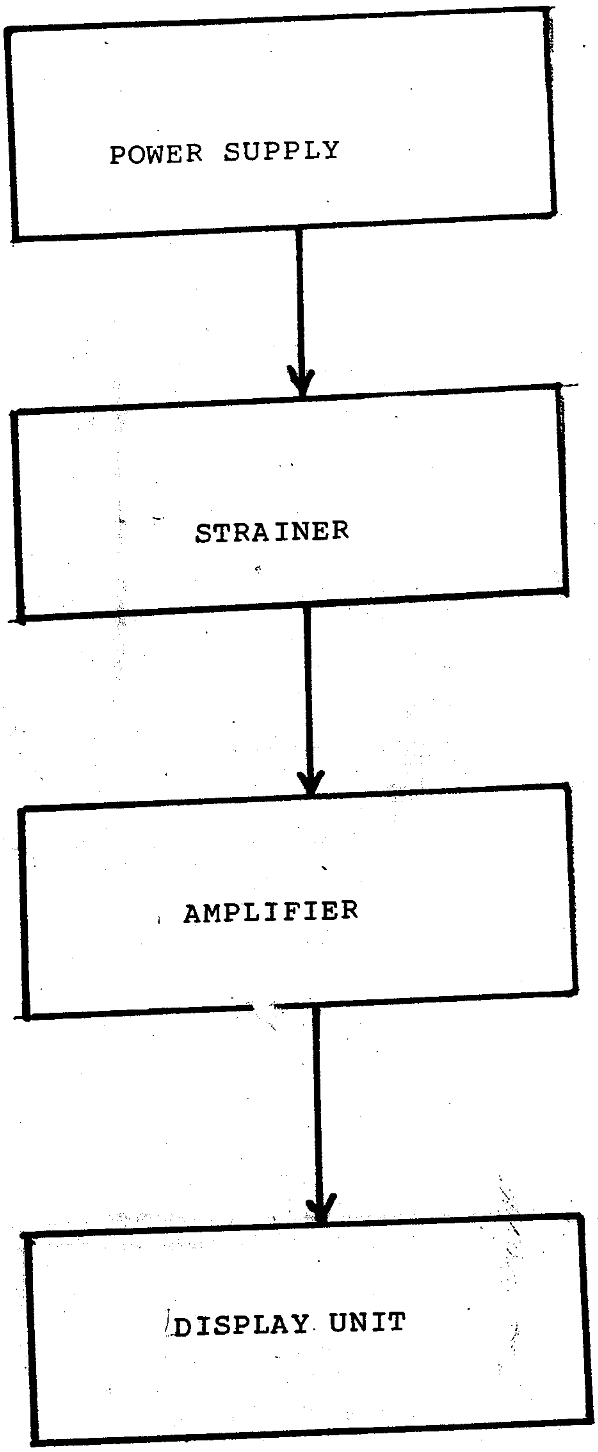


FIG. 3.2 BLOCK DIAGRAM REPRESENTATION OF STRAIN MEASUREMENT SCHEME

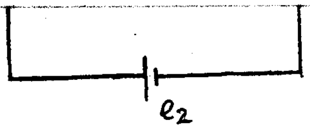
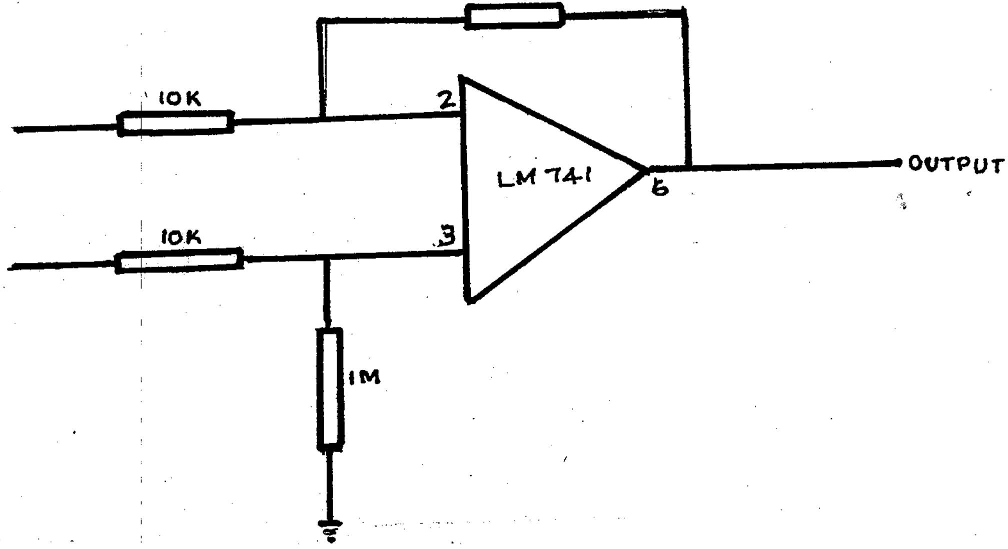


FIG. 3.5 DIFFERENTIAL AMPLIFIER CIRCUIT



CHAPTER - IV

MEASUREMENT OF TEMPERATURE

4.1 Principle of Thermo Electric Sensors (Thermocouple)

If two wires of different materials A and B are connected in a circuit with one junction at temperature T1 and the other at T2, an infinite resistance voltmeter detects an electromotive force E or if an ammeter is connected a current I is measured. The magnitude of the voltage E depends on the materials and the temperatures T1 and T2. The current I is simply E divided by the total resistance of the circuit, including the ammeter resistance. If current is allowed to flow, electrical power is developed this comes from a heat flow from the surroundings to the wires. A direct conversion of heat energy to electrical energy is thus obtained. The effect is reversible, so that forcing a current from an external source through a thermoelectric circuit will cause heat flow to and from the circuit.

The overall relation between voltage E and temperatures T1 and T2 which is the basis of thermo-electric temperature measurement, is called the seebeck effect. The temperatures T1 and T2 refer to the junctions themselves, whereas when using a thermocouple one is trying to measure the temperature of somebody in contact with the thermojunction. These two temperature are not exactly the same if current is allowed to flow through the thermo junction, since then heat is generated or absorbed at the junction, which must thus be hotter or colder than the surrounding medium whose temperature is being measured. This heating and cooling are related to the peltier effect. If the thermocouple voltage is measured with a potentiometer, no current flows and peltier heating and cooling are not present. When a millivoltmeter is used, current flows, and heat is absorbed at the hot junction (requiring it to become cooler than the surrounding medium) while heat is liberated at the cold junction, making it hotter than its surrounding medium. These heating and cooling effeccts are proportional to the current and fortunately are completely negligible when the current is that produced by the thermocouple itself in a practical millivoltmeter circuit.

Another heat-flow (reversible) effect, the Thomson effect, influences the temperature of the conductors between the junctions rather than the junctions themselves. When current flows through a conductor having a temperature gradient (and thus a heat flow) along its length, heat is liberated at any point where the current flow is in the same direction as the heat flow, while heat is absorbed at any point where these are opposite. Since this effect also depends on current flow, it is not present if a potintiometer is used. Even if a millivoltmeter is used, the effect of the heat flow on conductor temperature is completely nigligible. Finally it should be noted that in any current carrying conductor I^2R heat is generated, raising the circuit temperature above its local surroundings. Again potentiometric voltage measurements are not subsceptible to this error. Errors in millivoltmeter circuits are usually negligible also but can be estimated if heat transfer conditions are known.

4.2 Constructional Details

Common Thermocouples

Thermojunctions formed by welding, soldering, or merely pressing the two materials together give identical voltages. If current is allowed to flow the currents may be different since the contact resistance differs for the various joining methods. Welding (either gas or electric) is mostly used although both silver solder and soft solder (low temperatures only) are used in copper/constantan couples.

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While many materials exhibit the thermoelectric effect to some degree, only a small number of pairs are in wide use. They are platinum rhodium, chromel/Alumel; copper/constantan, and Iron /. constantan. Each of these pairs exhibits a combination of properties that suit it to a particular class of applications. Since the thermoelectric effect is somewhat nonlinear, the sensitivity varies with temperature. The maximum sensitivity of any of the above pairs is about 60 V/C° for copper / constantan at 350°C Platinum/platinum-rhodium is the least sensitive, about 6 V/C° between 0 and 100°C.

Platinum/platinum-rhodium thermocouples are used mainly in the range of 0 to 1500°C. The main features of this combination are its chemcial inertness and stability at high temperatures in oxidizing atmospheres. Reducing atmospheres cause rapid deteriorition at high temperatures as the thermocouple metals are condaminated by absorbing small quantities of other metals from near by objects (such as protecting tubes) This difficulty causing loss of calibration is unfortunately common to most thermo couple materials above 1000°C.

Several combination of dissimilar metals make good thermocoules for industrial use. These combination apart from baring llinear response and high sensitivity should be physically strong to withstand high temperatures rapid temperature changes, and the efffect of corrosive and inducing atmospheres. Based on years of experience in application ofthermocouples, industry has standardized a few wire combinations.

Theremocouples are seldom used as base wires except for detecting hot junction. A hot junction arrangement is a simple arrangement consisting of a pair of wires insulated by ceramic sleeves. The ends of the wires are either twisted together or welded as shown in fig. 4.2.

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4.4. AMPLIFIER CIRCUIT

The amplifier circuit used is shown in the fig. 4.4. the output of the thermocouple is connected to the non inverting point of the OPAMP.

The initial adjustments done are.

1) Apply signal in place of thermocouple and adjust R_3 for a gain of 245.7.

2) Short non inverting input of LM 308 A and output of LM 329 B to ground.

3) Adjust R_1 so that V_{out} = 2.982 V @ 25° C.

4) Remove short across LM 329 B and adjust R_2 So that V_{out} = 2.46 mV @ 25 ° C .

5) Remove short across thermocouple

LM 355 IC used is a precision temperature sennsor the specification of this IC is given latter.

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4.5 DISPLAY UNIT

The output of the amplifier is fed to the display unit which is 3 1/2 digit LED display DVM. The schematics of display unit is given in the chapter 5.

4.6 MERITS AND DEMERITS OF THERMOCOUPLES

MERITS:

- Thermocouples are cheaper than resistance thermometers.
- Thermocouples follow the temperature changes with a small time lag and as such are suitable for recording commparitively rapid changes in temperature.
- They are very convenient for measuring the temperature at one particular point in a piece of apparatus.

DEMERITS:

- They have a lower accuracy and hence they cannot be used for precision measurements.

* To ensure long life of thermocouples in their operating environments, they should be protected in an open or closed-end metal protecting tube or well. To prevent contamination of the thermocouple, when precious metals like platinum or its alloys are being used the protecting tube has to be made chemically inert and vaccum tight.

* The thermocouple is placed remote from measuring devices. Connections are thus made by means of wires called extension wires. Maximum accuracy of measurement is assured only when compensating wires are of the same material as the thermocouple wires. The circuitry is, thus, very complex.

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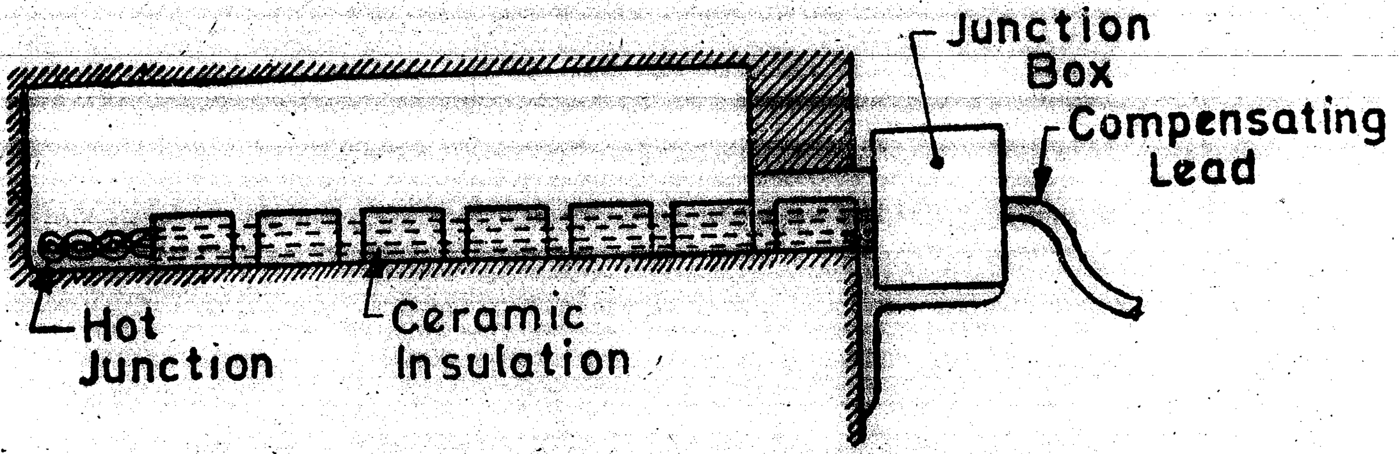

Fig. 4·2 Hot junction with ceramic insulations.

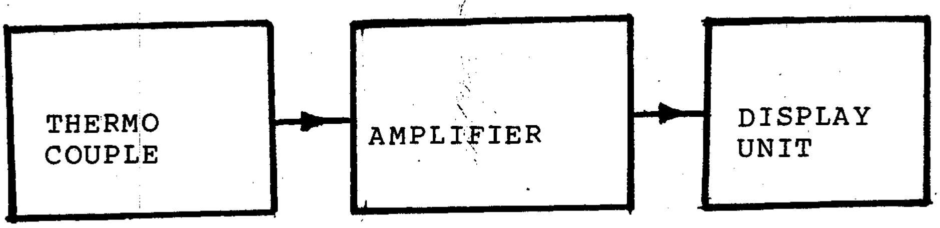

FIG. 4.3 BLOCK DIAGRAM REPRESENTATION OF THE TEMPERATURE MEASUREMENT SCHEME

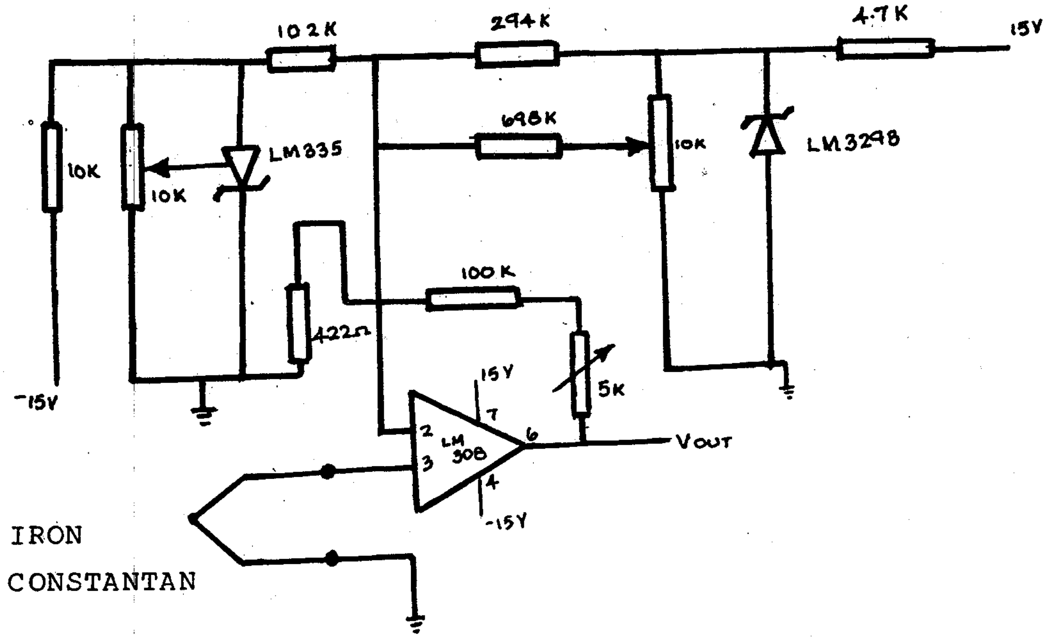

FIG. 4.4 THERMOCOUPLE WITH AMPLIFIER CIRCUIT

CHAPTER -V

5.1 Display Module:

The display used is a digital voltmeter module Analog input signals are converted into digital form in a LSI device type IC 7107. The IC L 7107 is a 3 1/2 digital single chip analog to digital converter containing all the necessary active devices on a cmos IC. Induced are seven segment decoders, display drivers, reference, and a clock. The device is designed to interface with a light emitting diode (LED) display.

High accuracy like autozero to less than 10 Volt zero drift of less than 1 volt / degree centrigrade Input bias current of 10 A maximum and role over error of less than one count are characteristic of this device. The true differential input is useful in measuring strain gages and other bridge type transducers. The chip operates with a single power supply and a complete panel meter can be built with the addition of only 7 passive components and a display, as shown in fig. 5.1.

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CHAPTER - VI

Fabrication and Testing:

The following sub systems/modules were tested and integrated

a) Wien Bridge Oscillator
b) Phase sensitive rectifier
c) Amplifier
d) Power supply

Single sided, printed circuit boards containing the above circuitry were fabricated. A transformer of the rating 12-0-12volts at 350 mA was designed and wound.

The wein bridge Oscillator was tested and the output frequency of 5 KHz and peak-to-peak voltage of 5 V were measured. The LVDT was existed with 5 KHz signal and output of the LVDT was rectified using a precision rectifier. The rectifier output was monitored in the digital voltmeter module.

CHAPTER-VII

CONCLUSION

Measurement setups for monitoring displacement, temperature and strain was developed and tested. The LVDT transducer setup for displacement measurement and the thermocouple based temperature measurement scheme were found to give fairly accurate results with suitable calibration steps. The strain gage setup was found to be subjected to drift problems, which require further modifications of preamplifier circuits.

The output signals were converted into digital form using single chip A/D converter with suitable display facility. The digitised output can readily be transferred to memories and / or microprocessor systems facilitating further processing of the data acquired. These data acquisition systems will be very useful in all process control applications.

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LM101A/LM201A/LM301A Operational Amplifiers

General Description

The LM101A series are general purpose operational amplifiers which feature improved performance over industry standards like the LM709. Advanced processing techniques make possible an order of magnitude reduction in input currents, and a redesign of the biasing circuitry reduces the temperature drift of input current. Improved specifications include:

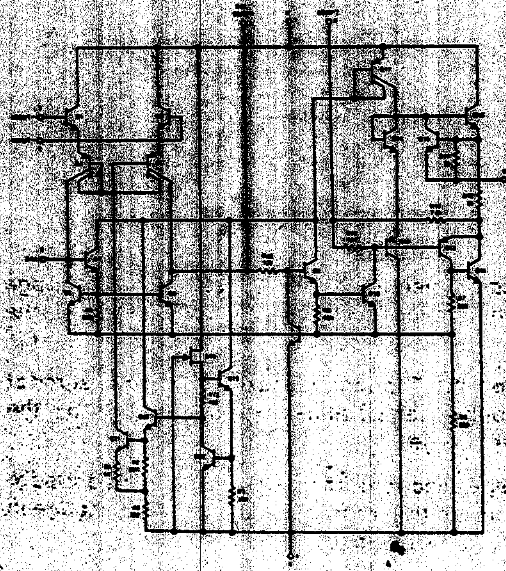
- Offset voltage 3 mV maximum over temperature (LM101A/LM201A)
- Input current 100 nA maximum over temperature (LM101A/LM201A)
- Offset current 20 nA maximum over temperature (LM101A/LM201A)
- Guaranteed drift characteristics
- Offsets guaranteed over entire common mode and supply voltage ranges
- Slew rate of 10V/μs as a summing amplifier

This amplifier offers many features which make its application nearly foolproof: overload protection on the input and output, no latch-up when the common mode range is exceeded, freedom from oscillations and compensation with a single 30 pF capacitor. It has advantages over internally compensated amplifiers in that the frequency compensation can be tailored to the particular application. For example, in low frequency circuits it can be overcompensated for increased stability margin. Or the compensation can be optimized to give more than a factor of ten improvement in high frequency performance for most applications.

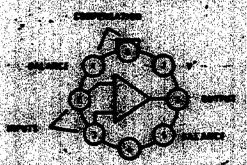
In addition, the device provides better accuracy and lower noise in high impedance circuitry. The low input currents also make it particularly well suited for long interval integrators or timers, sample and hold circuits and low frequency waveform generators. Further, replacing circuits where matched transistor pairs buffer the inputs of conventional IC op amps, it can give lower offset voltage and drift at a lower cost.

The LM101A is guaranteed over a temperature range of −55°C to +125°C, the LM201A from −25°C to +85°C, and the LM301A from 0°C to 70°C.

Schematic** and Connection Diagrams (Top Views)

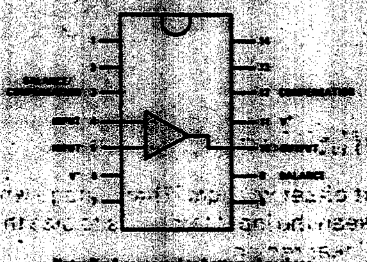


Metal Can Package



Order Number LM101AH, LM201AH or LM301AH
See NS Package H08C

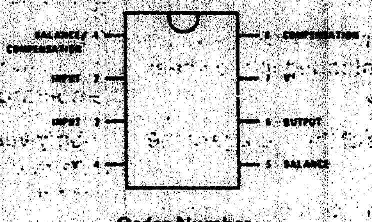
Dual-In-Line Package



Note: Pin 6 connected to bottom of package.

Order Number LM101AJ-14, LM201AJ-14 or LM301AJ-14
See NS Package J14A

Dual-In-Line Package



Order Number
LM101AJ, LM201AJ, LM301AJ
See NS Package J08A

Order Number LM301AN
See NS Package N08A

**Pin connections shown are for metal can.