AN ELECTRONIC CONTROLLER FOR BIO MEDICAL APPLICATIONS USING LVDT CHARACTERISTICS

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Abstract

This research paper deals with the designing of an electronic controller using LVDT transducerscharacteristics for the better and accurate pressure measurement for a given liquid flow which could be used in case of different bio medical applications. Further the study includes the monitoring of flow of pressure with respect to a middle acceptable range set such that the controller can work at three different conditions for the pressure value increasing beyond the acceptable range, decreasing below the acceptable range and value equal to acceptable range.

Keywords: *LVDT-Linear Variable Differential Transformer, C1&C2-Capacitors, VS1-Primary & VS2-secondary voltages*

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1. INTRODUCTION

Pressure transducers are used to measure pressure in liquid and gases electrically. Generally for pressure measurement of liquids pitot tubes are used to measure pressure of a flow by taking the differential pressure between two points with one static and the other point with the stream flow.The Linear Variable Transformer Differential (LVDT) is a displacement sensor widely used in industrial and medical sectors as part of the physical measurements system. The basic structure of LVDT consists of a primary coil and two secondary coils like an electrical transformer. However, LVDT has a movable magnetic core that when is moved from its null position, it varies the mutual inductances among secondary coils and the primary coil. It is applied an AC voltage E i/p, in the primary coil, as shown in Figure 1. The secondary coils are connected in series with opposing phase, so when the magnetic core is exactly at the physical Centre between them, then the output voltage will be zero, as the net output is the difference between the two secondary voltages, V out= VA-VB. If the core is moved from the Centre, then due to imbalance of magnetic flux intensities between the primary coil and the secondary coils an output voltage that is proportional to the core displacement is produced. This imbalance produces non-zero output voltage proportional to the core displacement.

1.1 Linear Variable Differential Transformers (LVDTs)

As LVDT output is a nominally linear function of core displacement within its linear range of motion, a plot of output voltage magnitude versus core displacement is essentially a straight line. Beyond the nominal linear range, the output begins to deviate from a straight line into a gentle curve leading to non linearity. Linear Variable Differential Transformer (LVDT) plays an important role to measure the displacement in various control system applications. Due to non linearity in output, the sensor is effectively being employed only in the linear range of operation. Therefore, if a sensor is used for full range of its nonlinear characteristics, accuracy of measurement is severely affected.

A lot of attempts have been made in the past to increase the linear range of operation of LVDT. The nonlinearity compensator designed by [4] uses the artificial neural network to overcome the non linearity in the output characteristics of LVDT. However, the proposed model involves high computational complexity. Also, in [5] the authors present a technique of dual secondary coils for self compensation of LVDT. Some DSP techniques have been employed in LVDT to achieve optimum result to overcome non linearity problem circuits [4][5]. The simple solution to overcome nonlinearity has also been achieved in [5] by square coils in which the core moves perpendicular to the axis instead of along the axis.

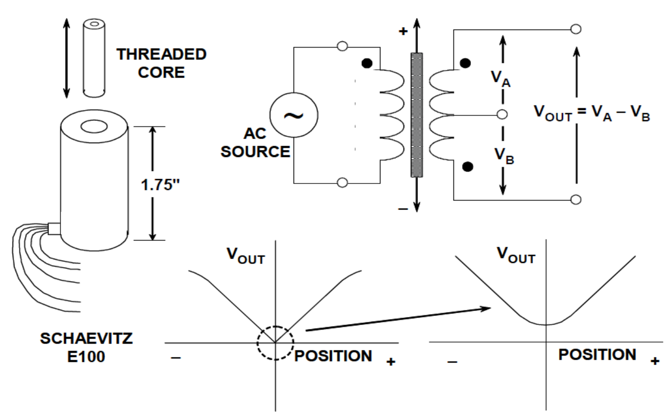

Fig 1 Linear Variable Differential Transformer

1.2 Modeling of LVDT

A Linear Variable Differential Transformer can be modeled in two ways, i.e Electrical parameter based model and geometrical parameter based model (CleonilsonProtásio de Souza1, Michel Bruno Wanderle, resistances and inductances, are used as the electrical parameters for electrical modeling and Geometric Parameter depending model uses geometrical parameters with the physical dimensions of the LVDT. The paper aims to allow interaction of electrical parameter based model with physical parameter based model to bring out an optimum design of LVDT.

1.2.1 Electrical Model

The Electrical Parameter based model uses all the electrical parameters as resistances and inductances to define the model. We can define and derive the Electrical Parameter dependent model of the LVDT by referring the figure 2 below, where, *Rp* is the primary coil total resistance, *Rs1* and *Rs2* are the secondary coils resistances, *LP* is the primary coil self-inductances, *Ls1* and *Ls2* are the secondary coil self-inductances, and *M1* and *M2* are the mutual inductances between primary coil and the secondary coils. Considering *Rs* as the total resistance of the secondary circuit, where, *Ros = Rs1 + Rs2 + Rt* and *Rt* is a load resistance.

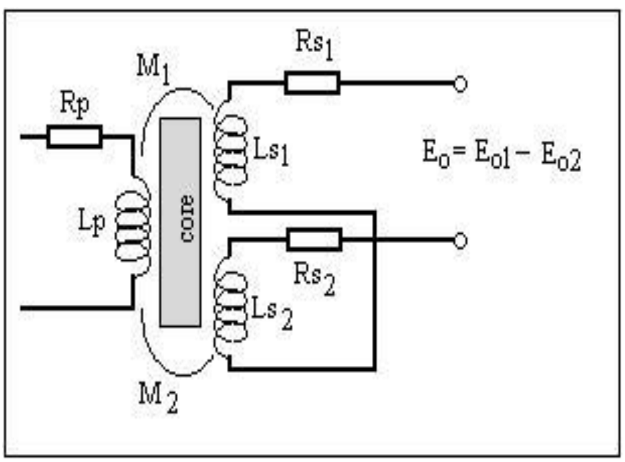

Fig 2 Electrical Model of LVDT

1.2.2 LVDT Primary and Secondary voltages

$$E_i = R_p I_p + sL_p I_p + s(M_1 I_s - M_2 I_s)$$

Where*M1, M2* are the mutual inductances which are dependent on core displacement and Ei, the excitation voltage. The net equation in the secondary circuit is given

$$s(M_1 I_p - M_2 I_p) + I_s R_s + s(L_{s1} I_s + L_{s2} I_s) = 0$$

Also the Output voltage Eo/p = Is* Rload.

Using the two equations as stated in [24] we get

$$E_{o/p} = E_{i/p} (\Delta m / L_p)$$

The output voltage is proportional to the difference in mutual inductance. Incase the core is not displaced from its null position, the Δm will be zero, thus no output voltage will be produced at secondary of LVDT. However, in case the core is displaced from its null position, the output voltage at secondary coil will be proportional to the difference in mutual inductance produced due to core displacement [10].

1.2.3 Magnetic Model

As explained [in CleonilsonProtásio de Souza1, Michel Bruno Wanderley, Magnetic conductance plays an important role in defining the geometric model of an LVDT. Magnetic conductance depends on the geometry and the permeability of the circuit. It is obtained from cross sectional area penetrated by magnetic fields, mean length of magnetic field lines and magnetic free space permeability. The magnetic conductance can be defined as

$$\text{Magnetic Conductance} = G = (\mu_o \pi R^2)/\partial 1$$

Magnetic flux produced by the primary coil can be divided into two main paths. The first path passes through the air gap of the end faces of the magnetic core and the magnetic shell, this is called the main flux ‘Φo’. The second path passes through the air gaps of the magnetic core sides, facing the two secondary windings and the magnetic shell, this is called the secondary flux ‘Φs’ [7].

As the structure of LVDT is symmetrical about its central axis, the conductance is parallel to each other and the total conductance can be written as

$$G = (G_{o1} + G_{s1}) \| (G_{02} + G_{s2})$$

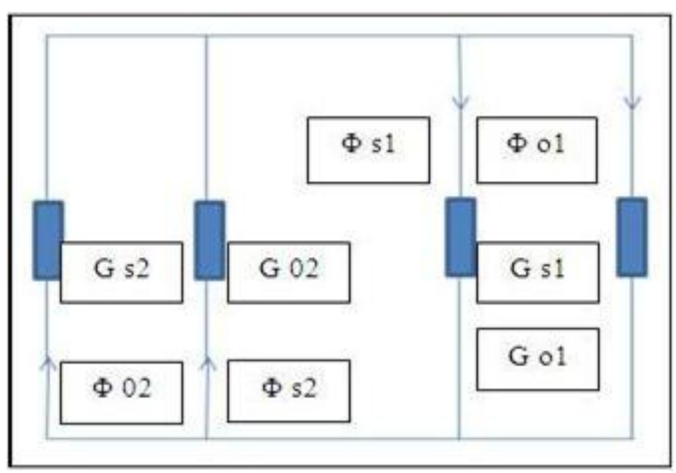

Fig 3 LVDT Magnetic Model

Magnetic Conductance (G01) = $(\mu o \pi R^2)/\partial 1$

Magnetic Conductance (G02) = $(\mu o \pi R^2)/\partial 2$

$\partial 1 = h1 – t1$, where $t1 = t0 + \partial t$

$\partial 2 = h1 - t2$, where $t2 = t0 – \partial t$

where ∂t is the steps or length of displacement

Also, due to secondary flux (Gs1) = $(h2- \partial 1)*g$

Due to secondary flux (Gs1) = $(h2- \partial 2)*g$

Where ‘g’ is specific magnetic conductance between cylindrical surfaces [9]

i.e $g = 2\mu o \pi / \ln (D/d)$

The equation for self and mutual inductance can be derived from [9] and can be written as

Self-Inductance, $Lp= N^2/G$

Mutual Inductance, $M1 = (Np*Ns *g*t1^2) / 4h2$

Mutual Inductance, $M2 = (Np*Ns*g*t2^2) / 4h2$

2. DESIGN OF ELECTRONIC CONTROLLER

Too great a pressure will cause the liquid to stretch and deform. Too low a pressure will cause the liquids to sag. The transducer, which supplies pressure information to the control circuitry, is an LVDT, shown in Figure1. If the liquidpressure increases, the liquid rises a little bit, causing the core of the LVDT to rise. If the liquidpressure decreases, the liquid drops down little. The LVDT contact also moves down due to the spring action of the arm. This causes core of the LVDT to move down. Therefore the output voltages from the windings of the LVDT are an indication of the pressure for a given liquid. Figure 4which is a schematic diagram of the electronic control circuitry. The frame of the LVDT is situated so that when the liquidpressureis in the middle of theacceptable range, the LVDT core is centered. In this condition the two secondary voltages are both equal and are rectified and filtered and applied to the inputs of differential amplifier op amp1. DI and D2 are germanium small-signal diodes with a low forward bias voltage. Thus the DC voltages appearing at the top of C1 and C2 are very nearly equal to the peak values of VS1 and VS2. If the liquid pressure further decreases than the midpoint of the acceptable range, the C1 voltage will be larger than the C2 voltage. If the pressure is somewhat increases further than the midpoint of the pressure range, the C2 voltage will be larger than the C1 voltage. This can be seen by looking at the direction markings by the LVDT core. Resistors R1 and R. are bleeder resistors to allow C1 and C2 to discharge to continually reflect the peak values VS1 and VS2. The voltages across C1 and C2, arc applied to R3 and R5, which are the input resistors of a differential amplifier having a gain of 4[3].

In equation form

$$Vout1= 4(VC2-VC1)$$

3. DISCUSSION

If liquidpressure is more than the midrange value, Vout1, is a negative DC voltage. If pressureis lesser than the midrangevalue, Vout1 is a positive voltage. Vout1 is applied to two voltage comparers, op amp 2 and op amp 3. Thesecomparers have the function of determining if the measured pressure is more or less. In other words, a certain deviation from the pressure midrange will be tolerated but beyond a certainpoint, corrective action will be taken. The op amp 2 comparer checks for pressureexceeding the limit for any decrease, while the op amp 3 comparer checks for pressure exceeding the limit for further increase. The limits themselves are adjustable and are set by potentiometers P1 (decreasing) and P2 (increasing). For purposes of discussion, suppose that P1 and P2 are set at + 8 and - 8 V. respectively. Then if Vout 1 goes more positive than +8 V, it means the measured pressure has exceeded the decreasing limit. When this happens, the + input of OP amp 2 goes more positive than the negative input, so Vout2 switches from negative saturation to positive saturation (from about —13 to + 13 V). This causes a + 5V Signal to appear at the top of zener diode ZD1. Therefore the appearance of +5 V at ZD1 indicates that pressure is too small and that corrective action is necessary. Whenever pressure does not exceed the decreasing limit, Vout2 is — 13 V, which forward-biases ZD1, causing a negative 0.6V signal at the cathode terminal of ZD1. If liquidpressure exceeds the increasing limit, Vout1 will go more negative than the P2 setting of -8V. When this happens, the negative input of op amp 3 is more negative than the + input, so Vout3 switches from — 13 to + 13 V, This causes the same result at zener diode ZD2 that was seen above for ZD1. That is, the cathode level changes from —0.6 to + 5V. This + 5-V signal represents the fact that pressure is too high and that corrective action is necessary [3].

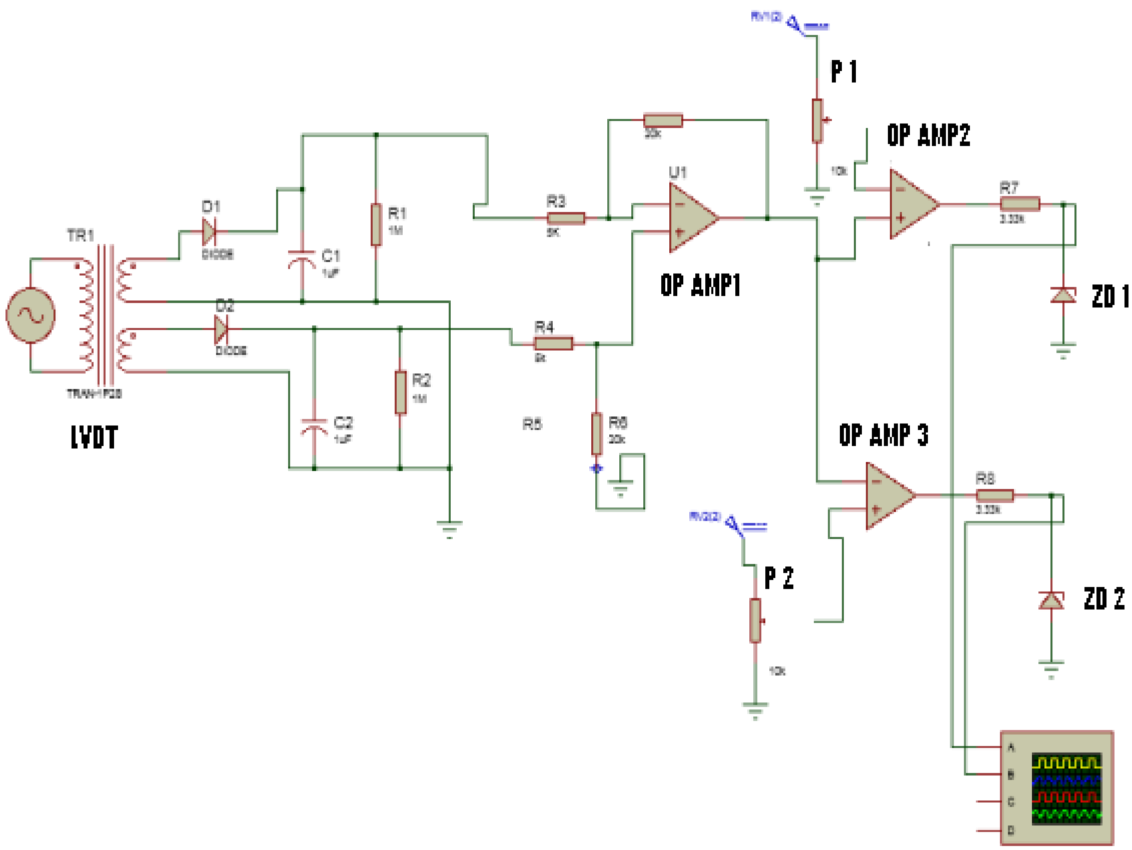

Fig 4 Schematic Diagram of the liquid pressure electronic control circuit

4. CONCLUSION

The designed theoretical approach works on the controlling of pressure with respect to a set middle point acceptable reference value of a LVDT transducer under different characteristics analysis and the pressure signal is converted into an electrical signal of corresponding strength and then can be compared by op amps for further necessary electronic actions to be given to external devices.

ACKNOWLEDGEMENTS

The authors are thankful to MuffakhamJah College of Engineering and Technology for providing financial grant under research proposal scheme.

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