DATA ACQUISITION FROM LVDT AND ITS ANALYSIS

A THESIS SUBMITTED IN PARTIAL FULFILLMENT OF

THE REQUIREMENTS FOR THE DEGREE OF

Bachelor of Technology in

Electronics and Instrumentation Engineering

By

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Department of Electronics & Communication Engineering

National Institute of Technology

Rourkela

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Under the Guidance of

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NATIONAL INSTITUTE OF TECHNOLOGY
ROURKELA

CERTIFICATE

This is to certify that the project report titled "**DATA ACQUISITION FROM LVDT AND ITS ANALYSIS**" submitted by Siniprabha Behera (111EI0432) in the partial fulfilment of the requirements for the award of Bachelor of Technology in Electronics & Instrumentation engineering during the session 2011-2015 at National Institution of Technology, Rourkela is an authentic work carried out by them under my supervision.

Prof. Umesh Chandra Pati

Date: Dept. of E.C.E.

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Abstract

Different A/D converters are used for low-speed analog data acquisition in various industry. Most of these converters are not fit for high-speed analog signal. This shows a high speed data acquisition system which interface with Data card .The design is based on NI USB-6211 data card and proposed for LVDT sensor detection to realize the high-speed analogical data acquisition of multichannel sensor in the LabVIEW. The deliberate results demonstrate that the estimation accuracy can achieves 0.01mm and this framework has great shared trait and in addition extensibility. Finally compensate the non-linearity region of LVDT using neural network algorithm using MATLAB programming. LabVIEW (Laboratory Virtual Instrumentation Engineering Workbench) software and MATLAB is used to simulate the process.

CHAPTER 1

INTRODUCTION TO DATA ACQUISITION

1.1- Data acquisition system

Data Acquisition system (DAQ) is characterized as the procedure of taking a real signal as voltage or current, into the PC, for preparing, examination, stockpiling or other information control. A physical phenomena speaks to this present reality signal we are attempting to gauge. Today, most researchers are utilizing PCs with ISA, PCI or LabVIEW for information procurement in research facility, research, test and estimation, and mechanical computerization applications. Numerous applications utilization module sheets to obtain information and exchange it straightforwardly to PC recollection. Others utilize DAQ equipment isolated from the PC that is fixed through parallel port, serial port or through information card. Regularly, DAQ module sheets are universally useful information obtaining gadget that are appropriate for measuring voltage signals. Not with standing, numerous true sensors and transducers yield flags that must be adapted before a DAQ board or gadget can adequately and effectively procure the sign. This front-end pre-processing which is by and large alluded to as incorporates capacities, for example, signal enhancement, sifting, electrical separation, and multiplexing. As it would turn out, numerous transducers oblige excitation streams or voltages, span fulfilment, linearization, or high enhancement for legitimate and exact process.

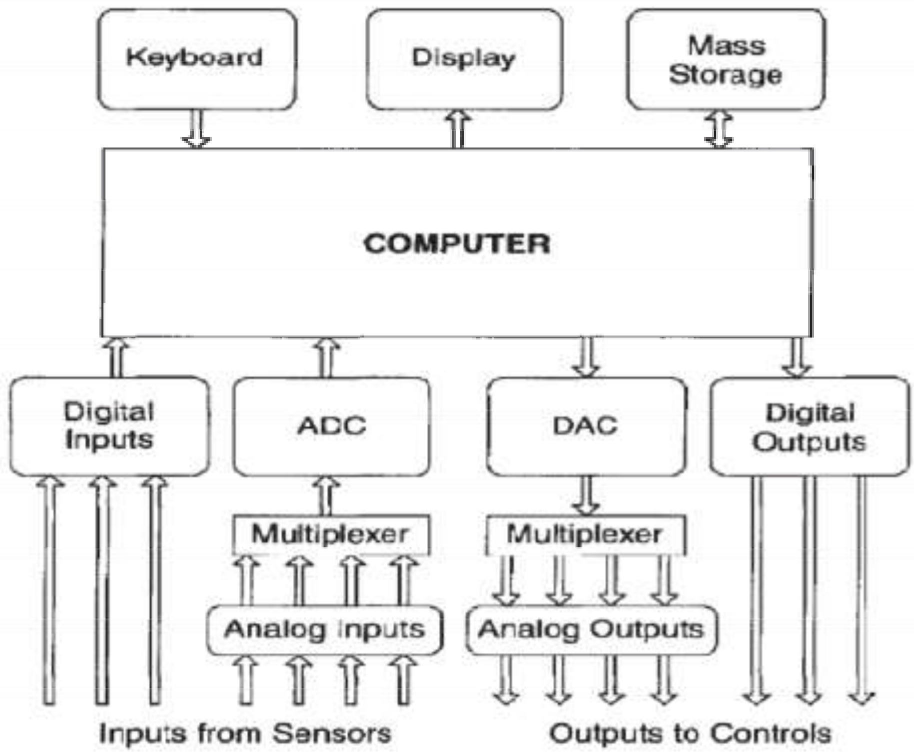

Fig 1.1: Simplified Block Diagram of a DATA ACQUISITION SYSTEM

1.2-Input/output ports

Notwithstanding its recollection, the personal computer has another altogether distinct location space. This is committed to exchanging information toward or after minor gadgets and is known as Input/ Output space (or basically I/O space). Pretty much as the PC's memory space is separated into independent byte areas, the I/O space comprises of numerous nibble measured I/O ports. Every port is addressable similarly as memory, in spite of the fact that an extra control line is utilized inside the PC to separate in the middle of memory and I/O port gets to. I/O space comprises of an adjacent arrangement of I/O discourses. Dissimilar to memorial space, the I/O location space is not sectioned and can't be paged. Truth be told, the processor orientations I/O ports by method for a 16-bit location and this implies that close to 65 536 I/O ports can be bolstered by the PC.

1.3- I/O port allocation

Equipment gadgets outline catalogues to particular I/O ports essentially by deciphering the PC's location transport and control lines. Along these lines, a particular combination of location and control lines is expected to bring about information to be exchanged from the record to the PC's information transport or the other way around. Some I/O ports must be perused or composed, while others are fit for bidirectional information exchange. Whether ports are perused just (R/O), compose just (W/O) or read-compose (R/W) is controlled by how the equipment unravels location and control lines.

1.4- LabVIEW

LabVIEW incorporates broad support for interfacing to devices, instruments and different tools. Users interface to tackle by either combining direct carriage orders (USB, GPIB) or using irregular state, gadget particular, motorists that give local LabVIEW capacity centres to supervisory the gadget. As far as execution, LabVIEW fuses a compiler that conveys neighbourhood code for the CPU stage. The graphical code is deciphered into executable contraption code by deciphering the sentence assembly and by arrangement. The LabVIEW punctuation is entirely supported amid the varying process and gathered into the executable machine code when requested to pursue or saving. LabVIEW is an intrinsically simultaneous dialect, so it is anything but problematic to catalogue various projects that are performed in parallel by technique for multithreading.

This is effortlessly done by illustration two or more parallel while circles. This is an extraordinary advantage for test framework robotization, where it is regular practice to run courses of action similar test sequencing, data recording, and tools interfacing in parallel. Numerous public library with an expansive number of volumes for information securing, signal era, examination, and so on. Alongside various graphical interface mechanisms are given in a limited LabVIEW bundle choices. The quantity of progressive mathematic squares for capacities, for example, reconciliation, channels, and other specific capabilities typically associated with information latch from tackle sensors is colossal. Also, LabVIEW includes a content based software design part called Math Script with extra worth for sign handling, investigation and math.

CHAPTER 2

LVDT (Linear Variable Differential Transformer)

2.1-LVDT Sensor

LVDT (Linear Variable Differential Transformer) is an electromechanical transducer that can alter the straight-lined motion of an objective to which it is attached mechanically into an equivalent electrical voltage signal. LVDT rectilinear position sensors are available for its presentation in measuring activities as small as possible. In detecting process, LVDT's primary winding is invigorated by alternating current of suitable amplitude and frequency basically known as electrical output signal is the differential AC voltage between the two auxiliary windings of transformer, which fluctuates with the hub spot of center inside the LVDT curl. Ordinarily this differential yield AC voltage is changed over by fitting electronic electrical framework to abnormal state DC voltage or current that is more lucky to utilize.

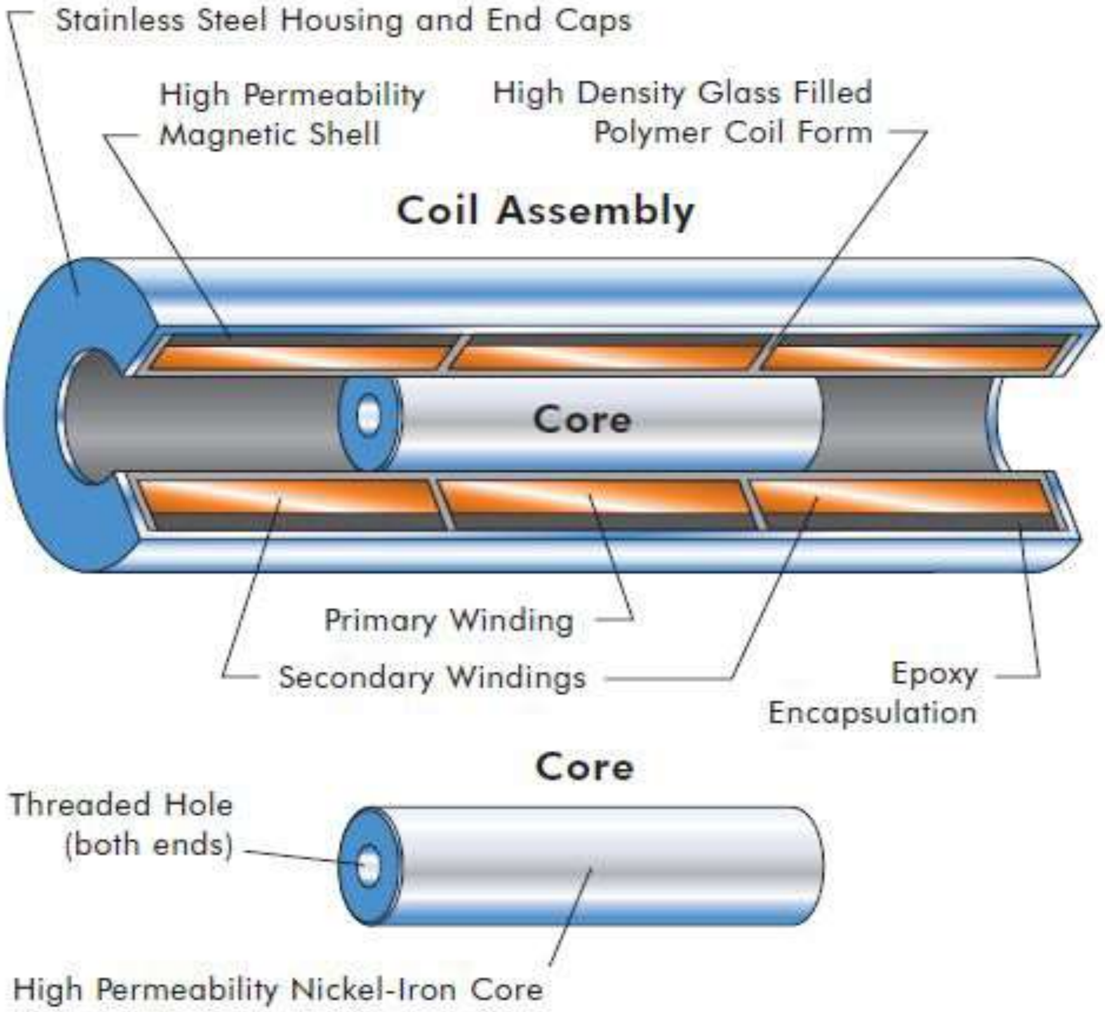

Fig 2.1: Schematic diagram of LVDT

2.2-Design consideration of LVDT

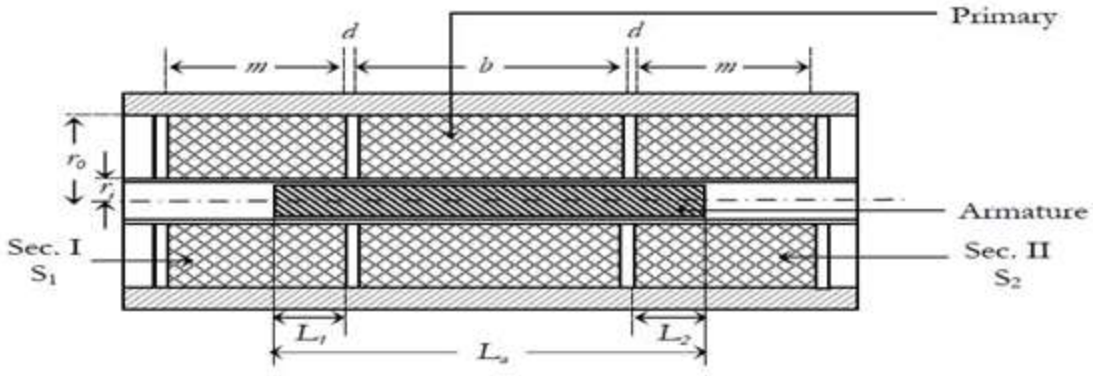

Fig 2.2: Crossectional view of LVDT

The lengths of primary and two equal halves of the secondary coils are *b* and *m* respectively. The coils have an inside radius r_i and an outside radius of r_0. The space between the coils is *d*. inside the coils a ferromagnetic bodywork of length *La* and radius r_i (neglecting the bobbin thickness) moves in an axial direction. The amount of turns in the primary coil is n_p and n_s is the number of cracks in each secondary coil. The cross-sectional view of LVDT is shown in above Fig.

$$e_1 = \frac{4\pi^3 * fI_p n_p n_s * (2L_2 + b) * x_1^2}{10^7 * \ln(\frac{r_O}{r_i}) * m * L_a}$$

$$e_2 = \frac{4\pi^3 * fI_p n_p n_s * (2L_2 + b) * x_2^2}{10^7 * \ln(\frac{r_O}{r_i}) * m * L_a}$$

$$e = k_1 x(1 - k_2 x^2)$$

$$e = e_1 - e_2$$

$$x = \frac{1}{2}(x_1 - x_2)$$

Where:

x_1 = Distance entered by the armature near the secondary coil S1,

And x_2 =Distance penetrated by the armature to the secondary coil S2,

For a specified exactness and maximum movement the complete length of the transducer is Minimum for $x_0 = b$, supercilious that at maximum displacement the armature does not Appear from the secondary coils. Compelling the length of armature $L = 3b + 2d$, neglecting $2d$ compared with b.

In the interest of a given essential sinusoidal excitation, the optional yield voltage e is nonlinear as for removal x. This limitation is inborn in all distinction frameworks and methodologies of wavering the reach have been anticipated by different architect by suitable outline and game plan of the loops.

(i) Composed linear tapering secondary coils. But the development in linearity is not significant.

(ii) Over-wound linear tapered secondary coil improves the linearity to a certain extent.

(iii) Balanced over-wound linear elongated secondary coils. Its performance is similar to all of them.

(iv) Stable profile secondary coils benefits in spreading linearity range by proper describing of the secondary coils.

(v) Use of complementary tapered winding ranges the linearity range but the winding is quite complex as it involves sectionalised winding.

CHAPTER 3

Data acquisition from LVDT

3.1- Data acquisition card

Data acquisition is the process of sample signal that measures real world physical signal or conditions and changing the result sample into digital numeric values that can be manipulated by a PC through different data acquisition card. Different works that can be operated by DAQ card is given below:

(i) USB data acquisition (DAQ) devices provide basic analog and digital I/O functionally.

(ii) Apart from the above DAQ cards have faster sampling and better counters and timing.

(iii) Ex. NI USB 6008, 6211, 6210, 6218, 6216.

(iv) Above data cards specify on basis of there I/O port, sampling rate etc.

Fig3.1: Schematic view of a data card

3.2- NI USB-6211

A basic overview on NI USB-6211 is given below:

16 analog inputs (16-bit, 250 KS/s)

2 analog out-put (16-bit, 250KS/s) 4 digital inputs,

4 digital outputs, 2 32-bit counters.

Bus-powered USB for high flexibility; constructed in signal connectivity.

Fig3.2: Schematic view of a data card

3.3- Data acquisition from LVDT

In production field, common A/D converter chips are extensively used for low-speed analog statistics acquisition. Maximum A/D converter are not fit for requirements of high-speed analog signal. This presents a high speed data achievement system which interface with Data card .The design is based on NI USB-6211 data card is projected for LVDT sensor detection and recognised the high velocity analogical information securing of multichannel sensor simple flags in the LabVIEW. The deliberate consequences of requesting demonstrate that the estimation precision can impacts 0.01mm and this framework has great solidarity and extensibility.

3.4-Simulations

Case 1. Voltage – time:

Fig [3.3] shows the block diagram of a data acquisition system and Fig [3.4] shows the output between voltage and time when we take N sample on demand with sampling rate 100 kHz. Fig [3.3] shows that DAQ Assistant detect the data and through x-y graph block it gives the required out-put.

Fig [3.3] shows that the input of LVDT through data card to the PC. Input of the data card through LabVIEW with different block operate different operation and give the desired output through X-Y graph block.

DAQ assistant take different sampling rate for different input data.

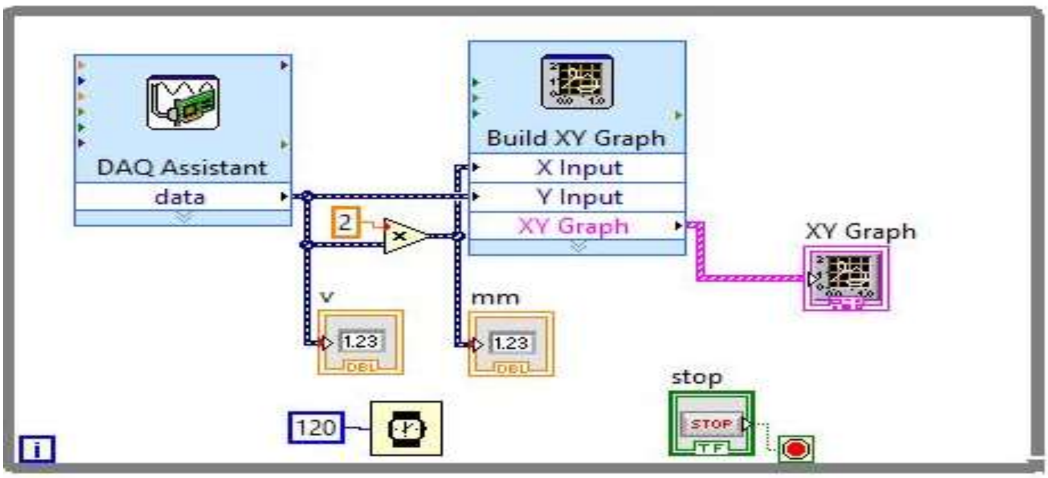

Fig3.3: Block diagram of LAB –VIEW based data acquisition of LVDT

Fig [3.4] shows the relationship between voltage and time when N number of sample taken into consideration under sampling frequency of 100kHz.

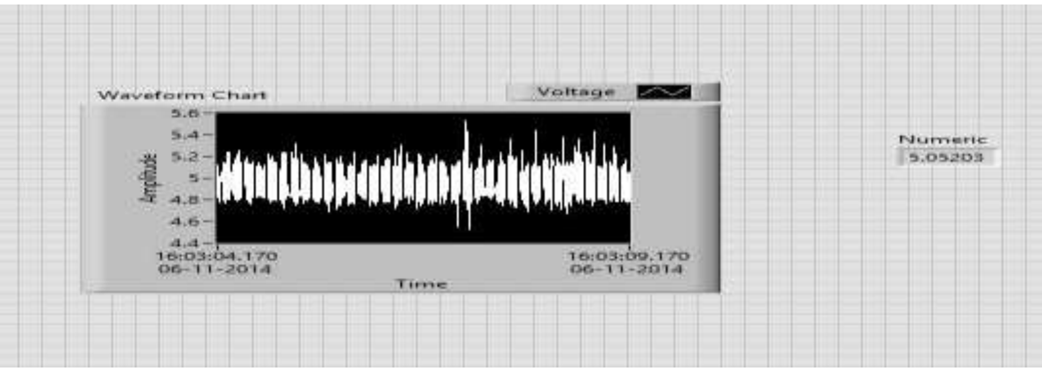

Fig3.4: Voltage – time output N sample on Demand (CASE: I) Sampling rate 100 kHz

Case 2. Displacement – time:

Fig [3.5] shows a relation-ship between Displacement and time with sampling rate of 100 kHz with N sample on demand. This shows the relationship between displacement and time with different displacement value of core and time which varies in between primary and secondary of the transformer.

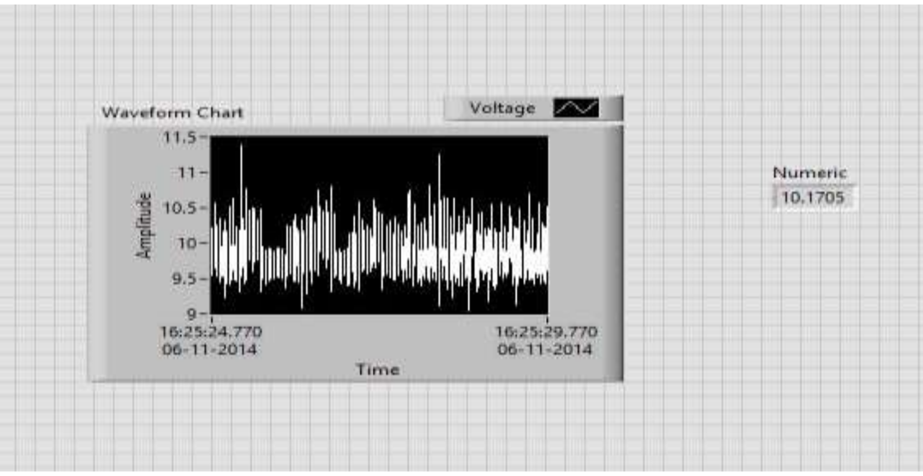

Fig3.5: Displacement-time output: N sample on demand with sampling rate 100 kHz

Case 3. Voltage –displacement:

Fig [3.6] shows a relation-ship between Voltage and displacement of core in LVDT. It shows that differential output voltage of LVDT varies linearly with core position. Centre of the core refer as null position or taken as origin. Above the null position refers as +ve x-axis and below that of null point refers as –ve x-axis.

Differential output AC voltage linearly varies with displacement over some certain region. In this region LVDT bounded with metal , so that the core can't move after a particular region.

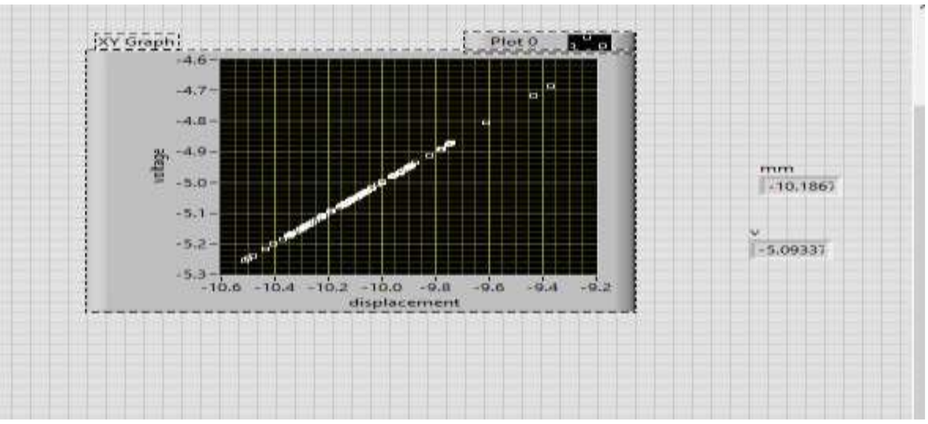

Fig3.6: Voltage-Displacement output: N sample on demand CASE III with sampling rate 100 kHz

Case 4. Signal conditioning output:

Time delay is a process which is required for change the displacement in LVDT sensor.Time delay helps us to take the reading manually by different time intervals.FOR loop helps us to take all the data how much we need and keeps in an array. Fig[3.8] shows the signal-conditioning out-put with time delay process.

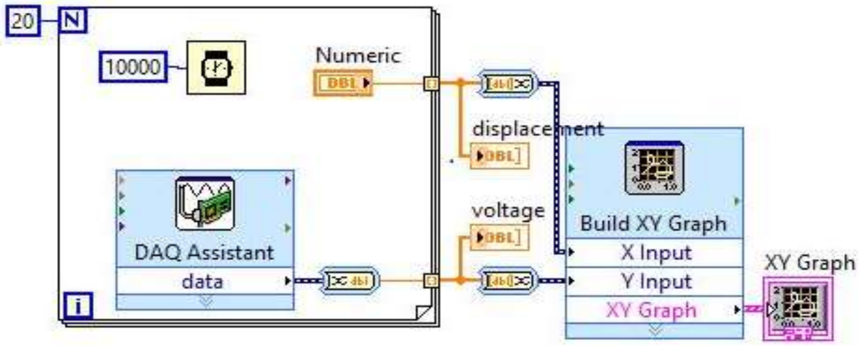

Fig3.7: Block diagram of LabVIEW based data acquisition of LVDT using FOR-LOOP

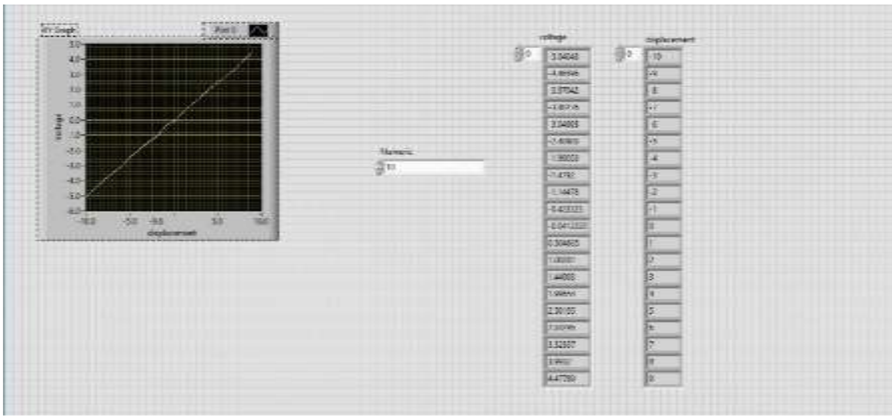

Fig3.8: Voltage – Displacement signal conditioning output (with time delay)

Case 5. Secondary output with offset:

Fig [3.9] shows a block diagram of data acquisition system which gives a secondary out-put of voltage and displacement, with offset value which shows in fig [3.10].

Off set voltage means it does not show fully linear relationship between displacement and voltage. There is some offset value which can properly detected in the graph.

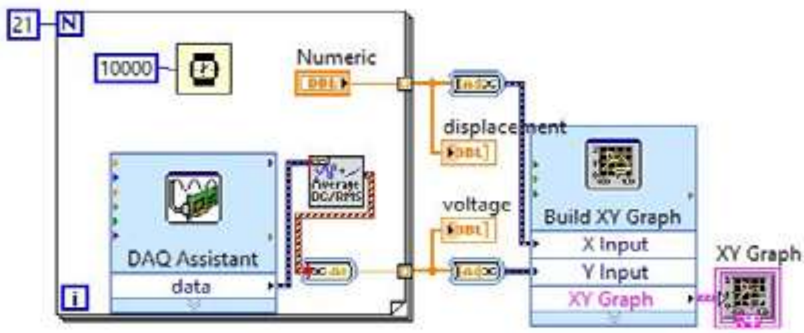

Fig3.9:Block –diagram for secondary out-put

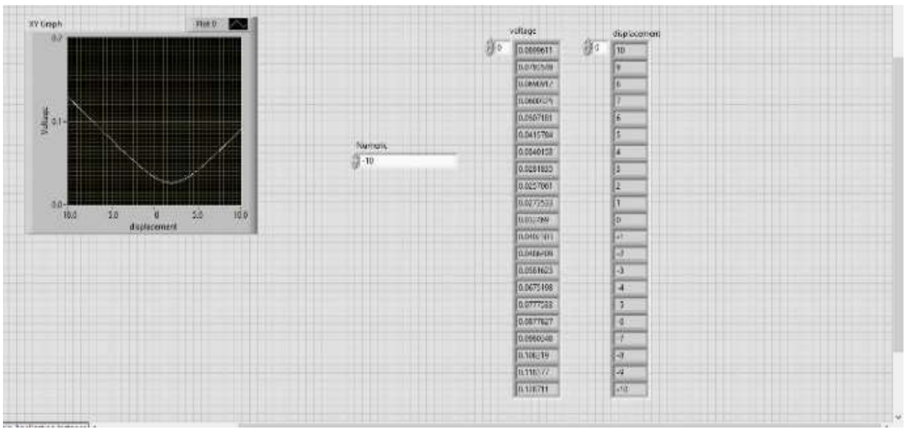

Fig3.10: Secondary out-put with off-set value

3.5-Detecting Process

LVDT is linear within the exact limits. So the linear error is defined as follows: Under the quantified conditions it is the percentage of maximum deviation of the sensor calibration between the close-fitting line (ΔY_{MAX}) and full scale output (Y):

$$\delta = \frac{\Delta Y_{MAX}}{Y} * 100\%$$

From result we found that ΔV_{Max} =0.00144V

$$\Delta V_{Max} = V_{Actual} - V_{Measured}$$

$$\delta = \frac{0.00144}{2} * 100\% = 0.0723\%$$

CHAPTER 4

Neural network

4.1-Artificial Neural Network (ANN)

Artificial neural system (ANN) takes their term from the system of nerve cells in the mind. As of late, ANN has been begun to be an imperative system for association and improvement tricky. There are wide utilizations of various sorts of ANN in the field of correspondence, controller and instrumentation. The ANN is equipped for execution nonlinear plotting between the information and yield space because of its huge comparable interconnection between diverse layers and the nonlinear administration qualities. A simulated neuron essentially be comprised of a processing component that accomplishes the weighted total of the data sign and the including weight. The aggregate is included with the limit and the resultant sign is then gone through a nonlinear capacity of sigmoid or hyperbolic digression sort. Every neuron is connected with three parameters whose learning can be balanced; these are the including weights, the predisposition and the slant of the nonlinear capacity. For the auxiliary perspective a NN may be single layer or it might be multilayer.

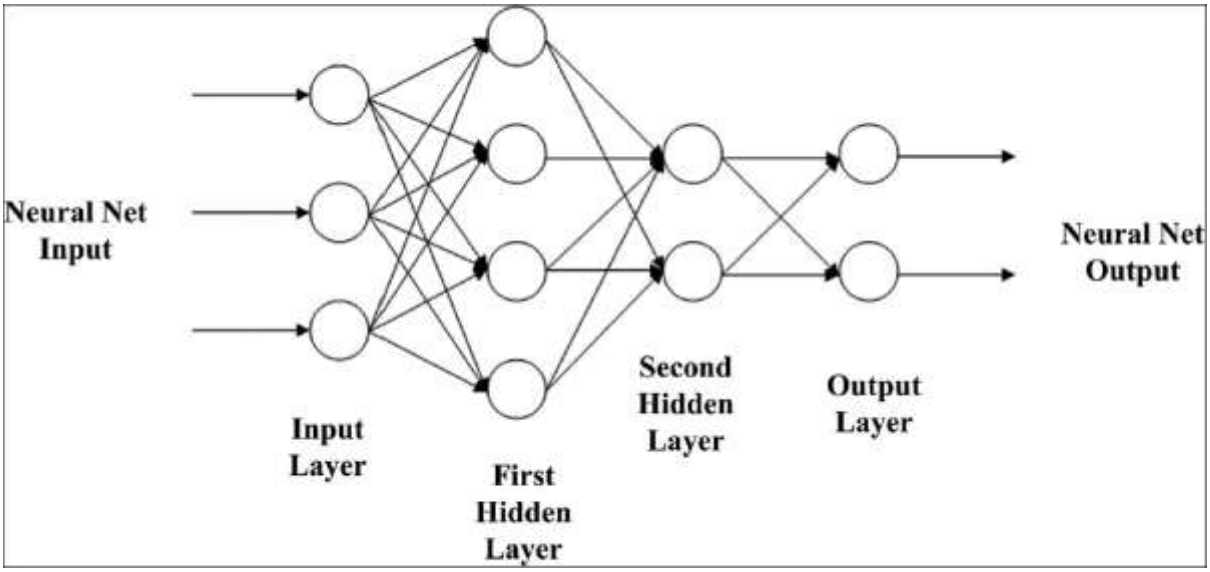

Fig 4.1:ANN (Artificial neural network)

In multilayer development, there is one or various simulated neurons in every layer and for a certifiable case there may be various layers. Every neuron of the one layer is related to all and every neuron of the following layer. The practical connection ANN is extra kind of single layer NN. In this kind of framework the info information is suitable to go through a helpful extension square where the data information are nonlinearly plotted to more number of focuses. This is acknowledged by utilizing trigonometric capacities, tensor items or force terms of the info. The yield of the utilitarian development is then gone through a solitary neuron.

4.1.1-Multilayer perceptron (MLP)

A multilayer perceptron (MLP) is a food forward fake neural system show that plots sets of info information onto an arrangement of suitable yields. A MLP includes of various layers of hub in a consumed diagram, with every layer completely related to the following one. However, for the data hubs, every hub is a neuron with a nonlinear incitement capacity. MLP utilizes a controlled learning system got back to spread for activity the system. MLP is a change of the standard straight perceptron and can separate information that are not directly separable.

On the off chance that MLP has a direct incitement work in all neurons, that is, a straight capacity that plots the weighted inputs to the yield of every neuron, then it is just demonstrated with direct polynomial math that any number of layers can be consolidated to the standard two-layer information yield model (perceptron). What grades a multilayer perceptron differing is that a few neurons utilize a nonlinear incitement capacity which was created to model the recurrence of activity capacities, or terminating, of natural neurons in the mind. This capacity is displayed in a few ways. The multilayer perceptron incorporates of three or more layers (an info and a yield layer with one or more concealed layers) of nonlinearly-initiating hubs and is subsequently measured a profound neural system. Every hub in one layer joins with a certain weight to each hub in the consequent layer. A few individuals do exclude the information layer when including the quantity of layers and there is disparity about whether ought to be deciphered as the weight from i to j or the other route around.

Multilayer perceptron utilizing a back engendering method are the standard calculation for any overseen learning example affirmation procedure and the subject of proceeding with examination in computational neuroscience and parallel spread preparing. They are valuable in examination as far as their capacity to tackle issues stochastically, which regularly permits one to get evaluated answers for massively complex issues like suitability assessment.

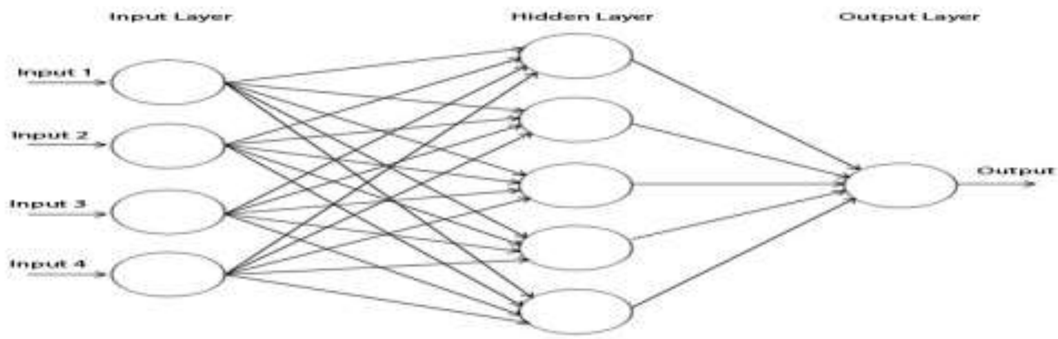

Fig4.2: MLP (Multilayer perceptron)

4.1.2-Fuctional link artificial neural network (FLANN)

FLANN and it is a novel single layer ANN structure fulfilled of framing haphazardly composite ideal districts by delivering nonlinear determination limits. Here, the beginning showing of an outline is enhanced by utilizing nonlinear capacity and hence the example estimation space is expanded. The practical connection exhibitions on a component of a configuration or entire example itself by making an arrangement of directly self-administering capacity and after that evaluates these capacities with the example as the contention. Thus flight of the examples gets to be thinkable in the upgraded space. The utilization of FLANN expands the learning rate as well as has less computational multifaceted nature.

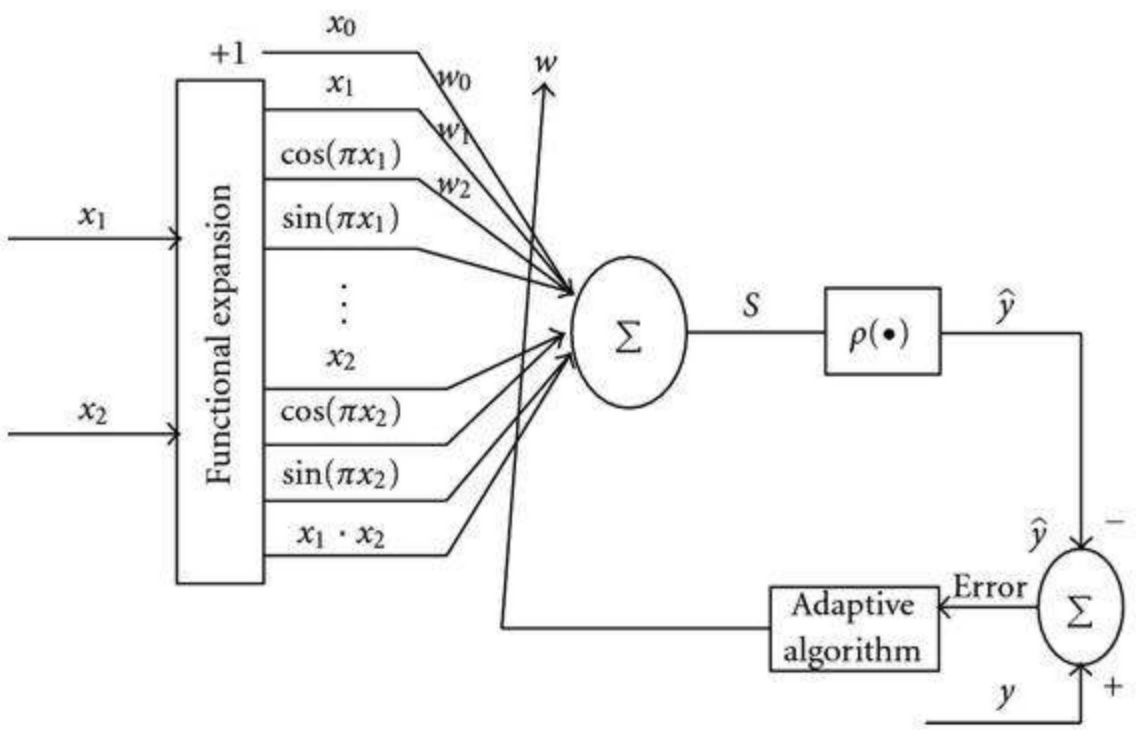

Fig 4.3: FLANN (Functional link artificial neural network)

4.2-Theory on computational complexity

Computational many-sided quality hypothesis is a branch of the hypothesis of calculation in hypothetical software manufacturing and arithmetic that attentions on arranging computational issues as per their characteristic trouble, and relating those classes to one another. A computational issue is known to be an assignment that is on a basic level manageable to being illuminated by a PC, which is equal to expressing that the issue may be tackled by mechanical use of scientific steps, for example, a calculation.

An issue is observed as characteristically difficult in the event that its answer requires huge assets, whatever the calculation utilized. The hypothesis ratifies this instinct, by acquainting scientific models of processing with study these issues and evaluating the measure of assets expected to fathom them, for example, time and capacity. Other multifaceted nature measures are likewise utilized, for example, the measure of correspondence (utilized as a part of correspondence many-sided quality), the quantity of appearances in a circuit (utilized as a part of circuit unpredictability) and the quantity of processors (utilized as a part of parallel registering). One of the parts of computational multifaceted nature hypothesis is to focus as far as possible on what PCs can and can't do.

Nearly related fields in hypothetical software engineering are examination of calculations and calculability hypothesis. A key refinement between computational multifaceted nature hypothesis and examination of calculations is that the previous is committed to breaking down the measure of assets required by a specific calculation to take care of an issue, while the last gets some information about every imaginable calculation that could be utilized to tackle the same issue. All the more correctly, it tries to order issues that can or can't be illuminated with fittingly confined assets. Thus, forcing limitations on the accessible assets is the thing that recognizes computational intricacy from process ability hypothesis: the last hypothesis solicits what kind from issues can, on a fundamental level, be understood algorithmically.

.

4.3-Different cases in complexity

The best, most noticeably poor and normal case multifaceted nature refer to three distinct methods for measuring the time complexity (or some other unpredictability measure) of diverse inputs of the same size. Since a few inputs of size n may be earlier to comprehend than others, we characterize the accompanying complexities.

(i) Best-case unpredictability: This is the multi-layered nature of tackling the issue for the best data of size n.

(ii) Worst-case unpredictability: This is the multi-layered nature of tackling the issue for the most conspicuously corrupt data of size n.

(iii) Average-case multi-layered nature: This is the unpredictability of tackling the issue on a normal. This intricacy is just characterized regarding a likelihood transportation over the inputs. Case in point, if all inputs of the same size are thought to be just as prone to show up, the normal case unpredictability can be characterized as for the uniform appropriation over all inputs of size n.

CHAPTER 5

Nonlinear compensation of LVDT

5.1-Non-linear region of LVDT

LVDT does-not work linearly within all the region. After a particular boundary region it acts as a non-linear element. This shows that beyond +10mm and -10mm scale of LVDT it works like a non-linear sensor. Over this linear region of LVDT, manufacturer sets in such a manner that it is restricted in that boundary region.

5.1.1-Simulation over non-linear region

DISPLACEMENT (in mm)	VOLTAGE (IN V)
0	.385
1	.66
2	1.15
3	1.58
4	1.91
5	2.13
6	2.23
7	2.221
8	2.1
9	1.86
10	1.58
-1	.64
-2	1.12
-3	1.31
-4	1.5
-5	1.59
-6	1.601

Table 5.1: Relation between Voltage-displacement

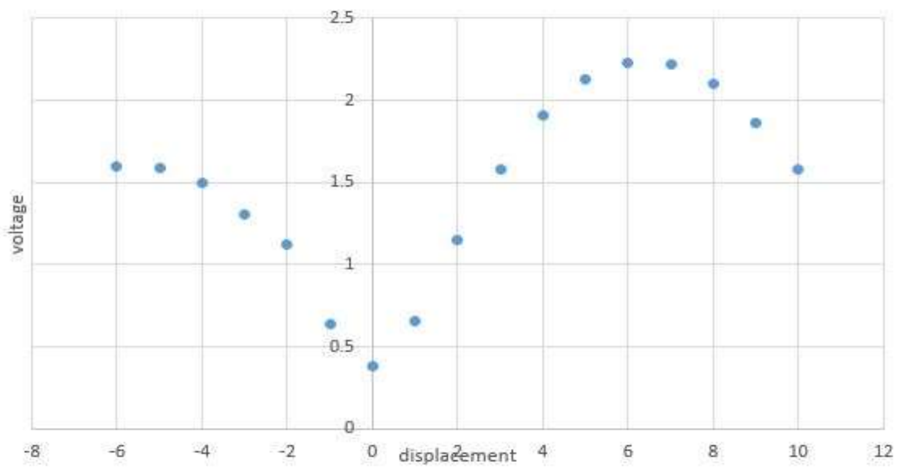

Fig5.2: Voltage- displacement graph shows non-linear characteristics

5.2-Non-linearity compensation of LVDT

This compacts with the non-linearity compensation of (LVDT). In many real-world systems LVDT is used as the sensing element for displacement. It is tough to have all LVDT invented in a factory at a time to be similarly linear. LVDT having different non-linearity existing in a control system errors at a time because of the change in sensor features. There are different ANN Models (MLP, FLANN) to recompense the non-linearity characteristics.

5.2.1-MLP (Multilayer perceptron) based non-linearity compensation

The differential voltage at the output of LVDT is normalized by isolating each value with the maximum value. The normalized voltage output is exposed to the input to the MLP (Multi – Layer Perceptron) based nonlinearity compensator. In case of the MLP, we used different neurons with dissimilar layers.

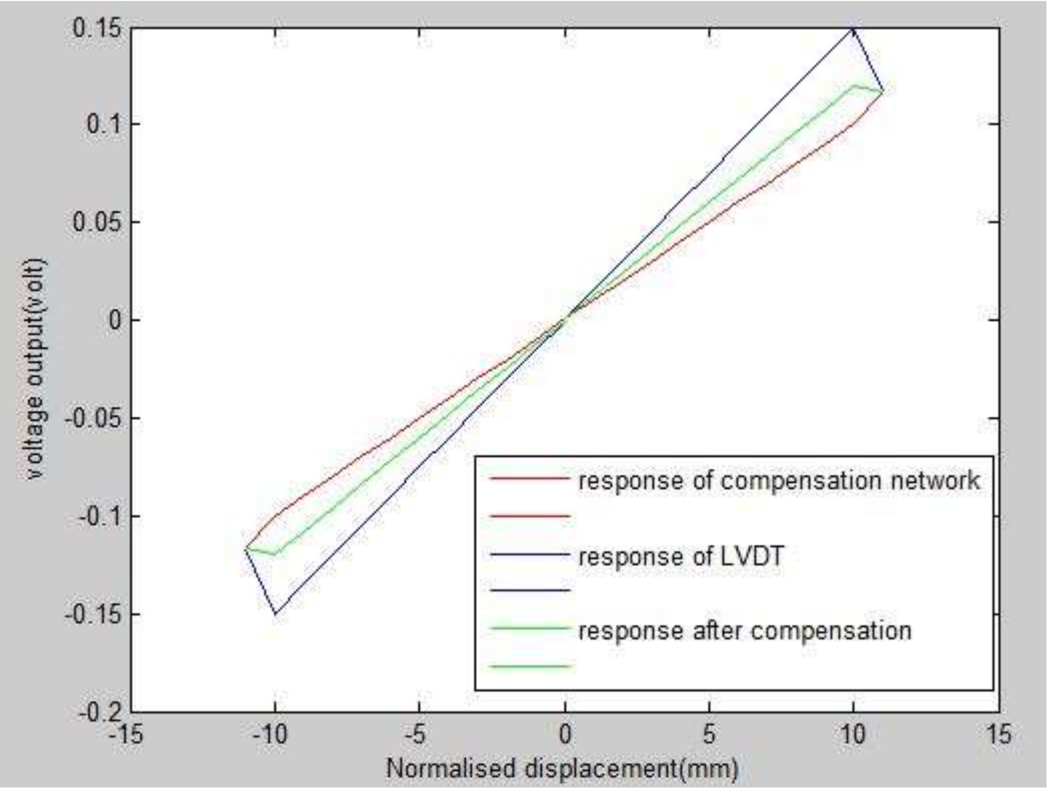

Fig5.3: MLP based compensation

5.2.2-FLANN (Functional link artificial neural network) Based non-linearity compensation

In case of the FLANN model, the differential output of the LVDT is functionally expanded. In this section we have used trigonometric functional expansion because it provides better nonlinearity compensation associated to other. The extended elements are then multiplied with a set of weights, and then summed to produce the final output. The output of the FLANN model is associated with the normalized input displacement of the LVDT to give the error signal.

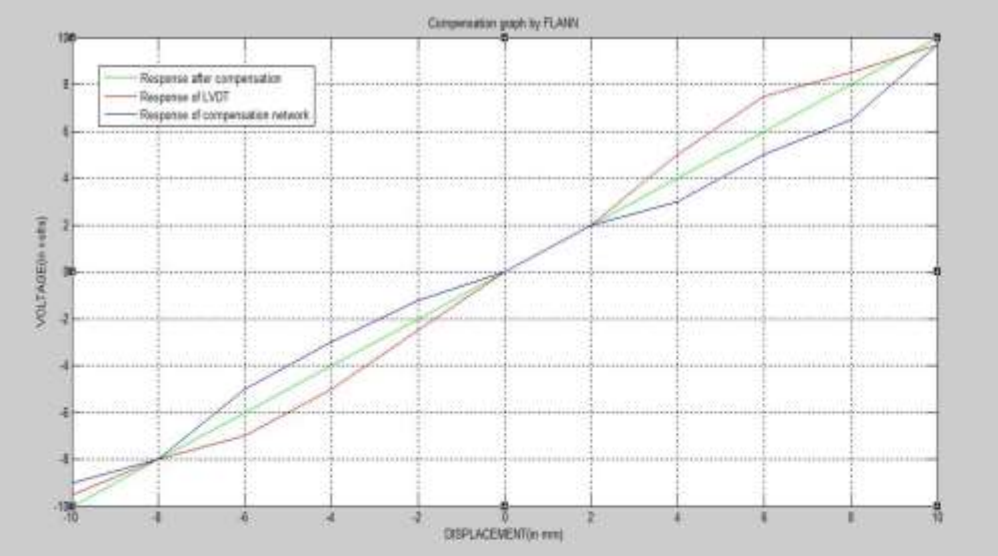

Fig5.4: FLANN based compensation

CHAPTER 6

Result and Discussion

6. Simulation result:

6.1-Detecting-process

LVDT is linear within the specific limits. So the linear error is defined as follows:

Under the specified conditions it is the percentage of maximum deviation of the sensor calibration between the fitted line (ΔY_{MAX}) and full scale output (Y):

$$\delta = \frac{\Delta Y_{MAX}}{Y} * 100\%$$

From result we found that ΔV_{Max} =0.00144V

$$\Delta V_{Max} = V_{Actual} - V_{Measured}$$

$$\delta = \frac{0.00144}{2} * 100\% = 0.0723\%$$

The performance of data acquisition through LVDT over linear region have been obtained using data card with displacement input in LabVIEW. Percentage of maximum deviation of the sensor calibration between the fitted line (ΔY_{MAX}) and full scale output (Y) shows 0.0723%.

6.2-Complexity and percentage of linearity

In case of MLP, the structure chosen is 1-H1-H2-1, i.e. number of input, hidden layer-1, hidden layer-2, and output nodes are 1, H1, H2, 1, respectively.

Three basic computations, i.e. addition, multiplication and computation of tanh(.) are involved in forward path of the MLP.

In case of FLANN along with the additions and the multiplications, some extra computations are required for calculating sin(.) and cos(.) functions.

Percentage of linearity = $PEL = \frac{(desired\ output\text{-}esitmated\ output)}{desired\ output} * 100$

In case of MLP, PEL=2.802%

In case of FLANN, PEL=0.7936%

FLANN model is more accurate and involves less computational complexity than MLP.

CHAPTER 7

Conclusion

7.1Conclusion:

For linear region of LVDT, input as displacement was applied through high speed data acquisition card to the LabVIEW and got both the secondary and signal-conditioning voltage as output. It was found that after a specific region it gave nonlinear output. For non-linear region of LVDT ANN based neural network was applied. It is found that there is equal left hand and right hand sensitivity which says LVDT is very good for measurement purpose with good accuracy. Error is about 0.07239%. In case of multilayer perceptron percentage of linearity was found 2.802% and for Functional artificial neural network was 0.7936%. The non-linearity compensation capability of MLP was poor so FLANN based non linearity compensation was applied to improve the linearity

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