Development of Level Sensor using load cell

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1. Abstract:-

Level measurement is one of the important measurements. Level is measured at the position of the interface between phases liquid-liquid, liquid-solid etc. Level is simply a measure of height of the liquid column. It is the surface where the two phases meet with respect to a reference point. The measurement of Industrial process level parameter is of great importance in the Industrial field. The level of liquid may affect both the pressure and rate of flow in and out of the tank or vessel.

Objective of this system is the measurement of level using Load cell. Generally load cell is used for the measurement of force, but in this project it is used for level measurement. Here diaphragm is used as the primary sensor, which is directly in contact with the liquid column. The liquid column pressure will act on diaphragm and then is transmitted to the load cell via metal connector.

The load cell will give an electrical output which is proportional to pressure acting on diaphragm, which is then calibrated to give level of liquid column.

Index Terms:-
Level Measurement, Load cell, diaphragm, Primary sensor, Liquid column, Electrical output.

2. Introduction:-

Level measurement is one of the oldest measurements. Level is measured at the position of the interface between phases, where the phases are liquid/gas, solid/gas, or immiscible liquid/liquid. Level is simply a measure of height. It defines the position of the interface, that is, the surface where the two phases meet with respect to a reference point. The measurement of Industrial process level parameter is of great importance in the Industrial field. The level of liquid may affect both the pressure and rate of flow in and out of the tank or vessel. This measurement is often converted to a volumetric or gravimetric quantity. Load cell will give an electrical output which is proportional to pressure acting on diaphragm, which is then calibrated to give level of liquid column.

The load cell which we are using is Shear beam load cell of 10 kg whose output is in voltage form, at no load condition it is 0.02mV and at full load it is 20mV.

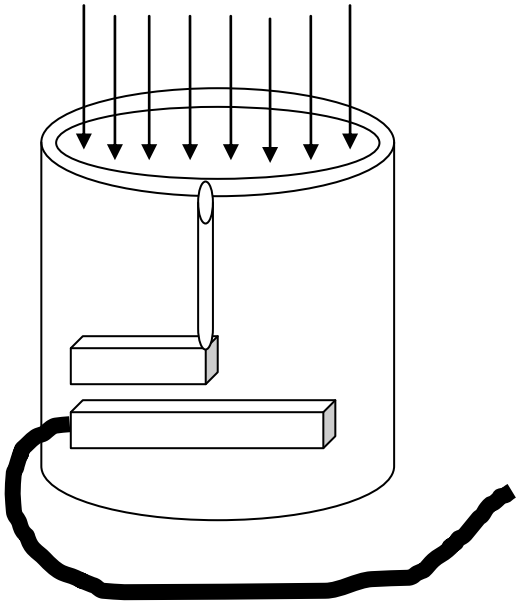

Fig.1 Direction of pressure of water column on diaphragm

OPERATING PRINCIPLE

Pressure is defined as a force per unit area

$$P=F/A$$

As pressure is commonly measured by its ability to displace a column of liquid in manometer, pressure are often expressed as depth of a particular fluid [e.g.

inches of water] The pressure exerted by a column of liquid of height h, density ρ is given by the hydrostatic pressure eqn.

$$P= \rho gh$$

Where , ρ =density of liquid

g=acceleration due to gravity

h=height of liquid column [in meters]

Other units can be used if the rest of the units used in the equation in consistent way

$$P[static] = h\times \frac{density\times S.G}{A}$$

Where

Density of substance is defined a mass per unit volume. Liquid densities changes considerably with temperature, but only with negligible amounts with pressure, except at extremely high pressures. Density of water at 0.0°C and at 1 atm pressure is 999.842 Kg/m³Specific gravity of fluid is its weight [or mass] ratio to standard. Water is considered as standard liquid.

2.1 BLOCK DIAGRAM SCHEMATIC

Fig2.1. shows the block diagram of overall system. The block diagram can be divided into three major blocks namely:

1. Measuring block (Transducer)
2. Signal Conditioning block
3. Controlling block (controller)

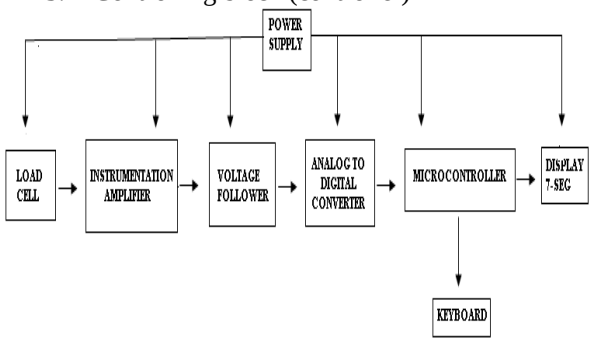

Fig.2 Block diagram of overall system

2.2.1 Measuring block: The major function of this block is to measure the parameter i.e. pressure exerted by water column on the load cell and give to the ADC via signal conditioning circuit.

Load cell

Load cell is typically an electro-mechanical transducer which translates changes in force or weight into changes in electrical signal. Load cell consists of four strain gauges in the form of Wheatstone bridge configuration, but is also available with one or two strain gauges. The electrical signal output is normally in the order of a few milivolts and requires amplification by an Instrumentation amplifier before it can be used.

2.2.2 Signal Conditioning:

Since output of load cell is vary small in the range of mV. Thus load cell signal conditioner required, which include amplifiers to boost the signal level to increase measurement resolution.

Instrumentation Amplifier

In a number of industrial and consumer applications, one is required to measure and control physical quantities. These physical quantities are usually measured with the help of transducers. The output of transducer has to be amplified so that it can drive the indicator or display system. This function is performed by an instrumentation amplifier .In this project we are using AD620 a monolithic (single chip) instrumentation amplifier.

Voltage Follower:

It is used to avoid loading effect also to increase current capacity of the circuit As output of voltage follower circuit is negative voltage follower is used to invert the output before giving to the analog to digital converter.

2.2.3. Controlling Block:

This block consists of ADC & Microcontroller along with Keyboard and display interfacing circuit. The amplified signal coming from Signal conditioner is given to the ADC for conversion of analog data into digital data.

Analog to Digital Converter:

ADC is more widely used devices in digital technology. This ADC converts an analog data into a binary coded data which can be fed directly to the digital processors. Here we use an analog to digital converter chip ADC 0804 which is widely used by the digital computing designers. It is connected to the port1 of microprocessor and port 3 signals used as hand-shaking signals.

Microcontroller

Microcontroller (MCU) is complete computer systems on a chip. They combine an arithmetic logic unit (ALU), memory, timer/counters, serial port, input/output (I/O) ports and a clock oscillator. In this project we are using 89C51 microcontroller chip. It has128×8 bit internal RAM, 32 programmable. I/O Lines, Two 16-bit Timer/Counter, 6- interrupt sources and many other important features. Also it is easy to program and it is easily available, also it is inexpensive.

Keyboard

The key board here we are interfacing is a matrix keyboard. This key board is designed with a particular rows and columns. These rows and columns are connected to the microcontroller through its ports of the micro controller 89C51. We have used 3*4 matrix key boards and used only one port of microcontroller i.e. port 0 to interface it. Here keyboard is interfaced basically to enter the density of unknown fluid, in order to calculate the level of that fluid.

Display [7- segment]

7 Segment displays are basically 7 LED's in a form of display device. This display is alternative to more complex dot matrix displays. The general advantage of LED displays are: lower power consumption, longer lifetime , compact size which is suitable for instrumentation and graphic representations, soldering bath ,can easily be interfaced with microcontroller, and also it is economical. Here we have used 4 digits of 7segment Display.

2.2.4 Power Supply:

This is required to provide a power supply to all the analog and digital IC's and to the load cell as per their requirements

3. Component Description:
3.1 DIAPHRAGM:

Pressure is basically a mechanical concept that can be expressed in terms of the primary dimensions of mass and length, and is a physical parameter encountered in many fields. It is defined as the force acting per unit area, measured at a given point or over a surface. Pressure is one of the significant properties of a fluid and is characterized by a compressive stress exerted uniformly in all directions. When the fluid is in equilibrium, the pressure exerted at a point is identical in all directions and is independent of the orientation. This condition is referred to as the static pressure. In the case of a moving fluid, various pressure components may exist in the medium. There are two types of pressure sensors (transducers).

In the gravitational type, the familiar manometer is the simplest device. In elastic transducers, the pressure exerted by a force over the area of an elastic device e.g. diaphragm. Here diaphragm is used as a primary sensor, which is directly in contact with the fluid whose level is to be measure. Fluid pressure on the diaphragm is to be transmitting to the L.C as a force by a force rod. Since thickness of diaphragm is very small; if contact of the diaphragm and force rod is a single point then total fluid column pressure acting on diaphragm is not transmitted as force to the L.C. In this case some amount of pressure is lost. Thus in order to overcome loss of pressure and to get proper transmission of fluid column pressure disc above force rod is connected.

Features of Diaphragm:

- Material: Natural rubber
- Thickness: 0 .7mm

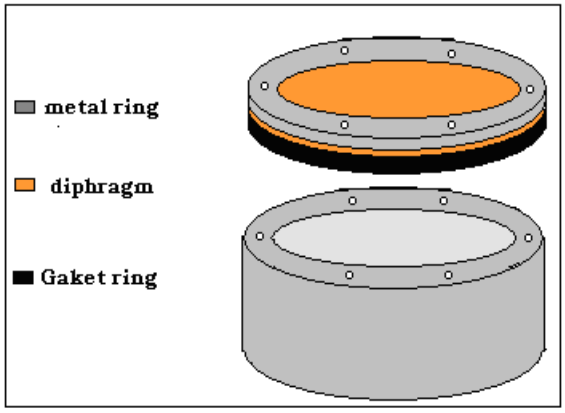

Fig.3 Diaphragm

3.2 LOAD CELL:

A load cell is typically an electronic device (transducer) that is used to convert a force into an electrical signal. This conversion is indirect and happens in two stages. Through a mechanical arrangement, the force being sensed deforms a strain gauge. The strain gauge converts the deformation (strain) to electrical signals. Normally, a load cell consists of strain gauges in a Wheatstone bridge

configuration. To understand how a load cell works, we need to first understand the basic theory behind the operating principle of strain gauge.

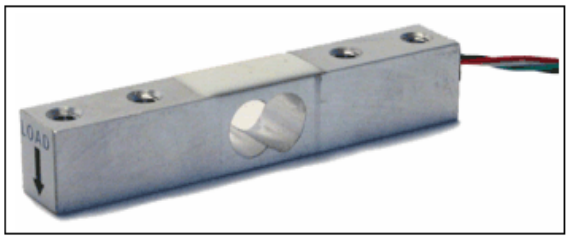

Fig. 4 Load Cell

Checking load cell for it's Linearity:

In order to check the linearity of load cell put some known weight on the load cell and record the output voltage given by the load cell. Then plot a graph of load cell vs. output voltage. Load cell used in this project has maximum capacity of 10Kg.Following table gives output voltage reading for known weight

WEIGHT (grams)	VOLTAGE (millivolt)
10	0.2
20	0.4
30	0.6
40	0.8
50	1.0
60	1.2
70	1.4
80	1.6
90	1.8

Table1 output voltage reading for known weight

From the table it is clear that load cell gives linear output .It has a off-set voltage of value 0.6mV

4. DEVICE DESIGNING:

This section is devoted to explain designing of various component of the Device.

4.1 HOUSING DESIGN:

According to L.C. dimensions device is designed. Housing is designed in such a way that L.C. and entire assembly accommodate with minimum clearance to make device more compact.

- **Circular Design:**

Easy & simple operation for circular design on lathe machine. After application of fluid pressure, if design other than circular is selected then stress at end points and at the corner will not be equal. In case of circular design, stress is equal at each point on the circumference.

- **Material selection: S.S.316**

Measurement of level is to be taken by sinking the device each time into fluid.

Advantage: To protect the device from corrosion, high quality steel is used.

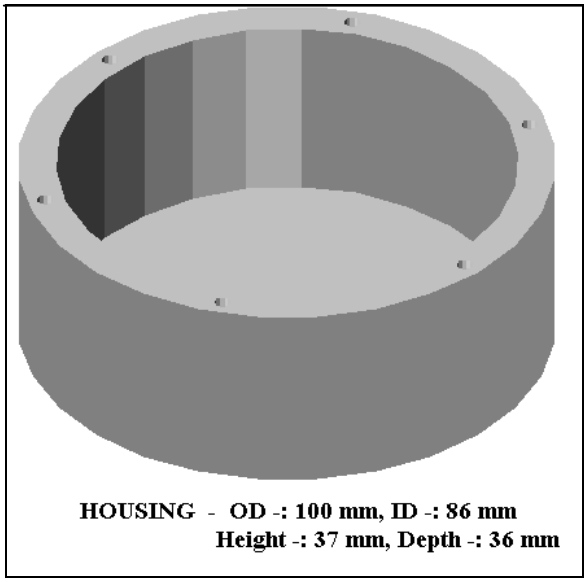

Fig.5 Housing arrangement for internal assembly

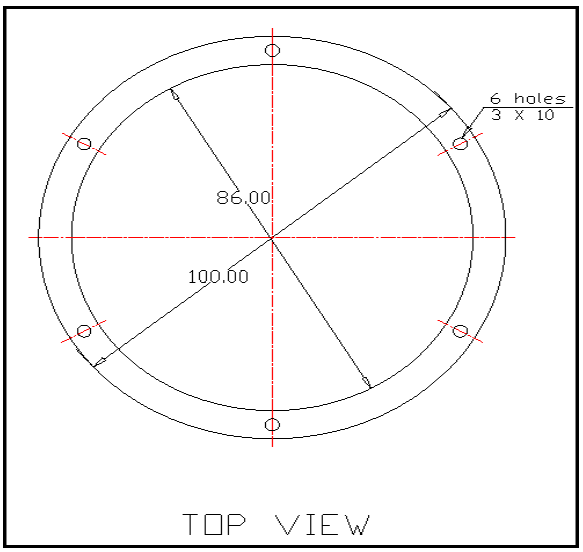

Fig.6 Top view of housing

4.1.2 INTERNAL ASSEMBLY:

Direction in which load is to be applied on L.C. is shown on diagram by an arrow. Since deflection of diaphragm is maximum at its centre; arrow on L.C. (point of application of load) must be centre of diaphragm. In this case to get centre of diaphragm, its radius should be equal to length of L.C. and housing diameter double of L.C. length. But it will make device more bulky.

To make device compact & linear deflection of diaphragm we connect L-shaped beam at point of application of load on L.C.

Length of beam is taken in such way that force rod on beam will be centre point of diaphragm.

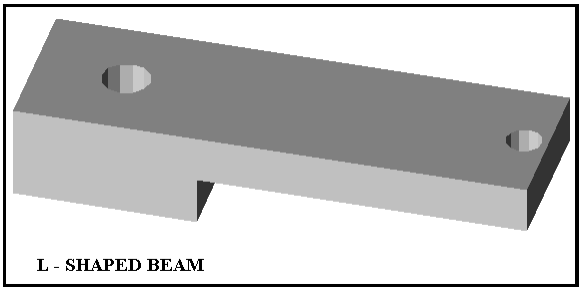

Fig.7 L-shaped Beam

- **Diaphragm selection:**

Initially thick diaphragm was used giving non-Linear deflection for small range hence a thin diaphragm is selected.

Specifications:

Thickness = 0.7mm
Diameter = 86mm
Material = natural rubber

- **Diaphragm Plate:**

Fluid pressure on the diaphragm is to be transmitting to the L.C as a force by a force rod. Since thickness of diaphragm is very small; if contact of the diaphragm and force rod is a single point then total fluid pressure acting on diaphragm is not transmitted by force rod to the L.C.

In this case some amount of pressure is lost.

Remedy: to overcome loss of pressure Disc above force rod is connected.

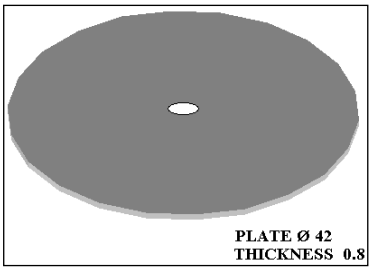

Fig 8 Diaphragm plate

- **Gasketing**:

There can be air gap between diaphragm and housing, even if tighten by screws. Gasketing to diaphragm is provided to make device leak proof.

Material: natural rubber

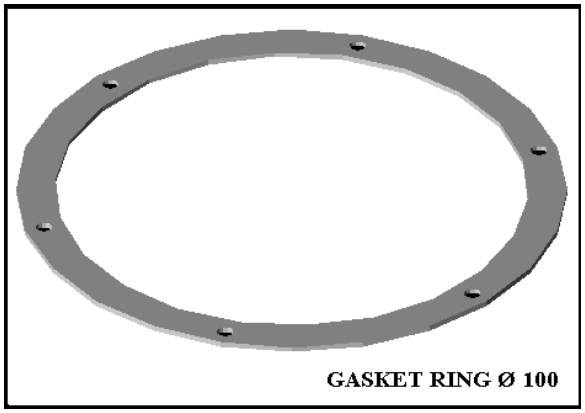

Fig.9 Gasket Ring

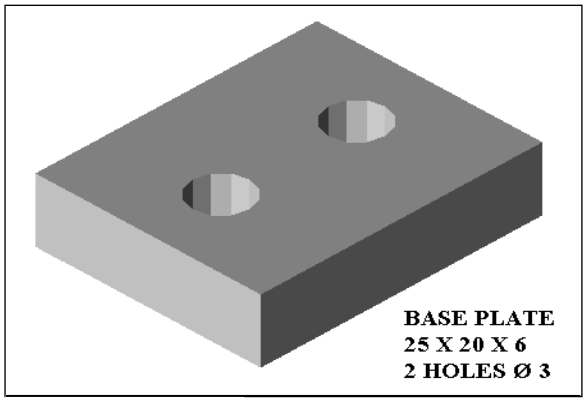

Fig 10 Base Plate

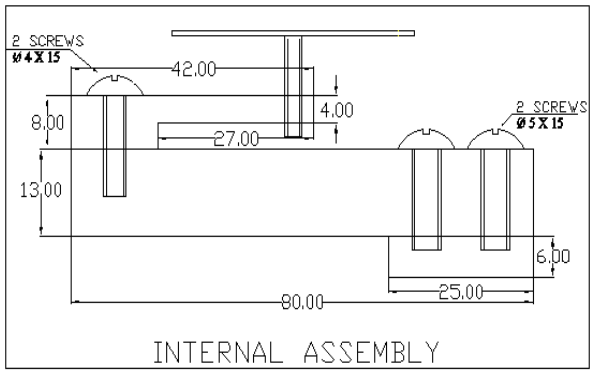

Fig 11. Dimensions of Internal Assembly

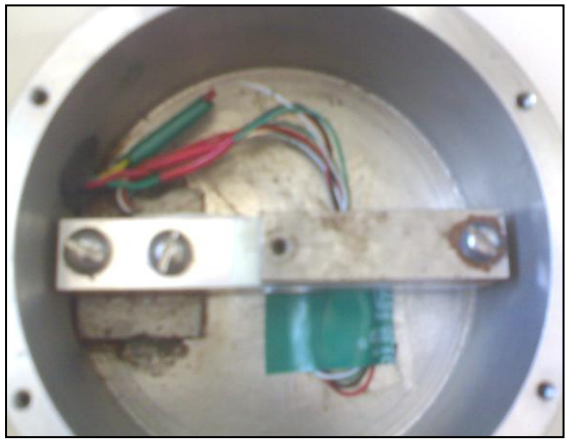

Fig.12 Internal assembly

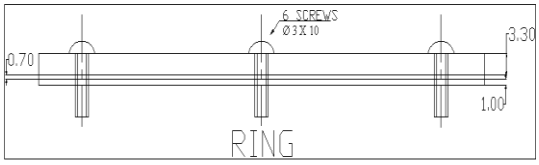

Fig 13 Placement of screws for metal ring, diaphragm and gasket

5. CIRCUIT DESIGN:

1. To give excitation to load cell
2. Amplifying load cell output
3. Converting analog output into digital signal
4. Interfacing of Microcontroller with Keyboard
5. Interfacing of Microcontroller with 7-seg Display

The designing and the working of the each part is discussed in brief.

5.1 EXCITATION TO LOAD CELL:

A load cell is a member of a family of force transducers. This implies that a load cell creates an electrical signal or response when acted upon by a force or load. Since it is a passive device, it requires

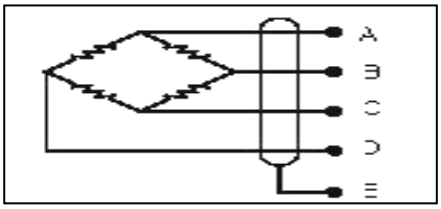

Fig 14 Internal resistance Bridge of Load Cell

significant excitation voltage to obtain reasonable level of output voltage. Load cell composed of strain gauges arranged in the form of bridge.

A: red (+) excitation

B: yellow (+) signal

C: black (-) excitation

D: green (-) signal

E: shield

Load cell measurement involves sensing extremely small changes in resistance. Therefore it is very important that the excitation voltage be very accurate and stable in order to calculate the correct strain. Load cell circuit typically requires a constant voltage source to power its bridge. It is very important that the excitation voltage be very accurate and stable. While there is no standard voltage level that is recognized industry wide, excitation can be 10V (recommended) to 15V (maximum). While a higher excitation voltage generates a proportionately higher output voltage, the higher voltage can also cause larger errors due to self-heating. Here

excitation voltage of 10V (recommended) is given to the load cell. Load cell excitation circuit diagram is shown below

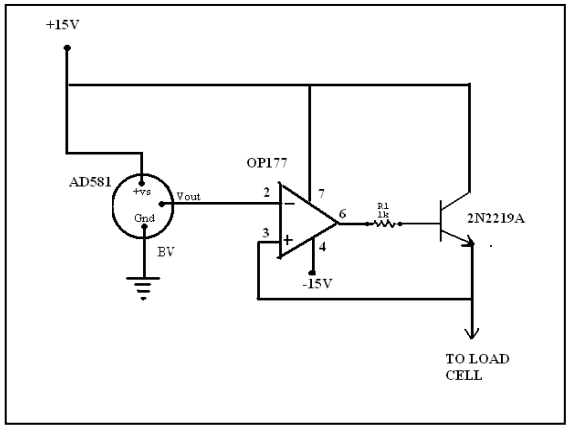

Fig. 15 Circuit diagram for Excitation of Load Cell

List of components used are:

- AD581: High precision 10V IC Reference
- OP177 : Ultra-precision Operational Amplifier
- 2N2219A:NPN transistor
- 15V Power Supply

Working:

In this circuit 10.000V bridge excitation is derived from an AD581high precision voltage reference with an OP177 and 2N2219A used as a buffer. The 2N2219A is within the OP177 feedback loop and supplies the necessary bridge drive current. This design has a minimum number of critical resistors and amplifiers, making the entire implementation accurate, stable.

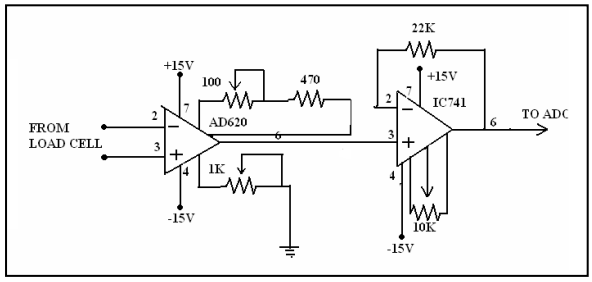

Fig. 16 Amplification of the Load Cell output

5.2 AMPLIFYING THE LOAD CELL OUTPUT:

The output of load cells and bridges is relatively small in the range of 0.2mVto 20mV. Therefore, load cell signal conditioners usually include amplifiers to boost the signal level to increase measurement resolution

Working:

The amplifying circuit includes a first amplifier AD620 of a gain 1 for amplifying an output voltage .The amplifier AD620 is an Instrumentation Amplifier. Resistor 470Ω and potentiometer of 100Ω are used to adjust the gain of the circuit. This design has a minimum number of critical resistors and amplifiers, making the entire implementation accurate, stable, and cost effective. Output terminal of first stage amplifier is connected to the input terminal of the second amplifier which is basically used for offset-nulling or zero balance.

6.1 Programming Software

Keil µ-vision 3 is an IDE (Integrated Development Environment) that helps to write, compile and debug embedded programs. It encapsulated the following components

- A Program Manager
- Tool Configuration
- Editor
- A powerful Debugger

Keil development tools for the 8051 microcontroller family support every level of developer from the professional applications engineer to the student just learning about embedded software development. The industry-standard Keil C Compilers, Macro Assemblers, Debuggers, Real-time Kernels, and Single-board Computers support ALL 8051-compatible derivatives.

The Keil Software 8051 development tools are programs to compile C code, assemble the assembly source files, link and locate object modules and libraries, create HEX files, and debug the target program.

6. FUTURE IMPROVEMENT

The work done is on Microcontroller based. Thus the expected future improvements make the computer as the centerpiece for the development of

the device. We can interface the device to computer via RS 232. Serial port.

Here we have used rubber diaphragm as a primary transducer, but it has many limitation. As device cannot be used for corrosive fluid, acidic fluid. Thus by changing the material of diaphragm we can use it for various fluids and also con increase the pressure range. Since this device cannot be used at high as well as at low pressure area e.g. at low pressure area the pressure inside the device is more than the outside pressure (as device is sealed), thus because of pressure difference, the diaphragm may get puffed So it may not possible to get accurate measurement. Thus to overcome with this problem It is possible to provide vacuum arrangement. We can keep pressure inside the device just above the vacuum pressure and can provide pressure adjustment.

6. References:-

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