People's Democratic Republic of Algeria
Ministry of Higher Education and Scientific Research

Ecole Nationale Polytechnique

Electronics Department

In partial fulfillment of the requirement for the
Master's Degree
(Electronics Engineering)

Fluid Flow Measurement Based on Infrared Waves

Youssouf SAMEUT BOUHAIK

Supervised by:
AP. Mourad ADNANE
AP. Rabie MESSAHLI

Publicly presented and discussed on 22/06/2016

Jury members:

President	Pr. Adel BELOUCHRANI	ENP Algiers
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ملخص

المشكل الرئيسي الذي يواجه مختلف المجالات العلمية هو قياس مختلف الخصائص. هذه القياسات تساعدنا في فهم عدة جوانب للموضوع. قياس تدفق السوائل يأخذ حيزا مهما في البحث في مجال الهيدروليك نظرا لفائدته في تفسير تصرف السوائل.

عدة طرق تقليدية استعملت لقياس التدفق. هذه الطرق لا تزال تعاني من بطء الإستجابة وضعف في الدقة والضبط. قياس تدفق الموائع بالمقاربة الإلكترونية قد يحل هذه النواقص. في هذا العمل، تم قياس فارق الضغط لاستنتاج تدفق الموائع بالإعتماد على معادلة برنولي.

الكلمات المفتاحية: موائع، تدفق، فارق الضغط، معادلة برنولي.

Résumé

Le problème majeur dans les domaines scientifiques est la mesure des différents paramètres. Cette mesure nous permet de comprendre plusieurs aspects du sujet. La mesure du débit des fluides prend une place importante dans la recherche hydraulique vue son utilisation dans l'interprétation du comportement du fluide.

Plusieurs méthodes traditionnelles ont été utilisées pour mesurer le débit. Ces méthodes souffrent encore des réponses lentes et d'une précision et résolution mauvaises. Utilisant une approche électronique pour mesurer le débit du fluide peut résoudre ces problèmes. Ce travail présente l'utilisation de la mesure de la pression différentielle pour déduire le débit du fluide en utilisant l'équation de Bernoulli.

Mots clés : Fluides, débit, différence of pression, équation de Bernoulli.

Abstract

The main problem in scientific fields is measurement of different parameters. This measurement helps us understand many aspects of the subject. Measurement of fluid flow takes an important standing in the hydraulic research due to its use in interpreting the fluid behavior.

Many traditional methods were used to measure flow. These methods still suffer from slow response and poor precision and resolution. Using an electronic approach to measure the fluid flow may solve these deficiencies. This work presents the use of the differential pressure measurement to deduce fluid flow based on Bernoulli's equation.

Key words: Fluids, flow, difference of pressure, Bernoulli's equation.

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Introduction

The hydraulic measurement includes the measurement of many fluid parameters such as, level, pressure, flow, etc.
In our previous work in the engineering paper, we have developed a system to measure fluid level and pressure in the hydraulic department's system. The main aim of this work is to continue our previous work designing a better system to measure fluid flow with higher precision and reliability.

Build an electronic solution facing the hydraulic problem is recommended considering the sensors size, performance and efficiency. The challenging task is to compare the devices' functionality within all the influencing parameters and environment.

This paper represents the problem faced of measuring fluid flow and the solution proposed using differential pressure flowmeter. In the first chapter, general concepts are presented explaining the principles of different methods used to measure fluid flow with their advantages and limitations.

The second chapter goes more deeply explaining explicitly the problem and the solution proposed with all the technical details, especially the level measurement using Infrared transducer, U-tube manometers for the pressure measurement and finally joining both to form the differential pressure flowmeter.

The third chapter is dedicated to the experimental results for both level measurement using Infrared sensor and the flow measurement using differential pressure measured by a U-tube manometer and two pressure transducers interpreting and comparing the results.

Chapter 1

General Concepts

1.1 Infrared Radiation

Infrared radiation is an electromagnetic radiation that have wavelengths longer (Lower frequencies) than those of visible light (red light), it extends from about 700 nm (430 THz) to 1 mm (300 GHz) [1]. IR radiation is one of the three ways heat is transferred from one place to another, convection and conduction are the other two ways. Every object that have a temperature above about 5 degrees Kelvin emits IR radiation. The sun gives off half of its total energy as IR, and much of its visible light is absorbed and re-emitted as IR, according to the University of Tennessee. The infrared position in the electromagnetic spectrum is shown in figure 1.1

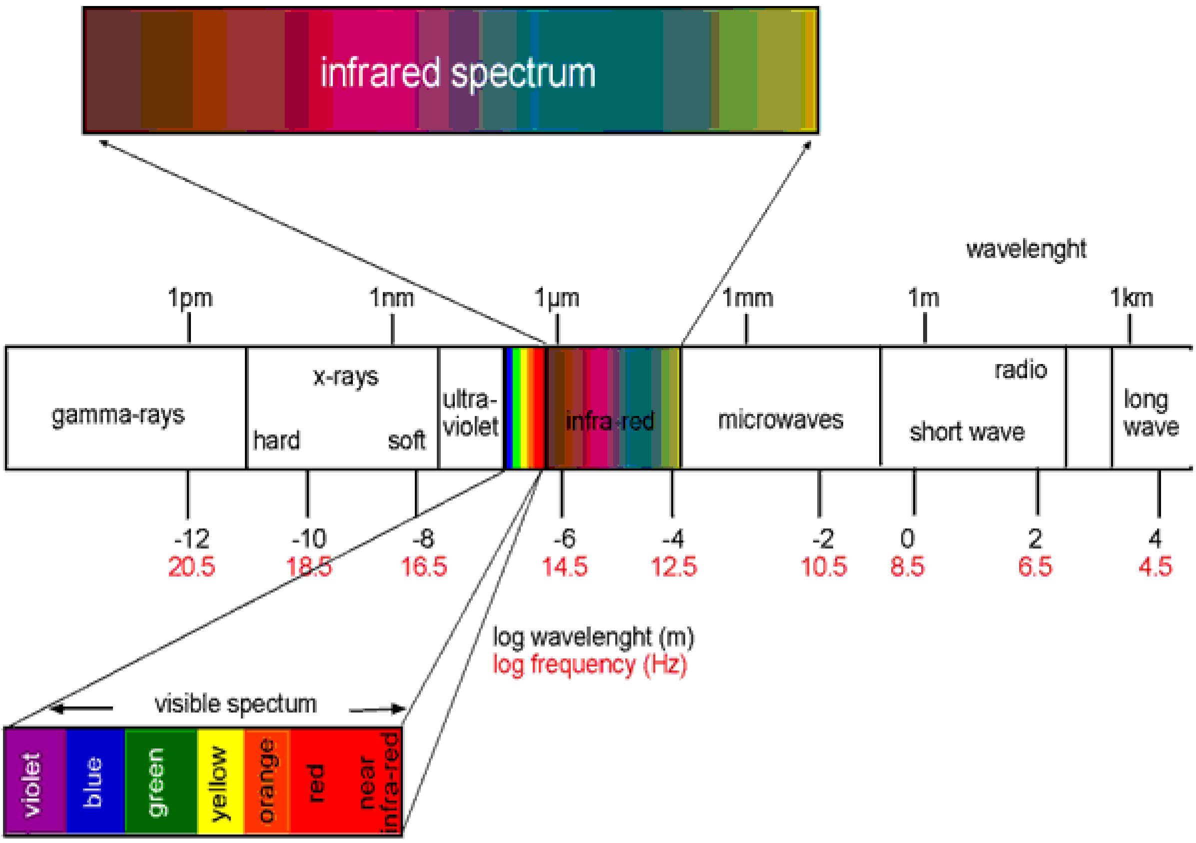


Figure 1.1: Infrared position in the electromagnetic spectrum [2].

Infrared radiation is attenuated due to absorption and scattering by atmosphere gases and aerosol particles. Atmospheric absorption is caused predominantly by the presence of molecule absorption bonds and is strictly a function of radiation wavelength. The amount of attenuation introduced by atmospheric absorption and scattering is an important factor in the design of IR sensors.

1.1.1 Infrared Applications

This section describes the applications of infrared and photonic technologies in different life fields and area:

A Thermography

Thermography is to determine the temperature of objects knowing the emitted wave using infrared radiation. Thermography (thermal imaging) is mainly used in military and industrial applications but the technology is reaching the public market in the form of infrared cameras (due to the massively reduced production costs) which can detect radiation in the infrared range of the electromagnetic spectrum.

B Medecine and Biological systems

Infrared lasers and photonic sensors are playing key roles in medical treatment and surgical procedures, Infrared digital cameras have produced high-resolution images of cellular and subcellular configurations.

C Tracking and surveillance

Infrared tracking is a passive weapon guidance system which uses the infrared radiation from a target to track and follow it. Since infrared is radiated strongly by bodies which emit heat. All objects that emit and generate heat including people, vehicle engines and aircraft are especially visible in the infrared wavelengths of light compared to objects in the background. Unlike radar, these systems provide no indication that they are tracking a target. This makes them suitable for direct attacks during visual encounters or over longer ranges.

D Night vision

When there is insufficient visible light to see, Night vision devices are used to provide sight using Infrared radiation. Infrared light sources can be used to increase ambient light for conversion by night vision devices, so we can increase the dark visibility without actually using a visible light source.

E Astronomy

Infrared also has been used largely in Astronomy and long-range systems. Infrared radiation with wavelengths slightly longer than visible light have been used a lot due to their similar behaviour to the visible light which made them easy to detect with the same devices used for the visible light.Astronomers have used infrared to discover and study the universe like all other forms of electromagnetic radiation.

1.1.2 Infrared Sensing

All objects emit infrared radiation or heat, this radiation can be detected by infrared receivers. The infrared sensor has a simple working principle to measure the intensity of received radiation. The sensor emits infrared light to sensing area. If an object exists in the sensing area, it reflects the light. The sensor detects the reflected radiation and measures its intensity. The general mechanism is shown in figure 1.2

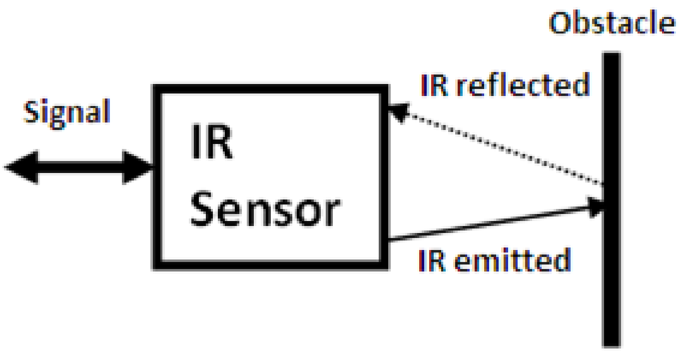


Figure 1.2: The main principle of infrared sensing.

This technique is used in many devices such as those used in night-vision goggles and infrared cameras.
An infrared sensor consists of an emitter, receiver (detector) and a supplementary circuit to assemble the two parts in a useful system. The emitter is simply an infrared LED (Light Emitting Diode) and the detector is simply an infrared photodiode which detects infrared light of the same wavelength as that emitted by the infrared LED. When infrared light achieves the photodiode, its resistance and its output voltage, change in proportion to the intensity of the emitted infrared light.

1.2 Flow Measurement

Flow measurement is generally to quantify the fluid movement, and that can be fulfilled by many methods, we will summarize some of them below:

1.2.1 Electromagnetic Flowmeters

When an electrical conductor is moved in a magnetic field which is perpendicular to the direction of motion and to the conductor, an electrical voltage is induced in the conductor whose magnitude is proportional to the magnetic field strength and the velocity of the movement. This characterization of the laws of induction also applies to the movement of a conductive liquid in a pipe through a magnetic field [3]. This principle is known as Faraday's law and stated by the following equation:

$$EMF = BLV10^{-8} \tag{1.1}$$

Where B is the magnetic flux density, L is the length of the conductor (cm) and V is the velocity of the conductor (cm/s).

Electromagnetic flow meters are best-suited for measuring flows of liquid metal such as sodium, mercury, potassium and liquids of poor conductors appeased of charged particles.
The operating principle of such devices is shown in figure 1.3

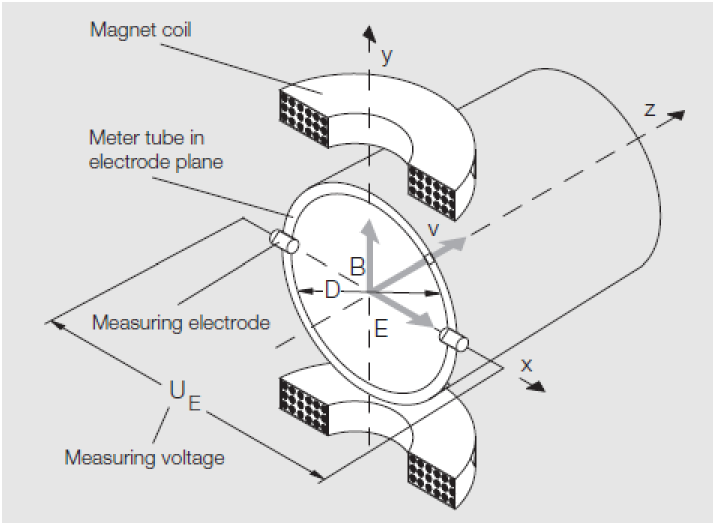


Figure 1.3: Operating Principle of an Electromagnetic Flowmeter [3].

1.2.2 Ultrasonic Flowmeters

An ultrasonic flow meter is a device to measure the velocity of a fluid using ultrasound waves to calculate the volume flow of the liquid. When a disturbance is created in the flowing fluid, it generates sound waves that propagates everywhere in the flow field. These waves travel faster in the flow direction (downstream) compared to the waves in the upstream direction. As a result, the waves spread out downstream while they are tightly packed upstream. The difference between the number of waves in upstream and downstream is proportional to the flow velocity. There are two basic methods for ultrasonic flow measurements:

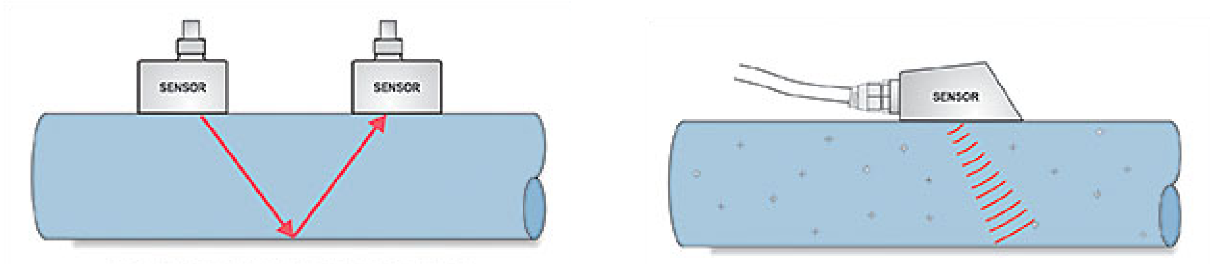
A Transit Time Method

This method involves two transducers located at certain distance l that alternatively transmits and receive ultrasonic sound waves, in the direction of the flow as well as in the opposite direction. The travel time for each direction can be measured accurately and the difference Δ t can be estimated (figure 1.4a). The average flow velocity V can be determined from the following relation (when K is a constant):

$$V = Kl\Delta t \tag{1.2}$$

B Doppler Effect Method

It measures average velocity along the sonic path. The piezo-electric transducers placed outside the surface of the flow transmits sound waves through the flowing fluid that reflects from the inner wall of the surface. By capturing the reflected signals, the change in frequency is measured which is proportional to the flow velocity (figure 1.4b) [4].



(a) Transit Time Method

(b) Doppler Effect Method

Figure 1.4: Basic principle of an ultrasonic flow meter [5].

Since the sound velocity is a function of the temperature, pressure and composition of the measuring medium, even small changes in these variables affect the Doppler shift and an appropriate compensation must be provided.

1.2.3 Vortex Flowmeters

When a flow stream encounters an obstruction in its path, the fluid separates and swirls around the obstruction. This leads to formation of vortex and it is felt for some distance downstream. It is a very familiar situation for turbulent flows and a short cylinder placed in the flow sheds the vortices along the axis. If the vortices are periodic in nature, then the shedding frequency is proportional to the average flow velocity. In other words, the flow rate can be determined by generating vortices in the flow by placing an obstruction along the flow and measuring the shedding frequency. The operation principle is shown in fig 1.5.

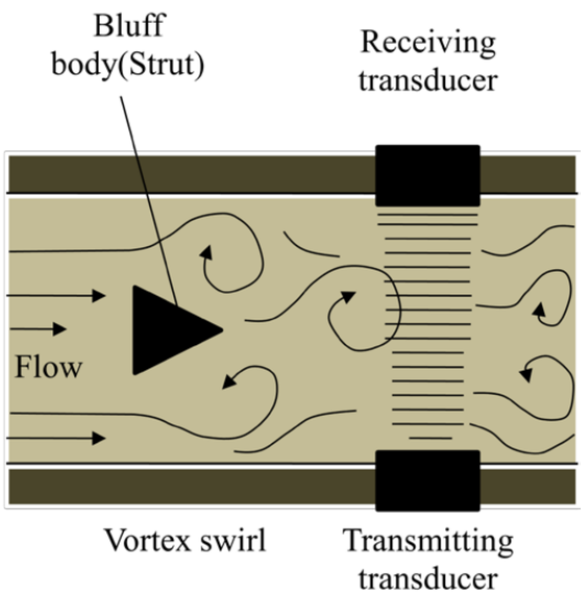


Figure 1.5: Operating Principle of a Vortex Flowmeter [4].

Accurate measurement in a flow environment is always desired in many applications. The basic approach of the given measurement technique depends on the flowing medium (liquid/gas), nature of the flow (laminar/turbulent) and steady/unsteadiness of the medium.

1.2.4 Differential Pressure Flowmeters

Differential pressure flowmeters use Bernoulli's equation to measure the flow of fluid in a pipe. Differential pressure flowmeters introduce a constriction in the pipe that creates a pressure drop across the flowmeter. When the flow increases, more pressure drop is created. Impulse piping routes the upstream and downstream pressures of the flowmeter to the transmitter that measures the differential pressure to determine the fluid flow (see figure 1.6).

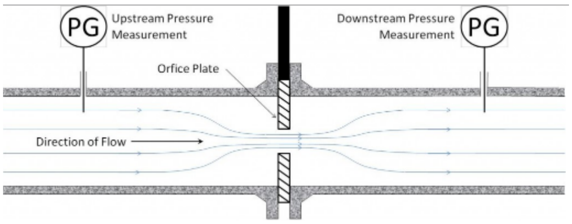


Figure 1.6: Operating Principle of Differential Pressure Flowmeters.

There are many practical advantages to this approach [6]:

- The technology is simple and easy to understand;
- There are no moving parts;
- The sensor is very compact;
- Works equally well for gas or liquid;
- Can be configured to measure bi-directional flow;
- Usable over a very wide range of sizes;
- Devices can be mechanical or electronic;
- Relatively inexpensive.

The calibration of the differential pressure transmitter can be affected by the accumulation of liquid or gas in the impulse tubing. In addition, the accuracy of the flow measurement system can be degraded when varying amounts of liquid can accumulate during operation and also when the viscosity goes high.

This measurement technique is simple and easy to implement and operate, but it gives only an average velocity because of the inertia in the pressure transmission line. The flow direction must be known a priori.

Chapter 2

Technical Concepts of System Components

2.1 Infrared Transceiver

Infrared transceivers are at the same time transmitter and receiver transducers that convert electrical signal into infrared radiation (transmitter) and infrared radiation into electrical signal (receiver). This sensors are easy to build, easy to calibrate and it provides a detection range of 10 to 80cm.

Infrared modules is composed of a small package, very low power consumption and a variety of output options. It is important to understand how these types of infrared sensors work, their effective ranges, and how to connect them, in order to maximize their potential and efficacy. Sharp GP2D12 infrared sensor is shown in figure 2.1.

Figure 2.1: Sharp GP2D12 infrared sensor.

2.1.1 Operation principle

There are two major types of Sharp's infrared sensors based on their output: analog rangers and digital detectors. Analog ranges provide information about the distance to an object in the ranger's view. Digital detectors provide a digital (high or low) indication of an object at or closer than a predefined distance.

These rangers all use triangulation to compute the distance and presence of objects in the field of view. In order to triangulate, a pulse of infrared light is emitted by the transceiver. The light travels out into the field of view and either hits an object or just keeps on going. In the case of no object, the light is never reflected, and the reading shows no object. If the light reflects off an object, it returns to the detector and creates

a triangle between the point of reflection, the emitter and the detector [7].
The transceiver can determine the incident angle of the reflected light, and thus calculate the distance to the object from the incident angle which varies based on the distance to the object. see figure 2.2.

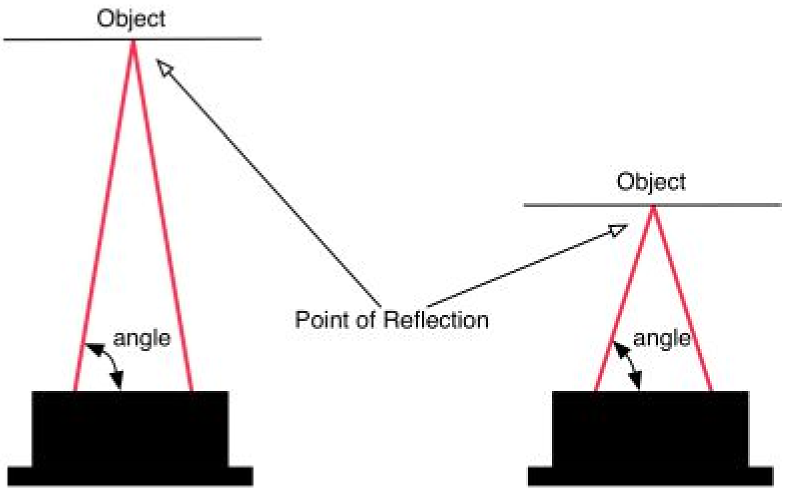


Figure 2.2: Infrared level sensor operation principle [7].

2.1.2 The sensor connection

the Sharp infrared sensors use a specific connector called the Japan Solderless Terminal (JST) connector (figure 2.3). This type of connectors have three wires: ground, Vcc, and the output to connect with the ADC input. Since the sensors fire continuously and don't need any clocking to initiate a reading, interfacing to them is simple, but they continuously use power and can potentially interfere with one another when multiple detectors are used.

Figure 2.3: Japan Solderless Terminal (JST) connector.

Two major problems face the using of these sensors. First, the non-linearity of the voltage output in function of the distance being measured, due to the trigonometry involved in computing the distance to an object based on the reflected light incident angle. The second problem that can face the functioning of an infrared sensor, is the ambient light and surrounding sources of infrared like the sun that can cause false detection of the sensor.
The ingenious solution that was developed to avoid this problem, is to emit pulses of infrared light at a certain frequency instead of a continuous beam, and build a receiver that would only detect infrared pulses of the same exact frequency, neglecting all pulses of different frequency.

2.2 U-tube Manometer

Pressure sensors using liquid columns in vertical or inclined tubes are called manometers. Probably one of the most common and oldest method for measuring pressure. The column level will change until its weight is in equilibrium with the pressure differential between the two ends of the tube, each end is connected to the region of interest while the reference pressure is applied to the other. The difference in liquid level represents the applied pressure, see figure 2.4. The pressure difference between the two level of a vertical

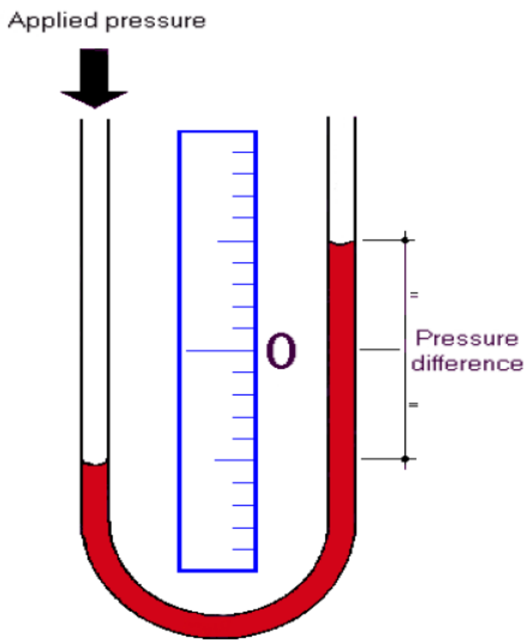


Figure 2.4: Principle of the U-tube manometer [8].

U-Tube manometer can be expressed as:

$$\Delta P = \rho g \Delta h \tag{2.1}$$

Manometers have many advantages, such as their low cost comparing to other devices, accuracy, simple to install and operate and they don't need any power supply. But still have problems of slow response, moving reference and limited to small pressure differences.

2.3 Using IR sensor in manometers

As explained before the U-tube manometer is used to measure pressure from the level of the fluid it contains. Instead of using classical observation with the naked eye, we can utilize infrared sensor in order to determine the level with high precision. With the aid of microprocessor we can measure the pressure in real time and with acceptable reliability and accuracy.

The difference with ultrasonic sensor is that the water is a strong absorber of near infrared, which makes the direct detection of water impossible using infrared sensor, the simple solution to that problem is by using a solid floating surface which can move freely accordingly to the water level movement, in our system we have used a plate of Polystyrene. Polystyrene reflects strongly the infrared light, so it can help us perfectly detecting water level by subtracting the plate thickness.

Using an electronic level sensor for a manometer will certainly enhance the efficacy of the measurement, makes it more automatic and increase its response speed to change comparing to classical observation with human naked eye. The operation principle is shown in figure 2.6

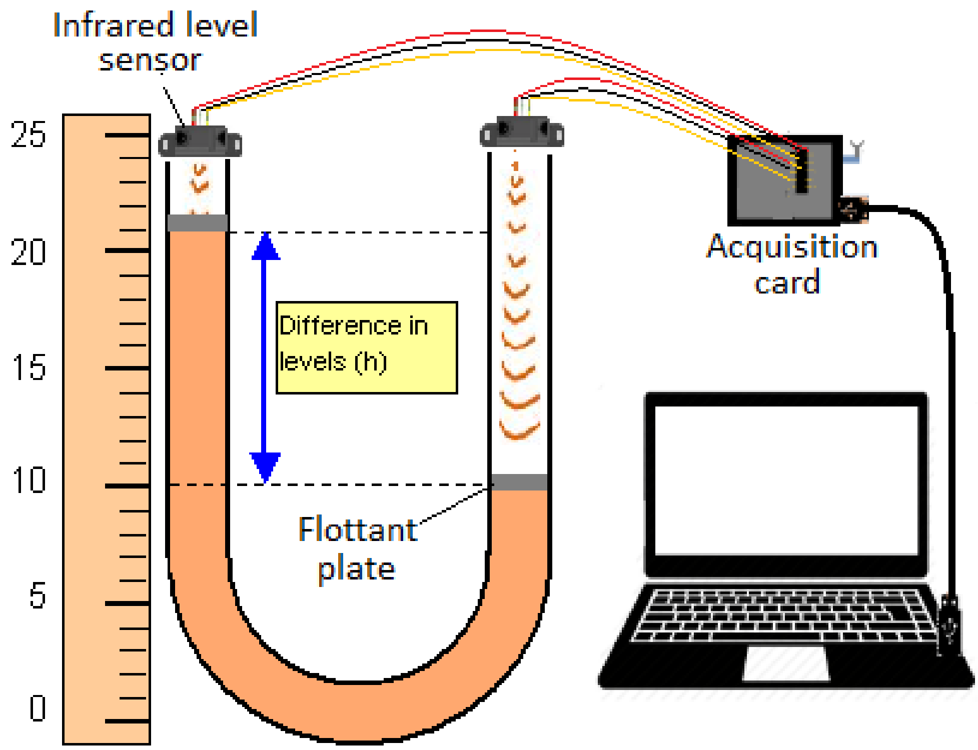


Figure 2.5: The operation principle of using infrared in manometers.

As shown in the illustration above, the pressure measured by the two transducers is handled by a microcontroller and then sent via USB to the computer in order to be treated and saved in a database.

2.4 Differential Pressure Flowmeter using Pressure transducer

Differential pressure flowmeters use Bernoulli's equation to measure the fluid flow in a pipe. For the principle, they introduce a constriction in the pipe that creates a pressure drop across the flowmeter. When the flow increases, more pressure drop is created [6]. This kind of flowmeters that use the Bernoulli principle (Decreasing pressure by increasing the fluid velocity) is called Pitot tubes, an example of these flowmeters is shown in figure 2.6.

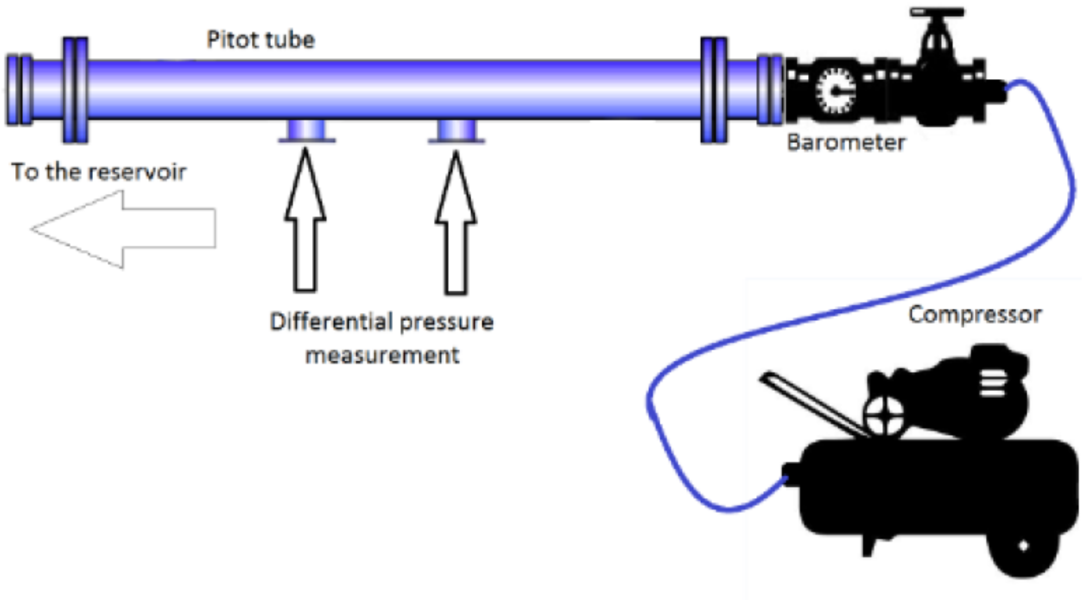


Figure 2.6: Using Pitot tube as a differential pressure flowmeter.

Bernoulli's equation states that the pressure drop across the constriction is proportional to the square of the flow rate.

$$\text{Total pressure} = \text{Static pressure} + \text{Dynamic pressure} \tag{2.2}$$

$$p_t = p_s + \frac{pv^2}{2} \tag{2.3}$$

From the last equation we can easily deduce the expression of the fluid velocity in relation to the difference of pressure

$$v = \sqrt{\frac{2(p_t - p_s)}{\rho}} \tag{2.4}$$

Where v is the flow velocity (m/s), ρ is the fluid density (kg/m^3).

In our system, we have used a Pitot tube with two pressure transducers (MPX4250AP) in order to measure the differential pressure and then deduce from it using Bernoulli's equation the fluid flow. The system is illustrated in figures 2.7 and 2.8.

(a) The hydraulic system used to measure flow.

(b) Measurement of differential pressure

Figure 2.7: The operating system to measure fluid flow.

Figure 2.8: The differential pressure flowmeter with pressure transducer.

All the results obtained using the two MPX4250AP Pressure transducers, along with its interpretations are explained in the next chapter.

Chapter 3

Experiments and Results

3.1 Flow measurement using differential pressure

3.1.1 Differential pressure using MPX4250AP transducers

The solution proposed facing fluid flow problem is to use differential pressure to deduce the flow using Bernoulli's equation, the system principle is explained in chapter 2. In the first test, we have used two pressure transducers (MPX4250AP) to measure the differential pressure as shown in figure 3.1

Figure 3.1: Using MPX4250AP to measure differential pressure.

A Results

The results obtained concerning differential pressure using the two pressure sensors is summarized in table 3.1.

Time (s)	P1 (kPa)	P2 (kPa)	P2-P1 (kPa)
1	106.8766	106.0015	0.87503
2	106.8766	105.5224	1.35422
3	107.1162	106.2411	0.8750401
4	107.3558	106.0015	1.35421
5	107.5953	106.4807	1.11463
6	107.1162	106.2411	0.8750401
7	107.8766	106.9182	0.9584
8	107.1162	105.7619	1.35423
9	107.1162	105.7619	1.35423
10	107.1162	106.2411	0.8750401
11	107.1162	106.2411	0.8750401
12	107.3558	105.7619	1.59381
13	107.1162	106.0015	1.11463
14	107.3558	106.2411	1.11463
15	107.1162	105.0432	2.07299
16	107.3558	106.0015	1.35421
17	107.1162	106.4807	0.6354499
18	107.1162	106.2411	0.8750401
19	107.1162	106.0015	1.11463
20	106.8766	105.7619	1.11463
21	107.1162	106.0015	1.11463
22	107.1162	105.5224	1.59381
23	106.3974	106.0015	0.3958602
24	106.3974	106.0015	0.3958602
25	107.1162	106.0015	1.11463
26	107.1162	106.0015	1.11463
27	107.1162	106.2411	0.8750401
28	106.8766	106.2411	0.6354499
29	106.8766	106.4807	0.3958602
30	106.8766	106.0015	0.87503
31	107.1162	106.2411	0.8750401
32	106.8766	106.2411	0.6354499
33	107.3558	105.0432	2.31257
34	106.8766	105.5224	1.35422
35	106.3974	106.0015	0.3958602
36	107.1162	106.2411	0.8750401
37	107.3558	106.0015	1.35421
38	107.3558	106.2411	1.11463
39	107.3558	106.4807	0.8750401
40	107.3558	106.2411	1.11463
41	106.8766	106.2411	0.6354499
42	107.3558	106.2411	1.11463
43	107.1162	106.7203	0.3958702

Table 3.1: Table of values for the differential pressure.

The results of differential pressure shown in the table above is plotted against time as seen in figure 3.2

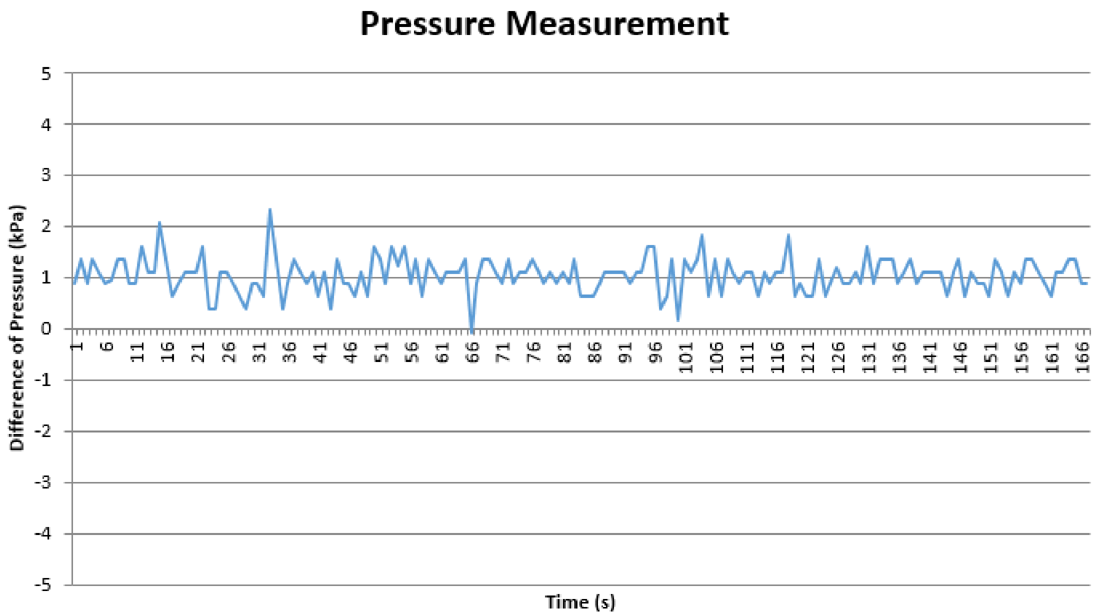


Figure 3.2: Differential pressure against time.

B *

Interpretation From the results obtained in our experiment, it should be remarked that the differential pressure values are very small (about 1 kpa). These values are less than the sensors precision which is about 3 kPa. This means that the results obtained in our experiments are insignificant because they can be just an error without any valuable data.

The MPX4250AP pressure sensor's precision is not enough for measuring fluid flow from the differential pressure. Accordingly, to solve this problem we have to use a sensor with higher precision in order to get a better results for pressure and therefore for fluid flow.

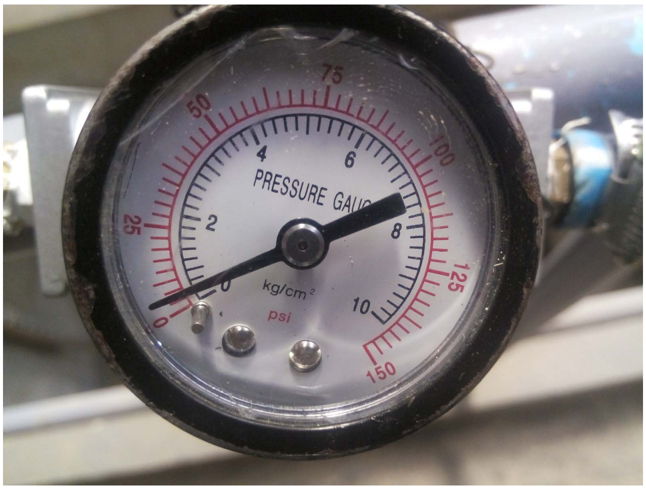
3.1.2 Differential Pressure using U tube manometer

For remedying this problem, we have chosen the U tube manometer which have a better resolution using water as a measuring liquid. choosing water ($\rho_w \simeq 1g/cm^3$) over other liquids like mercury ($\rho_m \simeq 13.6g/cm^3$) can enhance the precision thirteen times more because of its low density which affects directly the sensor precision.

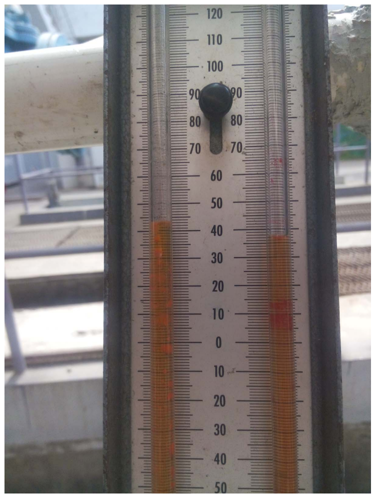
Using the U tube manometer to measure the differential pressure still have the same deficiencies of reading difficulty and real-time measurement.

A Experiments and results

Some examples of measurement of differential pressure using U tube manometer are shown in figures 3.3b and 3.4b, when 3.3a and 3.4a represent the compressor output pressure.

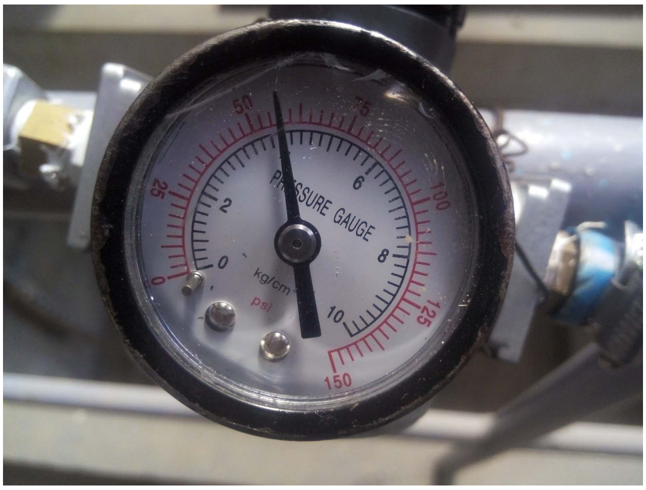


(a) Compressor output pressure

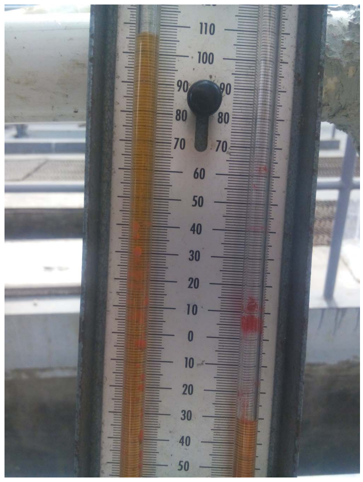


(b) The differential pressure

Figure 3.3: Measuring the differential pressure for $P_{in} = 0.2\ kg/cm^2$.



(a) Compressor output pressure



(b) The differential pressure

Figure 3.4: Measuring the differential pressure for $P_{in} = 4\ kg/cm^2$.

B Interpretation

Using U tube manomoter in pressure measurement helped us solving the problem of precision comparing to the pressure transducer MPX4250AP, but manual measurement still needs accuracy and real time measurement instead of human intervention which could introduce reading errors.
To deal with this problem we proposed using an electronic sensor for reading water level in the U tube manometer, and send the data in real time to the computer in order to analyse and save them.
For this purpose, we have used the infrared transducer to read the water level thanks to its advantages.

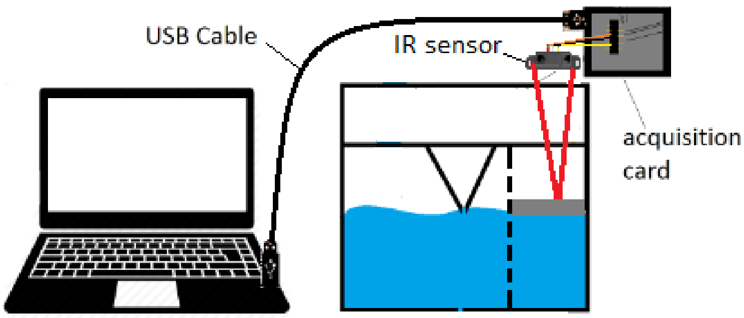
In the next section, we will prove the good functioning of the infrared radiation to measure level, in order to integrate it in our measurement of the differential pressure explaining its principle and advantages when comparing it to the ultrasonic measurement.

3.2 Level measurement using IR sensor

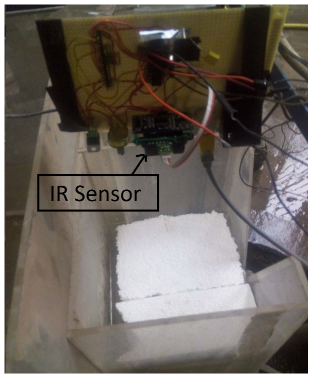
In our previous work in the engineering paper we have used Ultrasonic transducer as a sensor to measure level. The results obtained was more than satisfying and the measurement values were close enough to the real values.
In this work we will use the infrared transducer instead of the ultrasonic one, and then make a little comparison between the two.

3.2.1 The operating principle

As mentioned in the second chapter, since the water is an strong absorber of the infrared radiation, we need to use a floating surface or material which can move freely accordingly to the water level movement, in our system we have used a plate of Polystyrene. the measurement results is transmitted in the same time to the microcontroller which has the role of controlling the general process, and then sends the results to the computer via USB cable in order to treat, visualize and save them.
A schematic and a picture of the system realized to measure level using infrared transducer is shown in figure 3.5



(a) Schematic view



(b) The IR sensor

Figure 3.5: The operating system to measure level using IR sensor.

3.2.2 PIC Program

The data acquisition and processing is defined by a program that will be executed by the microcontroller PIC18F2550, this program is written in C language and compiled using the Mikroelectronika "MikroC" compiler.

```
// LCD module connections
sbit LCD_RS at RB4_bit;
sbit LCD_EN at RB5_bit;
sbit LCD_D4 at RB0_bit;
sbit LCD_D5 at RB1_bit;
sbit LCD_D6 at RB2_bit;
sbit LCD_D7 at RB3_bit;

sbit LCD_RS_Direction at TRISB4_bit;
```

```
sbit LCD_EN_Direction at TRISB5_bit;
sbit LCD_D4_Direction at TRISB0_bit;
sbit LCD_D5_Direction at TRISB1_bit;
sbit LCD_D6_Direction at TRISB2_bit;
sbit LCD_D7_Direction at TRISB3_bit;
// End LCD module connections

unsigned char readbuff[64] absolute 0x500; // Buffers should be in USB RAM,
   please consult datasheet
unsigned char writebuff[64] absolute 0x540;

void interrupt()
{
   USB_Interrupt_Proc();                // USB servicing is done inside the
       interrupt
}
int cnt=0;

void main()
{
  unsigned long b1;
  float b;
  int x;
  char txt4[10];
  TRISA = 0xF;
  ADC_Init();                         // Initialize ADC
  ADCON1=0x0C;
  Lcd_Init();
  Lcd_Cmd(_LCD_CLEAR);        // Clear display
  Lcd_Cmd(_LCD_CURSOR_OFF);   // Cursor off

  HID_Enable(&readbuff,&writebuff);  // Enable HID communication

  Lcd_Out(1,1,"Developed By");
  Lcd_Out(2,1,"PolyTech");
  Delay_ms(3000);
  Lcd_Cmd(_LCD_CLEAR);

  while(1)
  {
      b1=ADC_Read(2);
      b=b1;
      b=b*5/1023;
      b=b-0.105;
      b=259.6/b;
      b=b-4.2;

    if(b>100 && b<800)        //Check whether the result is valid or not
    { x=(int)b;
      IntToStr(x, txt4);          // Convert distance to string
      //IntToStr(d,txt);
      Ltrim(txt4);
      for(cnt=0;cnt<10;cnt++)
```

```
      writebuff[cnt]=txt4[cnt];
      Lcd_Cmd(_LCD_CLEAR);
      Lcd_Out(1,1,"Distance = ");
      Lcd_Out(1,12,txt4);
      Lcd_Out(1,15,"mm");
    }
    else
    {
      for(cnt=0;cnt<10;cnt++)
      writebuff[cnt]=txt4[cnt];
      Lcd_Cmd(_LCD_CLEAR);
      Lcd_Out(1,1,"Out of Range");
    }
    hid_write(&writebuff,64);
    Delay_ms(1000);
  }
}
```

Brief explanation of the program
This program contains 3 main parts :

- PIN instantiation and definition
- Variable declaration
- Processing instructions and function calling

The PIN instantiation serves to relate the internal variables to the external PINs. The external PINs can be defined as input or output PINs depending on the need.
The variable declaration is to define the type and the size of each variable in order to limit the memory space allocation.
The function calling is to use a predefined functions, that can be found in libraries or of our definition, in the program to realise a processing purpose.

The first part of the program is about the output PIN instantiation with the LCD screen PINs in order to manage the display. The second part declares the variables used in the program: long float variables for analog data acquisition, integer variables for digital data and counters and character tables for the display of data (ASCII code). The third part is the data processing that includes two sub-parts : one is for microcontroller registers definition, it means the specification of the parameters used and their functions, ex: the specification of the timer initial value.
The other one is for the arithmetic processing and calculation like the level calculation from the the output voltage received from the infrared sensor. The calculated value from the calibration equation is then shown on the LCD screen and sent via usb to the computer using USB-HID library.

After receiving the measurement results by the computer, these data is treated, visualized and saved to an excel file using a Graphic User Interface developed on "Visual Studio 2015" platform using C# language.

The communication between the microcontroller and the computer is acheived using USB communication protocol which has an advantage over other serial and parallel communication types.

3.2.3 Experience results

In this section we will show and compare the results obtained using the infrared radiation and the ultrasonic waves. And try to interpret the difference between the two. All the results obtained is summerized in table 3.2

Time (s)	Level US(mm)	Level IR(mm)
1	286	281
2	285	285
3	285	281
4	284	284
5	283	284
6	283	268
7	282	265
8	282	281
9	281	281
10	281	281
11	280	281
12	279	278
13	279	280
14	278	276
15	277	275
16	277	276
17	277	275
18	276	275
19	276	276
20	276	276
21	276	278
22	276	279
23	275	275
24	275	279
25	275	278
26	275	276
27	274	258
28	274	273
29	274	275
30	274	271
31	274	276
32	273	275
33	273	272
34	273	272
35	273	272
36	273	273
37	273	271
38	273	274
39	272	273
40	272	274

Table 3.2: Table of values for Ultrason and Infrared.

The results shown in table 3.2 are more explicit in the graph illustrated in figure 3.6 which shows more explicitly the slight difference between the two techniques.

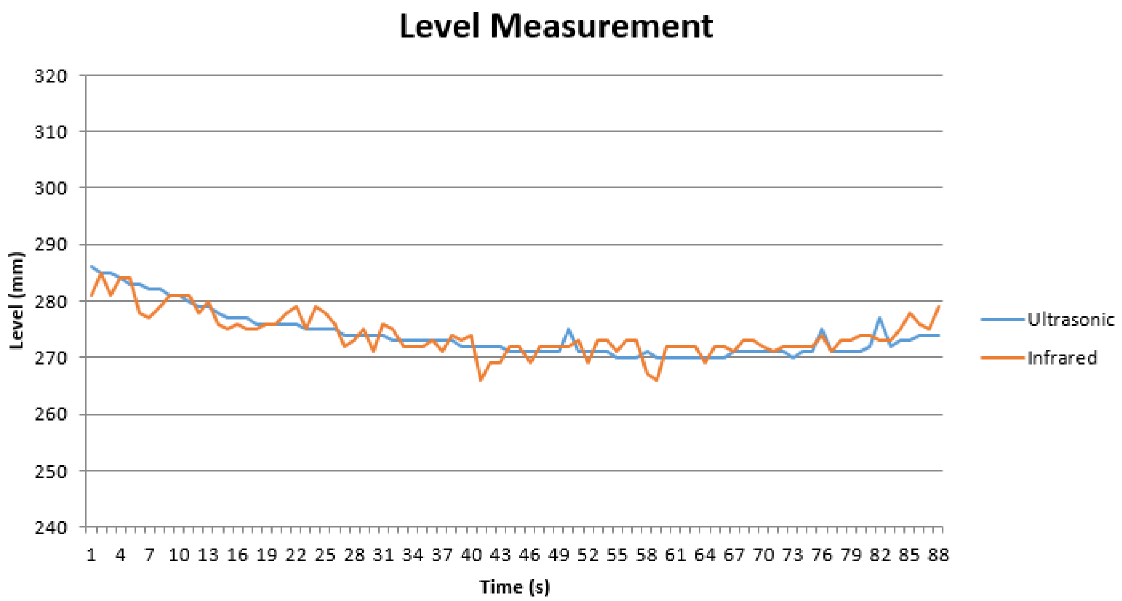


Figure 3.6: Infrared and Ultrasonic level measurement.

3.2.4 Interpretation and Comparison

Observing the results obtained using both sensors, it is easy to remark the striking similarity between them, both sensors succeeded to follow the level variation during the whole process. However, Two main differences should be noticed from the table of values and the representing graph:

A Pursuit and speed of variation

From the graph above, we can easily notice that the infrared graph is more dynamic, that means that the infrared sensor is less precise than the ultrasound one, and might mean that the infrared can follow the change in fluid level faster than the ultrasonic sensor whose graph is more stable and slow.
This difference in the variation is due to the speed of waves whom both sensors emit. In fact, the infrared sensor emits an infrared radiation with the speed of light ($\simeq$ 300000 km/s), when the ultrasonic sensor emits an ultrasonic wave with the speed of sound ($\simeq$ 340 m/s). That will obviously give the infrared sensor a great advantage in term of variation pursuit comparing to the ultrasonic sensor, this different may not be noticeable in our application due to the low level range, but it may be more important in other applications.

3.2.5 The need for a non-intrusive sensing

One of the main causes that convince us to choose the infrared sensor as level measurement in the U tube manometer is the need for a non-intrusive sensing in order to isolate the liquid from any interfering factors that might falsify the measurement.
Using a transparent cover, the infrared radiation will penetrate the transparent material easily comparing to the ultrasonic wave which will reflect from it.

Conclusion

Measuring fluid flow in hydraulic field is an inevitable task. For this purpose, many approaches are proposed to solve all the problems associated with it. Traditionally, mechanical approaches were used to solve the flow problems. However, these methods suffered from many errors due to human intervention and needed real time measurement for a fast and more accurate solution.

Lately, electronic methods have taken over the measurement field, thanks to its performance and reliability. These methods offer the possibility of easier processing and automatic display and storage in real time. Furthermore, the electronic sensors are becoming smaller, more accurate and easier to integrate in different systems and to control using a microprocessor.

Comparing the different methods used to measure fluid flow, we have chosen the differential pressure method as a continuity to our previous study for measuring pressure benefiting from the same circuit to measure the difference of pressure using pressure transducers and a U tube manometer when the last was more suitable due to its precision over the pressure transducers.

Taking advantage of the possibility for the infrared radiation to penetrate the transparent U tube, we can use the infrared transducer instead of the ultrasonic transceiver as a non-intrusive sensing method. Finally, we have been able to analyse, visualize and save all data on a computer.

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