THE DEVELOPMENT AND DESIGN OF A MICROCONTROLLER BASED UROFLOWMETRY DEVICE

A THESIS SUBMITTED TO

THE GRADUATE SCHOOL OF APPLIED SCIENCES

OF

NEAR EAST UNIVERSITY

By

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IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR

THE DEGREE OF MASTER OF SCIENCE

IN

BIOMEDICAL ENGINEERING

NICOSIA 2014

Nevzat Barış ÖZYURTLU : THE DEVELOPMENT AND DESIGN OF A MICROCONTROLLER BASED UROFLOWMETRY DEVICE

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ACKNOWLEDGEMENTS

First of all I want to thank my supervisor Prof. Dr. Doğan Ibrahim for his undivided attention, support and encouragement through this work and for introducing me to the world of communications. Also his suggestions and instructions through the postgraduate study an for always being kind and helpful to me all these years. Under his guidance, I successfully overcame many difficulties and learnt a lot about the electronic and medical devices.

Secondly, I would like to thank the entire Near East University academic staff and my lecturers especially to Assoc. Prof. Dr. Terin Adalı, the Head of Biomedical Engineering Department, who gave me support and encouragement during my postgraduate education.

Finally, I want to thank my family, especially my fiancee. Without their endless support and love for me, I would never achieve my current position. I appreciate their help.

ABSTRACT

The urinary track system is one of the important parts of the human body. The system consists of the following: kidneys, ureters, bladder, prostate and the urethra. Kidneys are responsible for extracting waste materials from the blood and converting them into urine. The urine then travels to the bladder where it is collected. When the bladder is full, the urine is pushed out of the body through the urethra with the help of the brain and the gravity.

The dynamics of the urinary track system is important and it is an indication of the health of the group of organs in this system.

This thesis is about the development and design of an intelligent microcontroller based uroflowmetry device. This device collects urine in real time from a patient and then analyses the results to find out whether or not the patient suffers from any urinary track disorders. The device is low-cost and is based on using a weight measuring load cell together with a low-cost microcontroller development system in order to measure the weight of the collected urine in real time. The collected data is then sent in real time over a serial link to a PC where a graph of the data is drawn (uroflow graph) and the data is analysed by using a MATLAB program on the PC.

The developed system is capable of indicating whether or not the patient suffers from any urinary track problems.

Keywords: Uroflow, Uroflowmetry, Measuring Urine, Urine Measurement Device, Microcontroller Based Uroflowmetry.

ÖZET

Bu çalısmada ürolojide yaygın olarak kullanılan üroflowmetri cihazının uygulaması gerçeklestirilmistir. İdrar sistemi insan vucudunun önemli bölümlerinden biridir. İdrar sistemi böbrek, üreter, mesane, prostat (sadece erkekler) ve idrar yolundan oluşur. Böbrekler kandan atık maddelerin ayrılmasını ve idrara dönüştürülmesinden sorumludur. Idrar toplanılan mesaneye ulaşır. Mesane dolduğunda idrar, beyin yardımıyla ve yerçekimi yardımıyla idrar yoluyla dışarı atılır.
İdrar yolunun dinamikleri önemlidir ve bu sistemdeki organların sağlıklı olduğunun bir göstergesidir.

Bu tez akıllı mikroişlemci tabanlı üroflowmetri cihaz geliştirme ve tasarımı ile ilgilidir. Uroflowmetri hastanın zamanında idrar toplayan ve daha sonra hastanın herhangi bir idrar bozuklukları olup olmadığını öğrenmek için sonuçları analiz eder. Cihaz düşük maliyetlidir ve yük hücresinin ağırlık ölçümünü kullanarak doğru zamanda hücrenin idrar ağırlığını ölçmek için düşük maliyetli mikro kontrol gelişim sistemiyle birlikte kullanılmaktadır. Uroflowmetri cihazında düşük maliyetli bir mikro denetleyici sistemi geliştirilmiş ile ağırlık ölçen bir yük ölçüm hücresin kullanılmıştır. Toplanan veriler seri bağlantı üzerinden gerçek zamanda bilgisayara aktarılır , daha sonra bir veri grafiği çizilir ve MATLAB programı kullanılarak veriler analiz edilmektedir.
Geliştirilen sistem hastanın, herhangi bir idrar yolunda sorun olup olmadığını gösterebilen bir sistemdir.

Anahtar Kelimeler: Üroflov, Üroflovmetri, İdrar Ölçme, İdrar Ölçüm Cihazı, Mikro İşlemci Tabanlı Uroflovmetri.

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LIST OF ABBREVIATIONS

A:	Applied Area
F:	Applied Force
L:	Metal Length
D:	Diametric
G:	Gain Amplifier
Ml/ s:	Flow Rate
BPH:	Benign Prostatic Hyperplasia
V:	Possion Ratio
TMAX:	Time to Maximum Flow
TFLOW:	Flow Time
TVOID:	Voiding Time
QAVG:	Avarage Flow Rate
TMAX:	Maximum Flow Rate
VOL:	Volume

CHAPTER 1

INTRODUCTION

Micturition (urination), urine is the process of urination. Natural period is started which is called micturition reflex with lapsed bladder actions and consequently urinary discharge is realized. Urinary liquids and the amount of other solutions and their densities are being balanced (homeostasis) sensitively and correctly. Urinary system and urinary are significant with providing homeostasis (Guyton et al., 2005). Micturition realizes with working more than one system together or sequential in the human body. As a result of some disorders of anatomical anomalies or physiological, infectious conditions, microbic, other forms of diseases, the micturition process can delay or can stop completely.

Urinary system performs the mission of urination. Urinary system consists of kidneys, urethra channels, bladder, sphincter muscles, other helping organs and muscles. In order to follow urinary system dynamics, many methods have been tested. Urinary exrection is urodynamic systems of all components for common activity, therefore many changes in the state of the system components reflected for urine excretion. It is possible to the measurement of urine flow regime and recording with improving medical electronics and the improvement of computer technologies.

Although there are several different methods used to determine whether or not a patient suffers from urinary track problems, currently the uroflowmetry is perhaps the cheapest and the easiest method. Uroflowmetry is the measurement method which records the changing of urinary flow rate in units of time during natural micturition. Usually, a two-dimensional graph is drawn to show this rate of change of the urine flow.

Uroflowmetry can be used to find out the urinary track problems in patients. For example, the shape of the uroflowmetry curve indicates whether or not the patient has bladder or prostate problems. In many developed countries, the uroflowmetry is a routine test where potential patients are tested at least once a year in order to find out whether or not they have any urinary track problems. Early detection of any urinary track problems is very important for successful treatment.

This thesis focuses on the development and design of an intelligent microcontroller based uroflowmetry device. The device is designed by the author collects the urine of patients and then with the help of a Matlab program and a PC it can draw the uroflow graph of the patient. The program can also determine whether or not the patient suffers from any major urinary track problems.

Chapter 1 is the introduction of the thesis.

In Chapter 2, the literature review is carried out on flowmetery and examples of previous work which is done in this field and the importance of uroflowmetry is explained.

Chapter 3 is about the development and design of the microcontroller based uroflowmetery device by the author. This chapter gives the complete design, including the urine collection and measuring hardware, microcontroller hardware, and the PC hardware. In addition, the details of the microcontroller software and the MATLAB software are given in this chapter.

Chapter 4 is about the results and conclusions. This chapter provides results of the uroflow tests which are carried out with real patients at the Near East University hospital.

The conclusions are given in Chapter 5.

Finally, various Appendices give further information about the electronic chips used in the design. In addition, complete listing of the microcontroller program and the MATLAB program are also given in the Appendices.

CHAPTER 2

LITERATURE SEARCH

2.1. Lower Urinary Tract

Lower urinary system is a group of micturition organs which include bladder, urethra and muscle in the human body (Guyton *et al.*, 2005). The function of the lower tract is the storage of urine produced by the upper tract and the voluntary expulsion of urine at an appropriate time and place. The lower tract may be affected by functional disorders such as bladder over activity and urinary incontinence or by carcinoma, lithiasis and obstructive disorders such as prostatic enlargement and stricture disease. A thorough knowledge of the relevant anatomy is vital to understand the path physiological mechanisms and appropriate management of these conditions. There are considerable variations in the anatomy and biomechanics of the male and female urinary tract and we depict these, in addition to providing a comprehensive description of the histology, vasculature and innervation of the lower urinary tract organs.

2.1.1. Lower Urinary Tract of Anatomy

As shown in Figure 2.1, the lower urinary track system consists of the bladder and another tube called the urethra, which transports urine from the bladder out of the body. The function of the urinary system is to remove liquid waste products from the body, regulate water and salt balance in the body, and to store and transport urine.

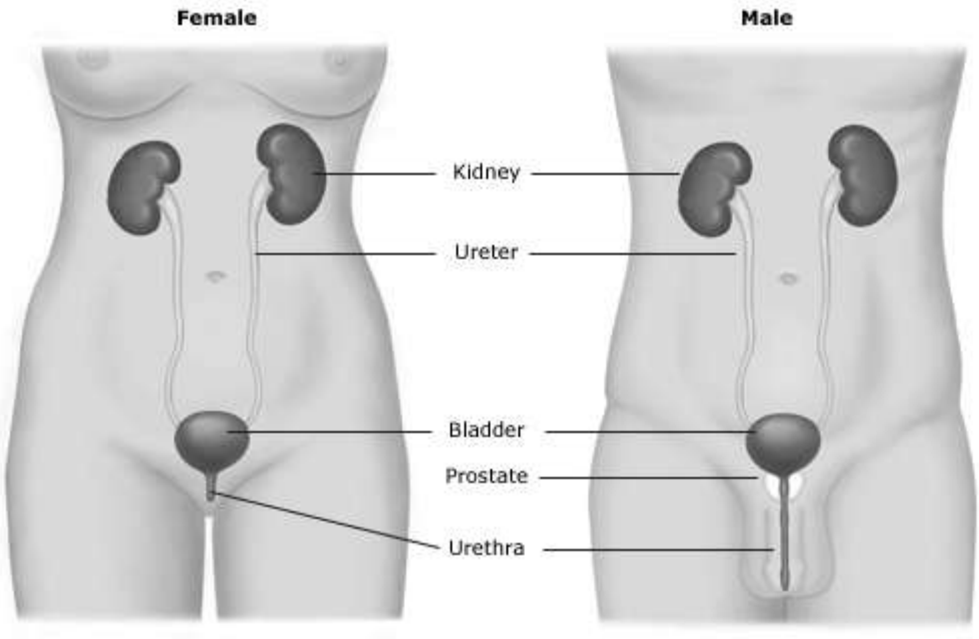


Figure 2.1: Lower urinary tract organs

Ureter canals are narrow tubing that carry the urinary waste from the kidneys into the bladder and there are two such canals, one for each kidney. Ureter canals have a structure which permits the urine to flow in one direction only, i.e. downwards from the kidneys to the bladder (Tanagho et al., 2003).

Urinary bladder collects urine (see Figure 2.2) with urinary canals which store urine. It is consisted of hollow musculars and distensible (or elastic) organ, the bladder sits on the pelvic floor. Urine enters the bladder via the two ureters and exits via the urethra. The urinary bladder is a muscular sac in the pelvis, just above and behind the pubic bone. When empty, the bladder is about the size and shape of a pear.

Urine is made in the kidneys, and travels down the two ureter tubes to the bladder. The bladder stores urine, allowing urination to be infrequent and voluntary. In healthy people, urination only occurs when the bladder is full. The bladder is lined by layers of muscle tissue that stretch to accommodate urine. The normal capacity of the bladder is 400 to 600 ml in healthy people.

During urination, the bladder muscles contract, and two sphincters (valves) open to allow urine to flow out. Urine exits the bladder into the urethra, which carries urine out of the body. Because it passes through the penis, the urethras in men (8 inches) are longer than in women (1.5 inches).

The ureter is the tube that carries urine from the kidney to the urinary bladder. There are two ureters in humans, one attached to each kidney. The upper half of the ureter is located in the abdomen and the lower half is located in the pelvic area. The ureter is approximately 12 inches long. The tube has thick walls which are composed of a fibrous, a muscular, and a mucus coat which can contract.

The ureters are paired muscular ducts with narrow luminal that carry urine from the kidneys to the bladder.

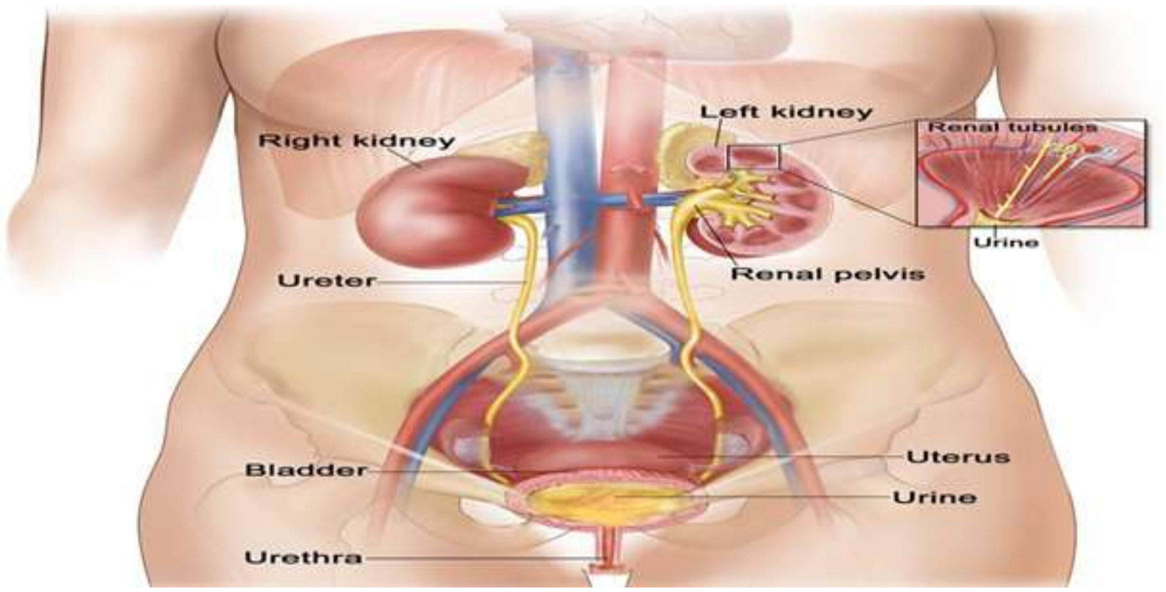


Figure 2.2: Urinary organs

There are two important muscle groups in the bladder neck. These are internal and external sphincter muscles. Sphincter muscle has a target to prevent uncontrolled version of urine which is accumulating out from the bladder. Internal sphincter muscle has been consisted of the detrusor muscles. Urethra gets through outer sphincter muscle which is junction point with the bladder neck. Outer sphincter is red muscle structure and it can be worked as deliberate. The internal sphincter is contraction normal to prevent to go out of urine. The internal sphincter muscle connects to the urethral. Urethral is connected to the urinary bladder then go out of urination tract. Urethra is connected to the point of the external sphincter muscle. External sphincter muscles consist of red muscles and voluntary muscles. The brain is in control of the external sphincter muscle and blocks urination (Guyton et al., 2005).

2.1.2. Lower Urinary Tract System Physiological and Micturition

Micturition is the urinary extrication process when urinary bladder gets full. This process must be realized in two steps. In the first step, the bladder which is the stress of the walls reach threshold level, lapse gradually and the bladder pressure initiates the start of the second step. Nerve endings which are disseminated in the bladder nerve, are stimulated with rising bladder pressure. Nerve stimulations constitute micturition reflex which is called neural stimuli in Spinal cord. Micturition reflex cannot always occur, in this case, consciousness urination desire is felt. Micturition reflex is comprised by itself and although micturition reflex is ordered by spinal cord, it can be prevented or promoted by the brain.

Urine is produced with the activity of kidneys afterwards, smooth muscle in the ureter duck is stimulated and ducts permit the flow which transmits the urine to the bladder. In case of urine out of the bladder, in the bag of the pressure is almost zero. Accordingly, wall pouch of the flexible structure, until the specific volume (300-400ml), pressure remains stable. However, after this volume, despite of the continuation of the stretch, pressure starts to increase. This increasing pressure stimulates nerve endings in detrusor which triggers to start of micturition reflex.

The comprising of micturition reflex with the order of detrusor muscle contraction, as for that external sphincter is ordered to softening. However, this order can be stopped by the brain. If micturition reflex is stronger than the order of brain, involuntary urination may occur. Unless it is, until pouch is filled and the order of reflex is got strong, micturation does not occur. In case of the approvation of urination, micturition reflex and detrusor muscle which straining, they raise the internal pressure of the bladder. In the meantime, stomach muscles strain in deliberate way and they raise the internal pressure of the bladder and help to occur micturition reflex. The order of softening is sent to sphincter muscle with the urination accrues. Normally, urinary is completely emptied from the bladder (Guyton et al., 2005).

2.2. Uroflowmetry

Uroflowmetry is the measurement of the amount of urine coming out of the body as time passes. This measurement is usually plotted in the form of a two dimensional graph with the vertical axis showing the urine volume and the horizontal axis is the time. Thus, the graph shows the rate change of the urine volume as the urine comes out of the body (Siroky et al., 1990). Measurements are usually carried out when the bladder is full. Thus, before the measurement, the person is asked to drink plenty of water to fill his or her bladder. The measurements then start by collecting the urine and measuring its volume as it comes out of the body.

Urinary flow, detrusor pressure, bladder created and applied to the abdominal muscles pressure, making it difficult or facilitating the flow of urine, urethra and sphincter resistance and others are a common consequence of all the factors (Abdelmagid et al., 1998). Due to urinary flow regime is monitored and recorded which affect all the organs and systems, information is being obtained. Uroflowmetry, a general physician is to provide data about the dynamics of the lower urinary tract, additionally, with some pathological findings reflect a significant measurement method. Furthermore, non-invasive is a method, hardware and implementation costs which are low and by the reason of there is not any known side effects, they are widely being applied on the patients (Willard et al., 1998).

Uroflowmetry is an important indication of the urinary health of person. By analysing the shape of an uroflowmetry graph, doctors can tell a lot about the functions of the kidneys, bladder and the ureters.

Uroflowmetry devices are electronic devices. In typical uroflowmetry applications, the urine is collected in a container which weight is measured constantly. Then, computer based electronic devices and sensors are used to measure the weight of the collected urine in real-time. As shown in Figure 2.3, a graph of the collected urine is then drawn in real time and presented to the doctor. The shape and the volume of the collected urine are an indication of the urinary state health of the person.

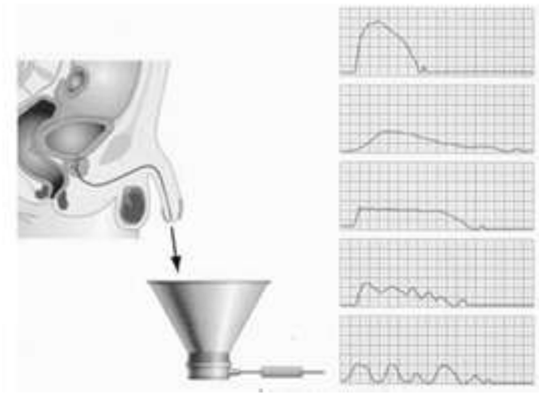


Figure 2.3: Basic diagram of Uroflowmetry

2.2.1. Methods of the Uroflowmetry Measurements

In general, two basic methods are used to measure the weight measurement and direct measurement for the flow rate. Apart from these, the highest flow rate and the measurement of the urine volume peak meters are used for a similar purpose (Colstrip et al., 1983).

The first method provides weight information which is measured according to the first derivative time of flow information, in case the second is the change derivative of the volume in the unit of time. Uroflowmetry based on the measurement of weight is applied by using load cells. It requires that patient must realize urine on the customized assembly. Urine is saved in a collection container and the weight of container is measured frequently. Weight information is obtained precise enough with the signal conditioner and it is digitised to transfer computer environment. In this thesis computer performs the visualization, recording and processing of data's. We can see block diagram of uroflowmetry machine in the Figure 2.4.

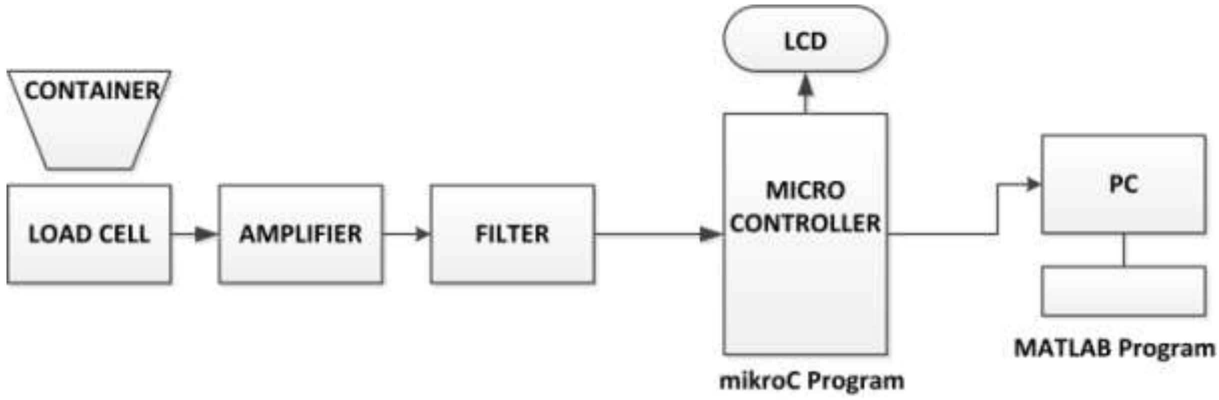


Figure 2.4: Severity methods of the Uroflowmetry

The second method provides flow of urine with the rotation of prop and measures the rotational speed of propeller. It is used more for water meters which are similar method; the information of urine flow is obtained by finding the number of round in per unit time. System which is part of computer is similar to first method form.

Nowadays, uroflowmetry which is based on gravimetry is used widely. However, there are advantages and disadvantages for both of methods. The method of gravimetry; uroflow graphs can highly be produced as the result of measuring urine gravity defencelessly. However, the collection of urine in the container imposes the obligation to empty container periodically. As for that, in the second method, urinary turns the prop then evacuates without saving. However, at the second method, because of the measurement, it cannot be always done sensitively, graph's diagnostic reliability is affected negatively (Kondo et al., 1978) (see Figure 2.5).

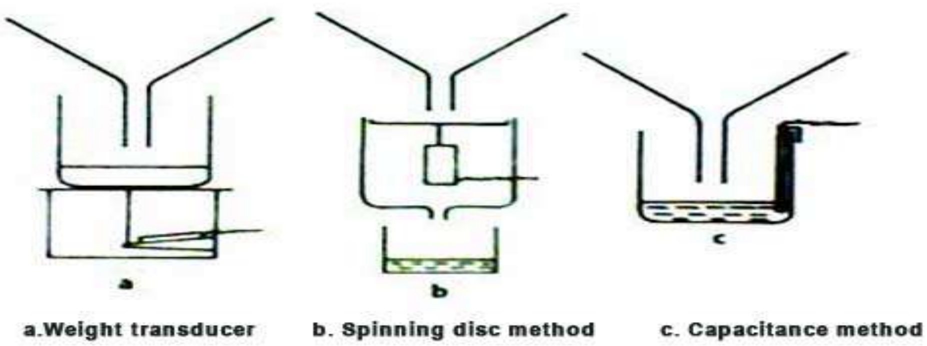


Figure 2.5: Uroflowmetry Method

In the third method, the capacitive method is urine which collects in a chamber mounted with a dipstick capacitor. When capacitance changes in the chamber due to urine, it is indicative of the flow rate.

2.2.2. Clinical method

Person’s bladder should be full before uroflowmetry. In consequence of measurement, the volume of urine needs to be 150 ml at least, 600 ml at the most in order to become meaningful clinically. Person is asked to drink appropriate amount of water which is requested by the medical doctor.

During measurement, it is important to produce the process of natural micturation at the nearest result for person. Individual should realize micturition at least ratio by affecting from the environment and the measurement system.

It is important that before the start of the measurements and urine collection, the person should be given plenty of plain water so that his or her bladder becomes full. The bladder is normally full when the urine content is about 600 ml. It is important that only plain water should be given to the person since other drinks such as orange juice, tea, or coffee may change the emptying behaviour of the bladder and the prostate (for men only).

2.3. Typical Uroflow Graph

It is seen that the typical uroflow curve of a health person is in the Figure 2.6. Uroflow graph reflects the natural dynamics of urinary system, including the bladder, prostate (in men), and the urethra. As shown in Figure 2.6, normally the flow of urine has a shape which is accelerating at first and then the process of decelerating, and finally terminating. Bladder drainage regime reflects the flexible structure naturally. The rate of urine flow increases sharply, then levels off, and then falls sharply before it stops completely. This is the normal dynamic emptying process of the bladder in healthy people.

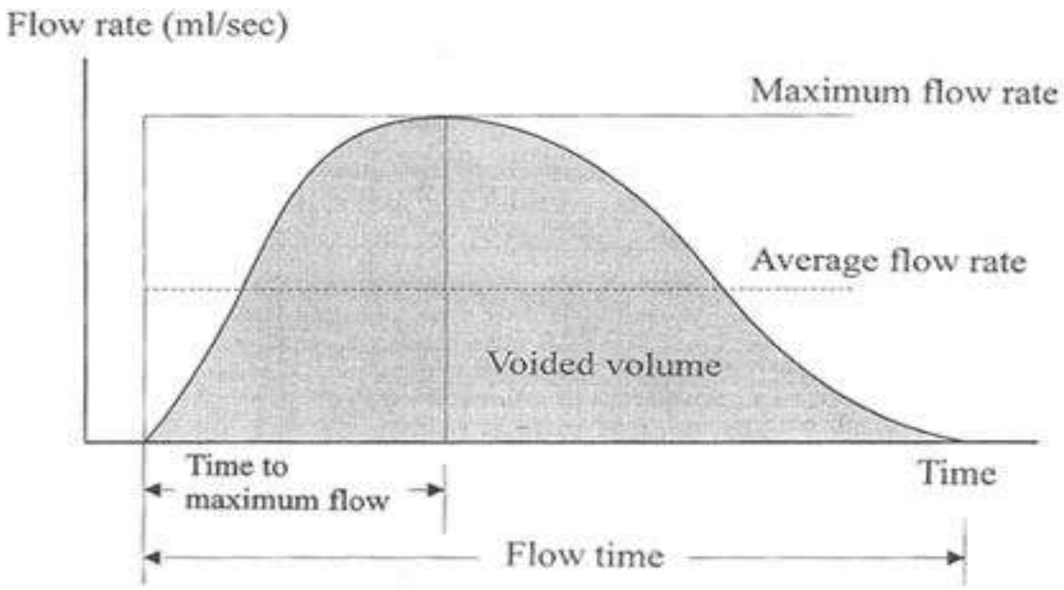


Figure 2.6: Normal graph of Uroflowmetry

2.3.1. Regular and Continuous Uroflow Graphs

Healthy persons' uroflow graphs are in the form of a bell curves. Any deviation from this curve is usually indication of some kind of problem with the operation of the urinary track. A typical bell shaped curve is obtained from a health person; it is shown in the Figure 2.7 (Abrams et al., 2003). The vertical axis is the urine flow rate (usually in ml/s), and the horizontal axis is the time (usually in seconds).

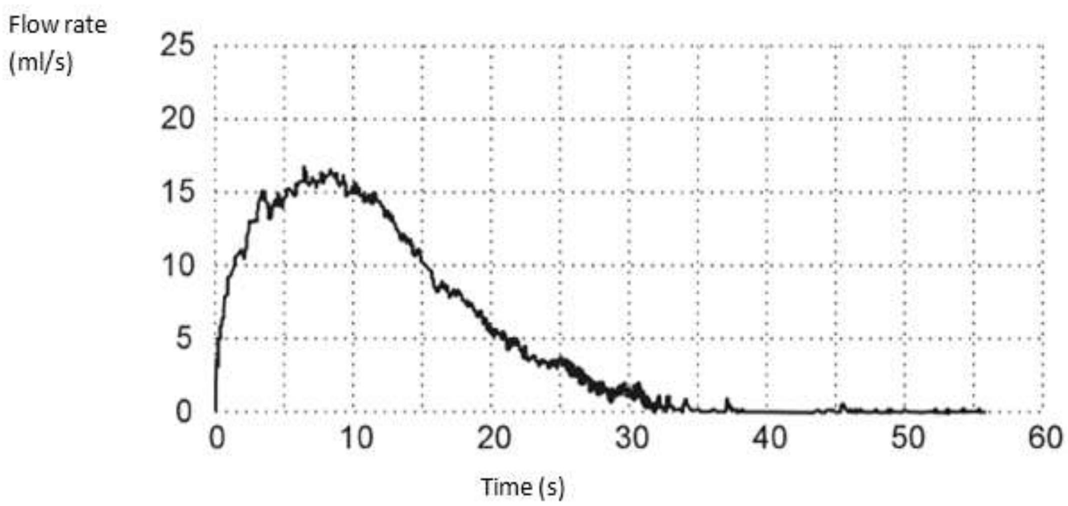


Figure 2.7: Uroflowmetry graph of healthy person

Excess Flow (over activity or super flow) is the situation in which urinary flow rate is going over the normal flow rate. Detrusor pressure is which increasing and / or falling of the lower urinary tract output resistance realizes in the anatomical / physiological disorders. Patients who occur excess flow of 40 ml / second is accepted to posses the highest healthy flow which is over the highest flow speed can be observed. Excess flow is characterized by the graph which rises very quick. Generally, excess flow takes shorter than usual and it can be often observed in proportion of men to women (Boone et al., 1998), (Rivas et al., 1996). The properties of the characteristic of excess flow is rapidly raising slope. The flow speed of slope/flow duration is higher than usual. One of the most high flow rate is observed. Excess flow, which is raising very quickly, graphic, is characterized (see Figure 2.8). Excess flow and usually takes less than usual, observed more frequently in women than men (Boone et al., 1998), (Rivas et al., 1996). The characteristic of excess flow is the slope of the rising very rapidly. The flow rate of curve/ flow duration proportion is higher than normal time.

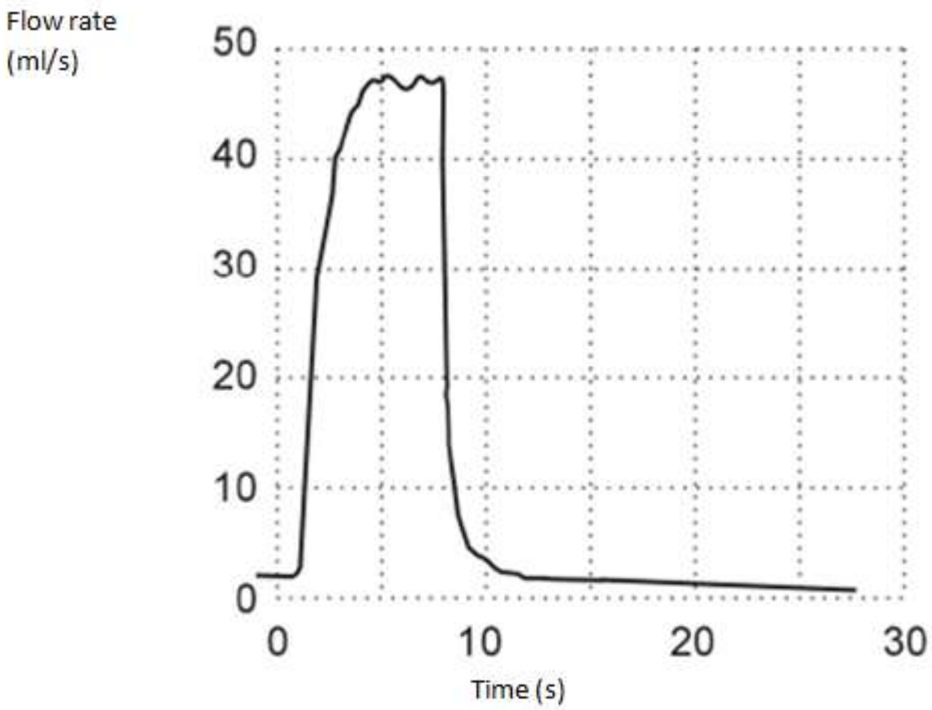
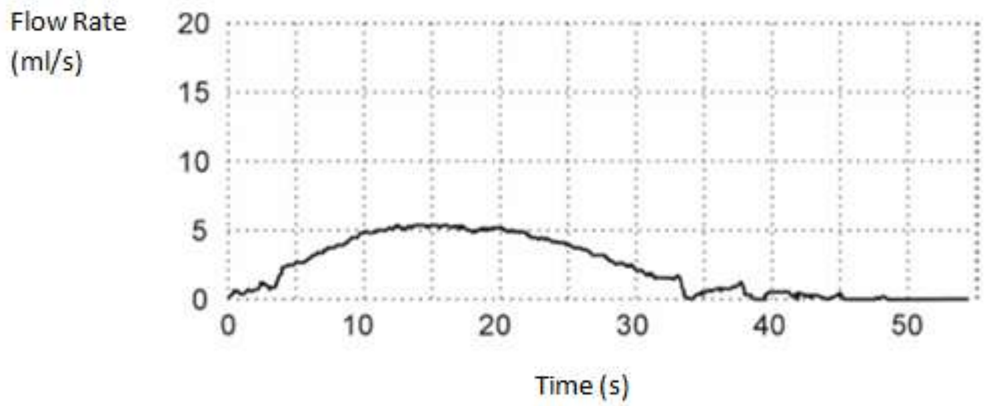
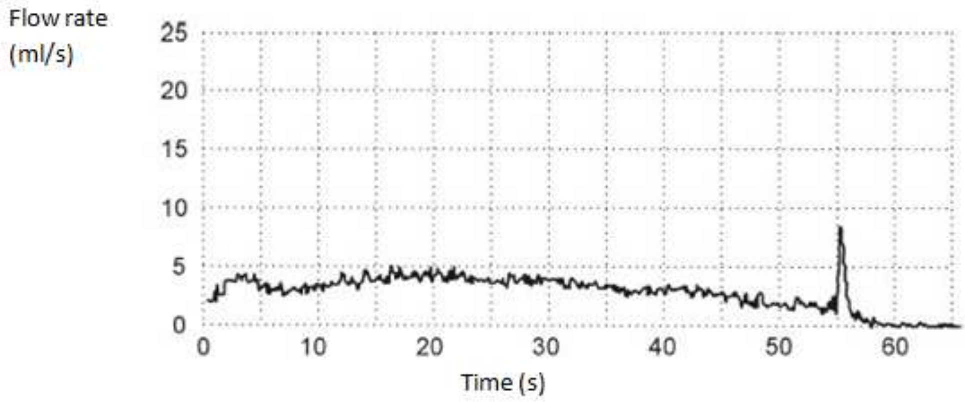


Figure 2.8: Typical Over-Flow graph

Obstructed flow is expressed to the obstacle of the bladder with a slowed and elongated flow. Detrusor pressure is observed which is falling subnormal and/or rising situations. The characteristic form is determined with the extended flow duration and the part of abortion which flows stable speed (see Figure 2.9). Obstructed flow, prostate which presses urethra and the result of making difficult to urinary, the increasing of resistance urinate status is the characteristic of uroflow curve.



(b)



(a)

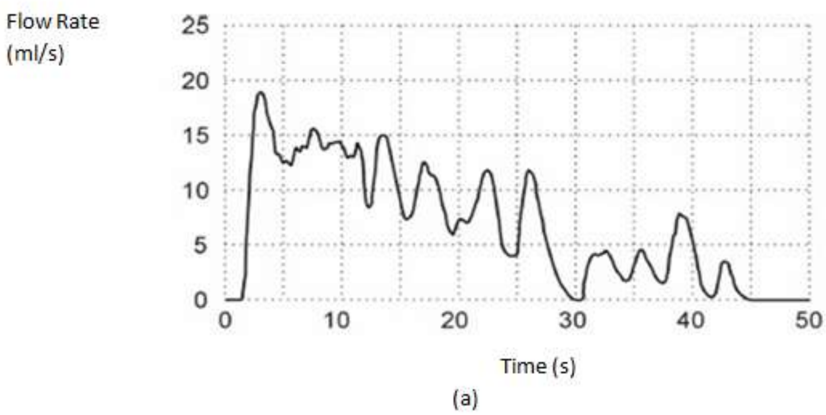
Figure 2.9: (a) First Obstructive Graph, (b) Second Obstructive Graph

2.3.2. Irregular Flow Graph

Flows which occur with any interruption or discharge along a few stops**.** There are two types of irregular flows. The first one is the fluctuating irregular flow. In this type, the flow occurs with which is sequenced each other and Qmax values decreasing monotonically, but which is not falling to zero, rising to new local Qmax value (see Figure 2.10.(a)).

The second type is definitely non-uniform flow, characterizes with the independent of each other short-term flows which sequence (see Figure 2.10). During urination, it can be situations like patient strains abdominal muscles which support to bladder pressure. Choppy non-uniform flow can be observed at this situation. This type of flows, individual is not only habit to urination, but also it is any reason to increase urination resistance in order to defeat, take a support for stomach muscles. Non-uniform flow occurs with the result of detrusor-sphincter dyssynergia disease which can be seen in Figure 2.10.(b).

In Figure 2.11 is not anatomic or physiologic of weld, patient’s occurs by herself or himself (excitement and stress or the intervention of flow), non-uniform flows are seen.



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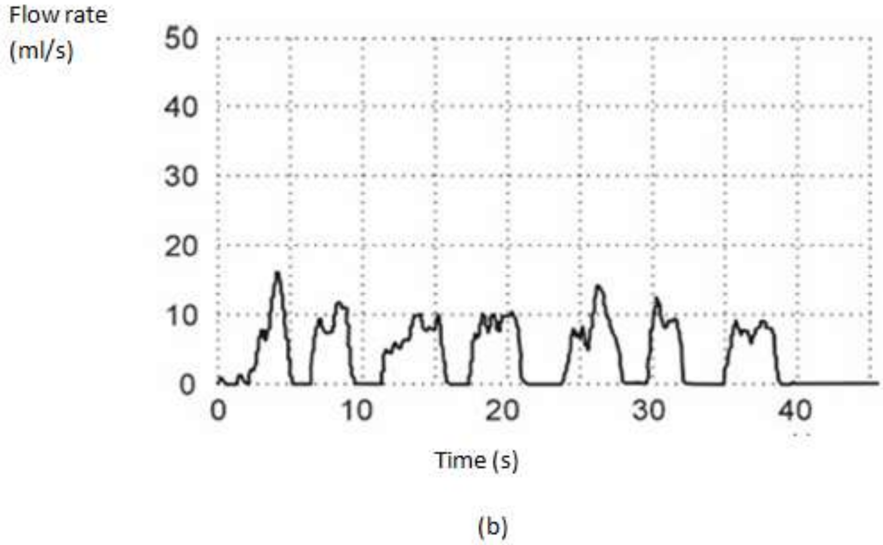

Figure 2.10: Wave graph of (a) Irregular, (b) Intermittent

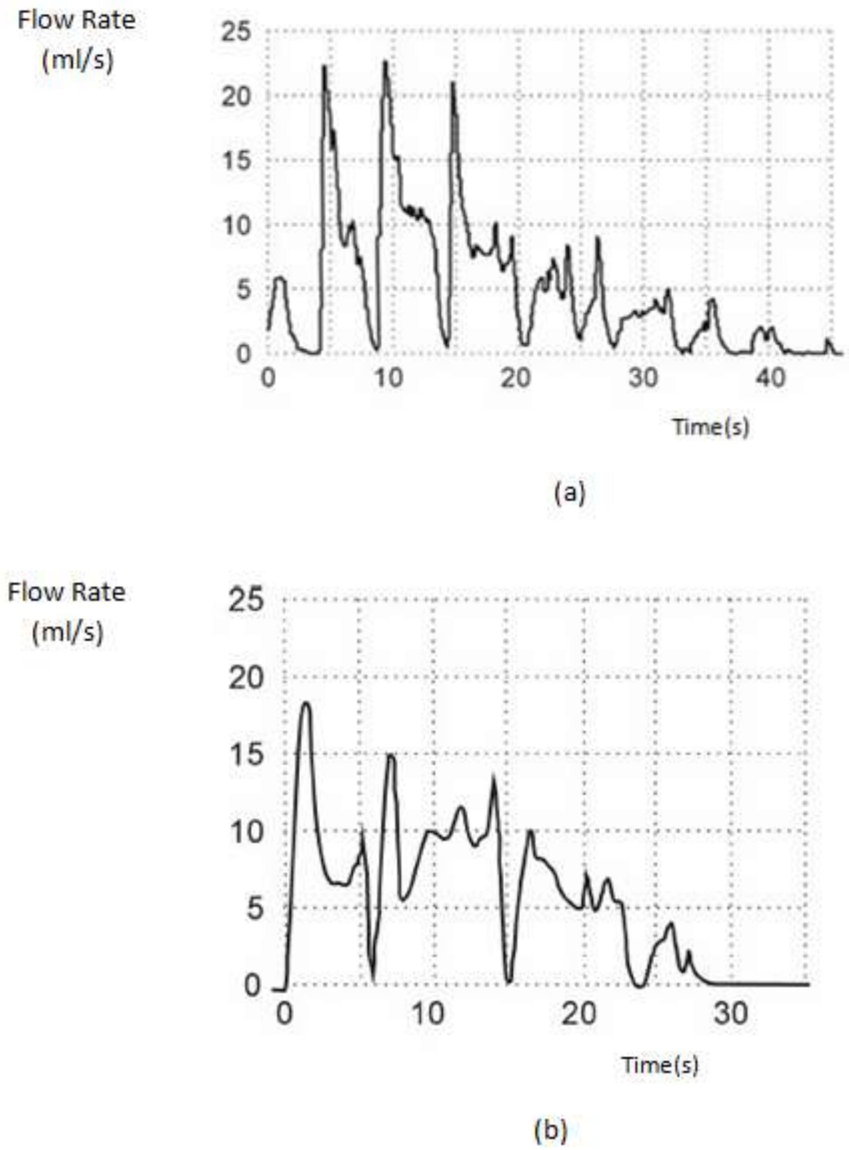

Figure 2.11: Irregular graphs which are not , (a) Anatomical, (b) Physiological

2.3.3. Numerical Parameters

The actual numerical values on the uroflow graph are also important since these values indicate the actual rate discharge of urine from the bladder. Some of the important parameters of the graph are shown in Table 2.1.

Uroflow numerical values of a composite graph, weight and gender vary according to the age of the individual. However, the general behaviour of the graph is the same. The numerical parameters of the urinary tract are clinically important. Statistical studies were done by using the highest value of flow rate or averages of flow rate values and age of the patients and nomograms were developed. Rate of flow is acceptable for age groups which gives the range of value nomogram, is commonly used. Nomograms are most frequently used by Bristol and Siroky (Siroky et al., 1979) (Haylen et al., 1990).

Tables 2.1: Uroflow specific quantitative parameters of the curve

Time to Max. Flow(TMAX)	Highest value of the flow rate
Flow time(TFLOW)	Flow time
Voiding Time(TVOID)	Total discharge time
Average Flow rate(Qavg)	Discharge volume/Discharge time
Maximum flow rate(TMAX)	The Highest flow rate measured

2.4. Diagnostic Reliability of Uroflow Graphics

The changing of urine flow will naturally affect the rate of flow in time. Diagnosis works are conducted with the uroflowmetry which depends on basic theory (Abdelmagid et al., 1998). The anatomic physiologic exchange/disorders which may occur in the components creating the urine system affect urinary regime. The Figure of uroflow graph and numeral parameter is achieved from graph, it is evaluated and also diagnoses proper diagnosis/ pre-diagnosis in consideration of patient's age, gender, physical examination findings and other detents by specialist physician. The uroflow graph, for instance, when the low flow rate is detected, it is possible to have more than one reason (Ather et al., 1998). Uroflowmetry can't produce the final diagnosis/pre-diagnosis in some cases. In spite of that uroflowmetry, although it is not interventional, it can produce precious data's clinically. Especially in men, prostate enlargement diagnosis can be identified only %60 to %90 by relying on uroflow graph (McLaughlin, 1990).

In order to determine the state of the patient in uroflowmetery tests, the patient's bladder must be filled with plain water. Most of the medical doctors prefer their patients to drink certain amount of water before the tests. In literature, in order to carry out a healthy measurement, urinary volume is emphasized to be over 150 ml and below 600 ml. Outside of this range volumes are kept out of assessment clinically (Gillenwater 2002).

CHAPTER 3

THE DEVELOPMENT AND DESIGN OF AN INTELLIGENT UROFLOWMETRY DEVICE

This chapter describes the development and design of an intelligent microcontroller which is based on uroflowmetry device. Figure 3.1 shows the basic parts of the uroflowmetry device which is designed and implemented in this thesis.

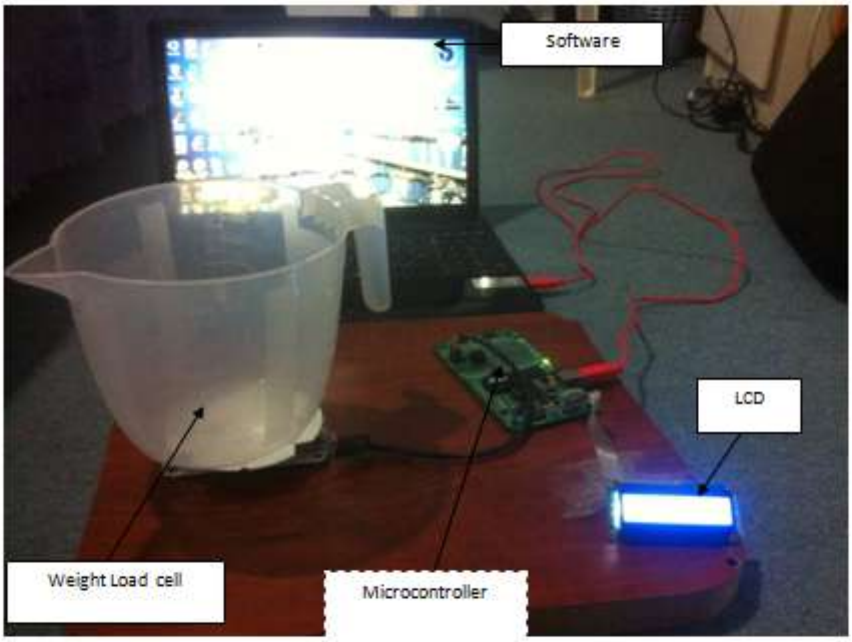

Figure 3.1: Uroflowmetry machine

The basic block diagram of the designed device is shown in Figure 3.2. Basically, a container is used to collect the urine. This container is placed on an electronic weight measuring load cell so that the mass of the collected urine can be measured at any time. Then, an amplifier circuit and a filter are used to clean the signal and measure the collected urine accurately. The measured quantity is fed to an intelligent microcontroller based electronic development system. The microcontroller converts the collected urine into volume and stores its variation in real time. An LCD connected to the microcontroller system shows the volume of the collected urine in real time and is used for confirmation purposes. The collected urine is then sent to a PC over an RS232 type serial link for analysis and graph plotting. A MATLAB program on the PC reads the collected urine data in real time and then draws a uroflow graph. In addition, important numerical values are calculated and displayed on the graph, again in real time. The MATLAB program analyses the shape of the graph and makes simple diagnostics to tell whether or not the urinary track of the person is normal or not.

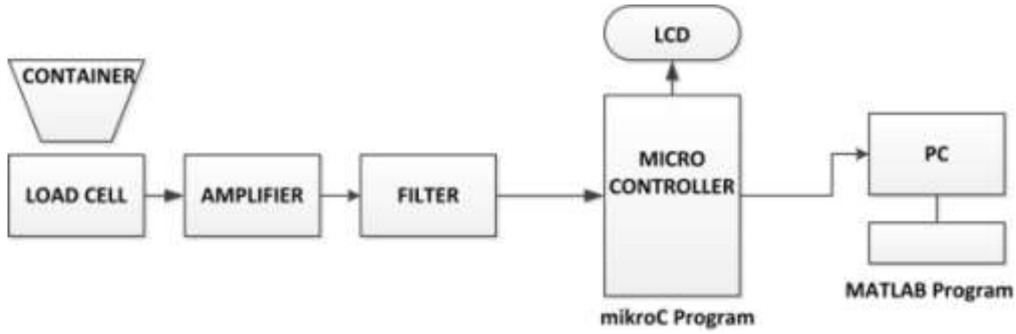

Figure 3.2: Uroflowmetry device block diagram

3.1. Gravimetry by Using Load Cell

Metals can change their shapes when a force is applied to them. Load cells are designed by using the property of flexion which is metal in presence of force. When extrinsic power is applied to a fixed material, it occurs tension and strain on the material. Stress test is resistance which is showing against force except for object, sprain is the internal displacement of object and it is defined as a formal distortion.

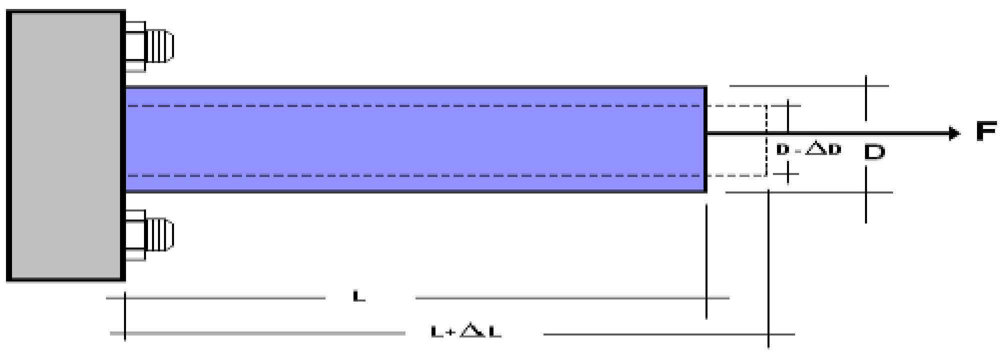

Figure 3.3: Deformation of metals in the application of force

$$V = \frac{\Delta D/D}{\Delta L/L} \quad (3.1)$$

V:Possion ratio, which $\Delta D/D$ is diametric tension and $\Delta L/L$ is longitutional tension. Applied to force on the material which occurs distension.

$$r = \frac{F}{A} \quad (3.2)$$

where F is applied force, A is applied area r is tension.

Sprain is the result of the forces which are applying to objects in the material dimension occurring forms at distribution is the percentage change in the size of that all affected. The amount of buckling is calculated from the first longitudinal section of change in the original length of the material. ε:Sprain.

$$\varepsilon = \frac{\Delta L}{L} \quad (3.3)$$

If buckling extension is smaller than 0.005 inch, the micro-buckling expression is used.

Microbuckling: Buckling x 10^{-6}

Buckling, in other words the result of pressure the physical change amount and distension is measured with load cells. The first studies of load cells are done by Lord Kelvin and when metallic conductive is subjected to strain, it is seen that electrical resistance changed. The first ideal type of load cell turns only the result of external stimuli change cell shape to the electrical resistance. Nevertheless, environmental temperature, manufacturing defects of the material, the adhesion amount of the load cell and the bottom surface of the metal resistance against to flexure physical stability affects the change of electrical resistance in the applications. Basically, all load cells (strain gauges) of mechanic movement are designed with regard to turn of electrical label.

Different materials are also different for the reaction of the same direction against to stress test. Load which is applied to material creates different axial tensions at the crystal level. As Poisson and tension can be measured except for the direction force of prime mover and all of these hugeness's can exemplify for them.

When shear force is under the pressure of the material, it is expressed as an angular correlation. For example, when book is applied to power at the top right hand corner, force compels book to take skewed shape. Shear stress which is composed in this situation, between the X and Y-axis angular rate can be considered a tangent.

In case Poisson tension is defined as a getting thinner and stretching of metal bar. This type of stress is also expressed as the opposite direction of the negative stress in accordance with strengthens. When extents increase and wire diameter falls down, conductivity also drops.

The most common method which is used for measuring the stress of material, against to applying load changing the electrical resistance the length of conductor measuring the microscopic change is measured. These types of load cells have the most common area. Capacitive and inductive type of load cells are manufactured and used, but remain vulnerable to vibration and hence to reduce errors caused by complex installation requirements and often be a malfunction, the use of such devices decreases. Load cell, when force applies, it gapes and the length can change on the metal and a special wire conductor (strain gauge) is performed by bonding. In uroflowmetry devices, load cells which are commonly used, metal bar the weight of cape grab by yielding extending measurement conductive is adhered to on the metal, is comprised. When a force is applied to the surface, the length change on the surface, the length of the cell is stretched out on a section tensile strength depending on the load cell affixed to the change in resistance is linear.

3.1.1. Weight Load Scale

In this Thesis, a low-cost weight measuring load cell is used to measure the quantity of urine. This cell operates with a 5V supply and has a maximum weight capacity of 4 Kg. A voltage variation corresponding to weight change will occur at the outlet of a load cell. When balance changes in the Wheatstone bridge, the output voltage changes linearly. In Uroflowmetry device, on the load cell are always in a weight. Therefore, the output of load cell, depending on the voltage of the Wheatstone bridge has always been a positive change, the increase of output voltage will be observed with the weight. The strain gauges are covered in a white epoxy for environmental protection. A weight (force) applied to the business end of the beam causes the beam to bend slightly causing the strain gauges on top to stretch and those on the bottom to compress.

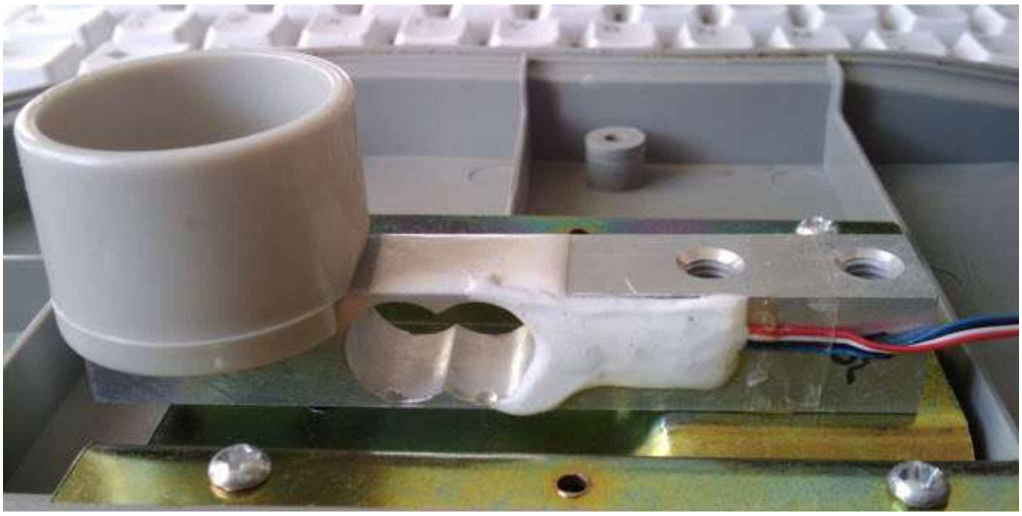

Figure 3.4: Weight load cell which is used in this thesis

A commonly used configuration comprises 4 strain gauges which are wired in a "full bridge" Wheatstone bridge. As shown in Figure 3.5, all four resistors of the bridge are strain gauges .Two on the top (R1, R4) and two on the bottom (R2, R3). This configuration provides good sensitivity to bending, and automatically compensates for resistance variation due to temperature.

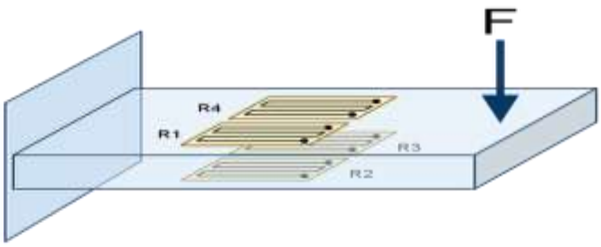

Figure 3.5: Interface of sensor

The interface to the sensor comprises 4 wires: the red and black wires are the 'excite' (labelled E+ and E- on the PCB) and white and blue are the sense wires (labelled S+ and S-). The changes in the resistance of individual strain gauges are too small to measure accurately by direct measurement. However, in a Wheatstone bridge configuration the tiny changes in resistance which causes the bridge to unbalance and measurable potential difference is generated on the sense wires.

The two sense wires are connected to an op amp in differential configuration (a ST Microelectronics TS9121N dual rail-to-rail op amp) set at moderately high gain produces a signal useable by an ADC(Analog Digital Converter).

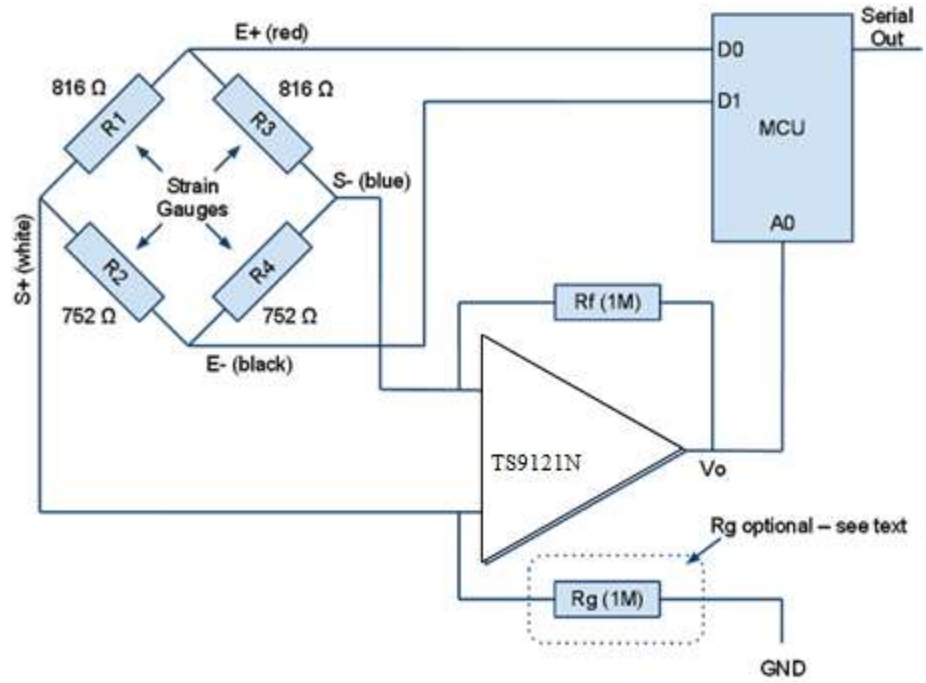

Figure 3.6: Wheatstone Bridge

Normally the R_g resistor is set to the same value as Rf. In this configuration Vo is 0V when no force is applied to the sensor and can swing up the supply rail (5 V). If R_g is omitted, the output is about 2.5 V from op-amp (V_o) at rest. Depending on how the sense wires are connected to the op amp, V_o can swing from 2.5 V to 5 V or from 2.5 V down to 0 V (the ground rail). So, it seems that we lose half of the ADC's dynamic range. However, we can put this situation to use better.

Let's call the voltage change due to the application of force on the sensor as ΔV. Instead of wiring the excite wires to the power/ground rail, two digital IO output lines D_0 and D_1 in the schematic) are used to excite the sensor. With D_0 set to logic high (5 V) and D_1set to logic low (0 V) a measurement is taken: a0 = 2.5 V + ΔV.. The measuring resolution is doubled. Another advantage of this setup is that to help eliminate common mode interference.

A word of caution: one must allow sufficient time for the signal to settle after changing the excitation polarity. As can be seen from the oscilloscope trace (taken at v_o where a grid square = 200 µs x 1 V) at least 500 µs is required for the sense voltage to settle after a reverse in direction.

3.1.1.1 Calibration

The required weight measurement accuracy is about ±0.5 g. In order to achieve this accuracy, we can actually use standard coins for calibrating the device. Freshly minted coins are the best, but any clean coin will suffice for this purpose in reasonable condition.

The following calibration chart was obtained by mounting Euro 10c (4.10 g), 20c (5.74 g) and 50c (7.80 g) coins on the scales.

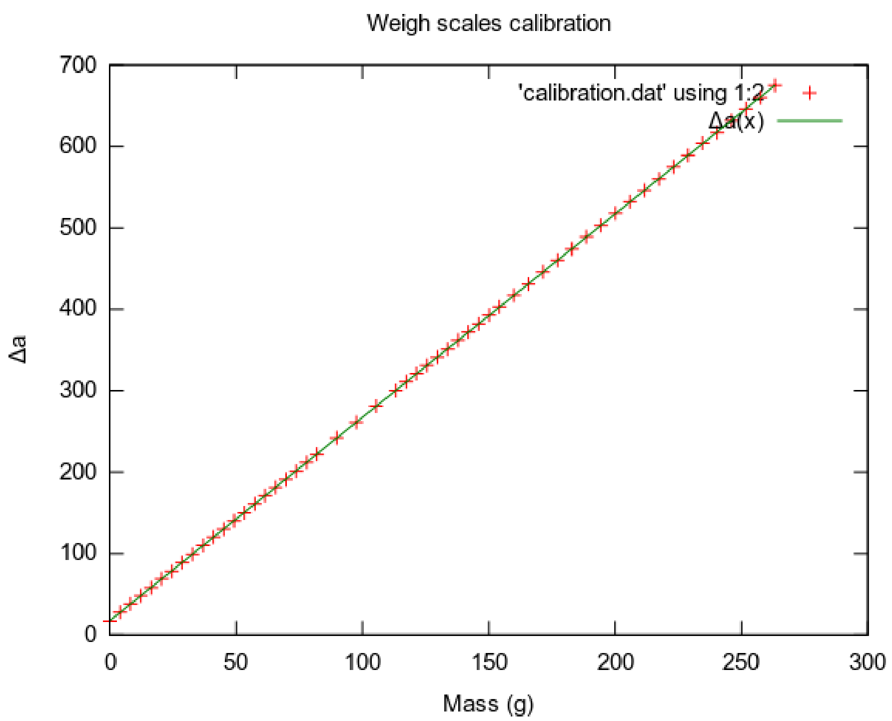

Figure 3.7: Calibration graph

Using Gnuplot to plot and curve fit the data to the equation of a line: $\Delta a(x) = c + mx$ where x is the mass in grams applied to the scale.

Gnuplot curve fit reports:

$$c = 5 \tag{3.5}$$

$$m = 0.48 \tag{3.6}$$

3.2. Amplifying the Signal

When weight is applied to the load cell, stress occurs and the output of bridge increases at the millivolt level. Microcontroller is operated with a supply voltage of 5 volts on the microcontroller analog digital transducers measuring the range of module between 0 and 5 volts. The output voltage of the load cell must be enhanced so that the voltage can be measured by the analog-to-digital converter on the microcontroller. In this Thesis, an operational amplifier based differential amplifier is used in order to amplify the signals level so that it can be detected and measured accurately by the analog-to-digital converter.

A differential amplifier is an amplifier which subtracts the voltages between its inverting and non-inverting inputs. A low-cost operational amplifier has been used as a differential amplifier in this study. An operational amplifier which is used as a differential amplifier has two inputs. Signal which is required to raise, is applied to operational amplifier of inverting and non-inverting input. Environmental electrical noise which is affected to load cell and connection cable, operational amplifier inverting and non-inverting inputs of the same sign will reach as the electrical signal. Decals upgrade makes the difference, the inverting and non-inverting input signals applied to the same sign, they should not produce an output voltage. Differential amplifier is called common signs of suppression for this feature. Differential amplifiers and signal amplification applications sign which is required to raise, is applied to input signal of the operational amplifier. Differential amplifier should derive a profit for required to raise a sign which is different from noise signal. Sign is a voltage difference between the input differential amplifiers so it will be seen the same signal 180 degrees out of phase as two different cases. As a result of the subtraction, a total of the 180 degree phase has different signals and earnings, it will return to the state and it will be derived a profit. Furthermore, the gain of operational amplifier with the heightened sign will be able to reach the required level at the amplifier output (Junk 2005).

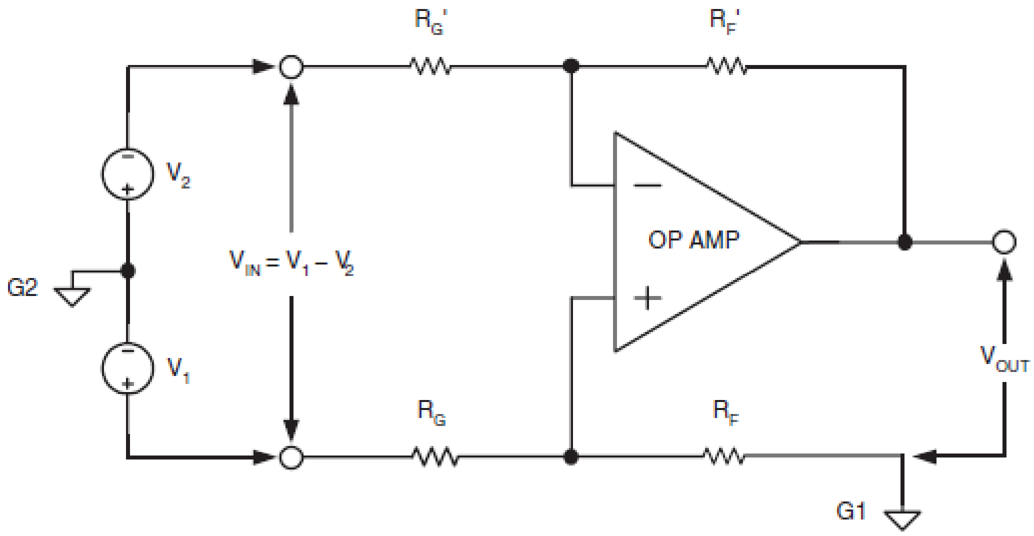

Figure 3.8: Operational amplifier with differential amplifier application (Junk 2005).

Gain: G

$$G = \frac{R_F}{R_G} \tag{3.7}$$

Operational amplifier with a differential amplifier application is observed. With the difference amplifier input: V_{in}

$$V_{in} = V_1 - V_2 \tag{3.8}$$

In this case, the overall amplifier gain equality is: G

$$G = \frac{V_{out}}{V_1 - V_2} \tag{3.9}$$

An operational amplifier in order to use as differential amplifier common signal rejection ratio should be at the required level. For a common signal suppression,

$$R_G = R_G' \tag{3.10}$$

$$R_F = R_F' \tag{3.11}$$

Must be equal.

Resistance values equal a complete application, the amplifier gain,

$$G = \frac{R_F}{R_G} \tag{3.12}$$

The TS9121N type operational amplifier was used in differential amplifier stage. The amplifier gain was found using equation (3.12), and it was set to 1000 (see Appendix 1).

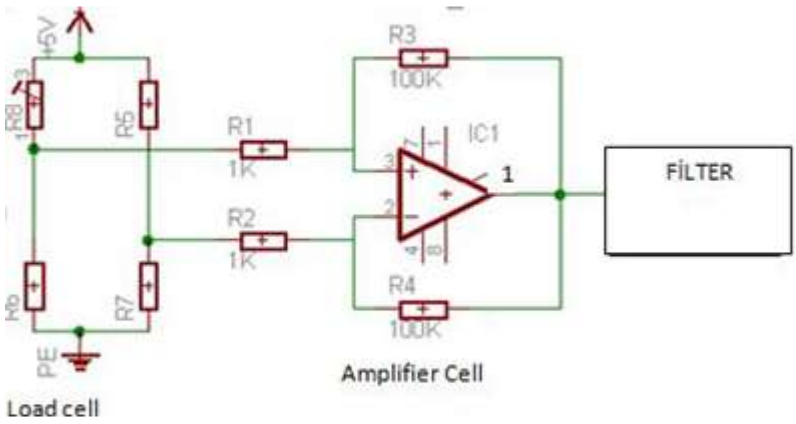

Figure 3.9: Amplifier circuit diagram

Amplifier output, potential high frequency noise signals, anti-aliasing error is filtered not to bring at the analog digital converters. In this work, 20 Hz cut-off frequency is varied by using a Low-pass filter as given in Figure 3.10.

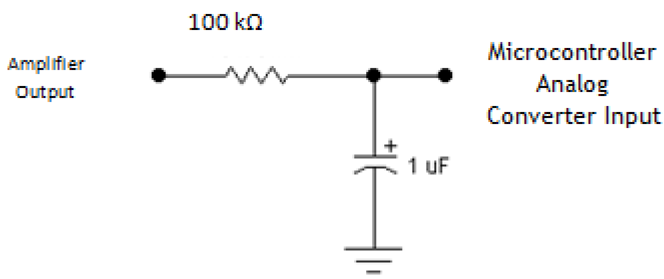

Figure 3.10: Filtration circuit

3.2.1. The Basic Features of TS912N

The TS912 is a RAIL TO RAIL CMOS dual operational amplifier designed to operate with a single or dual supply voltage. The input voltage range V_{icm} includes the two supply rails VCC + and VCC-. At 3 V, the output reaches: q V_{CC} - +30 mV V_{CC} + -40 mV with RL = 10 kΩq V_{CC} - +300 mV V_{CC} + -400 mV with RL = 600 Ω. This product offers a broad supply voltage operating range from 2.7V to 16V and a supply current of only 200µA/amp at VCC = 3V. Source and sink output current capability is typically40mA at VCC = 3V, it is fixed by an internal limitation circuit.

- Rail to rail input and output voltage ranges
- Single (or dual) supply operation from 2.7v to 16v
- Extremely low input bias current :1pa type
- Low input offset voltage: 2mv max.
- Specified for 600 Ω and 100 Ω loads
- Low supply current : 200 μa/amplify (V_{CC} = 3v)
- Latch-up immunity
- Esd tolerance : 3kv
- Spice macro model included in this specification

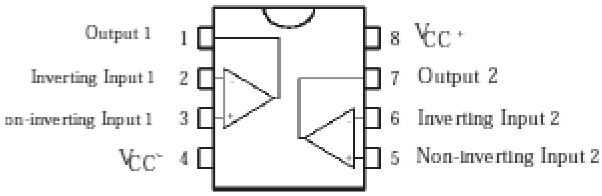

Figure 3.11: TS912N pin configuration

3.3. Clinician Control Unit

LCD is used to observe clinical environment changes. The total volume of the collected urine is observed on the LCD screen. In addition, the LCD display makes the system more user friendly since the users can visually see the urine collection in real-time.

Figure 3.12: 2X16 LCD display board

3.4. Ready PIC Board

Ready for PIC is a compact development tool for 28/40 pin PIC microcontrollers. The board by default is equipped with PIC16F887 MCU placed in a DIP40 socket but it provides connection holes to accommodate a 28-pin device. To program the MCU, you can use either the pre-installed boot loader or an external programmer. For using an external programmer, you need to make a few adjustments on the board. Please read the User's Manual for further instructions on ready PIC board. Four 2×5 male header pins are available on the board for easy access to the MCU I/O pins. On-board FT232RL chip provides a USB to asynchronous serial data which transfers interface so that the MCU can communicate with a PC through a virtual COM port by using a USB cable. The board has two LEDs marked with Rx and Tx blink when data transfer via USB UART module is active. The board can also be used with a 3.3 V type PIC microcontroller. There is an on-board jumper for selecting between 5 V and 3.3 V supply voltage for the MCU.

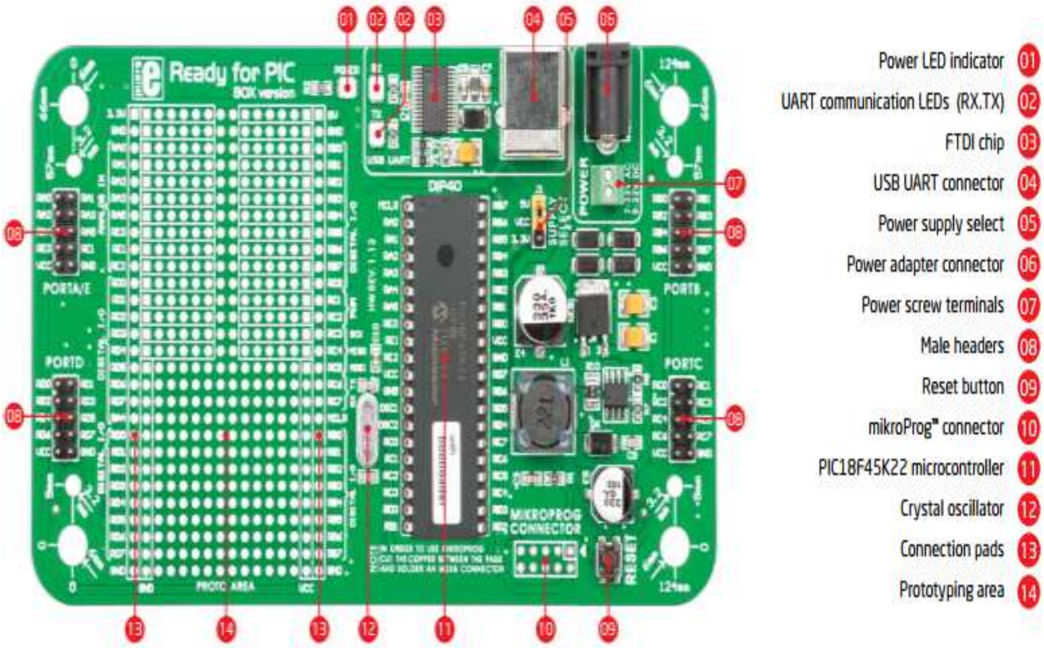

Figure 3.13: Ready for PIC board

3.4.1. Microcontroller processing

The microcontroller software was based on the highly popular mikroC Pro for PIC language, developed by mikroElektronika. This is a C language, developed for microcontroller applications. The development environment is actually called IDE (Integrated Development Environment). This is because the programmer can write the source code, then compiles it by using the microC Pro for PIC compiler. The generated code can then easily be loaded to the program memory of the target microcontroller. The program memory is in the form of flash memory and thus it can be programmed by using a suitable programming device.

The Ready for PIC development system used in this Thesis which is loaded by using a Boot loader mechanism. The boot loader is a program that resides at the bottom of the program memory. With the help of this program, the user code can easily be loaded to the program memory of the target microcontroller.

1. **<u>Programming with Boat loader</u>**

Boot loader program is required for programming microcontroller on the Ready for PIC board which is pre-installed in the MCU memory. To transfer the hex files from a PC to MCU, you need to use micro Boot loader (boot loader software) program. After downloading the boot loader program, it receives new program data externally via some communication means and writes data to the program memory of the processor so program can work on PIC.

- Step - 1 Identifying device COM port

Open Device Manager Window and expand ports section to see which COM port is assigned to ready for PIC board (in this case it is COM 3)

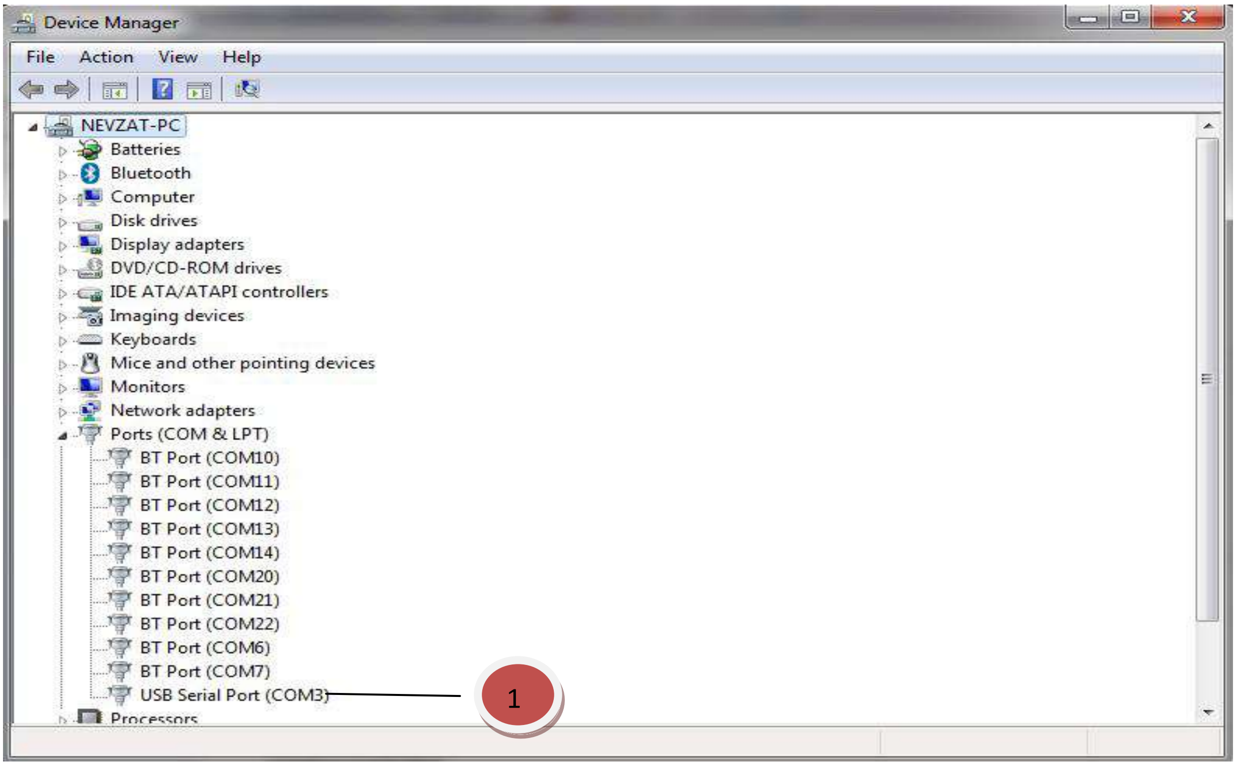

Figure 3.14: Identifying device COM port

- Step - 2 Choosing COM port

First of all change settings menu is selected on boat loader than USB COM port is detected (such case COM 3) Baud rate to set 19200 and lastly OK button is clicked.

Figure 3.15: Selecting COM ports on Boatloader

- Step – 3 Establish connection

Press the Reset button on Ready for PIC® board and click the Connect button within 5s, otherwise the existing microcontroller program will run. If it connected, the button's caption will be changed to disconnect.

Figure 3.16: Connecting with Mikrobootloader

- Step - 4   Browsing for .HEX file

As shown in figure 3.17, click the Browse for HEX button and from a pop-up window choose a .HEX file is to be uploaded to MCU memory.

Figure 3.17: Browse for HEX

- Step - 5   Selecting .HEX file

Select .HEX file using open dialog window Click the Open button

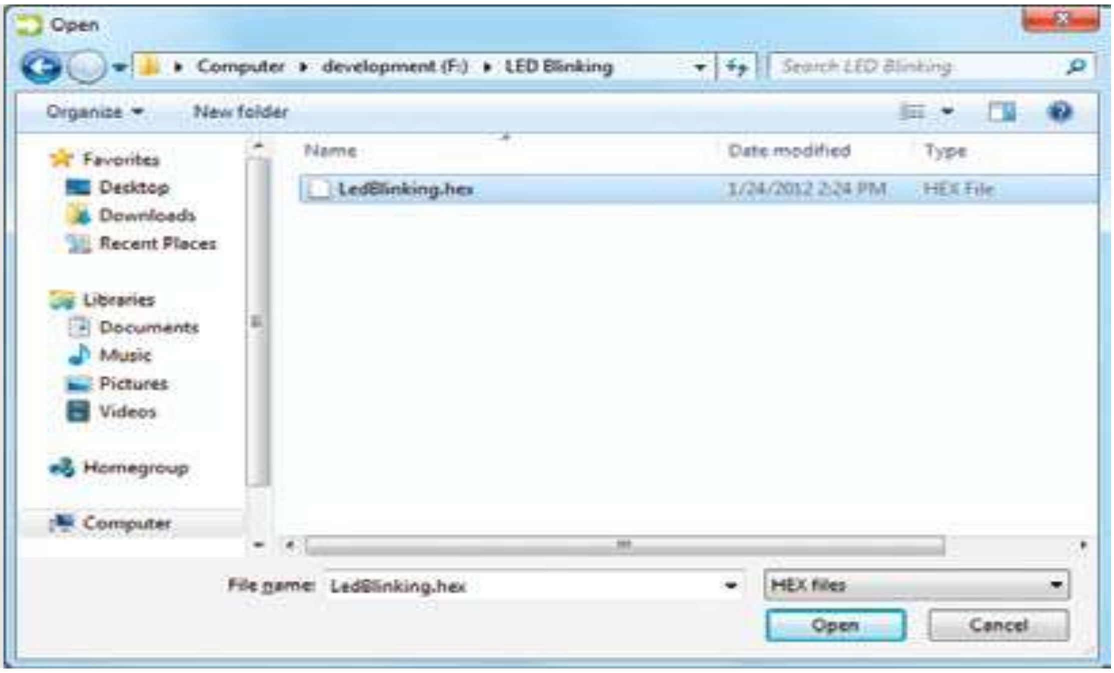

Figure 3.18: Selecting HEX file to the computer

- Step - 6 Uploading .HEX file

To start .HEX file bootloding click the Begin uploading button

Figure 3.19: Begin uploading

- Step - 7 Progress bar

Progress bar enables you to monitor. HEX file uploading

Figure 3.20: Begin uploading & Bootloading progress bar

- Step - 8 Finishing upload

Click OK button, after the uploading process is finished, press Reset button on Ready for PIC board and wait for 5 seconds. Your program will run automatically.

3.4.2 The PIC16F887 MCU

The PIC16F887 microcontroller chip is a product of Microchip that is built on ready for PIC board. This feature is almost for all modern modules of microcontrollers, high quality, wide range of applications, low power consumption, low industry and different values are practical method which is the applications for controlling different processes. The preference of the price and the easy usability of inspector are an important factor. The type of PIC16F887 microcontroller is pre-programmed by UART boot loader firmware. The module of on-board USB-UART provides the serial data transmissions between PIC and computers by using an sub-cable. Then, they have also got a reasonable size prototype area to attach more functionalities as essential. (Appendix 3)

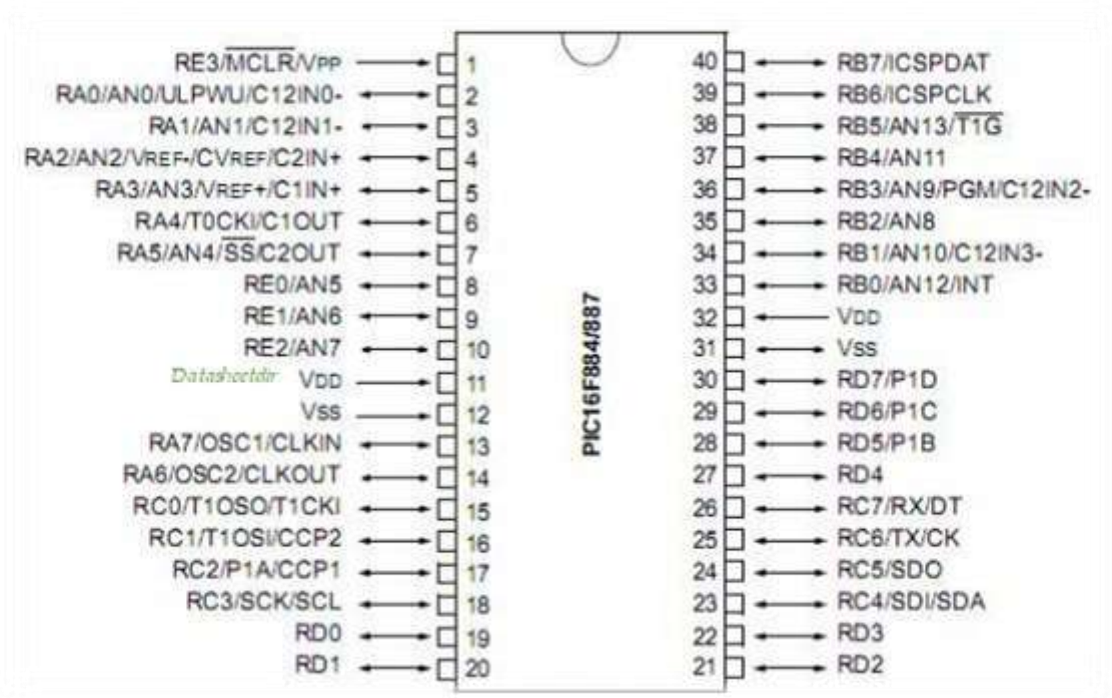

Figure 3.21: The PIC16F887 pin out

3.4.2.1 Memory of PIC16F887

The PIC16F887 contains three types of memory: ROM, RAM and EEPROM. All of them will be separately discussed since each has specific functions, features and organization.

3.4.2.1.1. ROM Memory

ROM memory is used to permanently save the program for being executed. This is why it is often called "program memory". The PIC16F887 has 8Kb of ROM (in total of 8192 locations). Since this ROM is made with FLASH technology, its contents can be changed by providing a special programming voltage (13 V).

3.4.2.1.2. EEPROM Memory

Similar to program memory, the contents of EEPROM are permanently saved, even the power goes off. However, unlike ROM, the contents of the EEPROM can be changed during operation of the microcontroller. That is why this memory (256 locations) is a perfect one for permanently saving results which are created and used during the operation.

3.4.2.1.3. RAM Memory

Ram Memory is the third and the most complex part of microcontroller memory. In this case, it consists of two parts: general-purpose registers and special-function registers (SFR).

Even though both groups of registers are cleared when power goes off and they are manufactured in the same way and acted in the similar way, their functions do not have many things in common.

Different processes in industry, machine control devices, measurement of different values etc. Some of its main features are listed below.

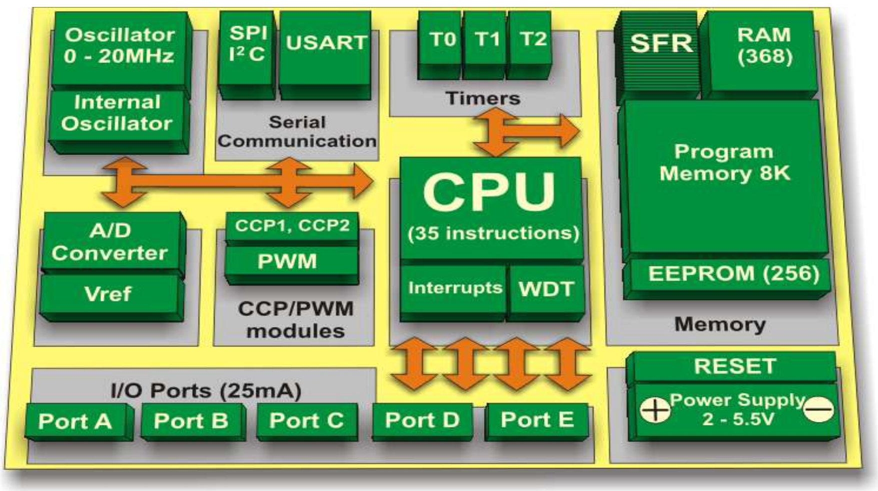

Figure 3.22: The PIC16F887 block diagram

3.4.2.2 The PIC16F887 Basic Feature

- RISC architecture
  - Only 35 instructions to learn
  - All single-cycle instructions except branches
- Operating frequency 0-20 MHz
- Precision internal oscillator
  - Factory calibrated
  - Software selectable frequency range of 8 MHz to 31 KHz
- Power supply voltage 2.0-5.5 V
  - Consumption: 220 μA (2.0 V, 4 MHz), 11 μA (2.0 V, 32 KHz) 50 nA (stand-by mode)
- Power-Saving Sleep Mode
- Brown-out Reset (BOR) with software control option
- 35 input/output pins
  - High current source/sink for direct LED drive
  - software and individually programmable pull-up resistor
  - Interrupt-on-Change pin
- 8K ROM memory in FLASH technology
  - Chip can be reprogrammed up to 100.000 times
- In-Circuit Serial Programming Option
  - Chip can be programmed even embedded in the target device
- 256 bytes EEPROM memory
  - Data can be written more than 1.000.000 times
- 368 bytes RAM memory
- A/D converter:
  - 14-channels
  - 10-bit resolution
- 3 independent timers/counters
- Watch-dog timer
- Analogue comparator module with
  - Two analogue comparators
  - Fixed voltage reference (0.6 V)

    - Programmable on-chip voltage reference
- PWM output steering control
- Enhanced USART module
    - Supports RS-485, RS-232 and LIN2.0
    - Auto-Baud Detect
- Master Synchronous Serial Port (MSSP)
    - supports SPI and I2C mode

3.5. Microcontroller Software Algorithm

In the Uroflowmetry system, measurement is needed to be done the most accurate, the easiest form and independent of the patient control. Therefore, the weight measurement is started automatically and algorithm is designed that the patient doesn't have to push any button. Uroflowmetry device is needed to use successively by different patients. In such cases, the urine collection vessel must discharge for each patient and the use of urine collection vessel will be difficult. The situation which does not change in a certain period of time, available weight is accepted 0, container tare weight is calculated and system is got ready for the new measurement. Analog voltage is being sampled 100 times per second and they are sent to the computer by taking arithmetic average of every 10 samples.

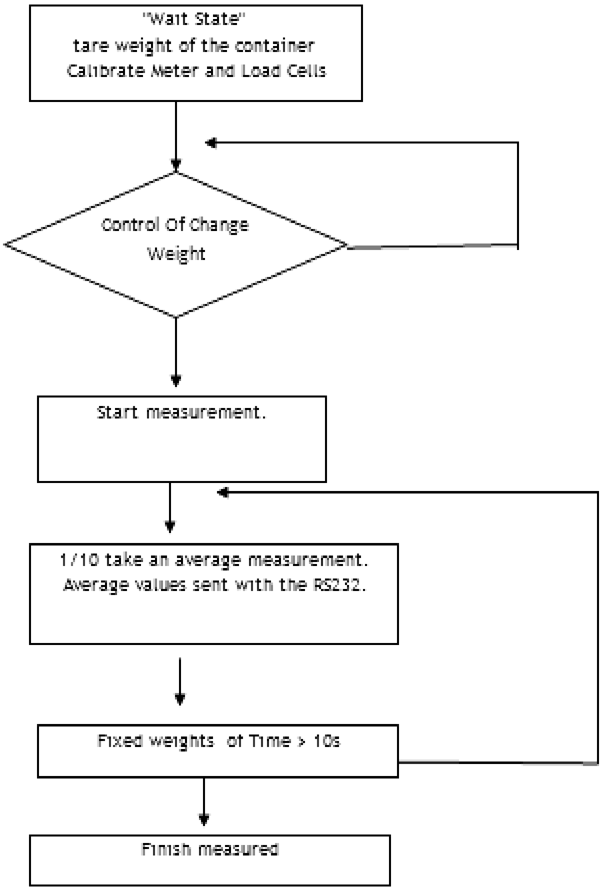

Figure 3.23: Microcontroller software algorithm of Uroflowmetry in this thesis

3.5. MATLAB Programming

The visualization of data's which are digitised with the uroflowmetry hardware, a two-phase order is developed with the purpose of storage and interpretation of computer software. The first stage of software, hardware via RS232 serial data from the microcontroller which acts taking visualize storage "Uroflow recording software" and it is written in "Matlab programming" language.

The second stage of the software, "Uroflow interpretation software" is written the data that is obtained to process and interpret data and it is written in the MATLAB environment the detail of the used MATLAB codes is presented in Appendix 4.

3.7. Uroflow Record

Microcontroller transmits weight values which are measured with the RS232 serial canal to the computer, transmission frequency is 10 times per second.

The measurement values of Uroflow which are taken from the microcontroller, are transmitted to the computer screen and they are converted to a continuous curve. Curve is drawn by way of 50ml / s measurement visualization. This value is defined to the highest flow rate of pathological urine which is required (Gillenwater 2002).

Interface vision user is designed with the purpose of increase the usability of registry software. It is possible to start to end by hand and reconsider measurements again which are done before with this interface.

Computer software decides time out in case of when it can’t be received data from micro-controller in a certain period of time and it finishes drawing. Computer software stores the information of patient’s age and gender in the hard drive.

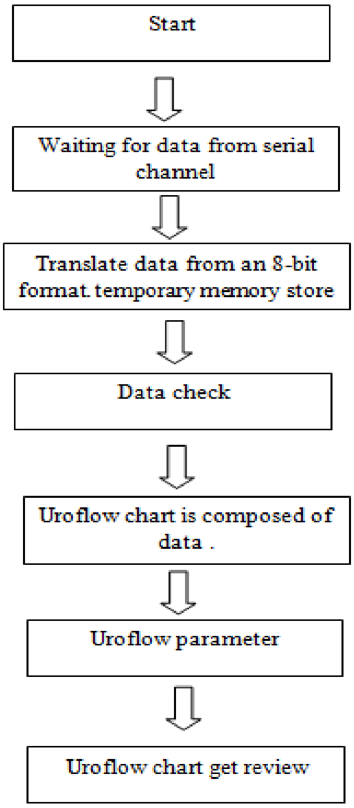

Figure 3.24: MATLAB Uroflow algorithm which is used in this thesis

Recorded uroflow curves and numerical values are opened with the interpretation software. A different visual user interface is designed for this software (see Figure 3.24). This interface is provided to open the desired recording and to follow interpretation results from screen.

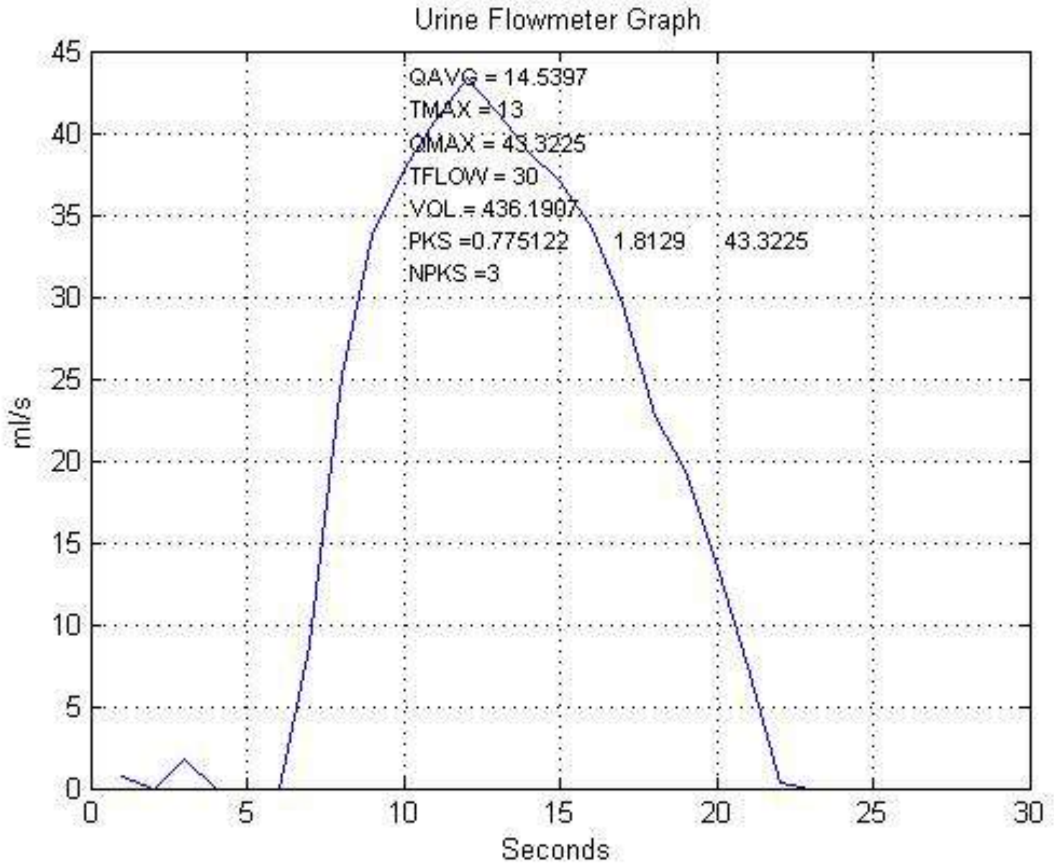

Figure 3.25: Interpretation software screenshot

Uroflow curves are the characteristic forms for normal and pathological statues. Several properties which are related to curve shapes, reflect patient's lower urinary tract of distinct behaviour. The elevation and declination of behaviours, such as; steady form, discontinuity, the existence of several properties which are considered by medical doctors, are specified with the feature inference of algorithm (see Table 3.1).

Uroflow curve is with the purpose of distinguishing features, sub-algorithms were written for each feature. The slope of the rise and fall of the curves, the general rise and fall of behaviours and local gradients are important. For this purpose, the highest overall point of the curve (global maximum) is determined. The rise point of the curve is the first point of differentiation from 0ml/s and the slope of the value which is calculated with these two points will confer the general rise of the curve behaviour. Similarly, the scale of the highest point of all micturition time is an attribute. The highest point to reach, the first 1/3 of the time should be occurred for healthy urine.

Indefiniteness between initial and final point of the curve is likely seen. In this case, discontinuity in the curve is occurred, the situation of curve which is more than ¼ of the ratio of the total time has been added to the list as a feature (Gillenwater, 2002).

Table 3.1: The features of Uroflow curves.

The First curve is greater and smaller than ½ of the value.
The last Drop curve is smaller and greater than ½ of the value
The first raise is total duration of the first 1/3
The curve peak point is flat
The presence of multiple peaks
In case of more than one peak, the local slope values are greater and smaller than ½
The curve is discrete
In case of discrete curve, disconnection delay is larger than the total duration of ¼
Curve peak / time ratio is smaller and larger than from ½.

3.8. Data Acquisition

Uroflowmetry device and computer software are prepared with the purpose of obtain uroflowmetry recordings. It is provided to be enough 1 mg accuracy of measurement for uroflowmetry device. (Abrams, 2003). Uroflowmetry device is tried which is prepared and it is observed that it can work (1 mg) necessary sensibility.

Also, a device which is designed in a hospital environment, to made patients use, and reliability of the results and to be reproducible, electrical reliability is connected to specific documents.

Data set is needed which is including all the types of diseases. Designed uroflowmetry device with this data sets creation and different disease types of related records in sufficient number to obtain take a long time, considering the data of an existing uroflowmetry device from the database compilation is decided.

Uroflowmetry data for training and testing of the Near East University hospital urodynamic system is established embody of urology clinic which is obtained from urodynamics system records (Nexus pro MMS). This system has been used for a long time and it is a source which is saved in databases which have wide variety of diseases.

3.9. Criteria for Use of Data

Each patient's data's which are applied to test, are recorded in the Near East University research hospital of urology clinic. In this study, data's are recorded for each patient. A total voiding volume is between 45-600 ml which have adult patient and uroflow curve data's which don't change with artificial effect, (measurement errors, the intervene of patient) is used (Abrams, 2003). Data's with the exception of these criterias are removed with the suggestions of specialists from education and test sets, the recommendations of specialist physicians have been removed from the training and test sets. We can see uroflowmetry graphics which have healthy and unhealthy individuals, is taken from hospital in below.

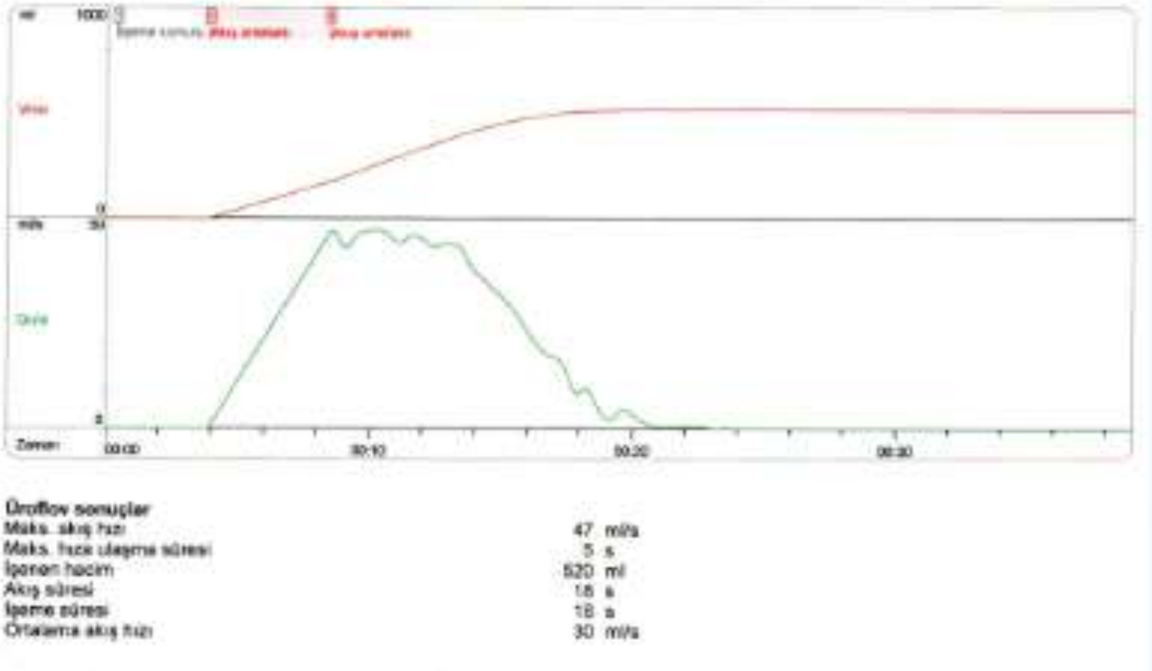

Figure 3.26: This Uroflowmetry graph is for healthy person

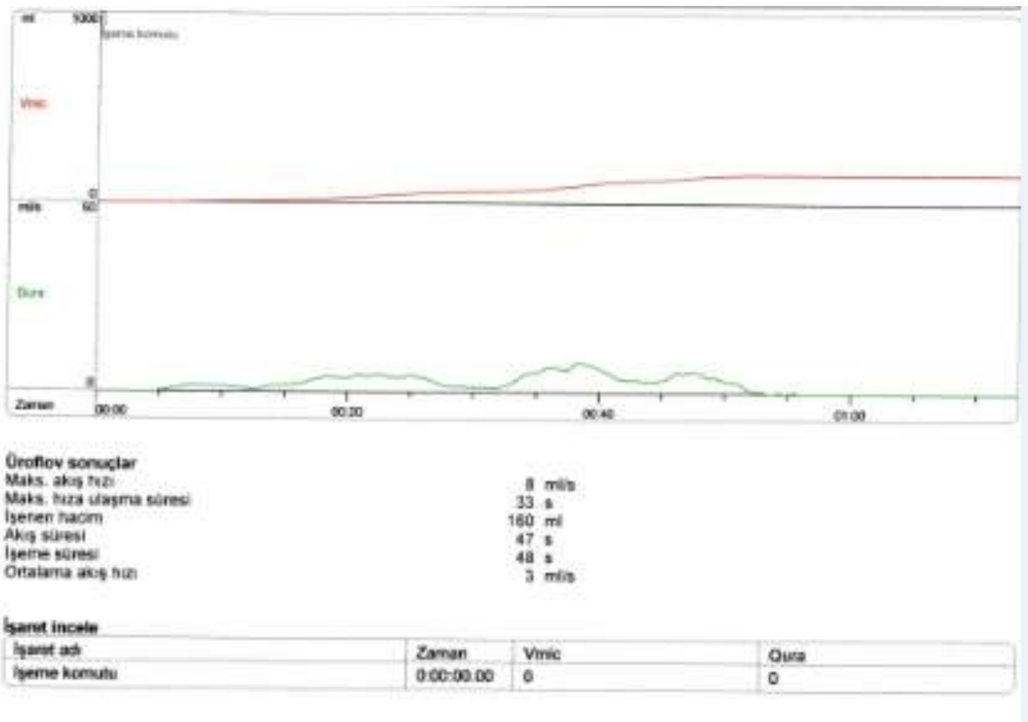

Figure 3.27: This Uroflowmetry Graph is for a person with prostate problems

CHAPTER 4

RESULTS AND DISCUSSIONS

Matlab consists of two layers which is used in this study basically (see Figure 4.1 and Figure 4.2). Login layer is the result of feature inference algorithm. Output layer extracts graphic which produces "healthy" and "possible prostate problem" results.

Pre-diagnosis are generated with the result of specialist reviews for graphics which are determinate and each uroflow graphs are recorded as “healthy" and "possible prostate problem". Healthy patients’ uroflow graphic is seen in the figure 4.1. Data’s are seen such as; the total urine volume, average flow rate and maximum flow rate in the output screen. The result of health is produced and this result is consonant with the doctor’s pre-diagnosis.

Possible pathological diagnosis is seen in the Figure 4.2. Uroflow curve’s is not a healthy situation which has more than one peak. The urinary flow rate changes in time can result from abdominal muscle of individual and bladder pressure application; it can also be the case such as originating urinary tract which cause obstacle or in order to stop stenosis. The first possibility is the natural and normal effect but for the second case, it is possible to be stenosis or prevention and it is probably pathological situation (Abrams, 2003). It is clear that to be unhealthy but it cannot certainly be indicated as pathological for this situation, system is produced to “possible pathological pre-diagnosis” as seen in the Figure 4.1.

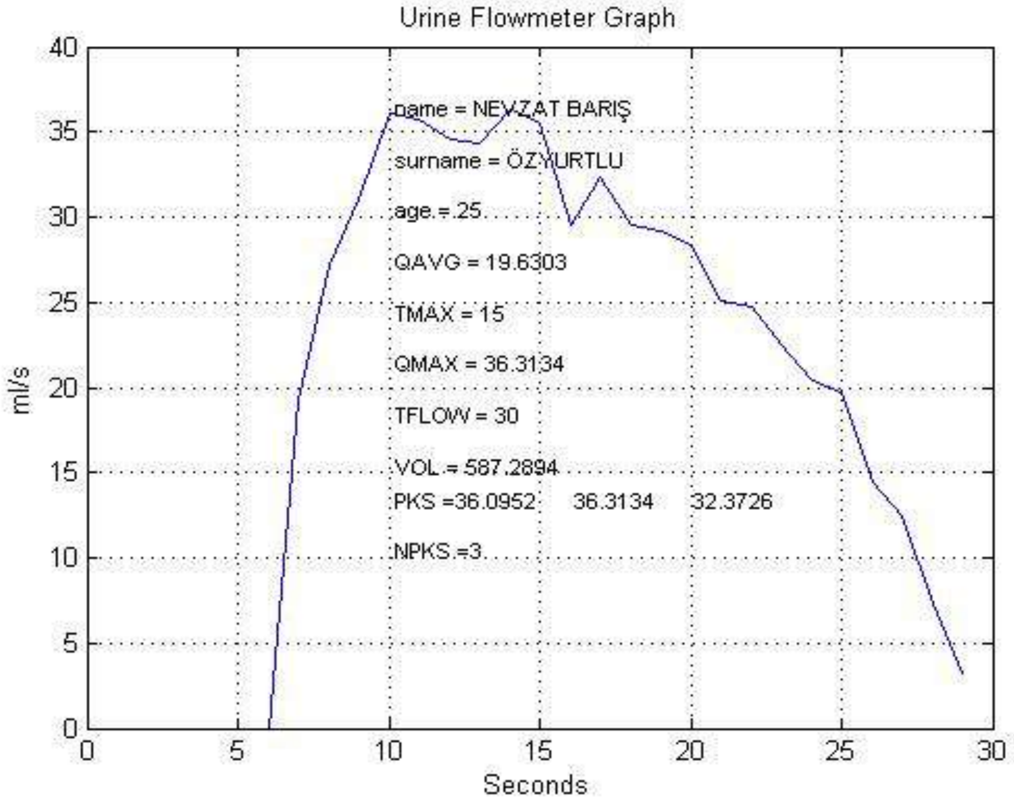

Figure 4.1: This Uroflowmetry graph for healthy person

Table 4.1. Parameters and result of healthy person

GRAPH PARAMETERS:
=================
QMAX = 36.3134
TMAX = 15
QAVG = 19.6303
TFLOW = 30
VOL = 587.2894
Peaks-Y = 36.0952 36.3134 32.3726
Peaks-X = 11 15 18
No of Pks = 3
XMAX = 36.3134
YMAX = 3.2366

END OF GRAPH PARAMETERS
FINAL RESULT: Healthy person

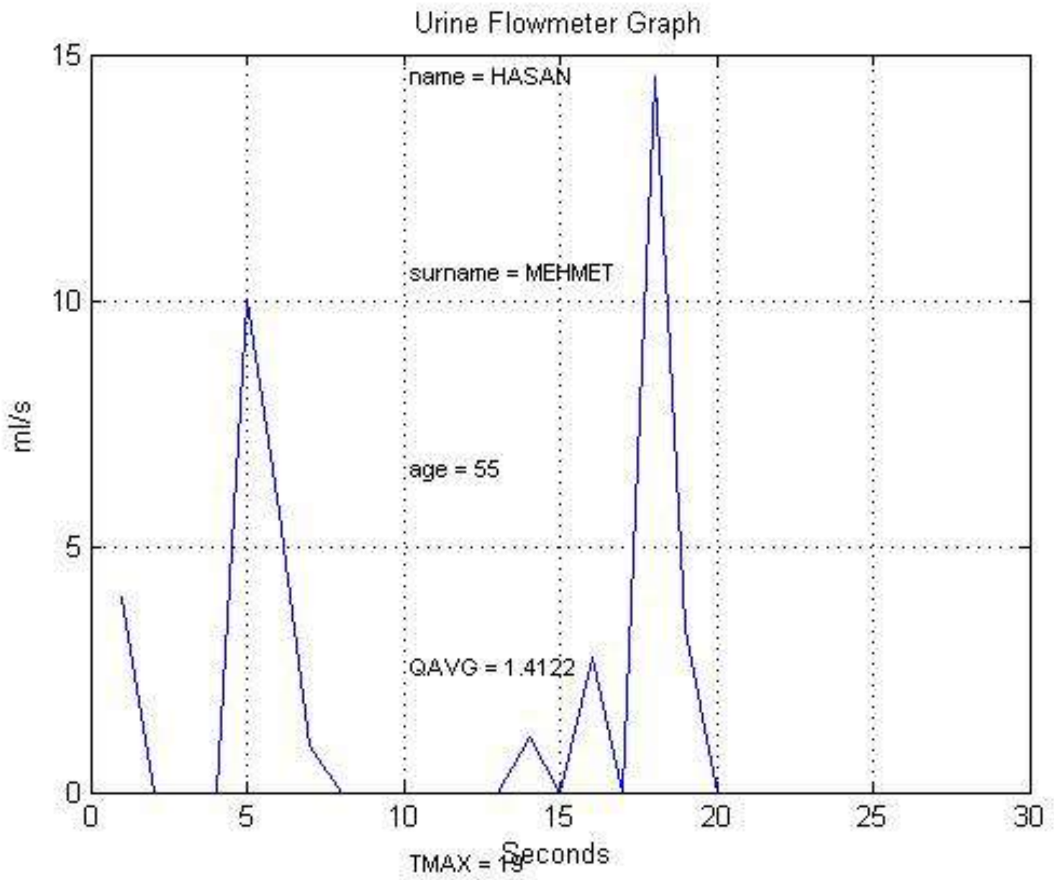

Figure 4.2: This Uroflowmetry graph for prostate problem person

Table 4.2. Parameters and result of prostate problem person

GRAPH PARAMETERS:
=================
QMAX = 14.5418
TMAX = 19
QAVG = 1.4122
TFLOW = 30
VOL = 42.3647
Peaks-Y = 3.96813 10.0266 1.09973 2.74265 14.5418
Peaks-X = 2 6 15 17 19
No of Pks = 5

XMAX	= 14.5418
YMAX	= 0
END OF GRAPH PARAMETERS	
ANALYSIS OF RESULTS	
More than 1 peak...Possible cause: prostate problem	
Max flow too small...Possible cause: prostate problem	
VOL too small... Possible cause: prostate problem	

CHAPTER 5
CONCLUSION

The designed microcontroller based uroflowmetry device has been successfully applied and tested on real patients who suffer from prostate problems at the NEU Training and Research Hospital.

This thesis focuses on the development and design of an intelligent microcontroller based uroflowmetry device. The device is low-cost and is based on using a weight measuring load cell together with a low-cost microcontroller development system in order to measure the weight of the collected urine in real time. The collected data is then sent in real time over a serial link to a PC where a graph of the data is drawn (uroflow graph) and the data is analysed by using a MATLAB program on the PC.

In the literature, uroflowmetry graphs are obtained using standard devices which output a graph as well as numerical flow values. These graphs are useful in determining whether or not a patient has urinary track problems. The novelty of the device developed by the author is that it can determine and also display whether or not the patient suffers from a urinary track problem.

Low urinary track system realizes the activity of micturation with running more than one organs together. Micturation is important part of the human life and some diseases such as; prostate enlargement affects patient’s life quality very negatively and they are caused to suffer serious pains. Healthy person urinates average 1 litre everday. If the process of urination is problem even painful, this is a serious situation. Statistics show that once in every 3 person lives prostate pain. Uroflow test applies to almost all complaints which based micturation. Uroflow data are interpreted with the software and produces prediagnosis which will be lodestar to doctors. Graph is consisted from uroflowmetry signals, this graph is considered by using pre-diagnosis which is developed, has been provided new decision support system for urologists. Only problem is that patient is affected from physical conditions, these tests are realized more than one, then we need to obtain accurate graphs. Uroflow curve causes possible pathological pre-diagnosis as a result of situation abdominal straining. The reason is that it applies pressure to the bladder with abdominal muscles, it can be a normal behaviour, it can also be reaction in order to overcome obstacle or obstruction which occurs in the urinary tract.

In conclusion, the uroflowmetry device is low-cost which is developed by the author, and it can determine intelligently whether or not the patient has any urinary track problems.

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APPENDIX 1

TS912N Data Sheet

TS912, TS912A, TS912B

Rail-to-rail CMOS dual operational amplifier

Datasheet − production data

Features

- Rail-to-rail input and output voltage ranges
- Single (or dual) supply operation from 2.7 to 16 V
- Extremely low input bias current: 1 pA typ.
- Low input offset voltage: 2 mV max.
- Specified for 600 Ω and 100 Ω loads
- Low supply current: 200 µA/amplifier (V_{CC} = 3 V)
- Latch-up immunity
- ESD tolerance: 3 kV
- Spice macromodel included in this specification

Related products

- See TS56x series for better accuracy and smaller packages

Description

The TS912 device is a rail-to-rail CMOS dual operational amplifier designed to operate with a single or dual supply voltage.

The input voltage range V_{icm} includes the two supply rails V_{CC}^+ and V_{CC}^-.

The output reaches V_{CC}^- +30 mV, V_{CC}^+ -40 mV, with R_L = 10 kΩ and V_{CC}^- +300 mV, V_{CC}^+ -400 mV, with R_L = 600 Ω.

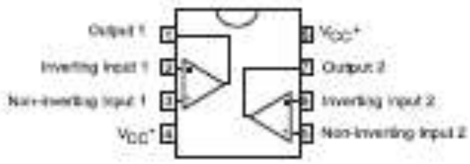
This product offers a broad supply voltage operating range from 2.7 to 16 V and a supply current of only 200 µA/amp. (V_{CC} = 3 V).

Source and sink output current capability is typically 40 mA (at V_{CC} = 3 V), fixed by an internal limitation circuit.

N
DIP8
(plastic package)

D
SO-8
(plastic micropackage)

Pin connections (top view)



APPENDIX 2

The Microcontroller Uroflowmetry Program Codes in Micro C for PIC16F887 Microcontroller

```
// LCD module connections
sbit LCD_RS at RB2_bit;
sbit LCD_EN at RB3_bit;
sbit LCD_D4 at RB4_bit;
sbit LCD_D5 at RB5_bit;
sbit LCD_D6 at RB6_bit;
sbit LCD_D7 at RB7_bit;

sbit LCD_RS_Direction at TRISB2_bit;
sbit LCD_EN_Direction at TRISB3_bit;
sbit LCD_D4_Direction at TRISB4_bit;
sbit LCD_D5_Direction at TRISB5_bit;
sbit LCD_D6_Direction at TRISB6_bit;
sbit LCD_D7_Direction at TRISB7_bit;
// End LCD module connection
void main()
{
  char i, flag,j;
```

```
int c1, c2;

float mV, FirstReading, Grams, m, C;

char Txt[]="              ";                          // Display millivolt

long sum;

const float lsb=5000.0/1024.0;


ANSEL  = 1;                         // Configure AN0 pin as Analog input

ANSELH = 0;                         // PORT B as digital I/O

TRISA = 1;

TRISC = 0;


Lcd_Init();                         // Initialize LCD


Lcd_Cmd(_LCD_CLEAR);                // Clear display

Lcd_Cmd(_LCD_CURSOR_OFF);           // Cursor off

Lcd_Out(1,1,"TEST");                // Write text in first row

Delay_Ms(2000);

flag = 1;                           // First time set to 0


 UART1_Init(4800);

 Uart1_Write(0x0D);

 Uart1_Write(0x0A);
```

```
for(j=0;j<30;j++)
{
    sum = 0;
    for(i = 0; i < 200; i++)
    {
      RC0_bit = 1;  RC1_bit = 0;                  // mode 1
      Delay_Ms(2);
      c1 = ADC_Read(0);

      RC0_bit = 0;  RC1_bit = 1;              // mode 2
      Delay_Ms(2);
      c2 = ADC_Read(0);

      sum = sum + (long)(abs(c1-c2));
     }

     mV = lsb*sum / 200.0;
     if(flag == 1)
     {
      flag = 0;
      FirstReading = mV;
```

```
    }
    mV = mV - FirstReading;
    if(mV < 0)mV = -mV;                          // voltage read
 //
 // convert to grams. Find values of "m" and "C"
 //
    m = 0.48;                                    // *** Estimate ***
    C = 5.0;                                     // *** Estimate ***
    Grams = m*mV + C;
//
// Display the voltage in millivolts
//
    FloatToStr(Grams,Txt+2);
    Lcd_Cmd(_LCD_CLEAR);
    Lcd_Out(1,1, Txt);                           // Display millivolts
    Delay_Ms(1000);
 //
 // Send data (Time and Grams)to the PC for processing
 //      UART1_Write_Text(Txt);
    UART1_Write(0x0D);
    UART1_Write(0x0A);
```

APPENDIX 3

PIC16F887 Data Sheet

MICROCHIP **PIC16F882/883/884/886/887**

28/40/44-Pin Flash-Based, 8-Bit CMOS Microcontrollers with nanoWatt Technology

High-Performance RISC CPU:

- Only 35 instructions to learn:
  - All single-cycle instructions except branches
- Operating speed:
  - DC – 20 MHz oscillator/clock input
  - DC – 200 ns instruction cycle
- Interrupt capability
- 8-level deep hardware stack
- Direct, Indirect and Relative Addressing modes

Special Microcontroller Features:

- Precision Internal Oscillator:
  - Factory calibrated to ±1%
  - Software selectable frequency range of 8 MHz to 31 kHz
  - Software tunable
  - Two-Speed Start-up mode
  - Crystal fail detect for critical applications
  - Clock mode switching during operation for power savings
- Power-Saving Sleep mode
- Wide operating voltage range (2.0V-5.5V)
- Industrial and Extended Temperature range
- Power-on Reset (POR)
- Power-up Timer (PWRT) and Oscillator Start-up Timer (OST)
- Brown-out Reset (BOR) with software control option
- Enhanced low-current Watchdog Timer (WDT) with on-chip oscillator (software selectable nominal 268 seconds with full prescaler) with software enable
- Multiplexed Master Clear with pull-up/input pin
- Programmable code protection
- High Endurance Flash/EEPROM cell:
  - 100,000 write Flash endurance
  - 1,000,000 write EEPROM endurance
  - Flash/Data EEPROM retention: > 40 years
- Program memory Read/Write during run time
- In-Circuit Debugger (on board)

Low-Power Features:

- Standby Current:
  - 50 nA @ 2.0V, typical
- Operating Current:
  - 11 µA @ 32 kHz, 2.0V, typical
  - 220 µA @ 4 MHz, 2.0V, typical
- Watchdog Timer Current:
  - 1 µA @ 2.0V, typical

Peripheral Features:

- 24/35 I/O pins with individual direction control:
  - High current source/sink for direct LED drive
  - Interrupt-on-Change pin
  - Individually programmable weak pull-ups
  - Ultra Low-Power Wake-up (ULPWU)
- Analog Comparator module with:
  - Two analog comparators
  - Programmable on-chip voltage reference (CV_{REF}) module (% of V_{DD})
  - Fixed voltage reference (0.6V)
  - Comparator inputs and outputs externally accessible
  - SR Latch mode
  - External Timer1 Gate (count enable)
- A/D Converter:
  - 10-bit resolution and 11/14 channels
- Timer0: 8-bit timer/counter with 8-bit programmable prescaler
- Enhanced Timer1:
  - 16-bit timer/counter with prescaler
  - External Gate Input mode
  - Dedicated low-power 32 kHz oscillator
- Timer2: 8-bit timer/counter with 8-bit period register, prescaler and postscaler
- Enhanced Capture, Compare, PWM+ module:
  - 16-bit Capture, max. resolution 12.5 ns
  - Compare, max. resolution 200 ns
  - 10-bit PWM with 1, 2 or 4 output channels, programmable "dead time", max. frequency 20 kHz
  - PWM output steering control
- Capture, Compare, PWM module:
  - 16-bit Capture, max. resolution 12.5 ns
  - 16-bit Compare, max. resolution 200 ns
  - 10-bit PWM, max. frequency 20 kHz
- Enhanced USART module:
  - Supports RS-485, RS-232, and LIN 2.0
  - Auto-Baud Detect
  - Auto-Wake-Up on Start bit
- In-Circuit Serial Programming™ (ICSP™) via two pins
- Master Synchronous Serial Port (MSSP) module supporting 3-wire SPI (all 4 modes) and I²C™ Master and Slave Modes with I²C address mask

APPENDIX 4

Uroflowmetry Pc Matlab Program

```
%=============================================================
%
%               UROFLOW GRAPH PLOTTING AND ANALYSIS PROGRAM
%               ------------------------------------------------------------------------------
%
% This program receives the uroflow data via the serial port. A digital scale
% is used to detect the urine sample and the measured weight is sent to the
% PC for graph plotting and analysis.
%
% The data is collected for 30 seconds, which should be enough for the patient
% to empty his or her bladder. The test would be carried out after the person
% drinks enough water to fill his/her bladder.
%
% The uroflow graph is drawn and the important parameters are extracted and
% displayed. In addition, a simple analysis is carried out to find out whether
% or not the results are normal.
%
%==========================================================

clear all;
close all;
%
% Get Patient Details
%
name = input('Name: ','s');
surname = input('Surname: ','s');
age = input('Age: ');
sex = input('Sex (M or F): ','s');
```

```
CURRENT_DATE = date;
%
% Define NORMAL values
%
NORMAL_QMAX = 20;
NORMAL_TMAX = 10;
NORMAL_QAVG = 5;
NORMAL_TFLOW = 30;
NORMAL_VOL = 20;

fileid = fopen('test.doc','w');
fprintf(fileid, '%s\n','UROFLOW ANALYSIS');
fprintf(fileid, '%s\n','==================');
%
% Write patient details into the file
%
fprintf(fileid, 'Date: %s\n', CURRENT_DATE);
fprintf(fileid, 'Name: %s\n', name);
fprintf(fileid, 'Surname: %s\n', surname);
fprintf(fileid, 'Age: %s\n', age);
fprintf(fileid, 'Sex: %s\n', sex);
fprintf(fileid, '\n');
fprintf(fileid, '\nRESULTS\n');
fprintf(fileid, '=======\n');



%
%
% Assign the serial port to read the uroflow data from the digital scale
%
s = serial('COM3');                                    % Assign to serial port
disp(' Setting serial port parameters…');
%
```

```
% Set serial port characteristics
%
s.BaudRate = 4800;                          % Speed
s.Parity = 'none';                          % No parity
s.DataBits = 8;                             % 8 data bits
s.InputBufferSize = 1024;                   % Buffer size
s.ReadAsyncMode = 'continuous';
s.Terminator =  'CR/LF';                    % Terminator
s.Timeout = 10;

%
% Open the port and read 30 records
%
disp(' Opening serial port…');
fopen(s)
disp(' Reading 30 records  from serial port…');
%
%
odd=0;
t = 1;
x = 0;                                      % x axis time values
%
% Start of the loop to read and plot the graph
%
while t<30;                                 % Get 30 records from serial
port
out = fscanf(s,'%e',14);                    % Read and store in vector out
out=out/1.02;
y=out-odd;

y=y-7;
if y < 0
  y = 0;
```

```
end

odd=out;
x = [x y];                                    % Store values in a vector
%
% Display the results as we go along
%
disp([num2str(t), '     ', num2str(y)]);
tt(t:t)=t;
yy(t:t)=y;
t = t + 1;                                    % Increment time
out = 0;                                      % Clear the buffer
end
%
% Plot the results
%
axis auto;
plot(tt,yy);
grid on;
title('Urine Flowmeter Graph');
xlabel('Seconds');
ylabel('ml/s');

%
% End of the loop to read the uroflow data from the serial port
%
% Close the serial port
%


fclose(s);
delete(s);
%clear(s);
```

```
%
%
% Display parameters
%
disp(' ');
disp('GRAPH PARAMETERS:');
disp('=================');
%
% Display QMAX
%
[QMAX TMAX]=max(x);
str=['QMAX      = ', num2str(QMAX)];
disp(str);
fprintf(fileid,'%s\n',str);
%
% Display TMAX
%
str=['TMAX      = ', num2str(TMAX)];
disp(str);
fprintf(fileid,'%s\n',str);

%
% Display QAVG
%
QAVG =mean(x);
str=['QAVG      = ', num2str(QAVG)];
disp(str);
fprintf(fileid,'%s\n',str);

%
% Display TFLOW
%
```

```
TFLOW=30;
str=['TFLOW     = ', num2str(TFLOW)];
disp(str);
fprintf(fileid,'%s\n',str);

%
% Display VOL
%
q=trapz(x);
str=['VOL       = ', num2str(q)];
disp(str);
fprintf(fileid,'%s\n',str);

%
% Display the Peaks
%
[pks,locs]=findpeaks(x);
str=['Peaks-Y   = ', num2str(pks)];
disp(str);
fprintf(fileid,'%s\n',str);

%
% Display the Peak oordinates
%
str=['Peaks-X   = ',num2str(locs)];
disp(str);
fprintf(fileid,'%s\n',str);

%
% Display the number of peaks, Npeaks
%
[m,npks]=size(locs);
str=['No of Pks = ', num2str(npks)];
```

```
disp(str);
fprintf(fileid,'%s\n',str);

%
% Display XMAX
%
XMAX=max(x);
str=['XMAX      = ', num2str(XMAX)];
disp(str);
fprintf(fileid,'%s\n',str);

%
% Dislay YMAX
%
YMAX=abs(max(y));
str=['YMAX      = ',num2str(YMAX)];
disp(str);
fprintf(fileid,'%s\n',str);

%
%
disp('END OF GRAPH PARAMETERS');
disp('=======================');
disp(' ');

%
%
XM = XMAX;
YM=t-20;
%
% Insert the important parameters on the graph
%
```

```
text(YM,XM,  [' name = ',num2str(name)],...'HorizontalAlignment','right',...
   'FontSize',8)
text(YM,XM-3,  [' surname = ',num2str(surname)],...'HorizontalAlignment','right',...
   'FontSize',8)
text(YM,XM-6,  [' age = ',num2str(age)],...'HorizontalAlignment','right',...
   'FontSize',8)
text(YM,XM-9,  [' QAVG = ',num2str(QAVG)],...'HorizontalAlignment','right',...
   'FontSize',8)
text(YM,XM-12,[' TMAX = ',num2str(TMAX)],...'HorizontalAlignment','right',...
   'FontSize',8)
text(YM,XM-15,[' QMAX = ',num2str(QMAX)],...'HorizontalAlignment','right',...
   'FontSize',8)
text(YM,XM-18,[' TFLOW = ',num2str(TFLOW)],...'HorizontalAlignment','right',...
   'FontSize',8)
text(YM,XM-21,[' VOL = ',num2str(q)],...'HorizontalAlignment','right',...
   'FontSize',8)
text(YM,XM-23,[' PKS =',num2str(pks)],...'HorizontalAlignment','right',...
   'FontSize',8)
text(YM,XM-26,[' NPKS =',num2str(npks)],...'HorizontalAlignment','right',...
   'FontSize',8)
%
% ANALYSIS SECTION
%

disp(' ');
disp('ANALYSIS OF RESULTS:');
disp('===================');
fprintf(fileid, '\n%s\n', 'ANALYSIS OF RESULTS');
fprintf(fileid, '%s\n', '====================');
fprintf(fileid, '\n');
FLAG=0;

%
```

```
% Analyse number of peaks
%
if npks > 1
   disp('More than 1 peak...Possible cause: prostate problem');
   FLAG=1;
End

%
% Analyse W+QMAX
%
if QMAX < 15
   disp('Max flow too small...Possible cause: prostate problem');
   FLAG=1;
End

%
% Analyse W+VOL
%
if q < 150
   disp('VOL too small... Possible cause: prostate problem');
   FLAG=1;
end
 disp(' ');
disp('FINAL RESULT:');
if FLAG == 0
  disp('NO PROBLEMS DETECTED - HEALTHY');
end
if FLAG == 1
  disp('PROBLEMS DETECTED - POSSIBLE PROSTATE PROBLEMS');
end
fclose(fileid);
```