Sudan university of science and technology

Faculty of post graduate

Early detection of stomach pain using reflexology

الاكتشاف المبكر لألم المعدة باستخدام علم المنعكسات

Thesis Submitted partial fulfillment for awarded the degree of M.Sc. in biomedical engineering

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الاية

بسم الله الرحمن الرحيم

سَنُرِيهِمْ آيَاتِنَا فِي الْآفَاقِ وَفِي أَنفُسِهِمْ حَتَّىٰ يَتَبَيَّنَ لَهُمْ أَنَّهُ الْحَقُّ ۗ أَوَلَمْ يَكْفِ بِرَبِّكَ أَنَّهُ عَلَىٰ كُلِّ شَيْءٍ شَهِيدٌ

(53)

سورة(فصلت)

صدق الله العظيم

Dedication

To my mother

To my father

To my sisters

To my brothers

To my best friends

Acknowledgments

I would like to express my deepest appreciation and gratitude to my supervisor Dr.Elyas Al siddig for his constant help, guidance and encouragement through the study ,which allowed me to complete my project effectively and efficiently in time.

Thanks to the college of engineering, department of biomedical and all of faculty members. My special thanks also are due to E.hashim batran, and E.Abdulla merghany for their generous help .Deep thanks to any person, who stand beside me in my life

Abstract

Pain detection using a quick response method is considered an important point that must be considered especially for emergency medicine. This project presents new technique that records the myoelectrical activity of the stomach, which is effective due to its non-invasive nature and its correlation with gastric motility .The procedure was simulated with the aid of MATLAB 7.8 to generate a reference signal and another signal to indicate to the patient's signal by using signal processing toolboxes -amplified, filtered using low pass filter (LPF).The comparison was carried out by using a step response -to achieve a prompt result and make a direct diagnosis decision. A normal or abnormal reading was illustrated by a corresponding graph with comments .The required system expressions were incorporated into the program code and operational flowcharts were designed for the sequential line of code.

المستخلص

الكشف عن الألم بطريقة سريعة يعتبر نقطة مهمة يجب أن تأخذ في الاعتبار خصوصا في طب الطوارئ. قدم هذا المشروع تقنية لتسجيل النشاط الكهربي للمعدة باستخدام اقطاب السطح(الحساسات) فهي وسيلة فعالة لعلاقتها الغير مباشرة بالمعدة وارتباطها بعملية الهضم .فقد تم توليد الاشارة المرجعية واشارة اخري تاخذ نفس المواصفات باختلاف التردد فهي تعتبر اشارة المريض حيث اجريت معالجة تحليل الاشارة باستخدام ادوات معالجة الاشارة من تكبير، ترشيح ومعرفة مدي الاستجابة للاشارتين بغرض المقارنة للحصول علي نتيجة سريعة في شكل تخطيط مصحوب بتعليق(طبيعي /غير طبيعي) يحدد وجود الالم من عدمه . تمت محاكاة النظام باستخدام برنامج الماتلاب اصدارة رقم 7.8هذا وقد ادرجت تعبيرات النظام المطلوبة للتصميم في البرنامج .وتم توضيح التسلسل التنفيذي للبرنامج علي شكل مخطط تشغيلي .

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LIST OF ABBREVIATIONS

ADC	Analog to Digital Converter
CPM	Cycles Per Minute
ECA	Electrical Control Activity
EGG	Electrogastrogram
ERA	Electrical Response Activity
GERD	Gastro Esophageal Reflux Disease
GMA	Gastric Myoelectrical Activity
ICC	Interstitial Cells of Cajal

Appendices

CHAPTER ONE

INTRODUCTION

1.1-Overview

Most of the people around the world face the problems related to health especially due to the food intake and disorders in the digestive system. Nowadays Endoscope procedure is followed to investigate the problems in the digestive system disorders, which is an expensive and invasive method. A non-invasive, low cost and painless method called Electrogastrogram (EGG) has been induced for the detection of electrical signal cutaneously from the stomach and it is an initial mode of investigation for gastric disorders before encouraging the Endoscope procedure for simple gastric disease and benign tumors

1.2 - Problem statement

Disappearing of a high speed method to detect the stomach pain at emergency department in any hospital, a proposed device was simulated trying to check the pain faster, easy to use and safe.

1.3 – Objectives

Thesis has two objects:

1.3.1General objectives

- Design and introduced new technical methods for the assessment of gastrointestinal motility disorders in an emergency medicine
- Determine the mode of stomach (normal /abnormal)
- Help the doctors in decision making for direct diagnosis
- Determine the patient's problem in a short time
- Reduce the number of laboratory tests
- Reduce the cost.

1.3.2 Specific objectives

Design a prototype device with a surface electrode, instrumentation amplifier and signal processing tools with the display unit, using a MATLAB program.

1.4 Hypothesis

This project will introduce the fast method to detect the stomach pain and implement the prototype device by using a MATLAB software program

1.5 Thesis Layout

This thesis contents of six chapter, chapter one shows an introduction, chapter two explain a theoretical fundamentals, chapter three illustrate reflexology, chapter four explain the methodology and the design, chapter five represent the discussion, chapter six represent the conclusion and recommendations ,at the end of this chapter show The References and Appendices.

CHAPTER TWO

THEORATICAL FUNDAMENTALS

2.1 Anatomy and physiology

2.1.1 The Stomach Anatomy

The digestive tract is a muscular tube extending through the body. It is composed of several parts: the mouth, pharynx, esophagus, stomach, small intestine, and large intestine as shown in (Figure2.1).

The digestive tract is sometimes called the alimentary tract, derived from a Latin word that means "food". It is more commonly referred to as the gastrointestinal (Gl) tract because of the major importance of the stomach and intestine in the process of digestion [1]

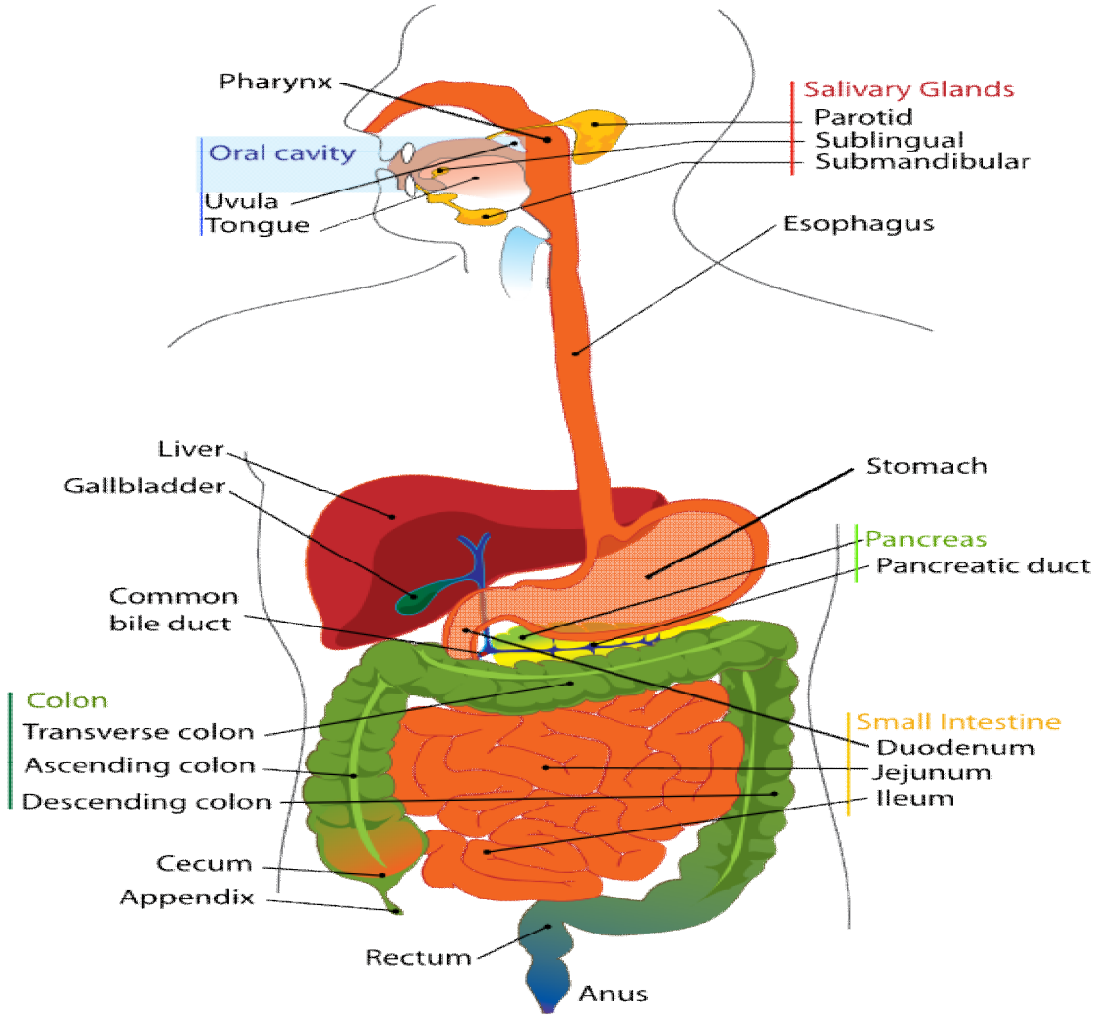


Figure 2.1: The digestive tract parts

The main function of the stomach is to process and transport food. After feeding, the contractile activity of the stomach helps to mix, grind and eventually evacuate small portions of chyme into the small bowel, while the

rest of the chyme is mixed and ground. Anatomically, the stomach can be divided into four sections (Figure2.2), each of which has different cells and functions

1. Cardiac region, where the contents of the esophagus empty into the stomach.
2. Fundus, formed by the upper curvature of the organ.
3. Body, the main central region.
4. Pylorus or antrum the lower section of the organ that facilitates emptying the contents into the small intestine.

Two smooth muscle valves, or sphincters, keep the contents of the stomach contained:

1. Cardiac or esophageal sphincter, dividing the tract above;
2. Pyloric sphincter or pyloric orifice, dividing the stomach from the small intestine.

In the antral area, the density of the smooth muscle cells increases. The area in the corpus around the greater curvature, where the split of the longitudinal layers takes place, is considered to be anatomically correlated with the origin of gastric electrical activity. The stomach wall, like the wall of most other parts of the digestive canal, consists of three layers: the mucosal (the innermost), the muscularis and the serosal (the outermost). [2]

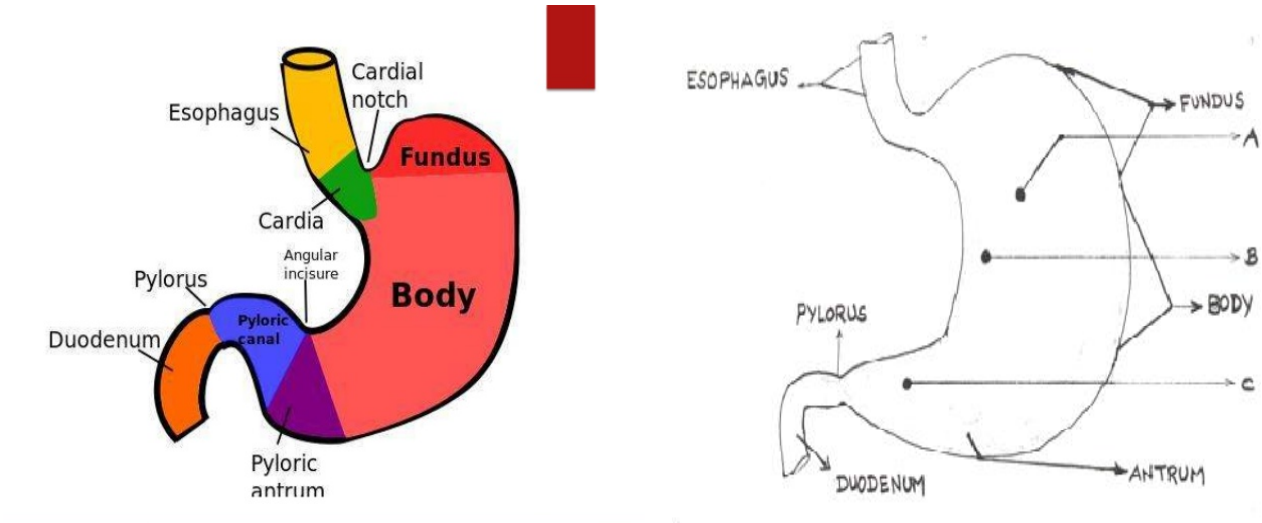


Figure (2.2): a) Diagram of the stomach , b) electrodes placement

2.1.2 The Stomach physiology

Myoelectrical activity is originated along the gastrointestinal tract. In vitro studies using smooth muscle strips of the stomach have revealed independent GMA from different regions of the stomach .

The highest frequency of the gastric myoelectrical activity was recorded in the corpus and the lowest frequency in distal antrum. However, in vivo studies demonstrated a uniform frequency in the entire stomach under healthy conditions, because the myoelectrical activity in the corpus with the highest frequency drives or paces the rest of stomach into the same higher frequency.

GMA is composed of slow waves and spike potentials. The slow wave is also called the pacesetter potential, or electrical control activity. The spike potentials are also called action potentials or electrical response activity.While slow waves originated from the smooth muscles, in vitro electrophysiological studies suggest that Interstitial Cells of Cajal (ICC) are responsible for the generation and propagation of the slow wave .

Frequency of normal slow waves is species-dependent, approximately 3 cpm in humans and 5 cpm in dogs, with little day-to-day variations. The slow wave is known to determine the maximum frequency and propagation of gastric contractions. Figure 2.4 presents an example of normal gastric slow waves measured from a patient. Normal 3 cpm distally propagated slow waves are observed. Spike potentials are known to be directly associated with gastric contractions, that is, gastric contractions occur when the slow wave is superimposed with spike potentials.

In man cyclic recurring electrical potentials, referred to as electrical control activity (ECA) [3],originate in the oral part of the corpus and travel aborally through the longitudinal muscle fibers to the pylorus . This constantly present ECA is generated at intervals of about 20 seconds, which corresponds with a repetition frequency of about 0.05 Hz. When phasic contractions occur, the ECA is accompanied by a second component with or without superimposed fast oscillating potential changes, which is referred to as electrical response activity (ERA) . Relatively little is known about pathological gastric myoelectrical activity.

Dysrhythmias and abnormal ECA frequencies have been described in patients after vagotomy . In gastric ulcer patients both abnormally high

frequencies and arrhythmias and normal frequencies have been observed . In rats and dogs with experimentally induced gastric ulcerations a disorganization of the fasting myoelectrical pattern and a decrease in amplitude of the postprandial fast oscillating potentials were found . It has been suggested that a relationship exists between symptoms of disordered gastric motility and episodes of increased (2-4 times) ECA frequency, referred to as tachygastrias or tachyarrhythmias . These were observed in some patients with chronic, unexplained nausea and vomiting.
Tachygastrias can, however, also occur in the absence of symptoms .[4]
Most of the above studies were performed either with peroral (suction) electrodes or with serosal electrodes placed during laparotomy, and recordings were made only in the fasting state. However, invasive methods are not very suitable for the study and follow-up of large groups of patients, and gastric myoelectricbal activity might bc disturbed by an intraluminal.[5]

2.2 Electrogastrography technique

Electrogastrography (EGG) is a technique for non-invasive recording of gastric myoelectrical activity [6]. The multichannel classic surface EGG signals are captured by three disposable electrodes placed on the anterior abdominal wall overlying the stomachas shown in figure(2.2b). This technique can be considered as a non-invasive method for investigating the propagation of slow waves in the stomach. Their normal frequency is about three cycles per minute (cpm) (0.05 Hz) in humans. The EGG examination may be helpful in diagnosis of gastric disorders. It could diagnose the patients with unexplained nausea, vomiting and other dyspeptic symptoms [7]. Typically, the EGG signals are collected during relatively long time (120–180 min), and the examination is split into three parts: the first a 30-min part before meal (pre-prandial), the second (5–10 min)—during a standardized meal, and the third one after the meal (postprandial). The EGG signals are characterized by following parameters: frequency ranges from 0.015 to 0.15 Hz and maximum amplitude is 500 μV(three cycles per minits). Usually in clinical applications the acquisition process is performed by commercial devices with relatively low sampling frequency (1–4 Hz) and EGG signals are conditioned by means of proper band pass filtering [8]. The detail description of both EGG processing methods and its diagnostic significance is available in Ref. [9], [10].

Besides EGG, also other signals are available on the stomach surface. They are related to electrical activity of other inner organs of the

digestive system such as the duodenum and colon, to heart activity and respiratory movements. The frequency components of these signals partially cover frequency range of EGG signals.

Commonly used conventional band pass filtering may cause loss of some part of information included in this signal especially signals from duodenum and colon or may introduce distortions of EGG signal[11].

2.3- Types of electrodes

Anna Kascika- Jonderko et al (2006) carried out a study on conductive area size of recording electrodes affecting the quality of a multichannel electrogastrogram and they found that type 2222 yields a stable between electrode- electrical conductivity throughout the examination and type 2660 (Ag/Agcl) is recommended because it offers a good performance in EGG acquiring and it is not require any supplementation with a conductive gel. They found single channel is a classical one and they declared that huge research work still has to be performed to overcome it. For analysis of EGG signal they applied three algorithms namely – A running spectrum analysis, overall spectrum analysis, cross channel analysis for both preprandial and postprandial condition. The authors found that 2-2.5 cm2 conductive areas is sufficient to obtain an accurate result with good quality of electrodes, careful observation is done in the procedure of skin preparation. They also declared that current system of bioelectrical signal acquisition, conditioning and analysis are to be perfect to avoid noisy source of a weak electrical signal across the abdominal wall from the stomach to the abdominal surface[12].

Figure 2.3 : electrodes and leads

2.4 EGG Signals

EGG signal for the normal activity is defined as an electrical signal at a frequency of 3 cpm and it is shown in Figure 2.4

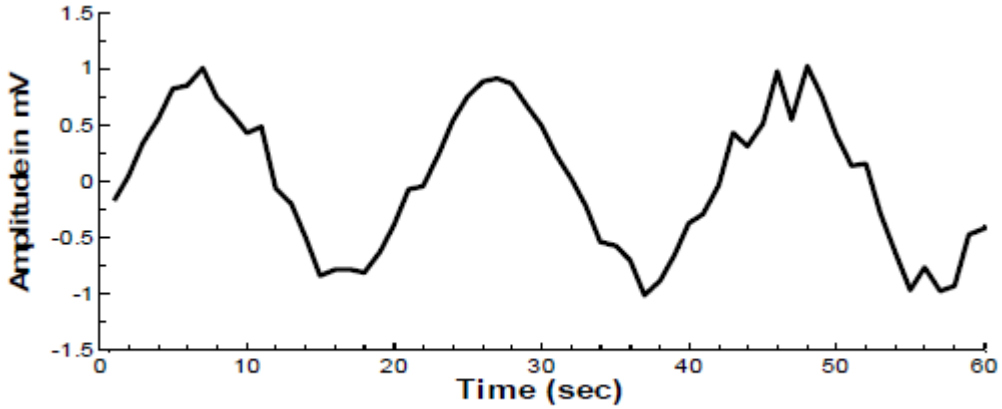


Figure 2.4: EGG of Normal Subjects

Digestive System disorders namely bradygastria, dyspepsia, nausea,

tachygastria, ulcer and vomiting are considered for the analysis in this investigation . Brief detail of the above mentioned disorders is presented below.

2.4.1 Bradygastria

Bradygastria is defined as a decreased rate of electrical pacemaker activity in the stomach which is less than 2 cpm for at least 1 minute. The EGG pattern for bradygastria is shown in Figure 2.5. It may be associated with nausea, gastroparesis, irritable bowel syndrome, and functional dyspepsia.

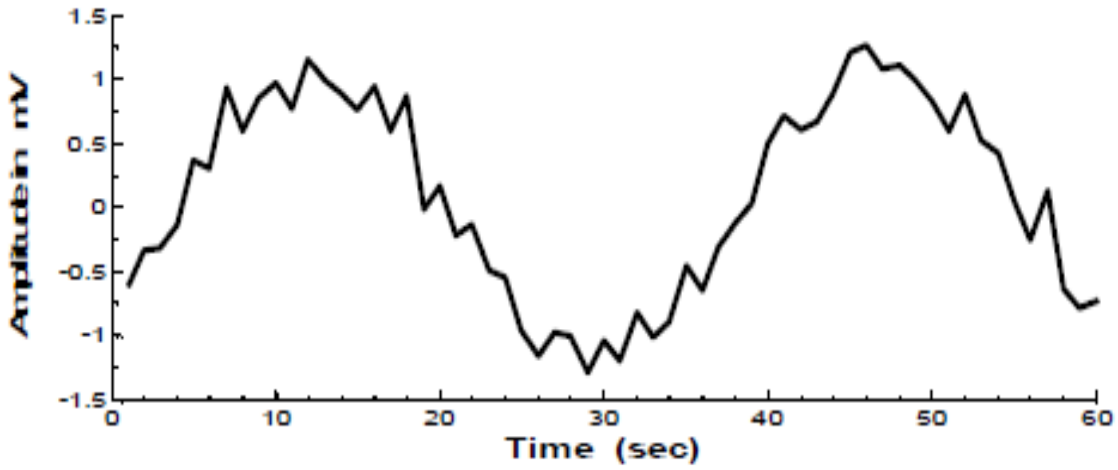


Figure 2.5 :EGG of Bradygastria

2.4.2 Dyspepsia

Dyspepsia (Indigestion) is a vague feeling of discomfort in the upper belly or abdomen during or right after eating or it is also known as upset stomach. This includes:

- A feeling of heat, burning, or pain in the area between the navel and the lower part of the breastbone.
- A feeling of fullness that is bothersome and occurs soon after the meal begins or when it is over.

It can be accompanied by bloating, belching, nausea, or heartburn. Dyspepsia is a common problem, and is frequently due to Gastro Esophageal Reflux Disease (GERD) or gastritis , but for some cases it may be the first symptom of peptic ulcer disease (an ulcer of the stomach or duodenum) and occasionally cancer. Figure 2.6 is the EGG for dyspepsia having a frequency of 4–5 cpm.

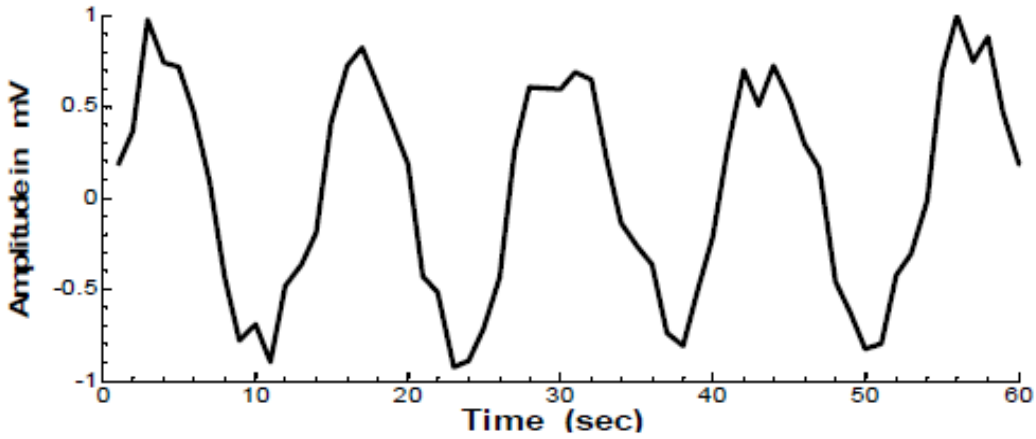


Figure 2.6: EGG of Dyspepsia Subject

2.4.3- Nausea

Nausea is defined as a sensation of unease and discomfort in the upper stomach with an involuntary urge to vomit. It often, but not always, precedes vomiting. A person can suffer nausea without vomiting. Some common causes of nausea are motion sickness, dizziness, fainting, gastroenteritis (stomach infection) or food poisoning. Nausea may also be caused by stress, anxiety, disgust, worry and depression.

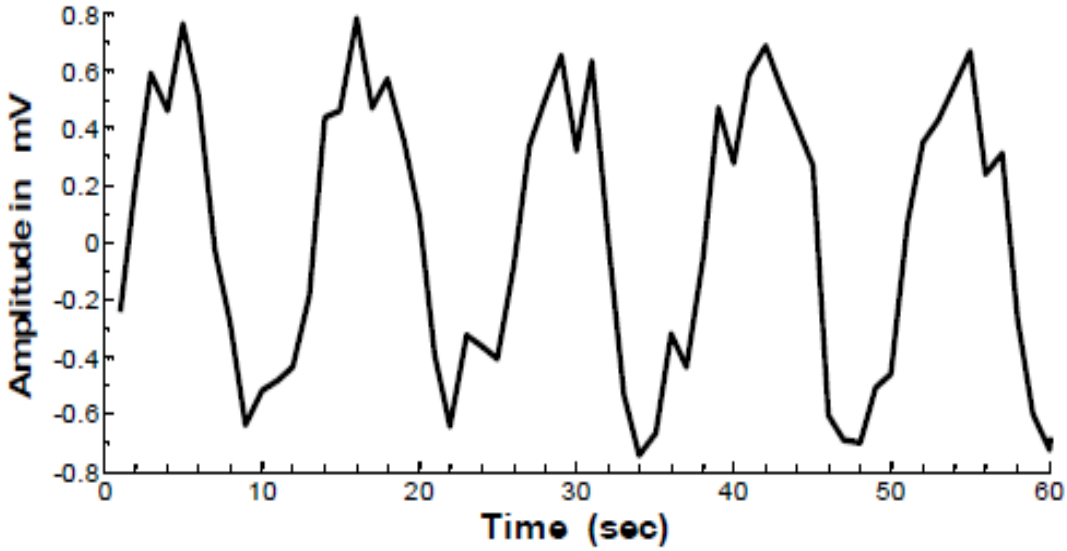


Figure 2.7 :EGG of Nausea Subject EGG pattern of Nausea having a frequency of 3.5–6 cpm

2.4.4 Tachygastria

Tachygastria is defined as the increased rate of electrical activity in the stomach. A one minute recording having more than 4 cycles is shown in Figure 2.8. It is associated with nausea, gastroparesis, irritable bowel syndrome, and functional dyspepsia.

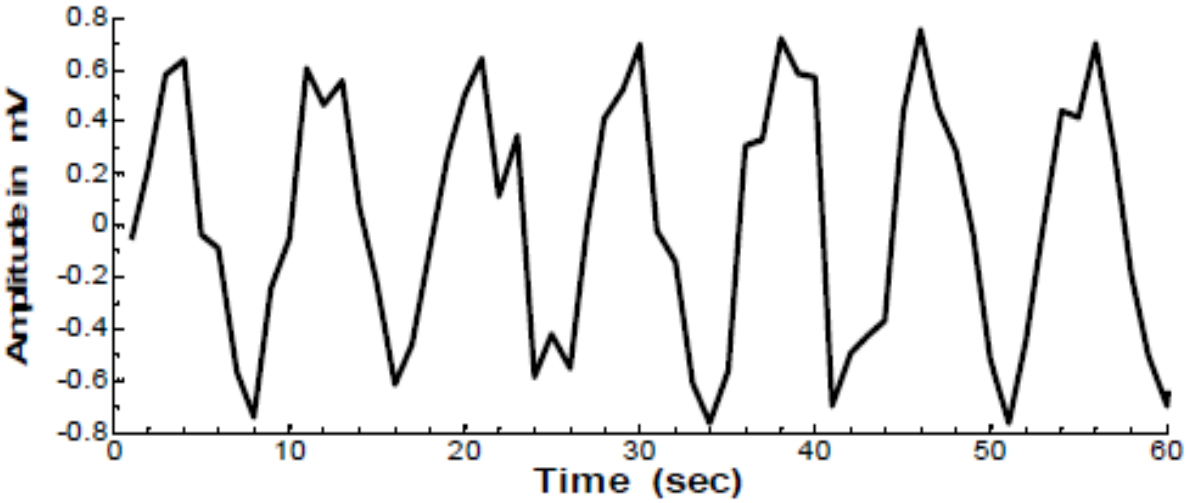


Figure 2.8: EGG of Tachygastria

2.4.5- Ulcer or Peptic Ulcer

Stomach ulcer or peptic ulcer is small erosion (hole) in the gastrointestinal tract. The most common type, duodenal, occurs in the first 12 inches of small intestine beyond the stomach. Ulcers of that form in the stomach are called gastric ulcers. An ulcer is not contagious or cancerous. Duodenal ulcers are almost always benign, while stomach ulcers may become malignant. A peptic ulcer is a sore in the lining of the stomach or the duodenum, the first part of the small intestine. Burning stomach pain is the most common symptom. The pain may come and go for a few days or weeks. May disturb one's activity when the stomach is empty.

EGG pattern of Ulcer having frequency of 6-8.5 cpm is shown in Figure 2.9.[8]

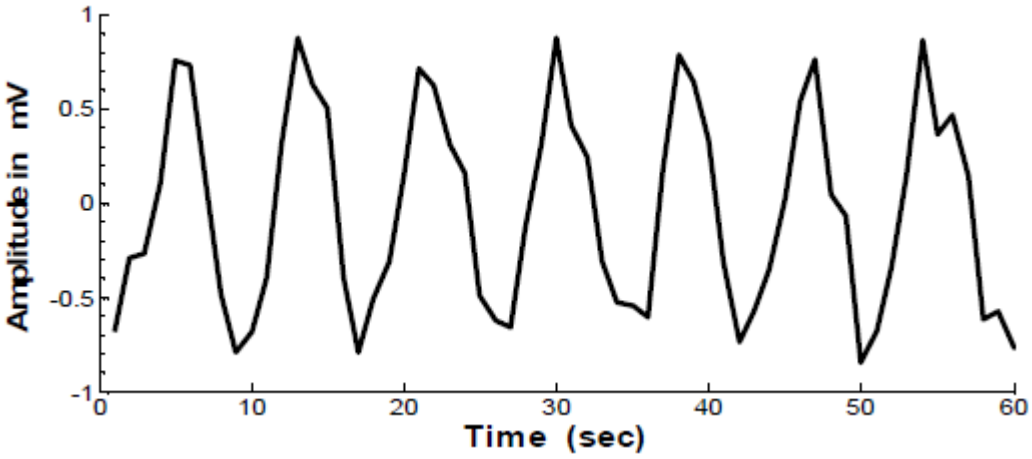


Figure 2.9 : EGG of Ulcer Subject

2.4.6-Vomiting

Vomiting is the forceful expulsion of contents of the stomach and often, the proximal small intestine. It is a manifestation of a large number of conditions, many of which are not primary disorders of the gastrointestinal tract. Regardless of the cause, vomiting can have serious consequences, including acid-base derangements, volume and electrolyte depletion, malnutrition and aspiration pneumonia.

Figure 2.10 shows the EGG recorded for a vomiting subject. The frequency is observed to be 5.5-6.5 cpm.

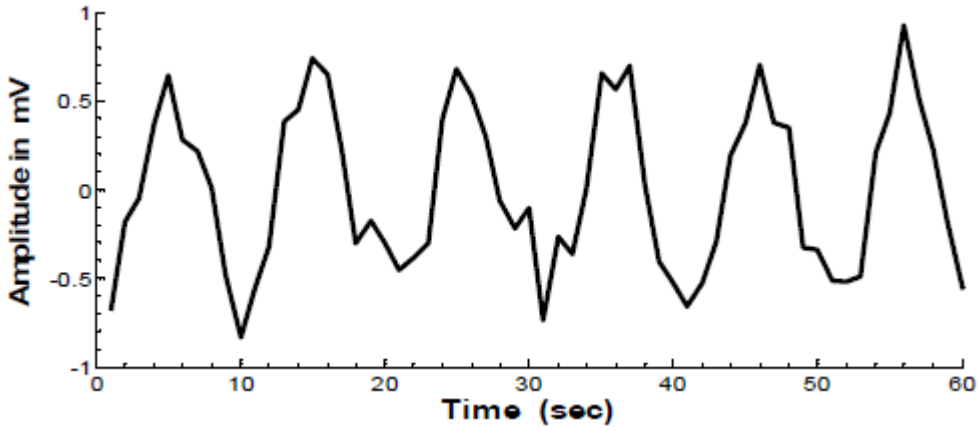


Figure 2.10: EGG of Vomiting Subject

CHAPTER THREE

REFLEXOLOGY

3.1 Definition of Reflexology

Reflexology is the art of reprogramming the atoms, cells, and electrons of the body to their original state through the triggering of signal points on the foot or hand. It is a science that deals with the principle that there are reflex areas in the feet and hands that correspond to all the glands, organs and parts of the body.

Reflexology is a unique method of using the thumb and fingers on these reflex areas. Reflexology includes, but is not limited to relieving stress and tension, improving blood supply, promoting the unblocking of nerve impulses, and helping nature achieve homeostasis.

The feet have a fundamental relationship to the body. Signal points on the feet provide a link of communication to the major organs, muscles, and the circulatory, respiratory, digestive, elimination, reproductive and skeletal systems. Reflexology is used to manage energy savings in the body, reduce stress, and build a greater body awareness. It combats the effects of improper diet and environmental pollutants, and aligns the physical, mental and emotional energies.

3.2 Reflexology Improves Nerve And Blood Supply

In order to keep the body at a normal balance, it is imperative that the blood and nerve supply to every organ and gland be at a maximum. Of course, the organs and glands contribute to the overall well-being of the body, each making contributions to maintaining an efficient, full operating mechanism, but all receive their instructions from the most intricate of all networks, the nerves. These cord-like structures, comprised of a collection of nerve fibers, convey impulses between a part of the central nervous system and other regions of the body. They are the wiring system of the house called the human body. As with any complex wiring system, a short circuit can mean trouble.

A short circuit is often caused by tension putting pressure on a vital nerve plexus or even a single nerve structure supplying a vital organ. As tension is eased, pressure on the nerves and vessels is relaxed, thus improving the flow of blood and its oxygen-rich nutrients to all parts of the body.

3.3 Background studies

Akin Korhan et al. (2014); said the Reflexology can serve as an effective method of decreasing the physiological signs of anxiety and the required level of sedation in patients receiving mechanically ventilated support[13].

Elizabeth et al.(2006 Sep-Oct);said reflexology is ancient form of natural healing that utilizes pressure on the soles of the feet to evoke a change in flow of energy through the body ,he said is a most applied to the feet, but it may also be utilized on the hands ;finally talk about who the first healthcare provider known to practiced reflexology in United State (Dr.Fitzgerald)which who introduced his theory of 'Zone Therapy in 1913.[14]

3.4 Pain definition

The breaking of the electrical circuits from an injury or the failure of electrical signals for other reasons, the signal to the brain is the same. Both are interpreted as pain.[15]

The failure of electrical connections between cells (blockage of "chi") is not only the cause of pain, but the cause of all degenerative diseases, according to Traditional Chinese Medicine. The theory is not so incredulous when we know that the brain works electrically and that we are "brain dead" when there is no more electricity going across the brain. All cells will die or become degenerate if electrical signals are broken or suppressed.

3.5 Pain Healing

Pain is healed when the body reconnects the broken circuits. When we hit our thumb with a hammer it hurts because electrical connections between the cells have been broken. It stops hurting when the body reconnects the broken circuits. This is the way the body heals pain and the only way we can heal pain– by finding and reconnecting the broken circuits that cause the pain. Suppressing the pain signal with drugs is treating the symptom, not the cause. The medication only masks the pain and does nothing for the broken circuits that cause it. How do you find and reconnect broken circuits? An instrument that measures electrical resistance can non-invasively detect where the circuits have failed. If the instrument also stimulates with the correct wave form, current, and frequency it is possible to reconnect the broken circuits. The Electro Reflex Energizer is a more discriminating method of electrical stimulation.

When there is pain the part of the body that hurts always has more electrical resistance. This means the electrical signals between cells are suppressed. If you can restore the flow of electricity through the painful area,

the pain will go away, often immediately. And if you can keep the circuits turned on, the pain will not return.

Reflexology embodies the relationship of the reflexes in the feet to all of the glands and organs in the body. Let's now discuss that relationship. Just how does one small area of the foot affect something like the pituitary gland? Just what is the link? This is where Zone Theory becomes significantly important to every Reflexologist.

The zones are like the wiring in a house. The reflexes travel through the zones similar to electricity through the wires, but please note that this analogy is not to be confused with the nervous system in the body. Reflexes as far as we know today, are not nerves. The link from the feet to the organs and the glands in the body is a series of imaginary longitudinal lines, each encompassing a zone. In order to locate the zones accurately in the arms and hands, the thumbs need to be placed toward the body, the opposite of the anatomical position. Any sensitivity located in specific areas on the foot will signal to you that there could be congestion in that area. It should become evident then, that by working the entire foot, the entire side of the body is being affected (the left foot representing the left half of the body). It is important to remember another significant aspect of Reflexology–an abnormality in any part of the zone may affect anything in that
zone.

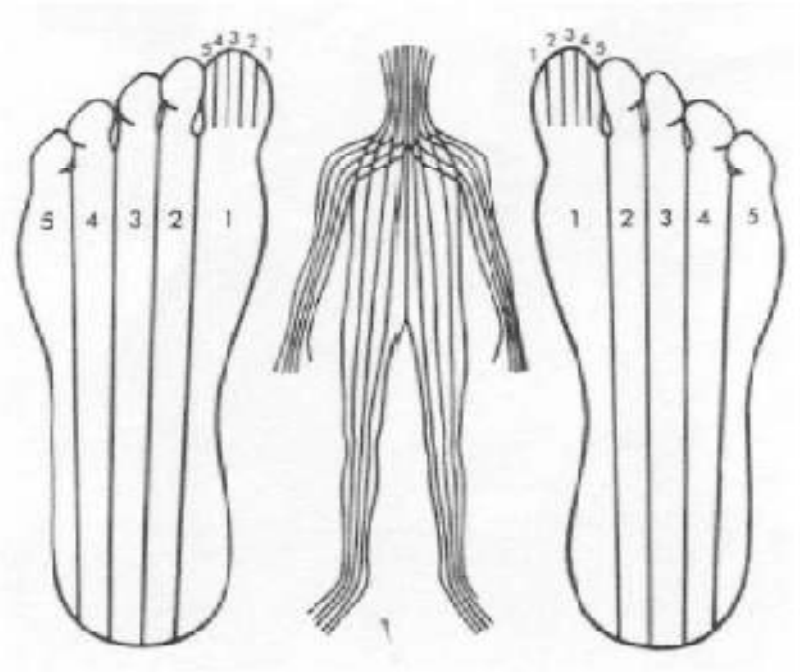


Figure (3.1): The Ten Energy Zones

Each zone can be considered a channel for the intangible life energy, called Chi in oriental medicine. Stimulating or "working" any zone in the foot by applying pressure with the thumbs and fingers affects the entire zone throughout the body. For example, working a zone on the foot along which the kidneys lie will release vital energy that may be blocked somewhere else in that zone, such as in the eyes. Working the kidney reflex area on the foot will therefore revitalize and balance the entire zone and improve functioning of the organ. The relationship between the foot reflex points and the organs of the body.(figure 3.2)

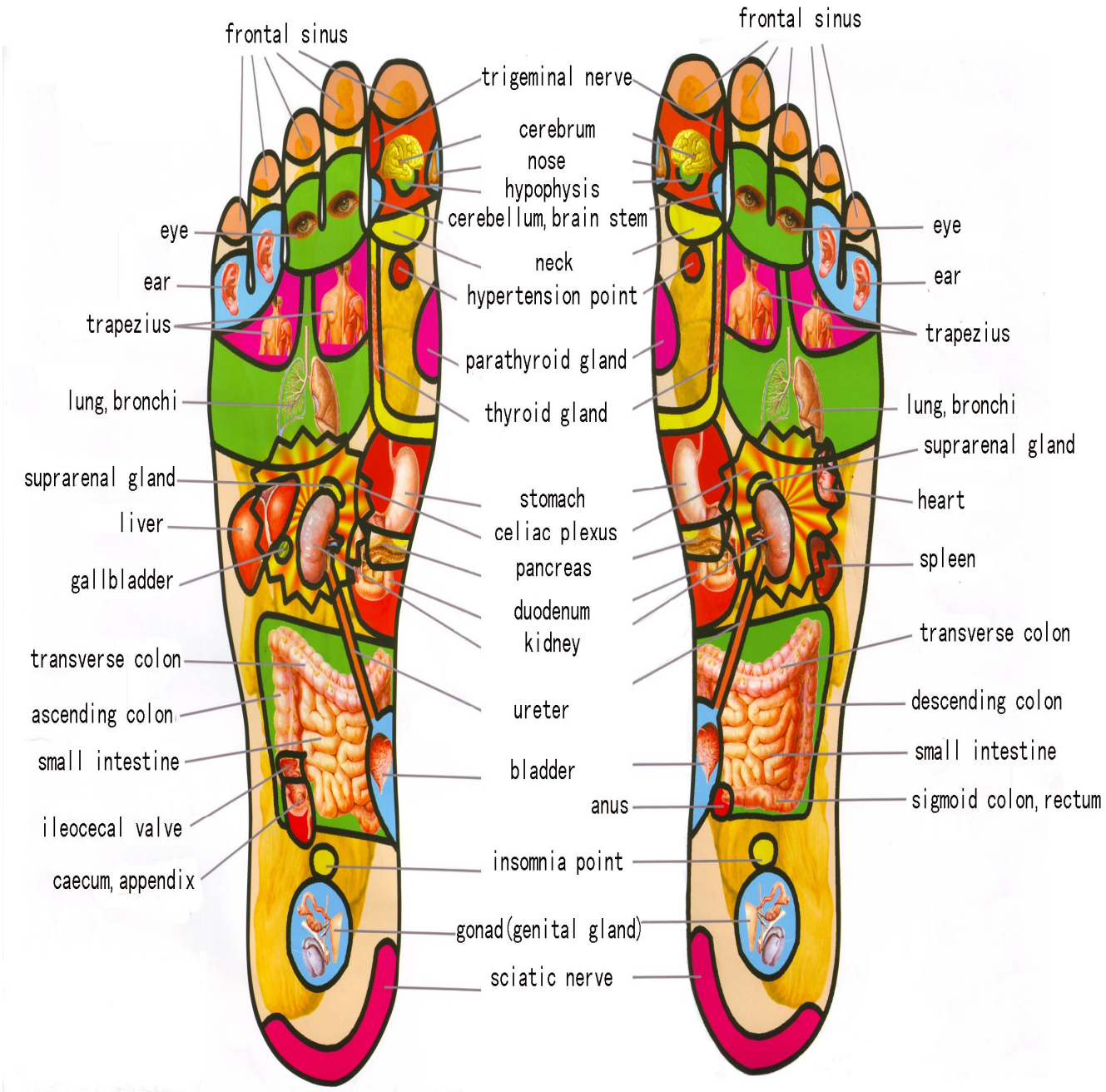


Figure 3.2 : reflexology points in sole of the feet

3.7 Acupuncture

Western medical acupuncture is a therapeutic modality involving the insertion of fine needles; it is an adaptation of Chinese acupuncture using current knowledge of anatomy, physiology and pathology, and the principles of evidence based medicine. While Western medical acupuncture has evolved from Chinese acupuncture, its practitioners no longer adhere to concepts such as Yin/Yang and circulation of qi, and regard acupuncture as part of conventional medicine rather than a complete "alternative medical system". It acts mainly by stimulating the nervous system, and its known modes of action include local antidromic axon reflexes, segmental and extrasegmental neuromodulation, and other central nervous system effects. Western medical acupuncture is principally used by conventional healthcare practitioners, most commonly in primary care. It is mainly used to treat musculoskeletal pain, including myofascial trigger point pain. It is also effective for postoperative pain and nausea. Practitioners of Western medical acupuncture tend to pay less attention than classical acupuncturists to choosing one point over another, though they generally choose classical points as the best places to stimulate the nervous system. The design and interpretation of clinical studies is constrained by lack of knowledge of the appropriate dosage of acupuncture, and the likelihood that any form of needling used as a usual control procedure in "placebo controlled" studies may be active. Western medical acupuncture justifies an unbiased evaluation of its role in a modern health service.

3.7.1Biochemical Theories

Acupuncture works to send signals by activating Myelinated Nerve Fibers to the spinal cord, and the central region of the brain that call Pituitary-Hypothalamus in the Diencephalon). has been discovered neurological studies conducted in the late seventies of the last century, the natural chemicals produced in the body and called endorphins . they stop the pain by binding to receptors anesthesia scattered throughout the neurological system and the area (pituitary brain bed) firing (Endorphins -beta) in the blood and cerebrospinal fluid in order to create an analgesic effect and that by blocking pain signals coming from access to the brain.

3.7.2 Biomechanical theories:

In 1975, Dr. Liu Wai as conduct research to study the location of acupuncture points in the motor nerve sites. And studies have proven that acupuncture points correspond to places where motor nerves enter skeletal muscle Calendar as well as in places that have a high density of nerves terminal on the surface. In addition to that it was found that these points containing dense clusters consist of areas covered by the independent nerves and receptors. As with automatic increases density by stimulation.[16]

3.8 The nervous system

The nervous system has two different major parts. The two parts are the central nervous system and the peripheral nervous. The central nervous system or the CNS contains the brain and the spinal cord. All together, the brain and the spinal cord serve the nervous systems command station. When the sensory input reaches the CNS, the spinal cord and the brain figure outs what it exactly means. After, they quickly orders out the body parts that needs to move faster.

Everything else but the CNS it is known as the peripheral nervous system. The peripheral nervous system or PNS contains the nerves, which leave the brain and the spinal cord and travel to certain areas of the body. The peripheral nervous system's main job is to send information gathered by the body's sensory receptors to the CNS as quickly as possible. Once the CNS has understood the information, the PNS will relay the specific orders back out the body. These nerves which carry information in a way of nerve impulses to and from the brain are called cranial nerves. The nerves that carry impulse to and are carrying information from the spine are called spinal nerves.

The PNS has two important parts. They are the motor division and the sensory division. The sensory division collects the impulses from the sensory receptors in areas like skin, muscles, and organs, and also carries those impulses through the nerves to the CNS. The motor division collects the outgoing messages from the CNS and delivers them to the appropriate body organs, telling them what to do. The motor division does the opposite from the sensory division. [17]

CHAPTER FOUR

METHODOLOGY AND THE DESIGN

4-1Methodology

Proposed a simple non invasive device for diagnosis abdominal region to give a result in display unit to investigate a high speed method for diagnosis stomach status (normal or abnormal),which works as follow :

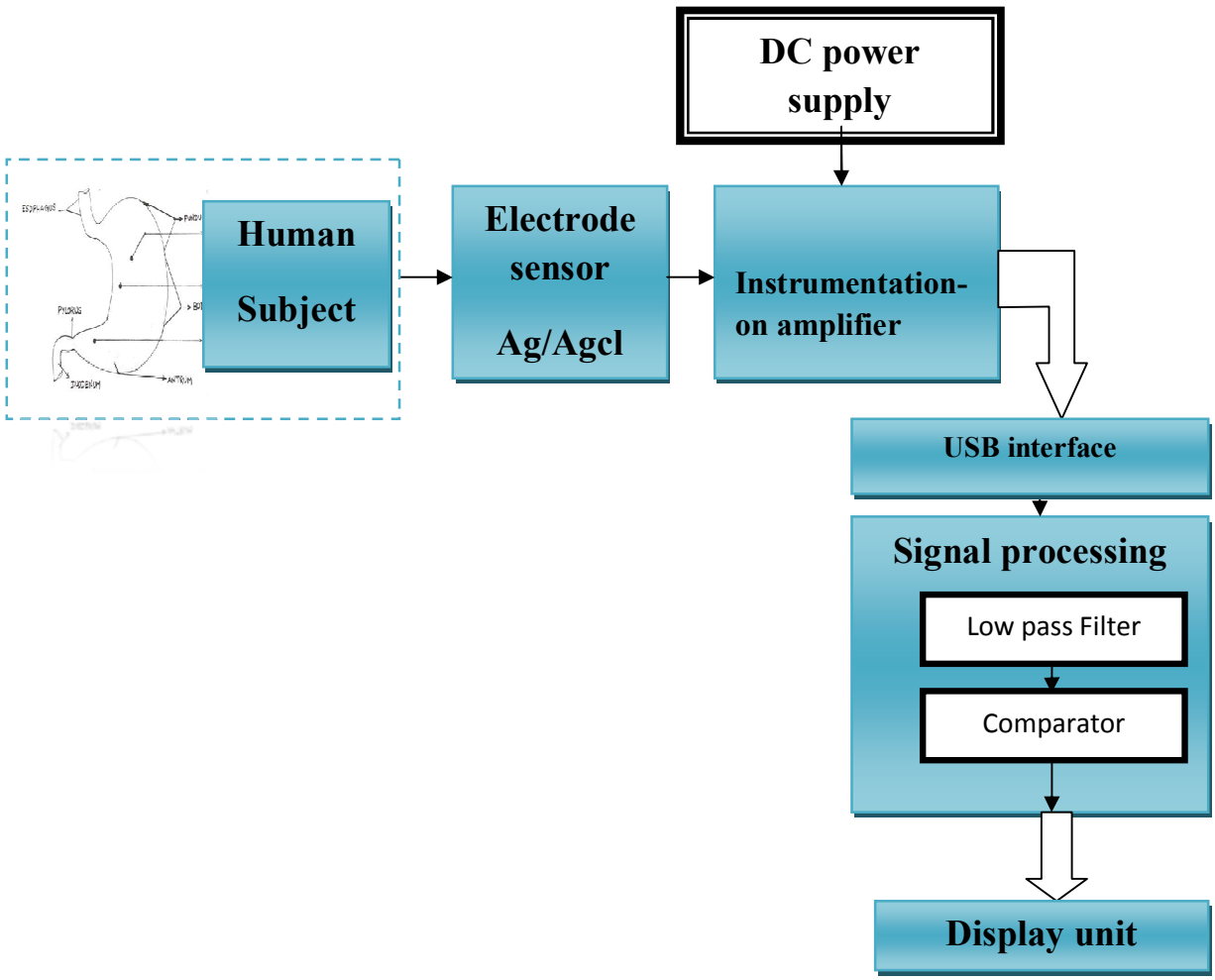
- Recording and Saving the normal signal specifications (with frequency 0.05Hz and 500μv) -3CPM-in device memory as a reference signal .
- Generated the myoelectrical activity which come from patient by cutaneous electrode through 60 second.
- After applying the signal processing - amplification ,filtering and determination the step response –which draw in the same figure-the doctor make a compression between the step responses for the reference signal and patient signal .
- The result shown graphically and gave a direct diagnosis normal or abnormal . if the step responses overlapped indicate to the normal state otherwise abnormal status .

Used the matlab version 7.8 to simulating a proposed device as a flow chart for generating the signals(reference and patient),but the stomach signal too weak so amplified by using high gain ,then designed the digital low pass filter by using ‘fdatool ‘[see appendix E] to exclude the stomach signals from other sources the ”heart ,small intestine and some colonic frequency’’ and remove some artifacts occurring as a consequence of respiration and movement .After that draw a step responses to be able comparing them to make a good decision for stomach diagnosis with quick method ,easy and safe.

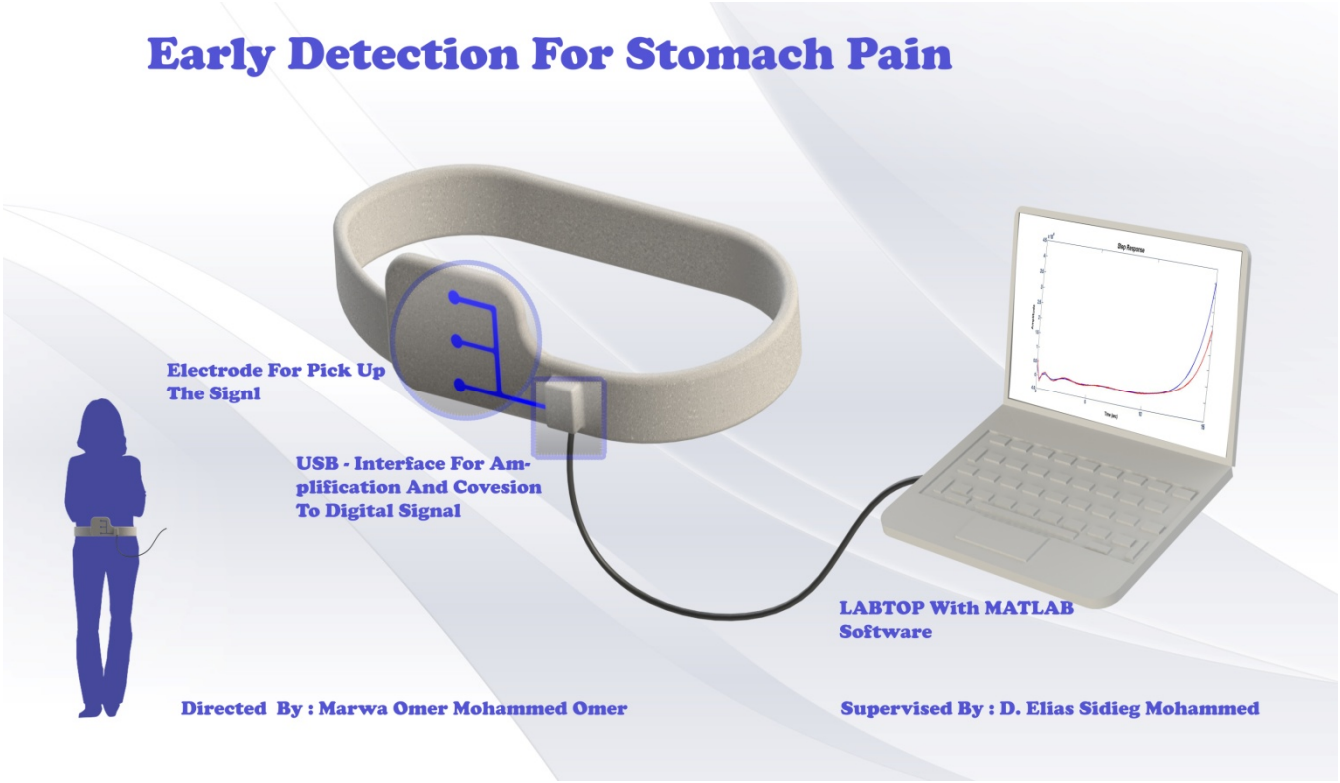
4.2 The design

4.2.1 PC based signals Descriptions

The proposed device system which show in figure (4.1) pick up the myoeletrical of gastric region using surface electrode and amplify the slow wave by instrumentation amplifier which is fed by DC power supply then the USB interface convert analog signal to digital signal in order to process by a MATLAB in the PC to filtering using the low pass digital filter when passing through and comparing with reference signal (0.05 Hz ,500μv,3cpm) to give the result on display unit as shown in figure(4.1a , 4.1b) .



Figure(4.1a): The block diagram of the proposed device system hardware unit.



Figure(4.1b): The design of proposed device

4.2.1.1 Electrodes

Electrodes are the sensors which tap the electrical signals from the outer layer of the stomach. Surface electrodes like silver/silver chloride (Ag/Agcl) shown in Figure 2.3 are used for this purpose which falls under the type 2222

It is available in two sizes, standard 20 mm and miniature 11 mm.

These electrodes provide stable recordings for various physiological measurements including sleep recordings, exercise testing, pediatric monitoring and the recording of low voltage DC and low frequencies like the signals from the stomach. Surface electrodes are very popular because of their small covering area and adhesive to provide highly accurate, optimal recordings

4.2.1.2 Instrumentation amplifier

The INA121(see Appendix C) shown in (Figure 4.2)is a FET-input, low power instrumentation amplifier offering excellent sensitivity . Here used a two stage for gain amplification ,one stage amplify with 100 times ,so total gain equal 10000 times to adequate showing the slow wave of myoelectrical activity

$$Gain = 1 + \frac{50k\Omega}{RC} = 100 \qquad (1)$$

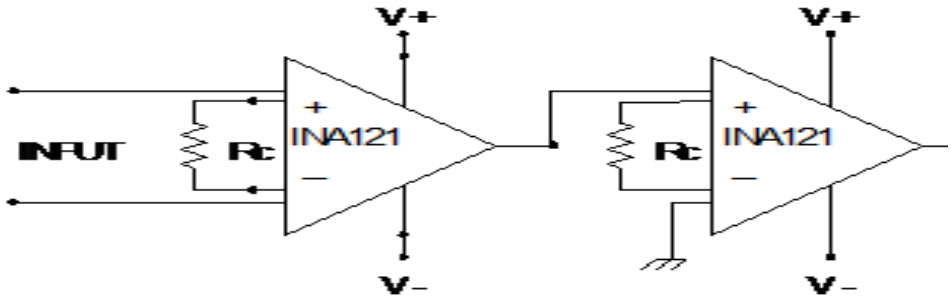


Figure (4.2) : Instrumentation Amplifier symbol in electrical circuits

4.2.1.3 The power supply

The power requirement for all the components used in this circuit falls within the 5Vdc and 15Vdc range. Therefore a suitable 5/15Vdc supply is designed by using a 15V battery, voltage regulators, capacitors and resistors of varying specifications.

4.2.1.4 PC interface

The signal sent to the PC by USB interface (see appendix D)for conversion and subsequent filtering then comparing. the interface have with an inbuilt ADC was used to convert the analog signal from the myoelectrical activity into digital signal. using a low pass filter with cutoff frequency 1Hz and sampling frequency 10Hz and comparing two signals using a MATLAB software

4.2.1.5 The display unit

PC displays the diagnosis status on MATLAB screen .

4.3 Software

MATLAB 7.8 is an excellent tool for simulating, analyzing and monitoring the filtering performance of filter systems.

4.3.1 Software Flow Chart

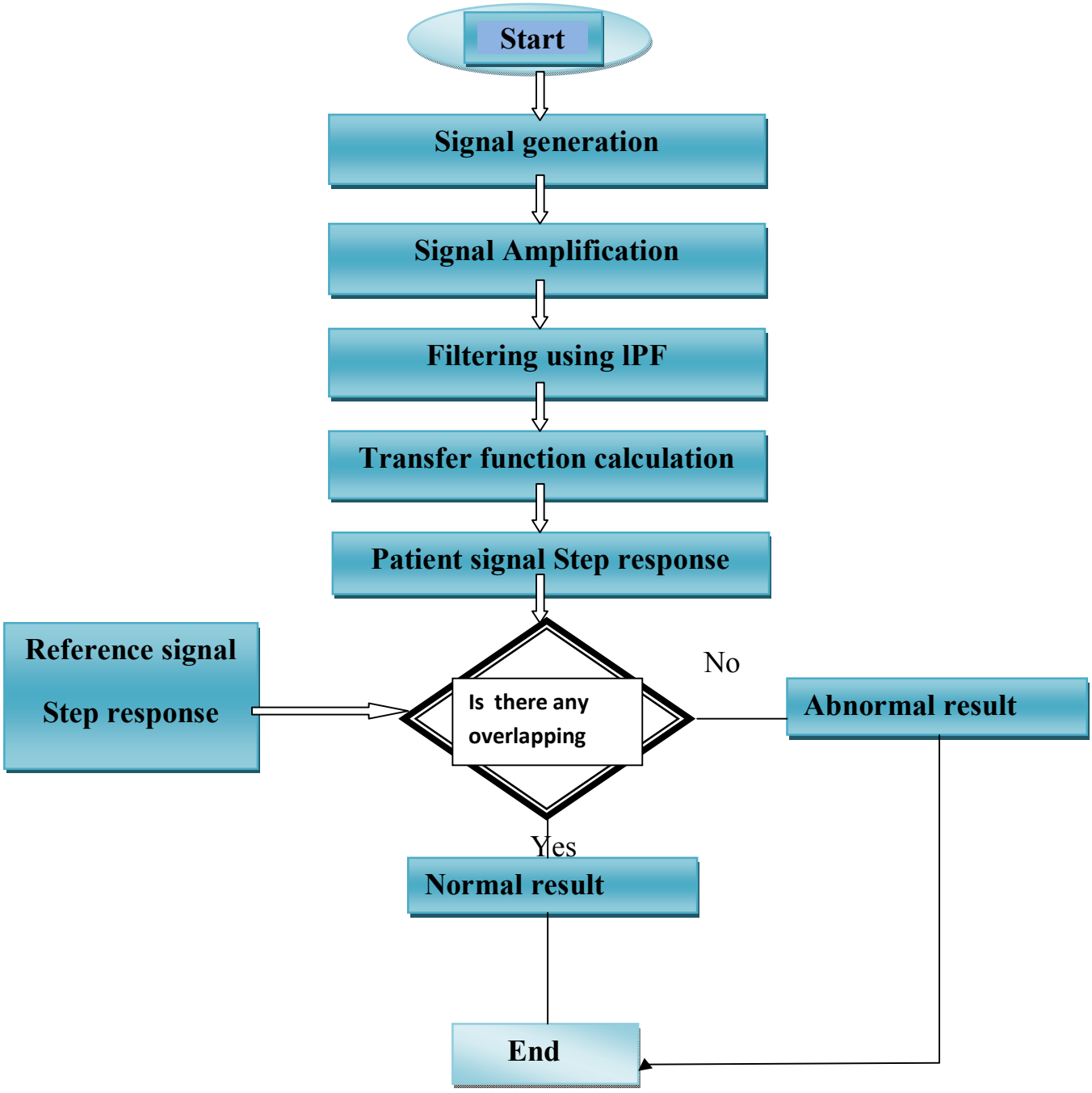


Fig 4.3: software program flow chart

4.3.2 The implementing steps

The system realized was modeled and analyzed with Matlab 7.8(R).

1- generated a normal signal shown in (Figure 4.4) by using the sinusoidal wave with an average normal frequency(0.05Hz) and average amplitude (500µv) added with an impulses signal-used zeros function- to make it same as stomach signal form .

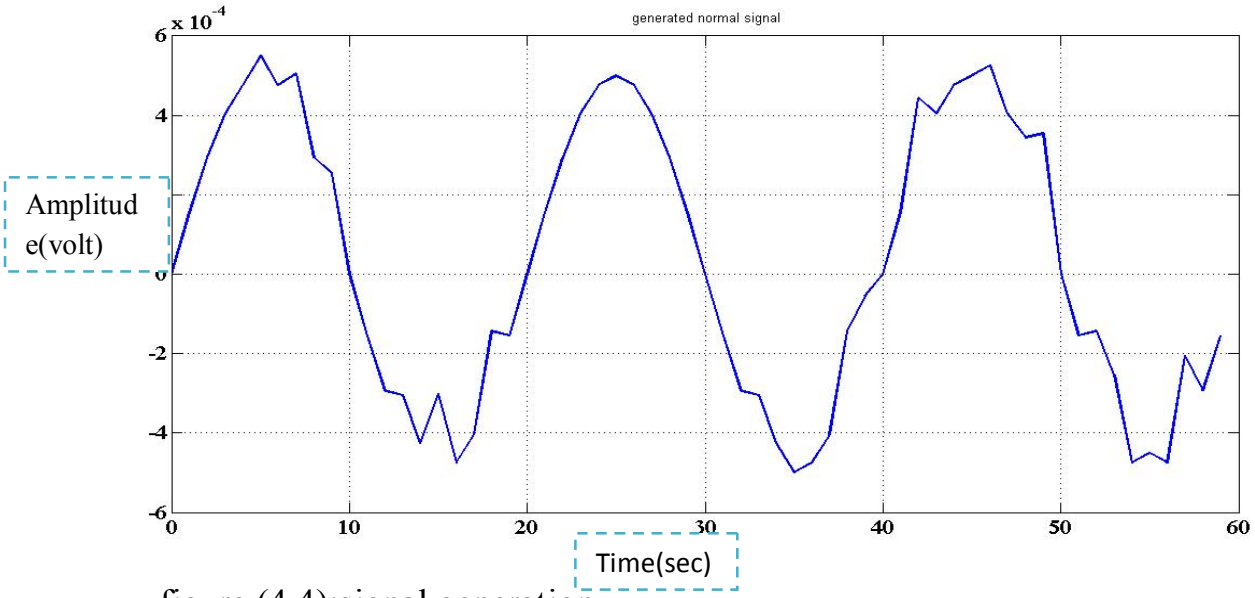


figure (4.4):signal generation

2- the signal amplified shown in (figure 4.4)with gain 10000,(notice in y-axis).

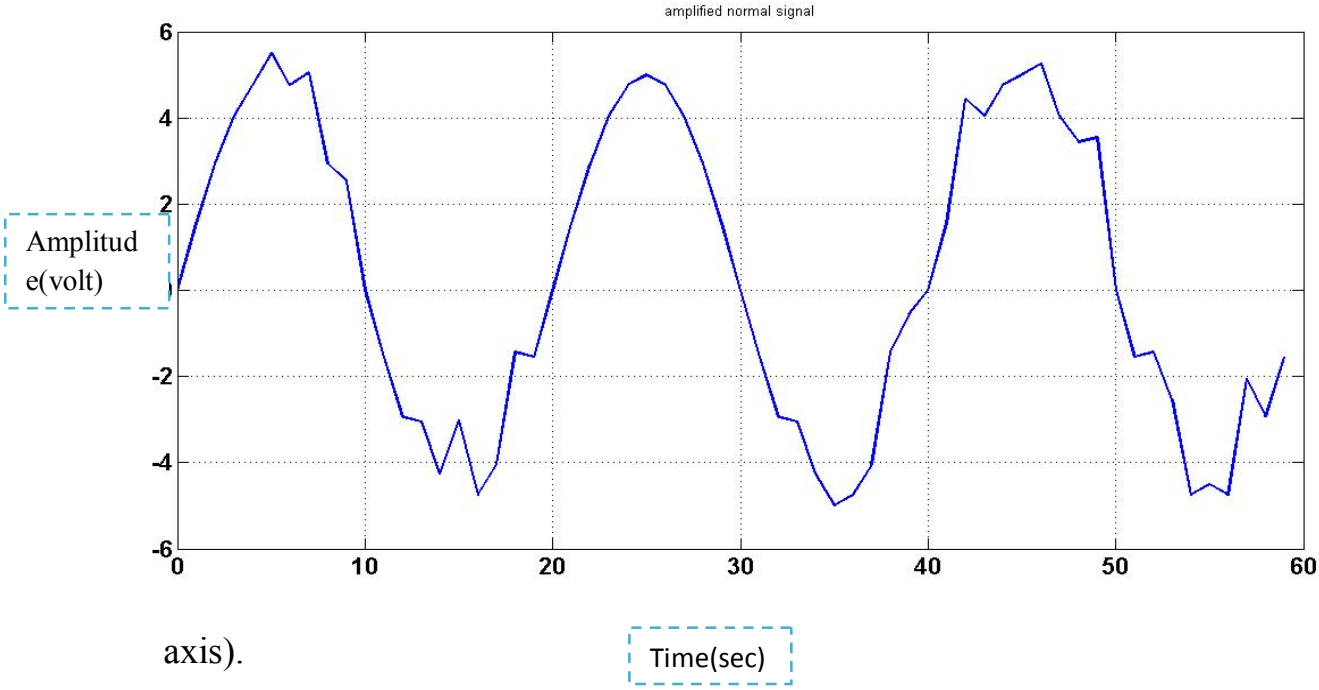
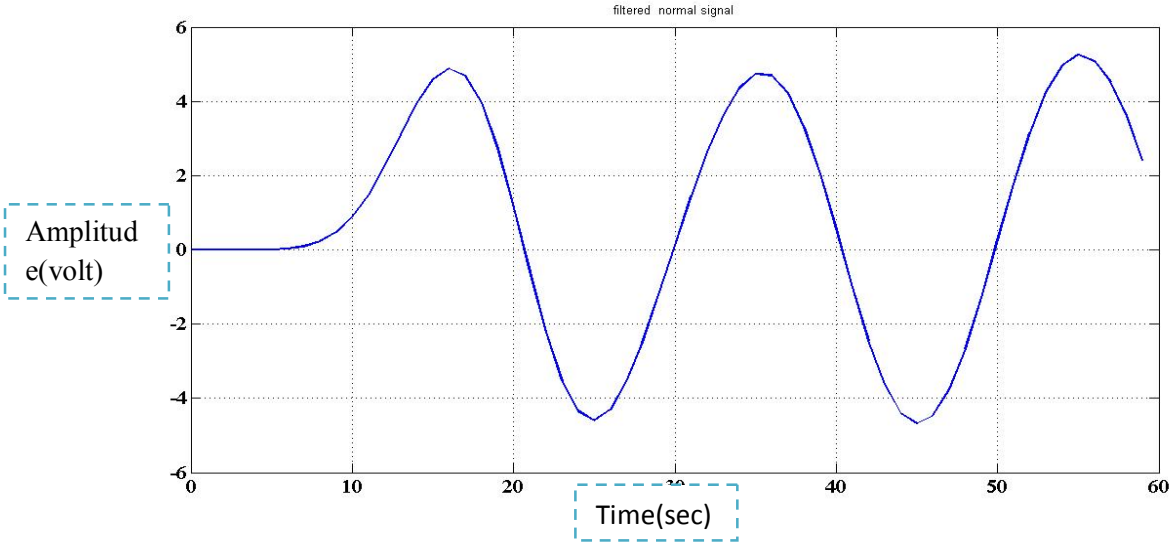


Figure (4.5): Signal amplification

3- Design a LPF with cutoff frequency 1Hz and sampling frequency 10Hz using **fdatool** (see Appendix E) function in the command window(see fig 4.6) ,then generated M-file from this realized filter and added this code to the main program



Figure(4.6):signal filtration

4- calculated the transfer function ,Transfer functions are commonly used in the analysis of systems such as single-input single-output filters, typically within the fields of signal processing, communication theory, and control theory. The term is often used exclusively to refer to linear, time-invariant systems (LTI),

In discrete-time systems, the relation between an input signal and output is dealt with using the z-transform, and then the transfer function is similarly written as

$$H(Z) = \frac{Y(Z)}{X(Z)} \qquad (2)$$

Where:

H (Z) is system response

Y (Z) is system output

X (Z) is system input

using (tf function showen in appendix F) for normal signal to be able show the step response for the signal(see figure 4.7),then repeated the steps applied on another signal(patient signal) with same sin wave but with variation value used an external control for input frequency –(input) MATLAB function

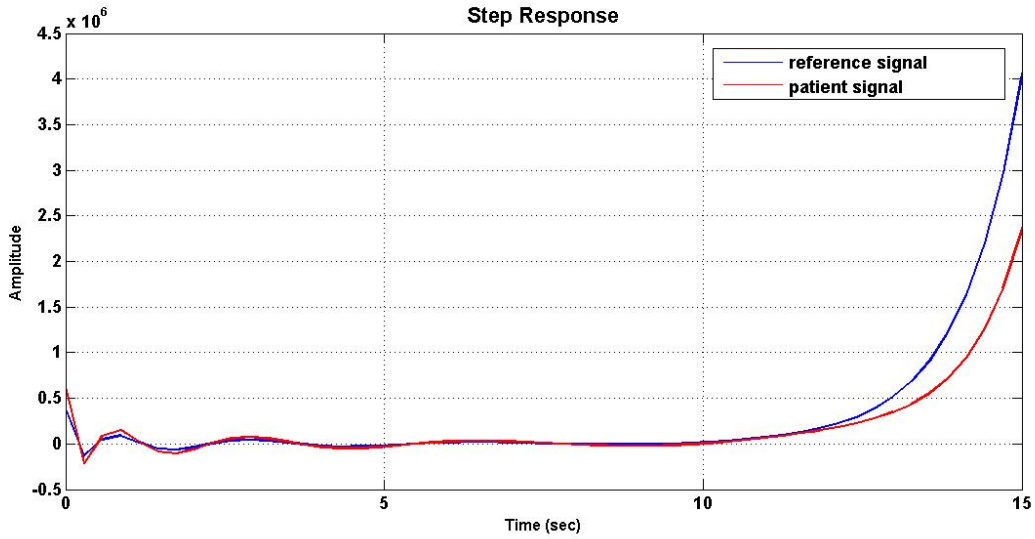


Figure (4.7): step response for signals

4.4 Results

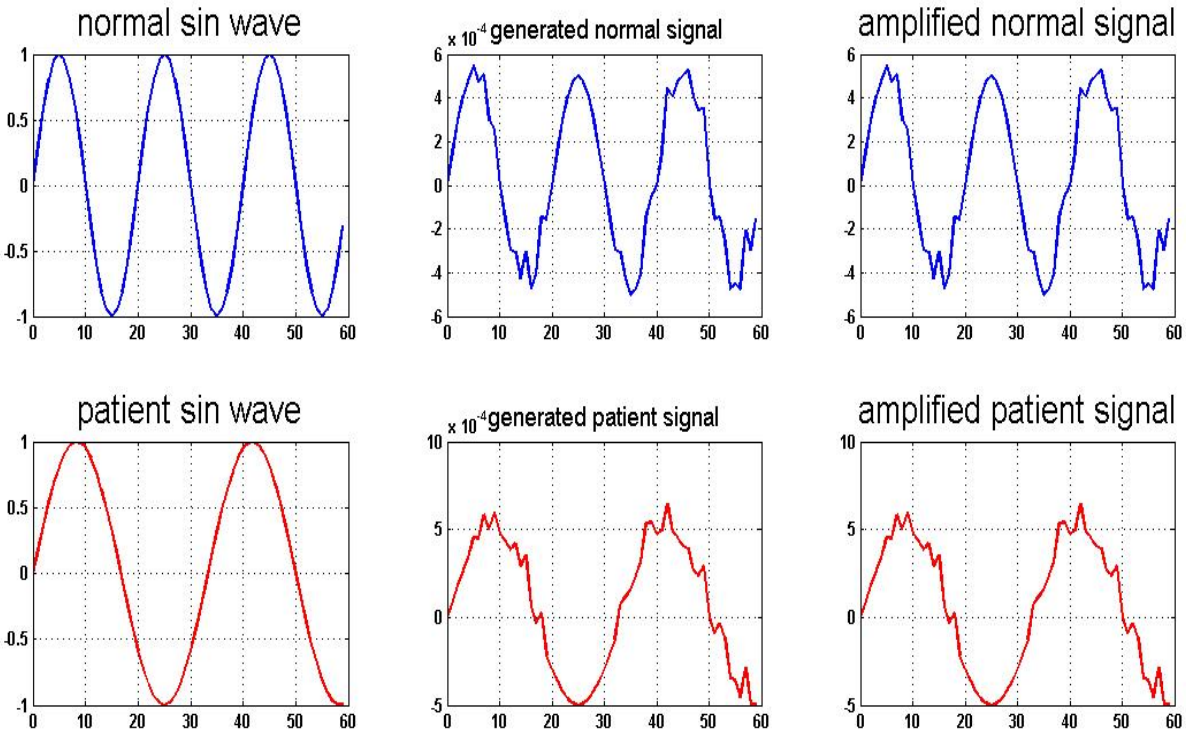
- **Case 1:**

Applied frequency for patient signal =0.03Hz;

That means the cycles per minute (cpm)=2cpm

So ,the step response different for normal & patient shown in (fig 4.8)

The diagnosis result is abnormal



[x-axis represent the time(sec) and y-axis represent an amplitude(volt)]

Figure (4.8a):signals generation and amplification

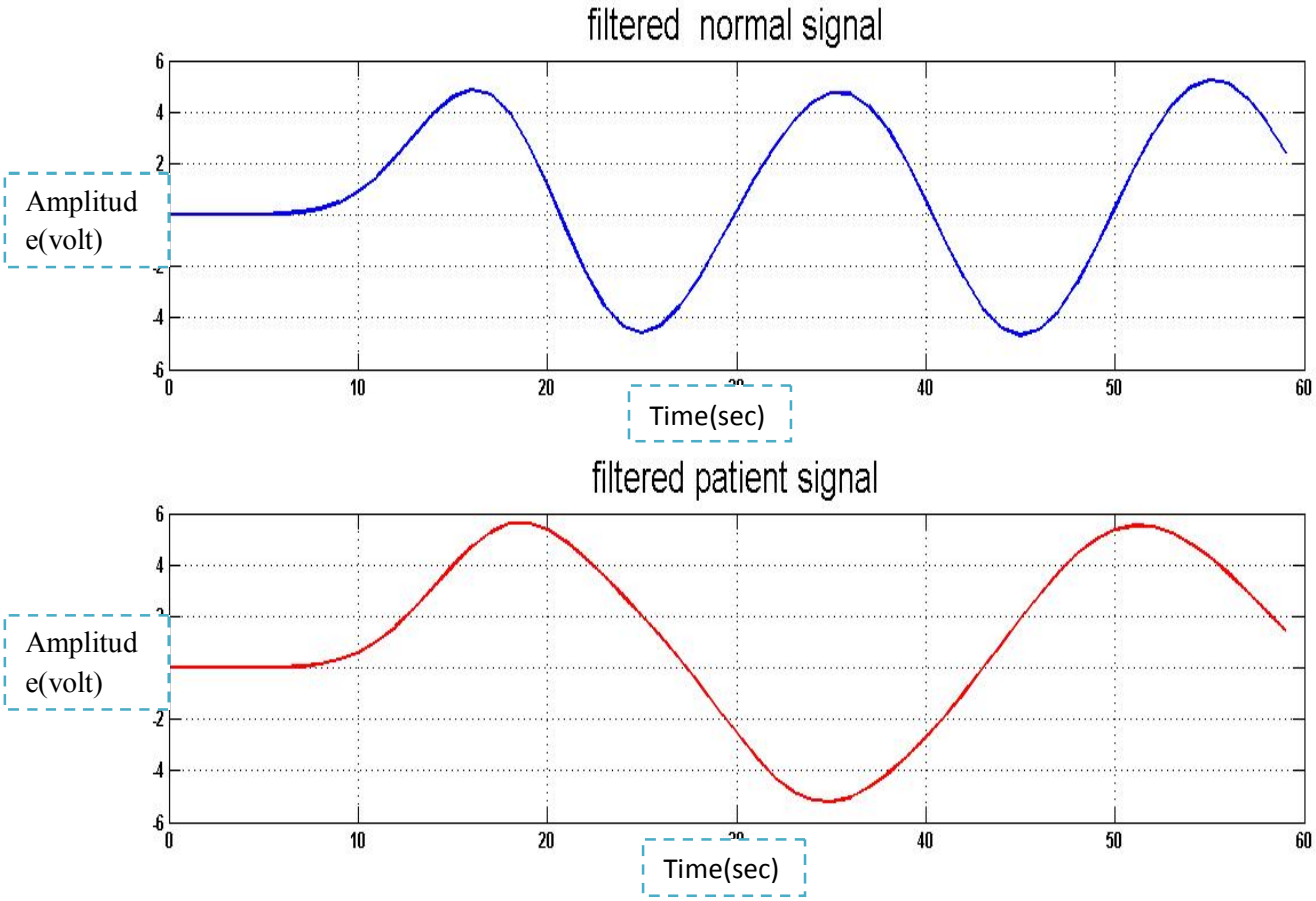
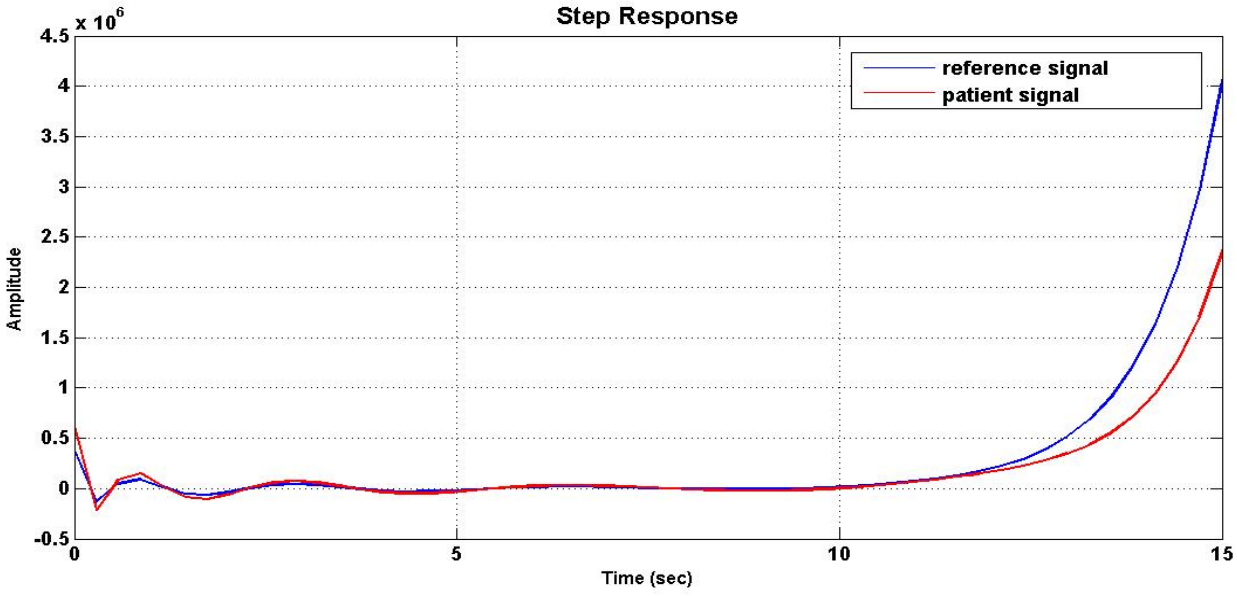


Figure (4.8b): signal filtration



Figure(4.8c): step responses for signals

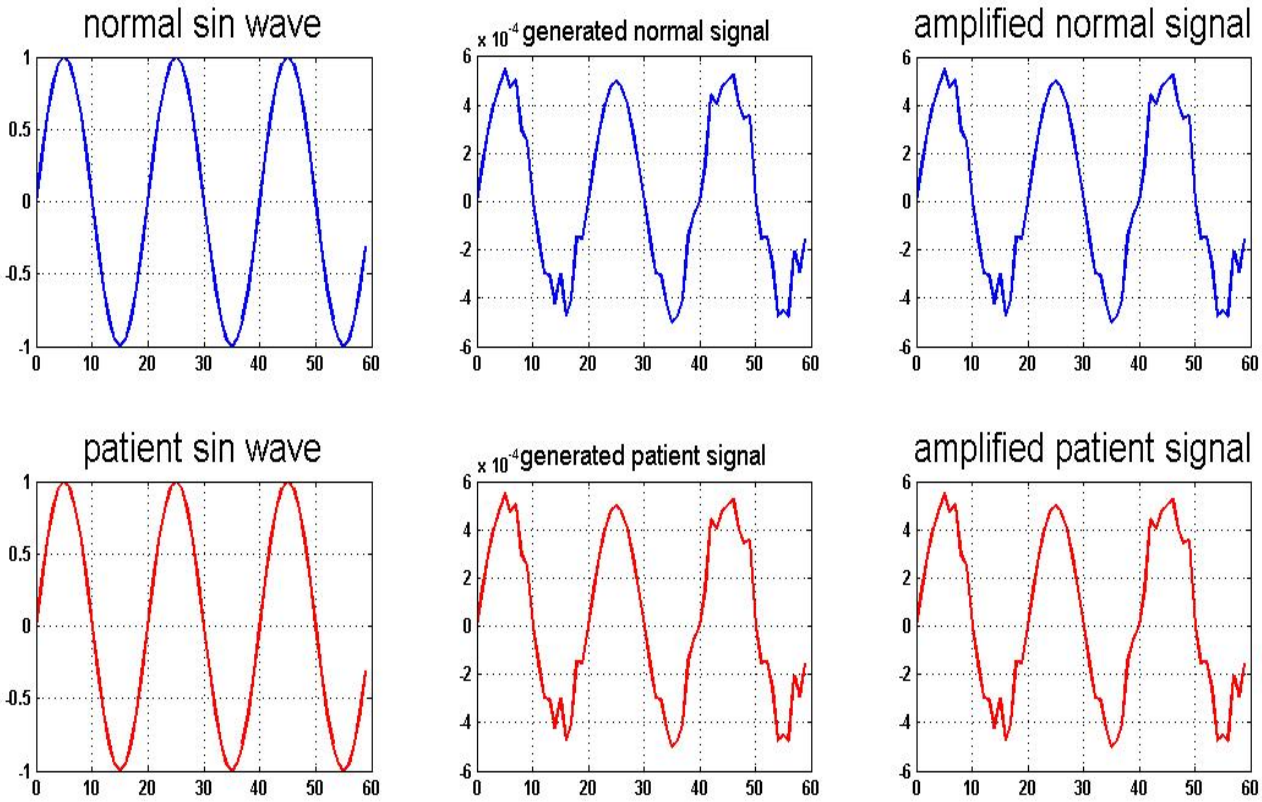
- **Case 2**:

Applied frequency for patient signal =0.05Hz

Then the cycles per minute (cpm)=3cpm

So ,the step response for normal & patient are the same as in (fig 4.9)

Over lapping wave ;The **diagnosis is normal state**



Notice:

[x-axis represents the time(sec) and y-axis represents an amplitude(volt)]

Figure (4.9a): signals generation and amplification

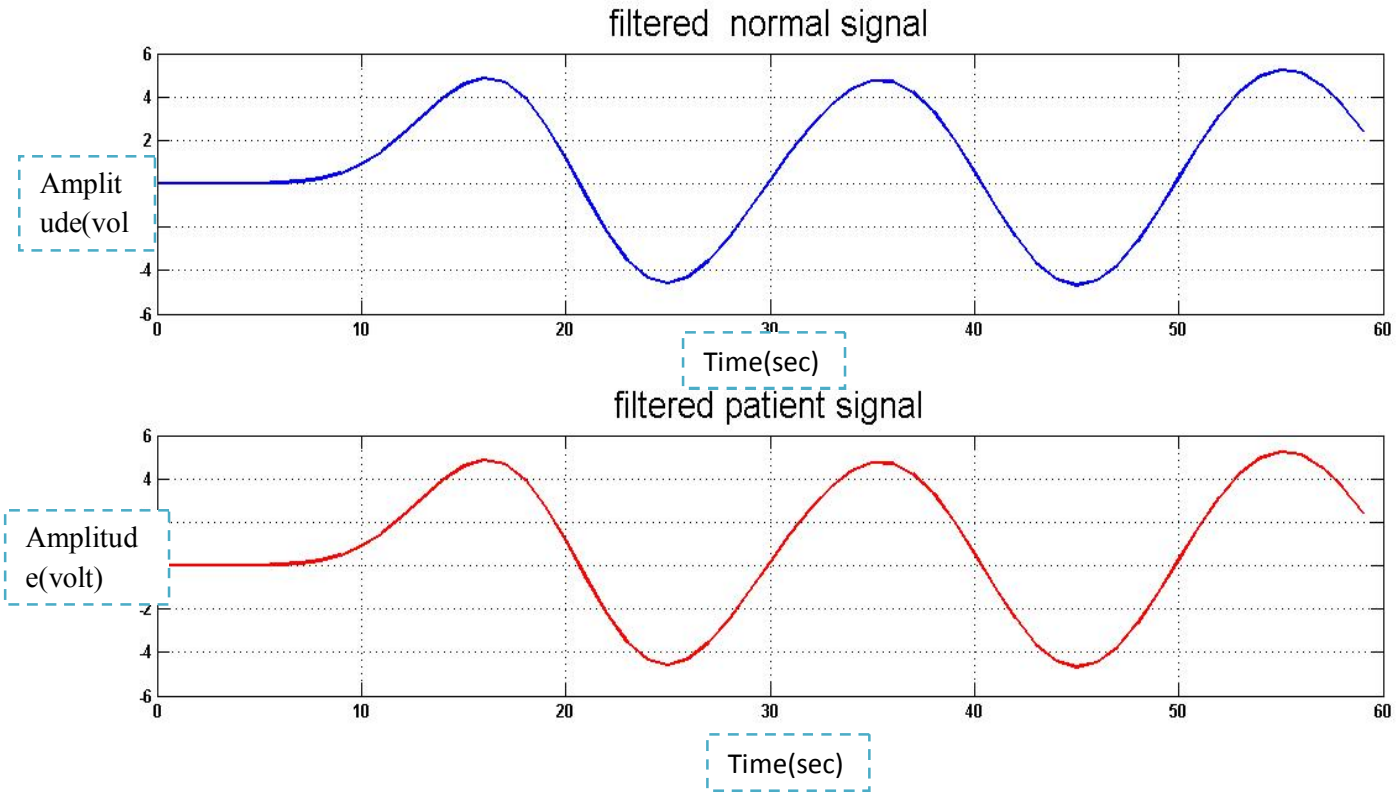


Figure (4.9b): signals filtration

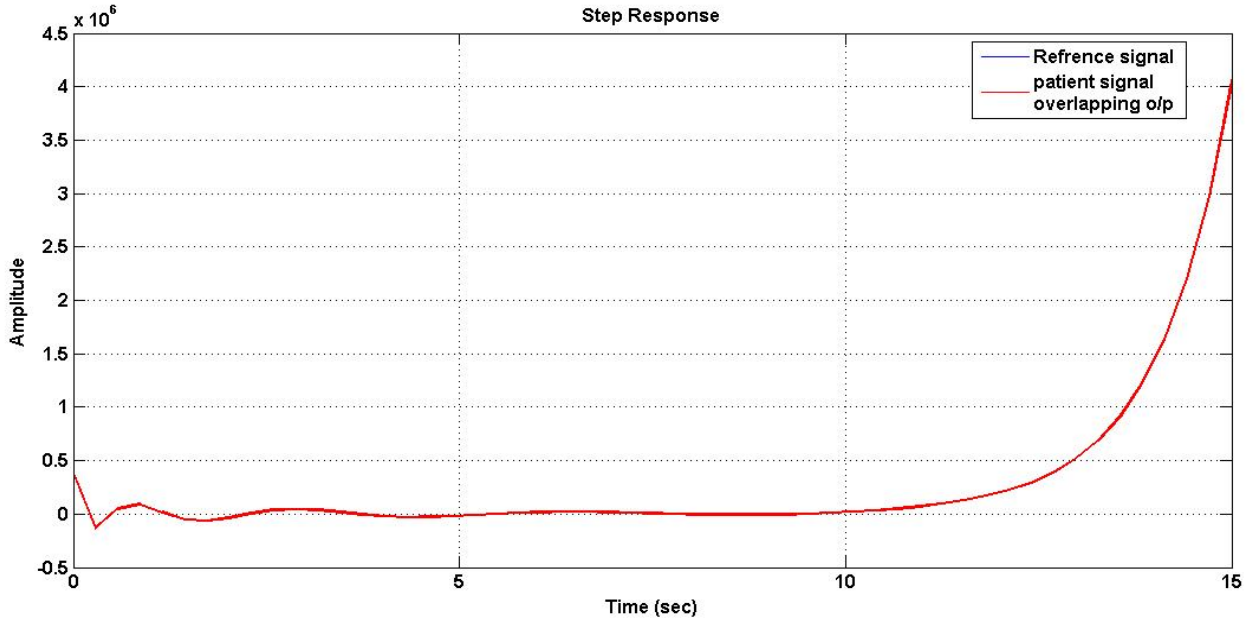


Figure (4.9c): step responses for signals

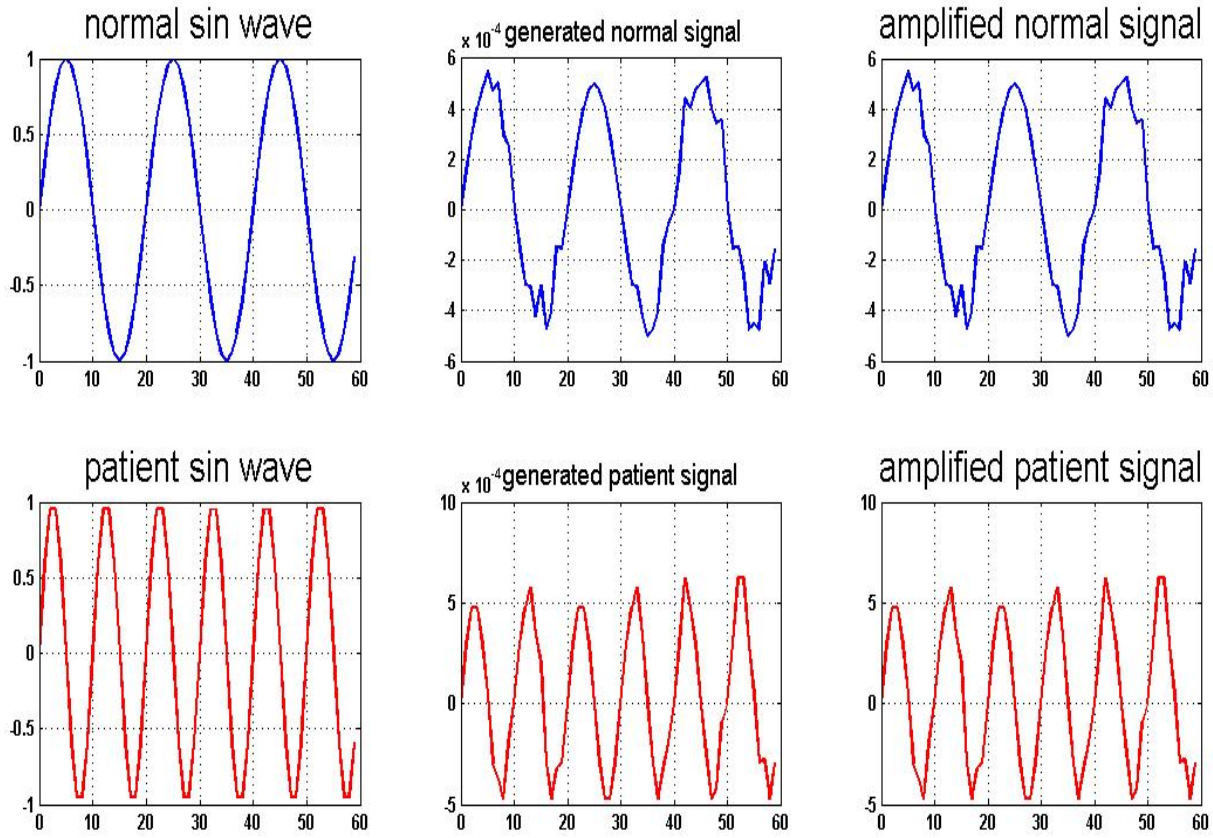
- **Case 3**:

Applied frequency for patient signal =0.1Hz

Then the cycles per minute (cpm)=6cpm

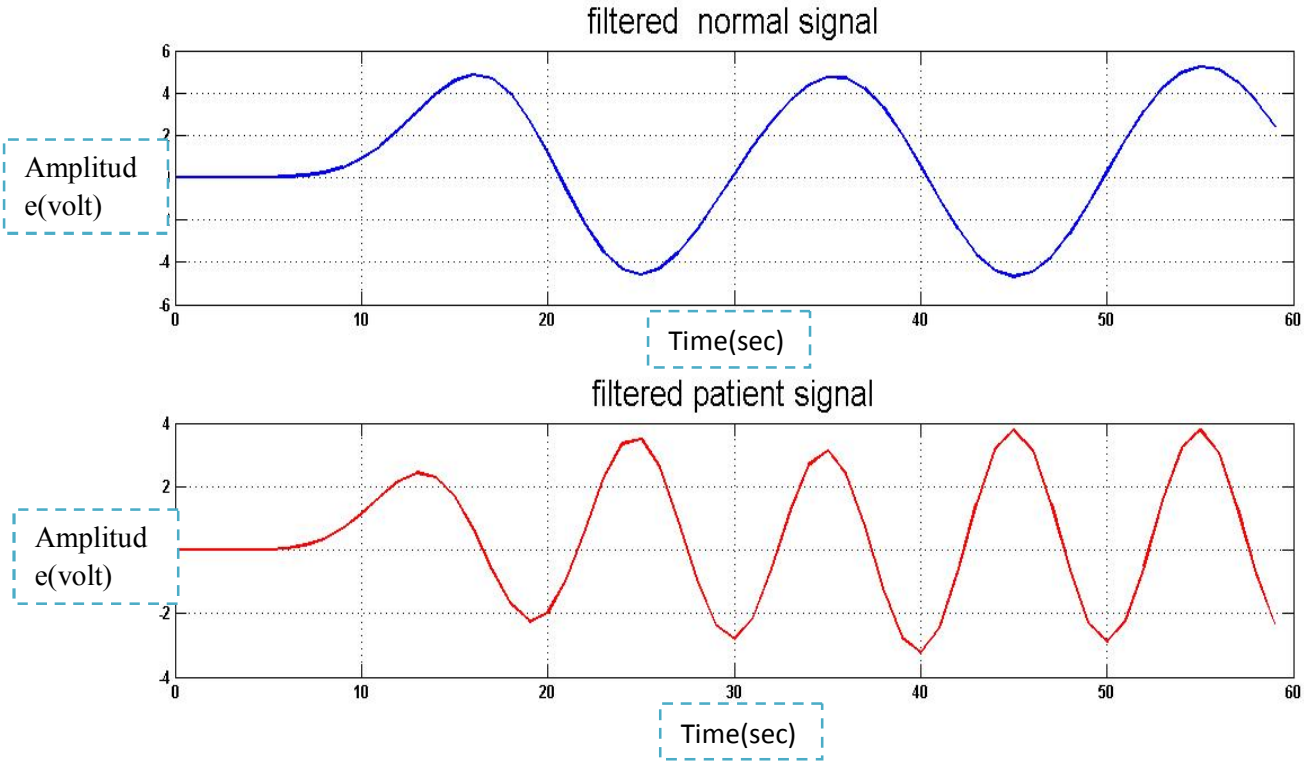
So ,the step response different for normal & patient as in (fig 4,10)

The diagnosis result is an abnormal



[x-axis represents the time(sec) and y-axis represents an amplitude(volt)]

Figure (4.10a): signal generation and amplification



Figure(4,10b): signal filtration

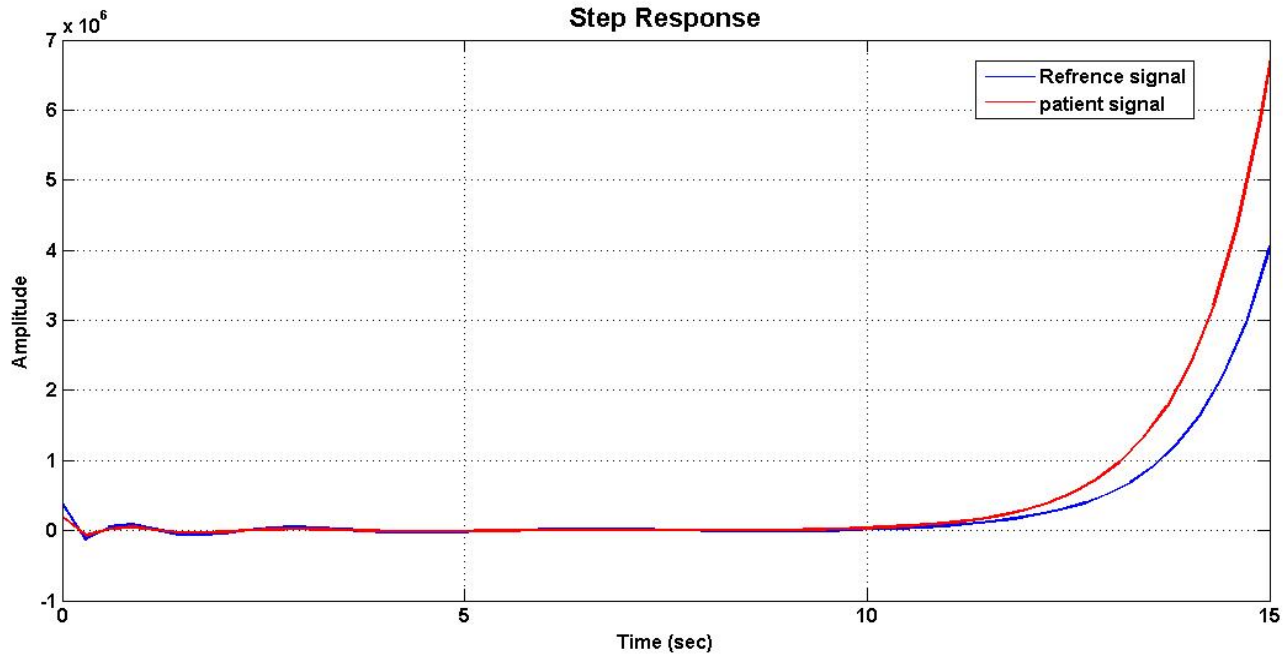


Figure (4.10c): step responses for signals.

CHAPTER FIVE

DISCUSSION

Discussion

The main idea for this project is to design a biomedical instrument special for use in emergency cases to detect the normal and abnormal status of organs located in the abdominal region. The initial design was for adults, but now being adopted for babies specifically.

This idea comes from life requirements related to common health problems which affect most babies in the primary period of their lives and need to be detected promptly because if cause of the pain continues for long time without healing, this may lead to more complications.

To implement this idea, we must be aware of the reference signal specifications for each organ so to record them in the proposed device memory for comparison with the patient's signal when used in an emergency.

The field of reflexology supposes that each body organ has a reflex point on the soles of the feet that corresponds with their nerve endings. Utilizing this concept as a basis, a sensor is used to pick up signal from each point.

In this regard, a discussion of the signal acquisition from soles of the feet with specialist doctors in the field neurology and physiotherapy, the result inconclusive as the device was not able pick up the signal from these points. Reviewing PNS biomechanical theories and electromagnetic theories indicates that massaging a specific point in the foot sends a message through nerve endings to the organ but the response is not received in the same point. The response may be received at original place of organ by using a special monitoring device.

Therefore the main idea for designing the device looked at each organ separately to detect pain location. This project considered the stomach as the first organ to be tested because it is one of the most common health complaint in emergency cases with GI system for babies specifically

Based on the information for stomach signal specifications, and how can acquire the signal using a non invasive method, an EGG electrode must be used but it not available in most of countries because EGG instruments are not used in the medical field for diagnosis ,but for research ,therefore was made with 3-M company (electrodes and cables manufacturer)to supply a suitable electrode and cable to detect stomach signals. The cost however proved prohibitive as their minimum order is a package of 1000 pieces and they have many different cable to proceed with a simulated preamplifier circuit using a PROTEUS simulation program but faced a big challenge when it came to amplifying a micro signal because the range for output results in PROTEUS is obtained by (mille volt)

In the end, we used a MATLAB to generate signal in place of an electrode to acquire stomach signal and then amplifying signal to substitute for the preamplifier circuit to access the full concept of the proposed device for detect pain location in the shortest time possible .

Discussion here illustrated in a table:

Comparing element	EGG system	Proposed device
Structure and Technique	Consist of electrodes ,amplifier ,ADC,RS-232 and **complex** software setup in computer system	Electrodes, amplifier using laptop interface USB port with MATLAB software to **compression**
Portable	No	Yes
Signal Recording speed	**Slow** because it take 30 **minute** at least	**Fast** because it takes 60 **second**
Result form	Graph**s** to show stomach signal	Graph to show step responses compression with diagnosis comment
Decision making	Depend on the doctor	Directly from result (normal or not)
Application area	Used rarely in clinics because complexity and more in research	Used in **emergency** and clinics

Table 5.1: Comparison between non-invasive devices

CHAPTER SIX

CONCLUTION AND RECOMENDATION

6.1- conclusion

The design of a proposed device has been achieved in this project. The design followed a detailed analysis of an existing system, modeling of new systems and subsequently designing the envisaged system. The end result whose output can also be monitored and analyzed using MATLAB 7.8 simulator. This results analyzed for stomach pain detection by fast diagnosis.

6.2- Recommendations

-Most of component needed to design proposed device hardware are not available in the country and some other countries due to lack of interest for stomach emergency case, so we implemented the design using simulation with MATLAB programming language

-The main problem in gastric motility is slow wave generation so to solve that in the future could be adding to this proposed device a modulation technique in primary stage of signal generation to rise a low frequency respect to maintain the original stomach information signal in order quick recording for the mioelectrical activity

-This system could be developd by applying same idea for all organs to detect their statuses if normal or abnormal depending on original specifications recorded and saved in device

-Finally ,could be designed in the form of apparel with wireless sensors over organ locations and via transmitter sending signal to receiver which putting on reflecting point for the nerve ending on soles of the feet. Thus the proposed device could be used to detect the pain in all organs in short time in emergency cases .

References

[1] Nega assefa, Yosief tsige, Human anatomy and physiology , Alemaya university jimma university,(2003)

[2] Ter verkrijging van de graad van doctor in de Geneeskunde aan de erasmus universiteit Rotterdam op gezag van de rector magnificus prof. dr. m. w. van hof en volgens besluit van het college van dekanen. de openbare verdediging zal plaatsvinden op ; electrogastrography , signal analytical aspects and interpretation, woensdag ,(15 February 1984)

[3] Sarna sk, gastrointestinal electrical activity,terminology(2001)

[4] Bertrand j, dorval ed, metman eh, de calan l, ozoux jp. electrogastrography and serosal electrical recording of the antrum after proximal vagotomy in man. gastroenterology 1984 gastroenterology (1975)

[5] Han geldof, evert j. van der schee, and& j. p. m. smout,joop p. van de merwe, mark van blankenstein, and jan l. grashuis myoelectrical activity of the stomach in gastric ulcer patients ,(1989)

[6] Parkman hp, Hasler wl, Barnett jl, Eaker ey: Electrogastrography: a document prepared by the gastric section of the american motility society clinical GI motility testing task force. neurogastroenterol motil (2003).

[7]Koch kl, stern rm: handbook of electrogastrography, oxford university press, new York, (2004).

[8] Electrogastrogram based digestion detection system for coma patients ,biomedical online website ,published on (may 15, 2012).

[9] Yin j, Chen jdz: Electrogastrography: methodology, validation and applications, j neurogastroenterol motil. (2013)

[10] riezzo g, russo f, indrio f: electrogastrography in adults and children: the strength, pitfalls, and clinical significance of the cutaneous recording of the gastric electrical activity, biomed res int (2013)

[11] komorowski, stanislaw pietraszek, ewaryst tkacz and ivo provaznik : the extraction of the new components from electrogastrogram (egg), using both adaptive filtering and electrocardiographic (ecg) derived respiration signal ,(2014)

[12] .jonderko k, kasicka-jonderko a, krusiec-swidergoł b, dzielicki m, strój l, doliński m, et al, how reproducible is cutaneous electrogastrography*? an in-depth evidence-based study. neurogastroenterol motil.(* 2005)

[13] akin korhan, esra phd; khorshid, leyla phd; uyar, reflexology: its effects on physiological anxiety signs and sedation needs, mehmet md(2014).

[14] blunt, elizabeth phd, rn, crnp, foot reflexology,(2006 sep-oct) .

[15] dwight c. byers, electro reflex energizer and reflexology, better health with foot reflexology, (1998).

[16] د.عبد المجيد عبد الرحيم الحاج احمد، العلاج بالضغط وطب المنعكسات، الطبعة الثانية، الخرطوم، 2013

[17]www.gwinnett.k12.ga.us/LilburnES/PromoteGA/biochemistry/Brain_CNS.html,access in (1/9/2015).

APPENDICES

Appendix A

Matlab Code

```
T=60;
t=0:T-1;
g=500*(10^-6);

fn=input('enter normal frequancy');
if fn>=0.045 && fn<0.055
    EN=sin(2*pi*fn*t);%generated sinsoidal wave
   fp=input('enter patient frequancy');
    EP=sin(2*pi*fp*t);

d=zeros(1,T);%impulses signal
d(6)=0.1;
d(8)=0.2,
d(10)=0.2;
d(14)=0.2;
d(15)=0.1;
d(16)=0.4;
d(19)=0.3;
d(34)=0.2;
d(35)=0.1;
d(39)=0.3;
d(40)=0.2;
d(43)=0.3;
d(47)=0.1;
d(49)=0.1;
d(50)=0.4;
d(54)=0.3;
d(56)=0.1;
d(58)=0.4;
d(53)=0.3;
y=g*(d+EN);%generated normal signal
y1=g*(d+EP);%generated patient signal
gain=10000*y;%amplification for normal signal
gain1=10000*y1;%amplification for patient signal
% Butterworth Lowpass filter designed using FDESIGN.LOWPASS.

% All frequency values are in Hz.
Fs = 10;  % Sampling Frequency

N  = 10;   % Order
Fc = 1;  % Cutoff Frequency

% Construct an FDESIGN object and call its BUTTER method.
h  = fdesign.lowpass('N,F3dB', N, Fc, Fs);
Hd = design(h, 'butter');
m=filter(Hd,gain);%filtered normal signal
```

```
m1=filter(Hd,gain1);%filtered patient signal

x=tf(t,m)%calculation of transfer function to normal signal
x1=tf(t,m1)%calculation of transfer function to patient signal
if m==m1
    disp('normal')
else
    disp('abnormal')
end


figure(1);
subplot(2,3,1)
plot(t,EN,'LineWidth',2)
title('normal sin wave','FontSize',20)
subplot(2,3,4)
plot(t,EP,'r','LineWidth',2)
title('patient sin wave','FontSize',20)
subplot(2,3,2)
plot(t,y,'LineWidth',2)
title(' generated normal signal','FontSize',14)
subplot(2,3,5)
plot(t,y1,'r','LineWidth',2)
title('generated patient signal','FontSize',14)
subplot(2,3,3)
plot(t,gain,'LineWidth',2)
title('amplified normal signal','FontSize',20)
subplot(2,3,6)
plot(t,gain1,'r','LineWidth',2)
title('amplified patient signal','FontSize',20)
figure(3);
subplot(2,1,1)
plot(t,m,'LineWidth',2)
title('filtered  normal signal','FontSize',20)
subplot(2,1,2)
plot(t,m1,'r','LineWidth',2)
title('filtered patient signal','FontSize',20)
figure(4);
step(x,x1,'r')%plot step response for normal & patient signal
else
    disp('frqequancy is out of range')
end
```

Appendix B

Equations

$$Gain = 1 + \frac{50k\Omega}{RC} = 100 \quad (1)$$

$$H(Z) = \frac{Y(Z)}{X(Z)} \quad (2)$$

Appendix C
Instrumentation Amplifier Data Sheet

BURR-BROWN®

INA121

FET-Input, Low Power INSTRUMENTATION AMPLIFIER

FEATURES

- LOW BIAS CURRENT: ±4pA
- LOW QUIESCENT CURRENT: ±450µA
- LOW INPUT OFFSET VOLTAGE: ±200µV
- LOW INPUT OFFSET DRIFT: ±2µV/°C
- LOW INPUT NOISE: 20nV/√Hz at f = 1kHz (G =100)
- HIGH CMR: 106dB
- WIDE SUPPLY RANGE: ±2.25V to ±18V
- LOW NONLINEARITY ERROR: 0.001% max
- INPUT PROTECTION TO ±40V
- 8-PIN DIP AND SO-8 SURFACE MOUNT

APPLICATIONS

- LOW-LEVEL TRANSDUCER AMPLIFIERS Bridge, RTD, Thermocouple
- PHYSIOLOGICAL AMPLIFIERS ECG, EEG, EMG, Respiratory
- HIGH IMPEDANCE TRANSDUCERS
- CAPACITIVE SENSORS
- MULTI-CHANNEL DATA ACQUISITION
- PORTABLE, BATTERY OPERATED SYSTEMS
- GENERAL PURPOSE INSTRUMENTATION

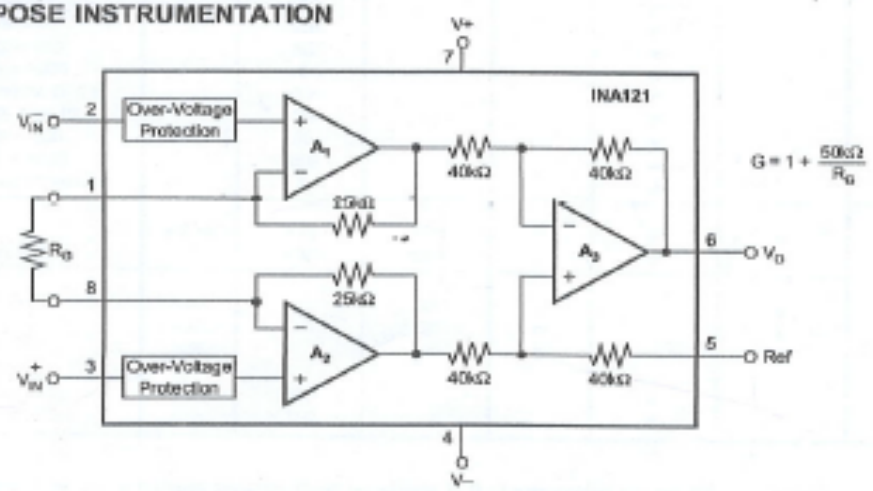
DESCRIPTION

The INA121 is a FET-input, low power instrumentation amplifier offering excellent accuracy. Its versatile three-op amp design and very small size make it ideal for a variety of general purpose applications. Low bias current (±4pA) allows use with high impedance sources.

Gain can be set from 1V to 10,000V/V with a single external resistor. Internal input protection can withstand up to ±40V without damage.

The INA121 is laser-trimmed for very low offset voltage (±200µV), low offset drift (±2µV/°C), and high common-mode rejection (106dB at G = 100). It operates on power supplies as low as ±2.25V (+4.5V), allowing use in battery operated and single 5V systems. Quiescent current is only 450µA.

Package options include 8-pin plastic DIP and SO-8 surface mount. All are specified for the –40°C to +85°C industrial temperature range.



International Airport Industrial Park • Mailing Address: PO Box 11400, Tucson, AZ 85734 • Street Address: 6730 S. Tucson Blvd., Tucson, AZ 85706 • Tel: (520) 746-1111 • Twx: 910-952-1111
Internet: http://www.burr-brown.com/ • FAXLine: (800) 548-6133 (US/Canada Only) • Cable: BBRCORP • Telex: 066-6491 • FAX: (520) 889-1510 • Immediate Product Info: (800) 548-6132

SPECIFICATIONS: V_S = ±15V

At T_A = +25°C, V_S = ±15V, R_L = 10kΩ, and IA reference = 0V, unless otherwise noted.

PARAMETER	CONDITIONS	INA121P, U			INA121PA, UA			UNITS
		MIN	TYP	MAX	MIN	TYP	MAX	
INPUT								
Offset Voltage, RTI			±200+200/G	±500±500/G		±300±200/G	±1000±1000/G	µV
vs Temperature			±2±2/G	±5±20/G		*	±15±20/G	µV/°C
vs Power Supply	V_S = ±2.25V to ±18V		±5±20/G	±50±150/G		*	*	µV/V
Long-Term Stability			±0.5			*		µV/mo
Impedance, Differential			10^{12} || 1			*		Ω || pF
Common-Mode	V_O = 0V		10^{12} || 12			*		Ω || pF
Input Voltage Range			See Text and Typical Curves			*		
Safe Input Voltage				±40			*	V
Common-Mode Rejection	V_{CM} = −12.5V to 13.5V							
	G = 1	78	86		72	*		dB
	G = 10	91	100		85	*		dB
	G = 100	96	106		90	*		dB
	G = 1000		106			*		dB
BIAS CURRENT	V_{CM} = 0V		±4	±50		*	*	pA
vs Temperature			See Typical Curve			*		
Offset Current			±0.5			*		pA
vs Temperature			See Typical Curve			*		
NOISE, RTI	R_S = 0Ω							
Voltage Noise: f = 10Hz	G = 100		30			*		nV/√Hz
f = 100Hz	G = 100		21			*		nV/√Hz
f = 1kHz	G = 100		20			*		nV/√Hz
f = 0.1Hz to 10Hz	G = 100		1			*		µVp-p
Current Noise: f = 1kHz			1			*		fA/√Hz
GAIN								
Gain Equation			1 + (50kΩ/R_G)			*		V/V
Range of Gain		1		10,000	*		*	V/V
Gain Error	V_O = −14V to 13.5V							
	G = 1		±0.01	±0.05		*	±0.1	%
	G = 10		±0.03	±0.4		*	±0.5	%
	G = 100		±0.05	±0.5		*	±0.7	%
	G = 1000		±0.5			*		%
Gain vs Temperature[1]	G = 1		±1	±10		*	*	ppm/°C
	G > 1		±25	±100		*	*	ppm/°C
Nonlinearity	V_O = −14V to 13.5V							
	G = 1		±0.0002	±0.001		*	±0.002	% of FSR
	G = 10		±0.0015	±0.005		*	±0.008	% of FSR
	G = 100		±0.0015	±0.005		*	±0.008	% of FSR
	G = 1000		±0.002			*		% of FSR
OUTPUT								
Voltage: Positive	R_L = 100kΩ		(V+)−0.9			*		V
Negative	R_L = 100kΩ		(V−)+0.15			*		V
Positive	R_L = 10kΩ	(V+)−1.5	(V+)−0.9		*	*		V
Negative	R_L = 10kΩ	(V−)+1	(V−)+0.25		*	*		V
Capacitance Load Drive			1000			*		pF
Short-Circuit Current			±14			*		mA
FREQUENCY RESPONSE								
Bandwidth, −3dB	G = 1		600			*		kHz
	G = 10		300			*		kHz
	G = 100		50			*		kHz
	G = 1000		5			*		kHz
Slew Rate	V_O = ±10V, G ≤ 10		0.7			*		V/µs
Setting Time, 0.01%	G = 1 to 10		20			*		µs
	G = 100		35			*		µs
	G = 1000		260			*		µs
Overload Recovery	50% Input Overload		5			*		µs
POWER SUPPLY								
Voltage Range		±2.25	±15	±18	*	*	*	V
Quiescent Current	I_O = 0V		±450	±525		*	*	µA
TEMPERATURE RANGE								
Specification		−40		85	*		*	°C
Operating		−55		125	*		*	°C
Storage		−55		125	*		*	°C
Thermal Resistance, θ_{JA}								
8-Lead DIP			100			*		°C/W
SO-8 Surface Mount			150			*		°C/W

* Specification same as INA121P, U.

NOTE: (1) Temperature coefficient of the "Internal Resistor" in the gain equation. Does not include TCR of gain-setting resistor, R_G.

Appendix D

Analog to Digital Converter (ADC) Interface

Some USB-GPIO Interface Adapters have several analog inputs connected to an Analog to Digital Converter (ADC). Analog to digital conversion has many applications. You can acquire data from various analog sensors and save it to your PC for further processing. You can also implement a real time analog data processing in your software. Combined with other USB-GPIO adapter modules you can implement feedback control over your hardware. Analog to digital conversion is well utilized for external analog signal reading such as current, voltage, temperature, distance, pressure, or even color information. Analog to Digital Converter inputs can generate events. If you adjust low or high threshold value, the adapter will send events once this threshold is crossed.

Analog-to-digital conversion is an electronic process in which a continuously variable (analog) signal is changed, without altering its essential content, into a multi-level (digital) signal.

The input to an *analog-to-digital converter (ADC)* consists of a voltage that varies among a theoretically infinite number of values. Examples are sine waves, the waveforms representing human speech, and the signals from a conventional television camera. The output of the ADC, in contrast, has defined levels or states. The number of states is almost always a power of two -- that is, 2, 4, 8, 16, etc. The simplest digital signals have only two states, and are called **binary**. All whole numbers can be represented in binary form as strings of ones and zeros.

Digital signals propagate more efficiently than analog signals, largely because digital impulses, which are well-defined and orderly, are easier for electronic circuits to distinguish from noise, which is chaotic. This is the chief advantage of digital modes in communications. Computers "talk" and "think" in terms of binary digital data; while a microprocessor can analyze analog data, it must be converted into digital form for the computer to make sense of it.

A typical telephone modem makes use of an ADC to convert the incoming audio from a twisted-pair line into signals the computer can understand. In a digital signal processing system, an ADC is required if the signal input is analog.

Appendix E

FDATOOL Filter Design & Analysis Tool.

FDATOOL launches the Filter Design & Analysis Tool (FDATool).

FDATool is a Graphical User Interface (GUI) that allows you to

design or import, and analyze digital Finite Impulse Responses FIR and Infinite Impulse Responses IIR filters .

If the Filter Design Toolbox is installed, FDATool seamlessly integrates advanced filter design methods and the ability to quantize filters.

Appendix F

Transfer function

TF Creation of transfer functions or conversion to transfer function.

Creation:

SYS = TF(NUM,DEN) creates a continuous-time transfer function SYS with

numerator(s) NUM and denominator(s) DEN. The output SYS is a TF object.

SYS = TF(NUM,DEN,TS) creates a discrete-time transfer function with

sample time TS (set TS=-1 if the sample time is undetermined).

S = TF('s') specifies the transfer function H(s) = s (Laplace variable).

Z = TF('z',TS) specifies H(z) = z with sample time TS.

You can then specify transfer functions directly as expressions in S

or Z, e.g.,

```
s = tf('s');  H = exp(-s)*(s+1)/(s^2+3*s+1)
```

SYS = TF creates an empty TF object.

SYS = TF(M) specifies a static gain matrix M.

In all syntax above, the input list can be followed by pairs

```
'PropertyName1', PropertyValue1, ...
```

that set the various properties of TF models (type LTIPROPS for details).

To make SYS inherit all its LTI properties from an existing LTI model

REFSYS, use the syntax SYS = TF(NUM,DEN,REFSYS).

Data format:

For SISO models, NUM and DEN are row vectors listing the numerator and denominator coefficients in

* descending powers of s or z by default

* ascending powers of q = z^-1 if the 'Variable' property is set to 'z^-1' or 'q' (DSP convention).

For MIMO models with NY outputs and NU inputs, NUM and DEN are NY-by-NU

cell arrays of row vectors where NUM{i,j} and DEN{i,j} specify the transfer function from input j to output i. For example,

H = tf({-5 ; [1 -5 6]} , {[1 -1] ; [1 1 0]})

specifies the two-output, one-input transfer function

[-5 /(s-1)]

[(s^2-5s+6)/(s^2+s)]

By default, transfer functions are displayed as functions of 's' or 'z'. Alternatively, you can set the variable name to 'p' (continuous time) and 'z^-1' or 'q' (discrete time) by modifying the 'Variable' property.

Arrays of transfer functions:

You can create arrays of transfer functions by using ND cell arrays for

NUM and DEN above. For example, if NUM and DEN are cell arrays of size

[NY NU 3 4], then

SYS = TF(NUM,DEN)

creates the 3-by-4 array of transfer functions

SYS(:,:,k,m) = TF(NUM(:,:,k,m),DEN(:,:,k,m)), k=1:3, m=1:4.

Each of these transfer functions has NY outputs and NU inputs.

To pre-allocate an array of zero transfer functions with NY outputs and NU inputs, use the syntax

SYS = TF(ZEROS([NY NU k1 k2...])) .

Conversion:

SYS = TF(SYS) converts an arbitrary LTI model SYS to the transfer function representation. The result is a TF object.