Design of Non-invasive IBS Diagnosis System Depending on Bowel Sounds

Project Team

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الإهداء

بسم الله الرحمن الرحيم

)قل إعملوا فسيرى الله عملكم ورسوله والمؤمنون (صدق الله العظيم.

إلهي لايطيب الليل إلا بشكرك ولايطيب النهار إلى بطاعتك .. ولاتطيب اللحظات إلا بذكرك .. ولا تطيب الآخرة إلا بعفوك .. ولا تطيب الجنة إلا برؤيتك .. الله جل جلاله.

إلى من بلغ الرسالة وأدى الأمانة .. ونصح الأمة .. إلى نبي الرحمة ونور العالمين .. سيدنا محمد صلى الله عليه وسلم.

إلى من كلله الله بالهيبة والوقار .. إلى من علمنا العطاء بدون انتظار .. إلى من نحمل أسمه بكل افتخار .. والدنا العزيز.

إلى من كان دعائها سر نجاحنا وحنانها بلسم جراحنا إلى أغلى الحبايب .. إلى منبع الحنان وتاج الرأس ومن تنحني لها جباهنا، كيف لا والجنة تحت أقدامها .. أمهاتنا الغاليات.

إلى من أمسك بيدينا وعلمنا حرفا .. إلى من كانوا سندا لنا إلى من لهم الفضل في وصولنا هنا .. إلى محبي العلم والمعرفة .. أساتذتنا الاكارم.

إلى من بذل جهده ووقته معنا وكان لنا مرشدا ناصحا .. إلى مشرفنا القدير الأستاذ علي عمرو.

إلى وطننا فلسطين الحبيبة و شهدائنا الأبرار و أسرانا البواسل .. نهدي نجاحنا و الحمدلله رب العالمين .

Abstract

Irritable bowel syndrome (IBS) is a chronic and debilitating functional gastrointestinal disorder that affects 9%-23% of the population across the world. The percentage of patients seeking health care related to IBS approaches 12% in primary care practices and is by far the largest subgroup seen in gastroenterology clinics. It has been well documented that these patients exhibit a poorer quality of life and utilize the health care system to a greater degree than patients without this diagnosis.

IBS is referred to as a functional disorder, which means that there is nothing wrong with the actual structure of patient bowel. Rather, the problem lies with how it is working. Several methods or techniques are used in the diagnosis of the diseases. One of them is using physical exam. During a physical exam the doctor listens to sounds within the patient abdomen using a stethoscope.

The aim of this project is to study the movements of the Bowel, which represent the Bowel sound (BS) since they are the noise produced by the movement of gas and fluids during peristalsis, and construct a recording system that can detect and analyse these movement. So that a system was created capable of recording bowel movement and displaying the signal on the screen so that it is equipped with bowel frequency, which helps the doctor diagnose Irritable Bowel Disease through frequency. The project was examined on 10 people, and we found out that one of the patients had irritable bowel disease, as the bowel frequency was more than 500 HZ, while the rest of the people had a normal bowel frequency, meaning that they were not infected.

الملخص

متلازمة القولون العصبي هي خلل في وظيفة القولون مما يؤدي إلى حدوث اضطرابات تؤثر على الأمعاء الغليظة في الجهاز الهضمي ، حيث تصل نسبة المصابين فيه %23-%9 من سكان العالم، ويشكل نسبة %12 ممن يسعون الى تلقي الرعاية الصحية لهذا المرض، حيث انهم يساهمون بأكبر نسبة مرضى سجلت في عيادات أمراض الجهاز الهضمي . مع العلم بأن هؤلاء المرضى يعيشون حياة صعبة رغم خضوعهم لنظام رعاية صحية بدرجة أكبر من غيرهم من مرضى الجهاز الهضمي .

وبما أن متلازمة القولون اضطراب وظيفي ، مما يعني أنه لا يوجد خلل في التركيب الفعلي لأمعاء المريض .تكمن المشكلة في وظيفتها وأدائها . يتم استخدام عدة طرق أو تقنيات في تشخيص الامراض . احدى هذه الطرق هي استخدام الفحص البدني، أثناء الفحص البدني ، يستمع الطبيب إلى الأصوات داخل بطن المريض باستخدام السماعة الطبية.

يهدف المشروع الى دراسة حركة الأمعاء والتي تمثل أصوات الأمعاء حيث أنها ناتجة عن حركة الغازات والسوائل داخل الأمعاء وبناء نظام تسجيل الاشارة الناتجة من حركة الأمعاء وبالتالي تشخيص مرض القولون العصبي .بحيث تم انشاء نظام قادر على تسجل حركة الامعاء وعرض الاشارة على الشاشة بحيث تكون مزودة بتردد الامعاء الذي يساعد الطبيب على تشخص مرض القولون العصبي من خلال التردد .تم فحص المشروع على 10 اشخاص ولقد تبين لنا أن احد المرضى مصاب بمرض القولون العصبي بحيث كان تردد الامعاء اكثر من 500 هيرتز اما باقي الاشخاص كان تردد الامعاء طبيعي بمعنى انهم غير مصابين.وتم وضع العديد من الصور التي تحتوي على اشارة الامعاء مع التردد .

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Chapter One

Introduction

Chapter One

Introduction

Irritable bowel syndrome (IBS) is a common disorder that affects the digestive system. It causes symptoms like stomach cramps, bloating, diarrhoea and constipation. These tend to come and go over time, and can last for days, weeks or months at a time. It's usually a lifelong problem. It can be very frustrating to live with and can have a big impact on the patient everyday life. The diagnosis of irritable bowel syndrome (IBS) using bowel sounds recorded by a non-invasive device could eliminate the need for costly techniques of diagnosing [1].

The idea of this project is to design a non-invasive bowel sound recording system that can provide the doctor with a signal to diagnose. IBS characteristics will be studied in this project. The system will be able to detect the BS using appropriate microphone, filter the desired signals depending on their frequency range, and amplify them. Abnormal bowel sounds are commonly present in patients with IBS. Computerized analysis of these sounds can assist in diagnosis and in evaluation during follow-up.

Project Objectives

- Study the characteristics of bowel sounds, as well as a physiological description of what causes them.
- Construct an electronic bowel movement recording system.
- Provide the user with the colon signal frequency readings, and display the results with the signal shape.

Project Importance

Keeping the patient suffering from Irritable Bowel Syndrome for a long time, it is a big problem, as Irritable Bowel Syndrome is diagnosed by more than one method, including colonoscopy and imaging tests so that there are risks to the patient if these methods are used, but the diagnosis of Irritable Bowel Syndrome via bowel sounds provides greater comfort and easier for the patient. Because it is a non-invasive method for diagnosis, low cost, low risk and easy to use for patients and doctors.

Literature Review •

Project study comes to accomplish a previous studies that include diagnostic case-control study, researchers have explored the use of bowel sounds to characterize IBS with a view to diagnostic use since 1900s [1]. Auscultation has been used as a non-invasive technique in medicine The most commonly studied organs were, and still are, the lungs and the heart, with doctors long using sounds to diagnose disease in the cardiovascular and respiratory systems.

Doctors have also listened to gut noises to diagnose conditions such as bowel obstructions and paralytic ileus based on the nature or absence of bowel sounds (BS). In 1905, the first scientific study of bowel auscultation was reported by Cannon. Cannon found that the gut produced rhythmic noises, most likely from the peristaltic movement of the intestines, plus continuous random noises varying in location and intensity. [2]

A study where researchers recruited participants with an existing clinical diagnosis of IBS or healthy (asymptomatic) digestive systems. Then recorded bowel sounds for 2 hours after fasting and then for 40 minutes after a standard meal. In these study they take 31 person with IBS and 37 healthy participants gave 90% sensitivity and 92% specificity for IBS diagnosis. These preliminary results provide proof of concept for the use of bowel sound analysis to identify IBS.[3]

Time Schedule •

This table illustrates the activities of the project, and the time of each one.

Table 1.1 Time schedule of spring 2020 semester

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Finding Project Idea	■	■													
Proposal		■	■	■											

Search and Collecting data															
Documentation															
Preparing for presentation															
Print documentation															

Table 1.2 Time schedule of the second semester 2021

Week Activities	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Collection of components															
the Built projectcircuit															
Print the project on PCB															
Built the project codes															
Interfacing usingArduino															
Testing the project															
Recommendation															
Conclusion															
Documentation															

List of Abbreviations •

Table 1.2 List of Abbreviations

Abbreviations	Full Word
BS	Bowel Sound
IBS	Irritable bowel syndrome
MMC	migrating motor complex
IBS_D	Irritable Bowel Syndrome with Diarrhea

CBC	Complete Blood Count
EGD	Esophagogastroduodenoscopy
CE	Capsule Endoscopy
EUS	Endoscopic Ultrasound
CT	Computed Tomography
MRI	Magnetic Resonance Imaging
SIBO	Small Intestine Bacterial Overgrowth
SB	Single Burst
MB	Multiple Bursts
CRS	Continuous Random Sound
HS	Harmonic Sound
CS	Combination Sound
RLQ	Right Lower Quadrant
LLQ	Left Lower Quadrant
RUQ	Right Upper Quadrant
LUQ	Left Upper Quadrant
dB	Decibel
CMRR	Common Mode Rejection Ratio
Cm	Centimeter
Hz	Hertz
dBV	Decibel level relative to one volt
SPL	Sound Pressure Level
SNR	Signal to Noise Ratio
ECM	Electret Condenser Microphone
NAM	Non-Audible Murmur
Mic	Microphone
Mv	Millivolt
Vin G	Gain
Vout	Output voltage
Rms	Root mean square

Economical study •

This section lists the overall cost of the project components that are used in implementation of the system.

Table 1.3 Estimated Component Cost.

Components	**Cost**	**Quantity**
Battery	40 JD	1
Amplifiers LM358	10 JD	2
Resistors	5 JD	7
capacitors	10 JD	3
ECM	15 JD	1
	Total Price = 80 JD	

Chapter Two
Human Digestive System

Chapter Two

Human Digestive System

Human digestive system, system used in the human body for the process of digestion. The human digestive system consists primarily of the digestive tract, or the series of structures and organs through which food and liquids pass during their processing into forms absorbable into the bloodstream. The system also consists of the structures through which wastes pass in the process of elimination and other organs that contribute juices necessary for the digestive process.

In this chapter, a brief introduction is given about the human digestive system structure, the structure and function of each part of a digestive system and the large intestine will be introduced. Disorder of large Intestinal motility and irritable of the bowel system with causes and symptoms will be discussed. This chapter mainly focuses on the brief discussion about the factors that affecting on the bowel of the digestive system and on the sound that come out from the bowel.

• Structures and Functions of the Human Digestive System

The digestive tract begins at the lips and ends at the anus as shown in Figure 2.1. It consists of the mouth, or oral cavity, with its teeth, for grinding the food, and its tongue, which serves to knead food and mix it with saliva; the throat, or pharynx; the esophagus; the stomach; the small intestine, consisting of the duodenum, the jejunum, and the ileum; and the large intestine, consisting of the cecum, a closed-end sac connecting with the ileum, the ascending colon, the transverse colon, the descending colon, and the sigmoid colon, which terminates in the rectum.

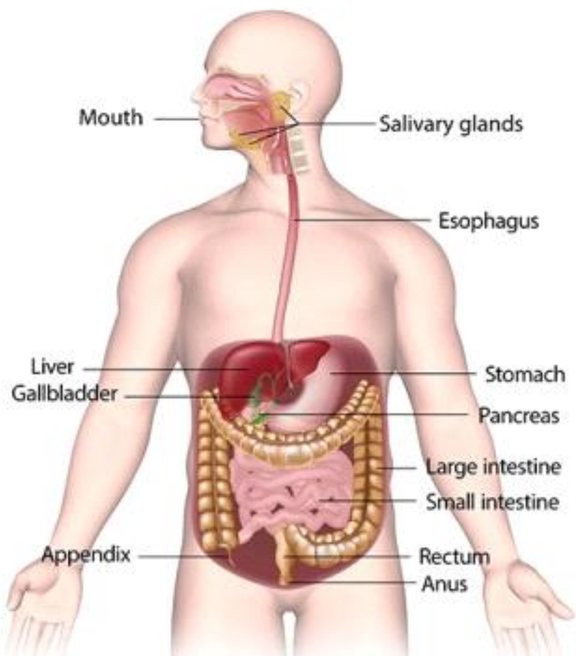

Figure 2.1 The Component of the Digestive System [4]

Food begins its journey through the digestive system in the mouth, it contains organs that aid in the digestion of food the tongue, teeth, and salivary glands. Inside the mouth the teeth chop the food into small pieces which are moistened by saliva mixed with enzymes before the tongue and other muscles push the food into the pharynx. The pharynx, or throat, is a funnel-shaped tube connected to the posterior end of the mouth. The pharynx is responsible for the passing of masses of chewed food from the mouth to the esophagus. The esophagus is a muscular tube connecting the pharynx to the stomach that is part of the upper gastrointestinal tract**.** It carries swallowed masses of chewed food along its length and trap food in the stomach. The stomach is a muscular, hollow organ. It is involved in the second phase of digestion, following chewing. It performs a chemical breakdown by means of enzymes and hydrochloric acid it secretes digestive enzymes and gastric acid to aid in food digestion. The pyloric sphincter controls the passage of partially digested food (chyme) from the stomach into the duodenum where peristalsis takes over to move this through the rest of the intestines, where fat , sugar and proteins are digested by the body .The intestines have two organs : small and large bowel ,The remaining bulk of partially digested food is travels to the large bowel (colon) where water is extracted what is left is waste it eliminated from the body as a bowel movement [3].While the colon expands , the stool accumulates before exiting the body, signals travel up the spine to the brain about the status of the digestion at any given moment . The Brain interprets the incoming signal to determine if the mechanism if normal or cause for an alarm.

The Small Intestine •

Inside the surface of small intestine is full of many ridges and folds. These folds are used to maximize the digestion of food and absorption of nutrients. By the time food leaves the small intestine, around 90% of all nutrients have been extracted from the food that entered it. It has small diameter of only about 2.54 cm, compared with 7.62 cm for the large intestine [5]. The small intestine can be divided into three regions. From proximal (at the stomach) to distal, these are the duodenum, jejunum, and ileum, as shown in figure 2.2.The shortest region is the 25.4cm duodenum, which begins at the pyloric sphincter. Just past the pyloric sphincter, it bends posteriorly behind the peritoneum, becoming retroperitoneal, and then makes a C-shaped curve around the head of the pancreas before ascending anteriorly again to return to the peritoneal cavity and join the jejunum. [5]

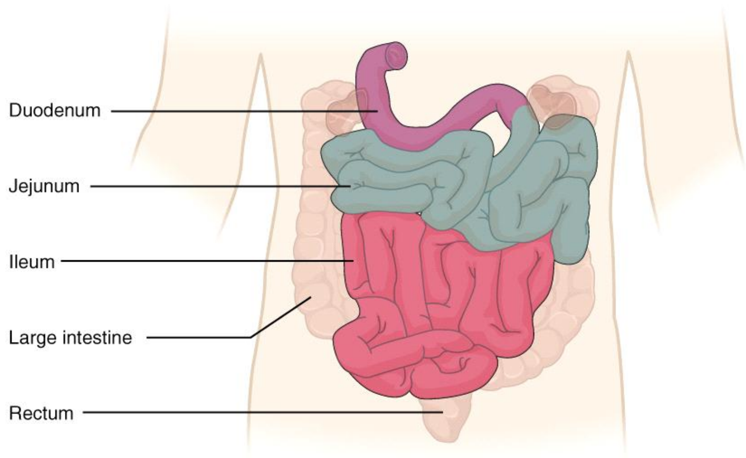

Figure 2.2 Small Bowel Parts [5]

The Large Intestine •

The large intestine, also known as the colon, is part of the digestive tract. The digestive tract includes the mouth, esophagus, stomach, small intestine, large intestine, and rectum as illustrated in Figure 2.3. The large intestine is approximately 5 feet long, making up one-fifth of the length of the gastrointestinal tract. The large intestine is responsible for processing indigestible food material (chyme) after most nutrients are absorbed in the small intestine. The large intestine is composed of 4 parts. It includes the cecum and ascending colon, transverse colon, descending colon, and sigmoid colon. The large intestine performs an essential role by absorbing water, vitamins, and electrolytes from waste material.

Fig 1. **Anatomy of the large intestine**

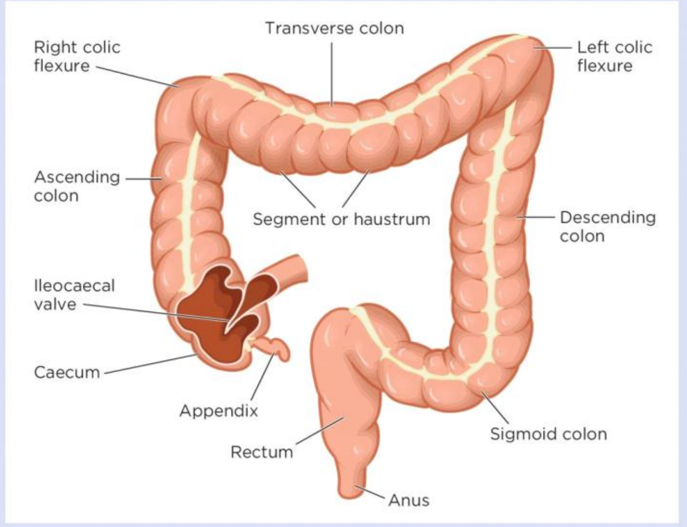

Figure 2.3 The Large Intestine components [6]

The large intestine has 3 primary functions: absorbing water and electrolytes, producing and absorbing vitamins, and forming and propelling feces toward the rectum for elimination. By the time indigestible materials have reached the colon, most nutrients and up to 90% of the water has been absorbed by the small intestine. The role of the ascending colon is to absorb the remaining water and other key nutrients from the indigestible material, solidifying it to form stool. The descending colon stores feces that will eventually be emptied into the rectum. The sigmoid colon contracts to increase the pressure inside the colon, causing the stool to move into the rectum. The rectum holds the feces awaiting elimination by defecation [7].

The intestinal wall is made up of multiple layers. The 4 layers of the large intestine from the lumen outward are the mucosa, submucosa, muscular layer, and serosa. The muscular layer is made up of 2 layers of smooth muscle, the inner, circular layer, and the outer, longitudinal layer. These layers contribute to the motility of the large intestine. There are 2 types of motility present in the colon, haustral contraction and mass movement. Haustra are saccules in the colon that give it its segmented appearance. Haustral contraction is activated by the presence of chyme and serves to move food slowly to the next haustra, along with mixing the chyme to help with water absorption. Mass movements are stronger and serve to move the chyme to the rectum quickly [8].

Absorption of water occurs by osmosis. Water diffuses in response to an osmotic gradient established by the absorption of electrolytes. Sodium is actively absorbed in the colon by sodium channels. Potassium is either absorbed or secreted depending on the concentration in the lumen. The electrochemical gradient created by the active absorption of sodium allows for this. Chloride ions are exchanged for bicarbonate ions across an electrochemical gradient.

The colon also plays a role in providing required vitamins through an environment that is conducive for bacterial cultivation. The colon houses trillions of bacteria that protect our gut and produce vitamins. The bacteria in the colon produce substantial amounts of vitamins by fermentation. Vitamin K and B vitamins, including biotin, are produced by the colonic bacteria. These vitamins are then absorbed into the blood. When dietary intake of these vitamins is low in an individual, the colon plays a significant role in minimizing vitamin disparity [9].

• Irritable Bowel Syndrome (IBS)

Irritable Bowel Syndrome (IBS), which is classified as a functional gastrointestinal disorder, is a chronic condition of the lower gastrointestinal that affects as many as 15% of adults in the Not easily characterized by structural abnormalities, infection, or metabolic disturbances, the underlying mechanisms of IBS have for many years remained unclear. Recent research, however, has lead to an increased understanding of IBS. As a result, IBS is now considered an organic and, most likely, neurologic bowel disorder.

IBS is often referred to as spastic, nervous or irritable colon. Its hallmark is abdominal pain or discomfort associated with a change in the consistency and/or frequency of bowel movements. Although the causes of IBS have not to date been fully elucidated, it is believed that symptoms can occur as a result of a combination of factors, including visceral hypersensitivity, altered bowel motility, neurotransmitters imbalance, infection and psychosocial factors.

• IBS Symptoms

The hallmark of IBS symptoms is abdominal pain or discomfort associated with either a change in bowel habits or disordered defecation. The pain or discomfort associated with IBS is often poorly localized and may be migratory and variable. It may occur after a meal, during stress or at the time of menses. In addition to pain and discomfort, altered bowel habits are common, including diarrhea, constipation, and diarrhea alternating with constipation. Patients also complain of bloating or abdominal distension, mucous in the stool, urgency, and a feeling of incomplete evacuation. Some patients describe frequent episodes, whereas others describe long symptom-free periods. Patients with irritable bowel frequently report symptoms of other functional gastrointestinal disorders as well, including chest pain, heartburn, nausea or dyspepsia, difficulty swallowing, or a sensation of a lump in the throat or closing of the throat [10]. Symptoms unrelated to the intestine (extra intestinal symptoms) are common in patients with IBS. These may include headache, sleep disturbances, post-traumatic stress disorder, temporomandibular joint disorder, sicca syndrome, back/pelvic pain, myalgias, back pain, and chronic pelvic pain Fibromyalgia and interstitial cystitis are also frequently encountered [11]

• IBS Causes

Functional disorders of the gastrointestinal tract have existed throughout history. Systematic investigation of these disorders, however, did not begin until the middle of the 20th century—and it is only within the last 20 years that physicians have developed a scientific understanding and concern for the treatment of patients with IBS [12].

Approximately 40–60% of patients with IBS who seek medical care also report psychiatric symptoms, such as depression, anxiety, or somatization. Interestingly, however, psychiatric symptoms in patients with IBS in the general population are not as prevalent. It is thought that these psychiatric disturbances influence coping skills and illness-associated behaviors. A history of abuse (physical, sexual, or emotional) has been correlated with symptom severity. More than half of patients who are seen by a physician for Irritable Bowel Disease report stressful life events coinciding with or preceding the onset of symptoms. Stress is known to alter gastrointestinal function. Patients who suffer from IBS have amplified colonic motility responses when compared to normal volunteers (those who do not have any symptoms of IBS). Researchers believe the limbic system (an area of the brain where stress is perceived and experienced) is critically involved as illustrated in Figure 2.4

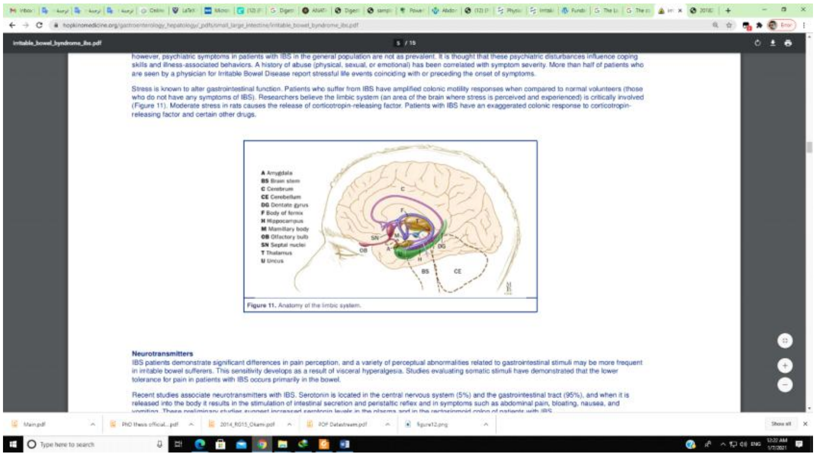
however, psychiatric symptoms in patients with IBS in the general population are not as prevalent. It is thought that these psychiatric disturbances influence coping skills and illness-associated behaviors. A history of abuse (physical, sexual, or emotional) has been correlated with symptom severity. More than half of patients who are seen by a physician for Irritable Bowel Disease report stressful life events coinciding with or preceding the onset of symptoms.

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Figure 11. Anatomy of the limbic system.

Neurotransmitters

IBS patients demonstrate significant differences in pain perception, and a variety of perceptual abnormalities related to gastrointestinal stimuli may be more frequent in irritable bowel sufferers. This sensitivity develops as a result of visceral hyperalgesia. Studies evaluating somatic stimuli have demonstrated that the lower tolerance for pain in patients with IBS occurs primarily in the bowel.

Recent studies associate neurotransmitters with IBS. Serotonin is located in the central nervous system (5%) and the gastrointestinal tract (95%), and when it is released into the body it results in the stimulation of intestinal secretion and peristaltic reflex and in symptoms such as abdominal pain, bloating, nausea, and

Figure 2.4 Anatomy of the limbic system [10]

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Other theories concerning IBS associate the inflammation of enteric mucosa or neural plexuses with symptoms. It is hypothesized that inflammatory cytokines may activate peripheral sensitization or hypermobility. One group of researchers was able to predict the development of IBS in patients with infectious enteritis in the presence of stressful life events and hypochondriasis. Researchers in Ontario recently demonstrated that post infection inflammation (Trichomonas spiralis) alters visceral sensitivity. In this particular study, NIH Swiss mice were infected with T spiralis. Six days after infection the mice experienced jejunal enteritis, which returned to normal after 28 days. Using a latex balloon placed in the distal colon, investigators found hyperalgesic sensory response following distension that persisted despite the lack of acute inflammation. There are many risk factor that may be effect on the patient, namely [14] Gender: IBS is common in women than men, Environmental factors, Genetic factors, Bacterial activity in the gut, Bacterial overgrowth, Food intolerance, Altered ability of the bowel to move freely, Oversensitive intestines, Altered nervous system processing, Altered hormonal regulation.[15]

Chapter Three

Theoretical Background

Chapter Three

Theoretical Background

Irritable bowel syndrome (IBS) is a disorder of gut–brain interaction characterized by abdominal pain associated with a change in frequency or form of bowel habit. Irritable bowel syndrome accounts for more than 40% of new referrals to gastroenterology outpatient clinics, although the disease is mostly managed by primary care practitioners [16-17].

This chapter talks about several background technologies to diagnose irritable bowel syndrome such as Blood Test, Stool Tests, Endoscopy, Imaging Tests, Breath Tests and Bowel Sounds.

- **Blood Test**

There are no blood tests that can directly diagnose IBS. However, blood analysis can determine inflammation in the body. Inflammation may be detected through a number of measurements involving blood cells and proteins in the blood. These tests will not reveal what's causing the inflammation, and best serve as an indicator that the physician needs to perform other types of tests to identify the inflammation's source [18].

In addition to being markers of inflammation, blood tests are useful in several other ways. A complete blood count (CBC) can also show signs of inflammation or infection through an increased white blood cell count. Anemia may be detected through red blood cell measurements. Blood tests may also assess liver and kidney functions, which can be affected by IBS or the medications used to treat the disease.

• Stool Tests

The stool ova and parasites exam is designed to look for eggs (ova) or adult parasites. Stool analysis for parasites can be useful in diagnosing IBS in patients with chronic diarrhea Generally, IBS-D patients experience the chronic diarrhea. A stool gram stain, is used to determine and identify the presence of bacteria in the stool. The stool gram stain is generally used in diagnosing IBS in cases with acute diarrhea [19].

Stool tests are not always performed in diagnosing irritable bowel syndrome because the stool sample may be mixed with urine, water, or toilet paper, and all of this will affect the result and be inaccurate. In addition, the stool test is limited value in identifying organic disease in patients without alarm symptoms.

• Endoscopy

Endoscopy is a procedure that lets the doctor look inside the body. It uses an instrument called an endoscope, or "scope" for short. Scopes have a tiny camera attached to a long, thin, flexible tube. When the patient have an endoscopy test, the physician will be able to see images of the patient intestine magnified on a screen during the procedure, to evaluate different areas of the gastrointestinal tract, to assess the intestinal lining, and to guide biopsies as shown in Figure 3.1. In the test of performing diagnostic endoscopy, the physician will take multiple biopsy samples of the intestinal lining to evaluate for microscopic inflammation.

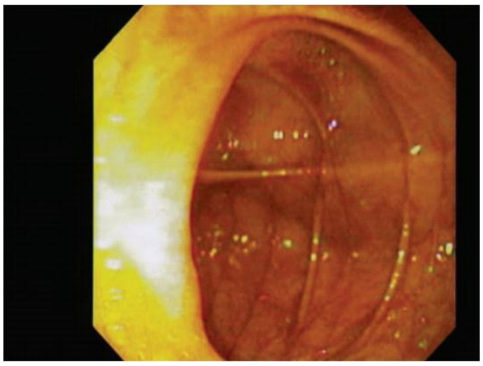


Figure 3.1 Endoscopy test image [20]

Endoscopy also allows the physician to utilize different types of scopes. Colonoscopies, sigmoidoscopies, and endoscopes are all forms of scopes. Although laboratory tests support the diagnosis of IBS, endoscopy plays the most important role. It helps the physician to see if inflammation is present, where it is located, assess its severity, and obtain biopsies to confirm the diagnosis.

- **Colonoscopy**

A colonoscopy is an exam used to detect changes or abnormalities in the large intestine and rectum. The colon and end of the small intestine are the most frequently involved in IBS, colonoscopy is the type of endoscopy most often performed to both diagnose and monitor IBS. A specially trained physician will guide a colonoscope into your rectum and through the entire length of the colon and end of the small bowel (terminal ileum). Typically, the patient will receive sedation prior to the procedure to minimize discomfort. Many patients sleep through the procedure and do not even recall that the test took place [21-22].

Colonoscopies are generally very safe procedures, but there is an extremely small risk of bowel perforation during the exam such as perforated intestine, bleeding, post-polypectomy electrocoagulation syndrome and adverse reaction to anesthetic.

- **Sigmoidoscopy**

A sigmoidoscopy is an endoscopic evaluation of the lower one-half to one-third of the colon. This is useful when the physician wants to confirm the presence of inflammation in this segment of the colon. In patients with ulcerative colitis, inflammation begins in the rectum. Therefore, a sigmoidoscopy can be a good diagnostic test to confirm the disease and to monitor the patient response to therapy. It is usually performed without sedation, because it is a very short procedure and is associated with less discomfort than colonoscopy. The preparation for this procedure is less complex than colonoscopy, usually requiring only one or two enemas the day of the procedure [23].

- **Upper endoscopy**

A common procedure that physicians use to evaluate a wide variety of symptoms, including, but not limited to, upper abdominal pain, nausea, vomiting, and difficulty swallowing. An endoscopy requires fasting after midnight until the test. Crohn's disease can occasionally affect the esophagus, stomach, and upper small bowel, which are investigated with an EGD. A longer upper endoscope, called an enteroscope, can be used to look for inflammation further into the small bowel. A standard enteroscopy can typically evaluate the first one-third of the small bowel.

• Capsule Endoscopy (CE)

A capsule endoscopy is a newer procedure that allows the physician to obtain pictures of the entire small bowel. The capsule or "pill" camera contains a light source and camera surrounded by a protective outer shell. It also requires fasting after the evening meal and sometimes bowel preparation prior to the procedure. The patient is fitted with a belt recorder, swallows an endoscopy capsule, which is about the size of a penny, and goes about regular activities. The capsule then travels through the small intestine and transmits approximately 60,000 images to the recorder. At the end of the day, the patient returns to the doctor's office for downloading of images. The capsule is excreted in the stool normally. Capsule endoscopy is not recommended for patients with Strictures or bowel obstructions as the capsule can become "stuck" or retained in the small bowel, resulting in symptoms of bowel obstructions and, rarely, requiring surgery. In addition, biopsies cannot be taken with the capsule [24].

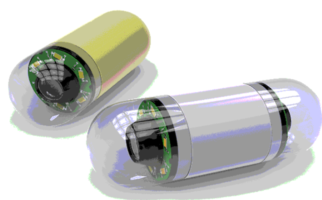


Figure 3.2 Capsule Endoscopy [20]

• Endoscopic ultrasound (EUS)

Endoscopic ultrasound is a relatively new technique that uses an ultrasound probe attached to an endoscope to obtain deep images of the gut below the surface. With IBS, physicians use EUS most often to look at fistulas in the rectal area. Fistulas are abnormal connections from the intestine to another part of the intestine, another organ of the body, or the surface of the skin [25].

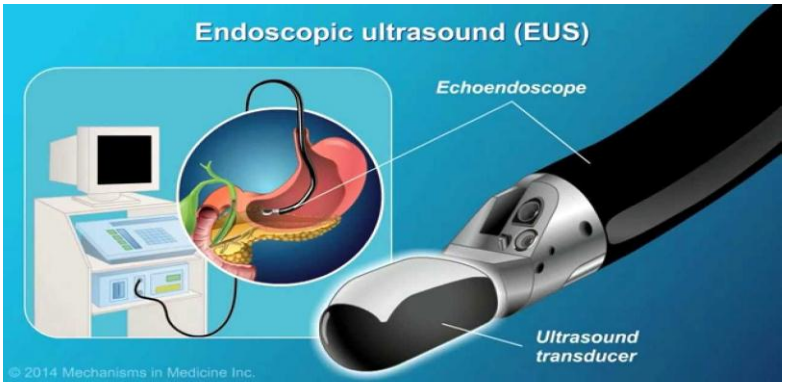


Figure 3.3 Endoscopic Ultrasound [21]

• Imaging Tests

In addition to capsule endoscopy, radiologic exams or diagnostic imaging are performed to evaluate these segments of intestines as well as to evaluate areas outside the bowel.

There are many types of imaging techniques used in IBS, including: X-rays, Computed Tomography Enterography, Magnetic Resonance Imaging and Ultrasound. General descriptive information about these types is given in the following paragraphs.

X-rays are the oldest way of imaging the inside of the body. X-rays are inexpensive, effective and useful for detection of blockages in the small or large intestine. Patients with inflammation and/or scarring of the small bowel that narrows the intestine and prevents the easy passage of stool and air. This is called a small bowel obstruction. The large bowel can also become blocked and dilated. Rarely, people with ulcerative colitis can develop a widening of the large bowel called toxic mega colon. These are serious complications that can be seen on a plain X-ray.

A CT scan, takes simultaneous X-rays from several different angles to reconstruct a realistic image of the internal organs as shown in Figure 3.4. It may involve a contrast material delivered orally, rectally, or intravenously to improve the quality of the test. During the test, the patient will be on a special table. A CT of the abdomen takes five to 20 minutes to complete. The CT scan is used to rule out complications of IBS, such as intra-abdominal abscesses, strictures, small bowel obstructions or blockages, fistulas, and bowel perforation.

Figure 3.4 CT scan Image [20]

Magnetic resonance imaging (MRI) is useful method to obtain a high quality image for internal organs, muscles, soft tissue, and the brain without using radiation. It converts a signal into a realistic image of the body, giving clear images free of interference from overlying bowel loops. MRI is also useful in seeing disease outside the intestine [26].

Ultrasound technology is used to study many organs in the abdomen, typically the liver, gallbladder, and those in the pelvic area. Currently, endoscopic ultrasound and MRI are both used to diagnose IBS. Physicians in the US do not typically use ultrasound to evaluate the small bowel; however, in Europe, they use ultrasound more often to assess for blockages in the small bowel. Ultrasound emits no radiation, and relies on the shadows cast by inaudible sound waves. Although ultrasounds do not usually require preparation other than not eating for a few hours before the test.

All these imaging techniques involve some risk, there are many research that indicates radiation as a risk factor for cancer. It is clear that health-related radiological scans contribute the most to radiation exposure for the majority of patients. CT scans currently generate the largest amount of radiation among the types of scans discussed in the previous. Despite the radiation exposure associated with CT, it is a still a very useful test for diagnosing IBS and its complications. However, other exams such as MRI and ultrasound are being used increasingly to decrease radiation exposure for patients.

- **Breath Tests**

The doctor uses breath test that may determine if a patient has irritable bowel syndrome (IBS). Commonly, breath tests are used to measure the amount of hydrogen and methane in the breath. These gases are produced by bacteria. Breath tests may be used to determine if the patient's symptoms are caused by lactose intolerance, small intestine bacterial overgrowth.

Patients with IBS are more likely to be lactose intolerant than the general public. Lactose intolerance means the body has difficulty digesting the sugar lactose, which is found in milk and other dairy products. And it presents with similar symptoms to IBS, including diarrhea, nausea, abdominal bloating, abdominal cramping and gas. When the patient has swelling, it is caused by the overgrowth of bacteria in the small intestine, so that the bacteria multiply in large numbers and the symptoms of the overgrowth of bacteria become chronic diarrhea and other symptoms similar to those of Irritable Bowel Syndrome. That SIBO is more prevalent in patients with IBS than in the general public, leading to a theory that SIBO may be the primary cause of IBS [27].

• Bowel Sounds

Bowel sounds refer to the sounds heard when contractions of the lower intestines propel contents forward .Unfortunately, there is no reference of what can be considered normal bowel sound activity, thus, only subjective description of the acoustic impression of normal BS exists, employing terms such as "rushes" or "gurgles". Nevertheless, time and frequency domain characteristics of BS could be used as a means for defining normal BS. In particular, BS with frequency content in the range of 100-500 Hz, with durations within a range of 5-200 msec, and with widely varying amplitudes, could be characterized as normal BS.

In many BS of the colon corresponds to frequencies within 500 to 700 Hz and time durations within 20 msec Moreover, differences in the sound to sound intervals of BS from different pathologies, i.e. IBS, Crohn’s disease, and from controls, establish a time domain tool for associating changes in BS characteristics with bowel pathology.

There are two general types of BS, Hyperactive bowel sounds, load, gurgling rushed sounds typically indicate an increase in intestinal activity. And Hypoactive bowel sounds, soft, low, widely separated sounds such as one or two occurring in two minutes.

BS classifications Sensor localization, and Sensor types used in BS measurement will be explained in the following sections.

3.6.1 BS classifications

Five typical types of BS, they were identified according to their time and spectrogram information expanded based on short time Fourier analysis .These five types of BS are classified as a single burst (SB), multiple bursts (MB), continuous random sound (CRS), harmonic sound (HS) and a combination sound (CS), as shown in figures 3.5 .[28]

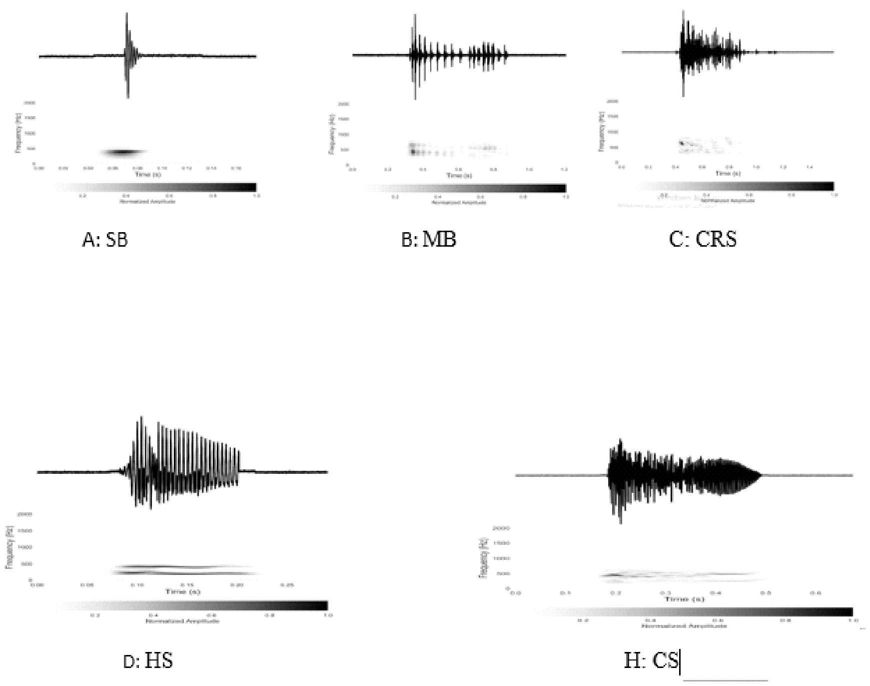


Figure 3.5 BS Classifications [28]

The most frequent type of BS shown is the SB, which is a simple pulse probably caused by a single contraction of the bowel muscle [28]. The duration of the single burst is short, only 10–30 ms. MB can be described as a repetitive SB with a shorter interval time between adjacent components. Each component in the MB looks quite similar in the spectrogram with slight differences in bandwidth and amplitude, which indicates that the MB consists of several similar individual components. The duration of MB is much longer than the SB and ranges from 40 to 1500 ms [29]. The waveform of the CRS is usually continuous over long periods of time ranging from 200 ms to 4000 ms, the CRS is usually recognized as a random sound because it has no clear rhythm or pattern. The CRS waveform is also less regular compared to other types of BS although it occurs more often than the HS and

CS. It is also clear that the CRS often appears in a combination of other types of BS to construct a CS.

The duration of the HS ranges from 50 ms to 1500 ms, a few peaks could be observed in the HS with no defined silent gaps between each peak. HS have been described with the descriptions: rhythmic noises, whistling sweeps, and regular pattern.

3.6.2 Sensor localization

Two way to divide the abdomen, the first one can be divided into four quadrants by drawing a line down the midline over the umbilicus and another across the abdomen bisecting it at the same point. This will be given the standard right upper quadrant, right lower quadrant, left upper quadrant and left lower quadrant. Knowledge of the structures within each area to help determine what the bowel sounds mean.

Sensor localization refer to four quadrants as parts of colon lying in these quadrants. The descending colon located in LLQ and LUQ , sigmoid colon located in LLQ, Ascending colon located in RLQ, Splenic flexure of colon located in LUQ , Hepatic flexure of colon located in RUQ .

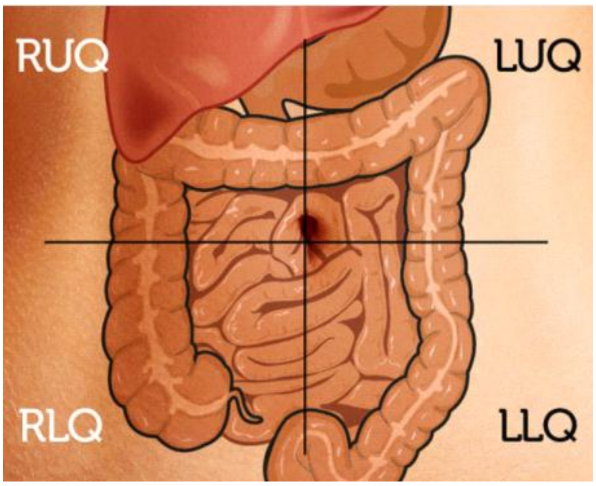


Figure 3.6 Four Quadrants of the Abdomen [29]

The other way to localization sensor by dividing abdomen in to 9 pieces, by two horizontal lines and two vertical lines. These lines when intersect each other, make nine abdominal quadrants, as shown in figure 3.7. The nine quadrants are:

- Right hypochondrium
- Epigastrium
- Left hypochondrium
- Right lumbar region
- Umbilical region
- Left lumbar region
- Right iliac fossa
- Hypogastrium
- Left iliac fossa

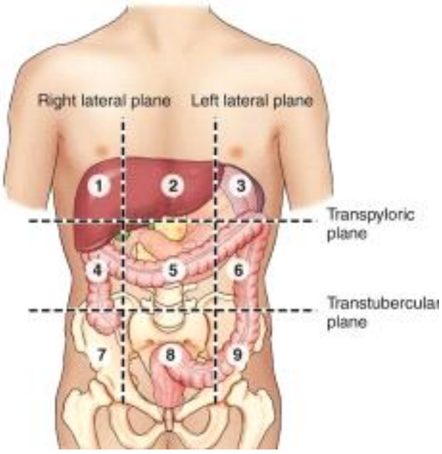


Figure 3.7 Quadrants of the Abdomen [30]

First examined the ability to measure the location of the origin of a bowel sound based on the time of arrival. The abdomen was a hollow cavity and the speed of sound was therefore approximately 340 ms .localizing sensor refer to nine quadrants: ascending colon located in right hypochondrium quadrant (no.1) and right lumbar region (no.4)**.** Transverse colon located in epigastric region (no.2)**.**

Descending colon located in left hypochondrium (no.3), left lumbar region (no.6) and left iliac fossa (no.9). Sigmoid colon located in hypogastrium (no.8) and Left iliac fossa (no.9) splenic flexure of colon located in Left hypochondrium (no.2). [30]

3.6.3 BS Sensors

Sound sensors are defined as a module that detects sound waves through its intensity and converting it to electrical signals , many modules are designed with different specifications and different principle of works .In general the input of these sensors are sound and the output represent electrical signal that's depend on the futures of the sensor .

There is some specification for sensors will be explained because they are very important to know. The decibel (dB) scale, directional pattern, frequency response, sensitivity, SNR, Overload SPL

a. The decibel (dB) scale: is logarithmic scale, which provides the perception of equal-sized increment, the dB-scale is a relative scale. Thus, you can express any change by db. A change of 0 dB is no change at all. Any positive dB number indicates a positive change (the value now is higher than before). Any negative dB number indicates a negative change (the value now is lower than before.

b. Directional pattern: is a graphic way to show the acceptance angle of a microphone. Each circle represents a dB level, usually starting with 0 dB at the outer circle. A reference point, marked as 0°, is defined at the top of the outer circle. Each shift between emphasized circles indicates a 5 dB step typically as shown in figure 3.8 .It is common to name the directionality of a microphone by the pattern it exhibits in the polar plot:

- Omnidirectional: The response curve follows the outer circle all the way around. The microphone picks up sound evenly from all directions
- Cardioid: The microphone picks up sound from the front and the sides, but not from the back.

• Super cardioid: The microphone picks up sound from the front and a little from the rear but is deaf to sound at approximately ±135°.

• Figure-of-eight: The microphone picks up sound equally from the front and the rear but not from the sides

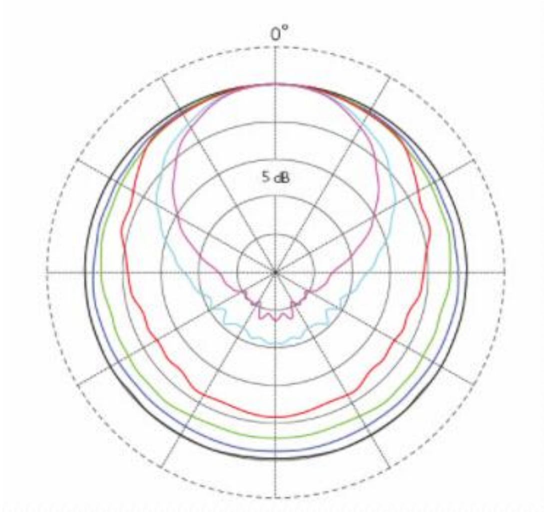


Figure 3.8 Directional Pattern [30]

c. Frequency response: indicates the complete frequency range at which the microphone responds to sound signal. The flat response is perfect frequency response .figure3.9 shown an example for frequency response for condenser microphone.

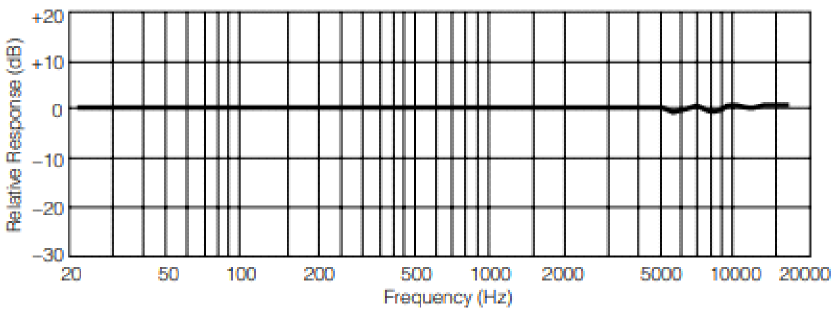


Figure 3.9 Frequency Response Curve [30]

- Sensitivity: expresses the microphone's ability to convert sound pressure to an electric voltage. The sensitivity of a microphone is one of the most important parameters as it states how much output voltage the microphone

Sensitivity = Δoutput/Δinput
Equation 3.1

Sensitivity dBV = 20 Equation 3.2

Where Output $_{AREF}$ is the 1000 mV/Pa (1 V/Pa) reference output ratio

In sound transducer definitely will find dBV describing the sensitivity. The stated sensitivity is nominal, which means that deviations from this value exist. For this reason, it is essential to state the tolerances, the sensitivity within ±2 dB or ±3 dB depending on the microphone type.

- SNR: is defined as the ratio of the power of original signal (meaningful input) to the power of background noise (meaningless or unwanted input). Because many signals have a very wide dynamic range, signals are often expressed using the logarithmic decibel scale.

Equation 3.3

- Overload SPL: microphone's response to extreme sound pressure. In many recording situations, it is practical to know the maximum Sound Pressure Level (SPL) a microphone can handle and what output voltage to expect in that situation.

- In BS detection several types of sensors that can be used to convert body sounds into an electric signal. Microphones and accelerometers are the common choice of sensor for sound recording. These sensors have a high-frequency response that is quite adequate for body sounds. Rather, it is the low-frequency region that might cause problems. The microphone is an air coupled sensor that measure pressure waves induced by bowel movements while accelerometers are contact sensors which directly measures bowel movements. For recording of body sounds, both kinds can be used. More precisely, condenser microphones and piezoelectric accelerometers, shown in figure 3.10, have been recommended. Both transducers are popular in sound recording. However, accelerometers are typically more expensive than microphones, are often fragile, and may exhibit internal resonances. Thus, this concludes that the microphone is perfect for the application. Hence, microphone is chosen for this project[31,32]

ECM b. piezoelectric accelerometer •

Figure 3.10 Condenser Microphones and Piezoelectric Accelerometers [31]

Two of the most commonly use mic, ones are condenser and dynamic mic. Following table 3.1 shows the comparison between the dynamic and condenser mic.

Table 3.1 comparison between the dynamic and condenser mic

Dynamic Microphone	**Condenser Microphone**
Do not have flat frequency response	Have a flat frequency response
Operate with the principle of Electromagnetism as it does not require voltage supply	Employs the principle of electrostatics and consequently, require voltage supply across the capacitor for it to work

It is suitable for handling high volume level	It is not ideal for high volume work as its sensitivity makes it prone to distortion
The signal produced are strong therefore making them sensitive	. The resulting audio signal is stronger than that from a dynamic. It also tends to be more sensitive and responsive than dynamic.

Condenser mic generally have flatter response than dynamic , and therefor mean that a condenser mic is more desirable if accurate sound is a prime consideration as required in this design .

There are two types of condenser mic; standard condenser and electret condenser. A standard condenser mic consists of a small diaphragm that vibrates in response to acoustic pressure. It have very high output impedance, so they are not suitable for transferring signal over even a very small distance.

An electret condenser mic combines a condenser mic with a Field Effect Transistor (FET), which amplifies the signal and transforms the impedance to a more useful level. This characteristic of electret condenser mic makes them very sensitive to small sounds. Many types of electret condenser microphones are available in local markets but the choice of a suitable mic was quite ambiguous, the reason was that most of the founded were with no available datasheets even on the internet. Which means that no available mic characteristics to count on for the design of the device acquisition circuit.

The working principle of an electret condenser microphone is that the diaphragm acts as one plate of a capacitor. Vibrations produce changes in the distance between the diaphragm and the back plate. The voltage maintained across the diaphragm and the back plate changes with the vibrations in the air, according to the capacitance equation ($C = Q / V$), where Q = charge in coulombs, C = capacitance in farads and V = potential difference in volts. This change in voltage is amplified by the FET and the audio signal appears at the output, after a dc-blocking capacitor as shown in figure 3.11

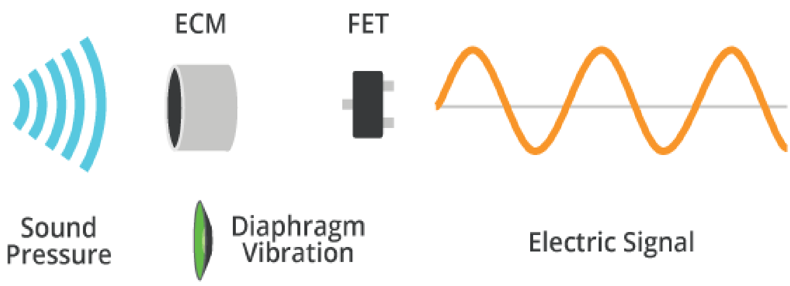


Figure 3.11 Working Principle of ECM [32]

Capacitance of a capacitor depends on the distance between its plates. When the air pressure makes the diaphragm move back and forth, capacitance varies accordingly and thus voltage varies too. This varying voltage produces a variable electric current which is in accordance with the sound vibrations at the diaphragm. A cross section of the entire electret microphone module is shown in figure 3.12.

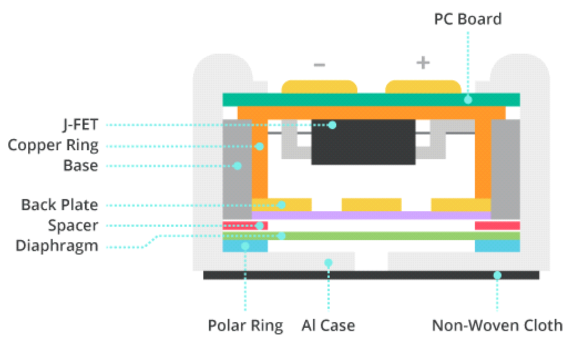


Figure 3.12 ECM Structure [32]

Chapter Four
System Design

Chapter Four

System Design

This chapter includes the hardware and software stages that required for design, all stages of design Components will be further explained in detail in the following sections, the hardware components of each stage are chosen carefully to achieve the desired objective.

The conceptual design of the system shown in Figure 4.1. MIC, filtration, gain amplifier, power supply will explain here. Starting with detection bowel sounds then filtration the signal passing it to amplifier for display it.

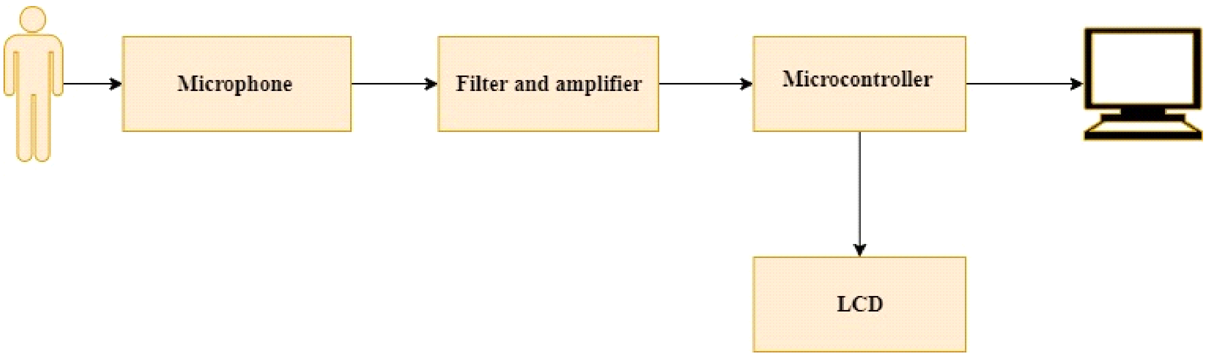


Figure 4. 1 Main Block Diagram of the System

- **Microphone**

After studying several types of sensors, ECM CMA-4544PF-W ECM was chosen with high accuracy in the presence of environmental noise. With high SNR equal 60 dB, with low cost implementation and also available with high sensitivity -37dBV, 0.5 mA current consumption. The recommended operating voltage is 2V but it can withstand up to 10V, in this design 5V was chosen to operate the MIC.

Figure 4.2 CMA-4544PF-W ECM [33]

This voltage is fed into the microphone through a resistor (1KΩ to 10KΩ) here 2.2k so resistor (2.2K) is used to limit the current flowing through the microphone (maximum should be 0.8mA) and capacitance equal to 1µf, figure 4.3 ,is used to filter the DC noise that might be coupled along with the analog electrical signals (output).

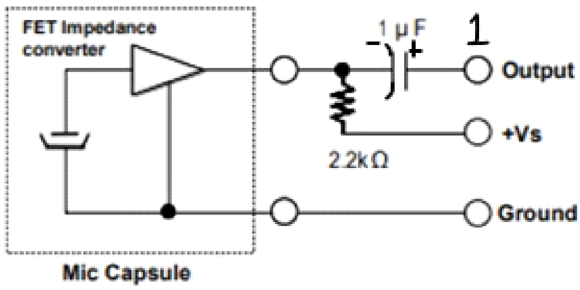


Figure 4. 3 Schematic Diagram for CMA-4544PF-W ECM

Filter and Amplifier Circuit •

After acquired the signal as shown in the first stage, the next stage showing filtration process also amplification the signal.

The MIC in the acoustic sensor needed to be biased in order for proper operation. In addition, the output of the microphone is on the order of millivolts, which is relatively small in magnitude this makes it challenging for the Arduino to detect changes in sensor output. In order to address both these issues, a bias, amplifier and filter circuit was designed and implemented to interface the sensor output with the Arduino. The goal of the circuit was to properly bias the microphone and amplify the sensor output to detect voltage swings caused by sounds also to isolate the desire Signal from the noise signals.

A simple voltage divider circuit with identical 700 Ω resistors was used to reduce the voltage to 2.5 V to bias the microphone. The output of the microphone was passed through a capacitor to remove the DC offset. With two 700Ω resistors in parallel with the output of the microphone 2.2kΩ, the equivalent output impedance of the sensor is roughly 300Ω. Using a 1 µF capacitor, a simple high pass filter with a cutoff frequency around 500Hz was designed, since abdominal vibration contains spread spectrum noise signals dominated by the heartbeat, noise from talking and walking, lungs and other interferences, so there is need to design filter circuit to get rid of these interferences.

The DC signal was connected to the positive input (Vin+) of an operational amplifier to boost the signal amplitude. Because the Arduino measures voltages between 0 and 5V, the Vin+ line of the op-amp was biased to 2.5 V in order to capture the largest magnitude of positive and negative swings from the MIC output. This biasing was implemented with another voltage divider circuit using identical 20k resistors, as shown in figure 4.4, The values of these resistors were chosen to be larger than the resistors in the previous voltage divider in order to avoid affecting the equivalent output impedance of the previous stage.

- **Amplifier**

Microphone signals are weak so there is need for amplify this signal for being heard LM358 amplifier was chosen since it operates with a single power supply voltage rage from 3.0 V to 32 V, have true-differential inputs, and remain in the linear mode with an input common-mode voltage of 0 VDC, low power drain ideal for battery operation. These amplifiers operate over a wide range of power supply voltage with little change in performance characteristics. According to the datasheet [Appendix B].

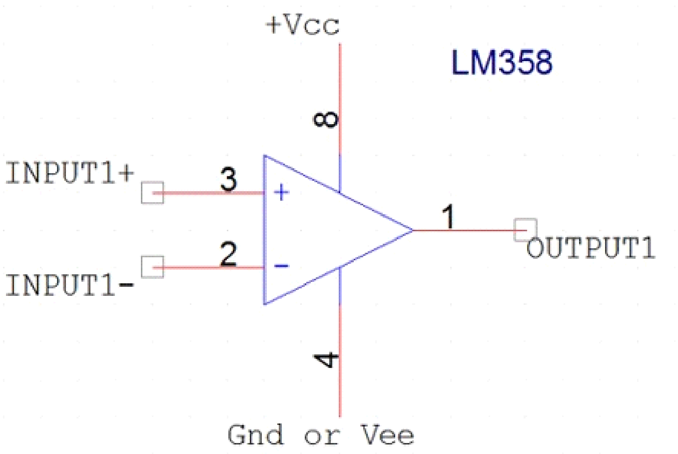


Figure 3.13 the Structure of LM358 [35]

The difference also between them depends on the specification of each one , for example the max operated power supply , single or dual supply , input and output impedance ,gain ,CMRR , SNR and other futures witch depend on the application will be used for.

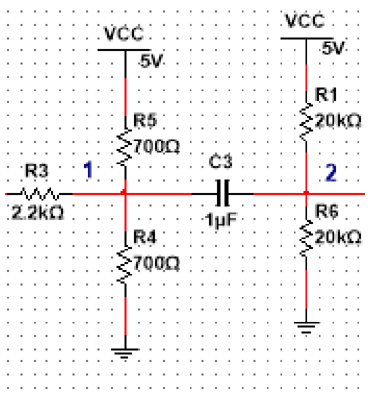


Figure 4. 4 MIC Bias and HPF

In this circuit, the output of the MIC passes through LM358 operational amplifier, as shown in figure 4.5. For signal amplification, a non-inverting op-amp configuration was used. The gain of the circuit is defined by the following equation:

(4.1)

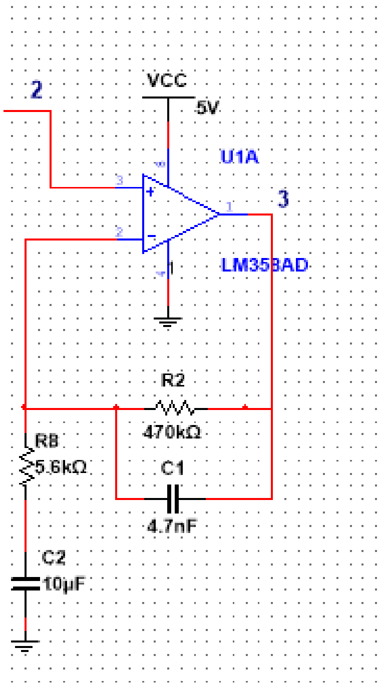


Figure 4. 5 Amplifier and LPF

This circuit amplifies the signal by gain equal 86. A capacitor was added in series with resistor R8 in the op-amp feedback loop to create a system with unity gain for DC voltage inputs. The unity gain at DC is important to prevent amplification of the 2.5 V bias at the Vin+ node. Without this additional capacitor, the output of the amplifier would saturate to 5 V when the microphone did not detect any sounds. A 10 uF capacitor was selected for C1 in order to achieve a high pass filter cutoff of approximately 2 Hz, which is close to DC in order to pass all non-DC signals. A 4.7nF capacitor was selected for C3 in parallel with a 47kΩ resistor in order to create a low-pass filter with a cutoff frequency of approximately 700 Hz. With all of these basic hardware filter realizations, the effective frequency range of the filtered output signal is between 500– 700Hz.

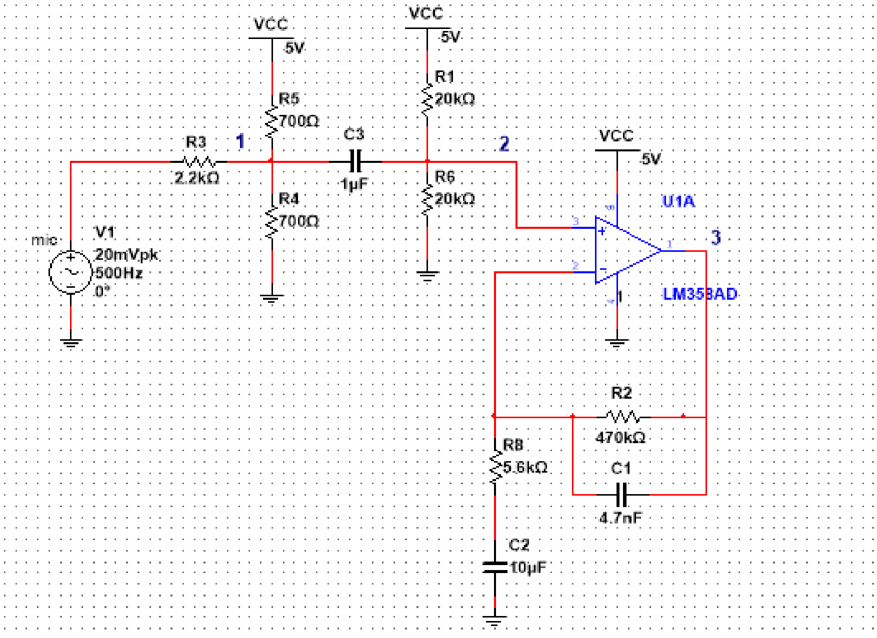


Figure 4. 6 Project Circuit Design

Calculation •

To calculate the total gain, the sensitivity of mic -37dBV so the output of mic can calculated by equation 3.2.

Sensitivity dBV = 20 (3.2)

-37 dBV = 20

-37 /20 dBV =

x = 14mv rms

x = 20mv VP, where x the output of mic and its represent the input voltage for the system since bowel sound has 40dB intensity and mic can give 115dB for level sound pressure.

94 dB spl 1v/pa [16]

115dBspl Y

Y=1.22v rms

Y= 1.73 VP witch represent the output voltage for the system

The amplification gain was calculated with reference to the equation of:

Let

Then

- High pass filter with , as mention above so we need to find , HPF used to attenuate the frequencies less than

Witch come from two 700Ω resistors in parallel with the output of the Microphone 2.2kΩ

.

- Low pass filter with , used to attenuate the frequencies above

Let

The Transfer Function :

A(s) = (1+R2/R8)/1+2πfcR1C1

A(0) = 1+R2/R8 witch calculated when c are open circuit

• Microcontroller

A microcontroller is a computer present in a single integrated circuit which is dedicated to perform one task and execute one specific application.

It contains memory, programmable input/output peripherals as well a processor. Microcontrollers are mostly designed for embedded applications and are heavily used in automatically controlled electronic devices such as cellphones, cameras, microwave ovens, washing machines, etc.

Features of a microcontroller:

Far more economical to control electronic devices and processes as the size and cost involved is comparatively less than other methods. Operating at a low clock rate frequency, usually use four bit words and are designed for low power consumption. Architecture varies greatly with respect to purpose from general to specific, and with respect to microprocessor, ROM, RAM or I/O functions .Has a dedicated input device and often has a display for output. Usually embedded in other equipment and are used to control features or actions of the equipment. Program used by microcontroller is stored in ROM. Used in situations where limited computing functions are needed.

The Arduino software is easy to use and flexible enough for advanced users. It runs on mac, windows, and Linux. Teachers and students use it to build low cost scientific instruments, to prove chemistry and physics principles, or to get started with programming and robotics. Designer and architects build interactive prototypes, musicians and artists use it for installations and to experiment with new musical instrument. There are many other microcontrollers and microcontroller platforms available for physical computing. Parallax Basic Stamp, net media's BX-24, phi gets, MIT's handy board, and many others offer similar functionality. All of these tools take the messy details of microcontroller programming and wrap it up in an easy to use package. Arduino also simplifies the process of working with microcontrollers, but it offers some advantage for teachers, and interested amateurs over other systems.

The control unit is the system brain which sends orders and receives data from other system components. An Arduino Nano are used. The following sections describe their function.

Arduino Mega Microcontroller •

The Arduino Mega 2560 is a microcontroller board based on the ATmega2560. It has 54 digital input/output pins (of which 15 can be used as PWM outputs), 16 analog inputs, 4 UARTs (hardware serial ports), a 16 MHz crystal oscillator, a USB connection, a power jack, an ICSP header, and a reset button. It contains everything needed to support the microcontroller; simply connect it to a computer with a USB cable or power it with a AC-to-DC adapter or battery to get started. The Mega 2560 board is compatible with most shields designed for the Uno and the former boards Duemilanove or Diecimila. The Mega 2560 is an update to the Arduino Mega, which it replaces.

Figure 4. 7 Arduino Mega

LCD •

Liquid Crystal Display is a type of flat panel display which uses liquid crystals in its primary form of operation. It used for display the result on it .TFT LCD 2.8 inch with resolution: 240 x 320 dots and power consumption 10 mA.

• Power Supply

The hardware system needs power supply to provide its components with the required power. As the system may be required to be portable a battery that has the following characteristics is required:

- provide required system power
- Has relatively long life
- light weight

This system will be supplied by 5v buttery with flat discharge voltage curve Max. Discharge 150mA continuous due to limitation of power supply in the system , choosing of system parts should fulfill the need for an optimal with minimum current consumption leading to increase the life time of the battery.to calculate the no. of hours of buttery work see table 4.1

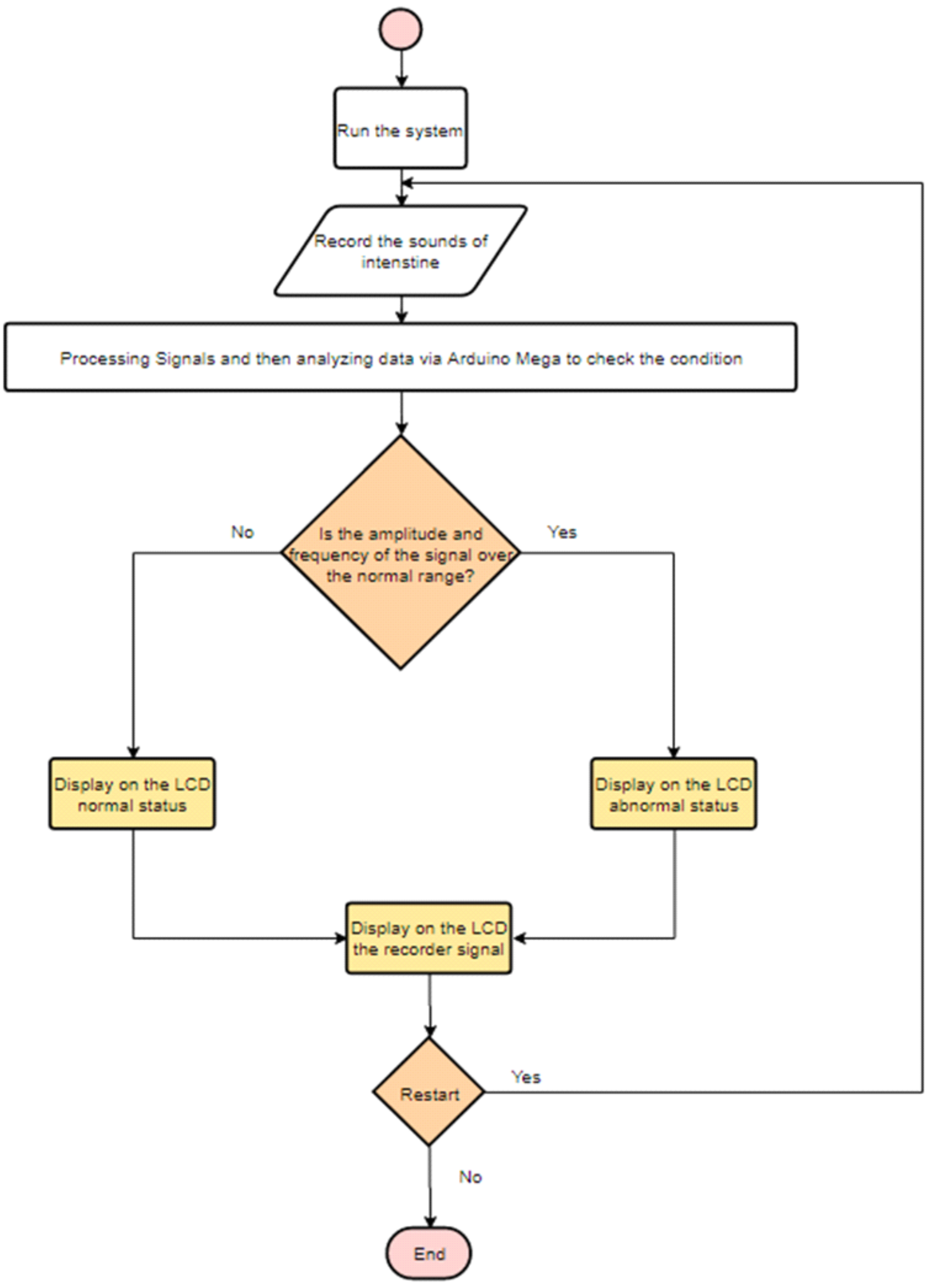
IC name	No of piece	Quiescent Current
LM358	1	1.2mA
MIC	1	0.5mA
Arduino	1	300mA
LCD	1	10mA
Total current		311.7mA

Total current = 311.7mA

we need a 5volt buttery has a consumption time= 7480.8mAhou

• Flowchart

The following flowchart shows the stages of the project in its entirety to show and display the final results.



Chapter Five

Test and Implementation

Chapter Five

Test and Implementation

In this chapter the hardware system designed in the preceding chapter is implemented to accomplish the project as a one unit which achieves the purpose of the project. In this section, the system circuits will be implemented before final implementations to the system.

• Project Implementation

In the beginning, all the stages of the system were examined separately by applying a wave signal to ensure that they performed the required task, as a sin-wave signal was applied to all stages, and then all the electronic parts were welded to a metal face, and the pieces appear in the following Figures.

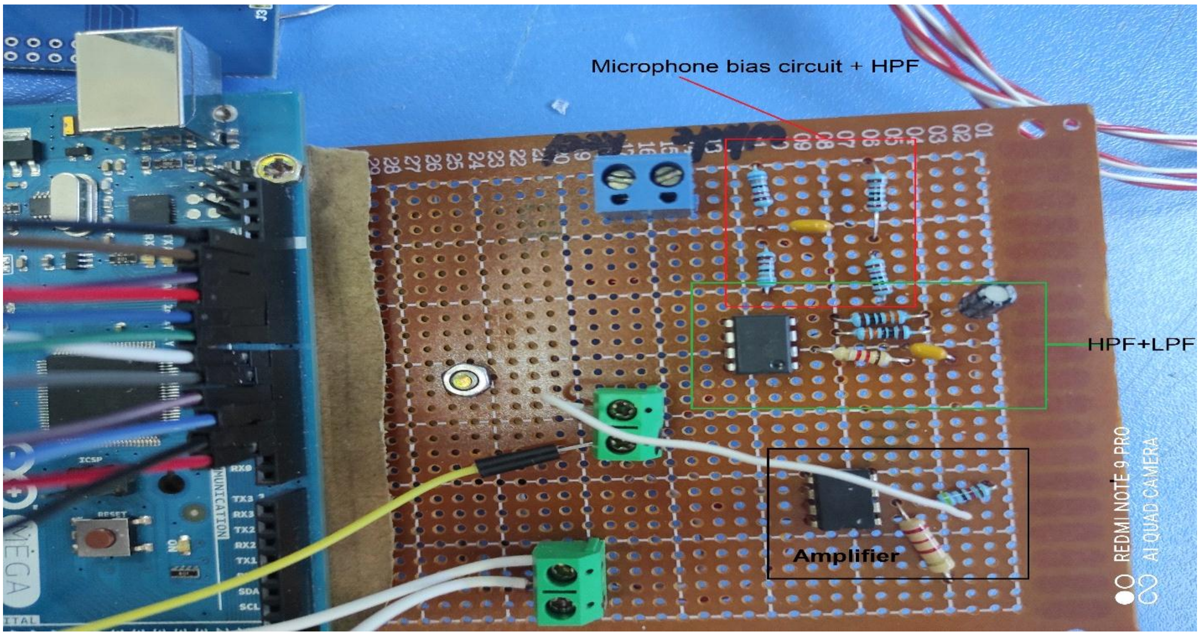


Figure 5. 1 Processing circuit

• Controller and LCD Connection

As mentioned in the previous chapter, the Arduino Mega is the brain of the project, which is used to draw the colon sound signal on the TFT LCD and on the serial plotter of the Arduino Mega., so the system circuit and TFT LCD are connected to it. This section will show these connections in the following figure 5.2.

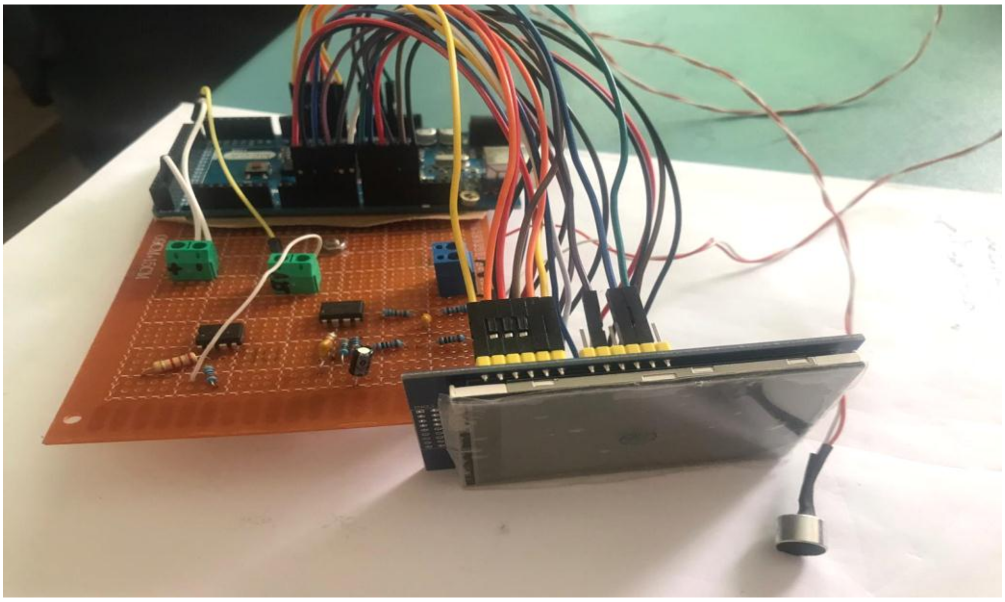


Figure 5. 2Controller and LCD Connection

- **Project Testing**

According to the project objectives, the system is supposed to provide the user with the colon signal frequency readings, and display the results with the signal shape on the TFT LCD screen. Additionally, the colon sound signal is displayed using serial plotter and the system displays the final result of the diagnosis on the TFT LCD screen. The following figures (5.3 and 5.4) display the serial plotter signals on Arduino Mega microcontroller, and figures (5.5 and 5.6) display the result on the TFT LCD.

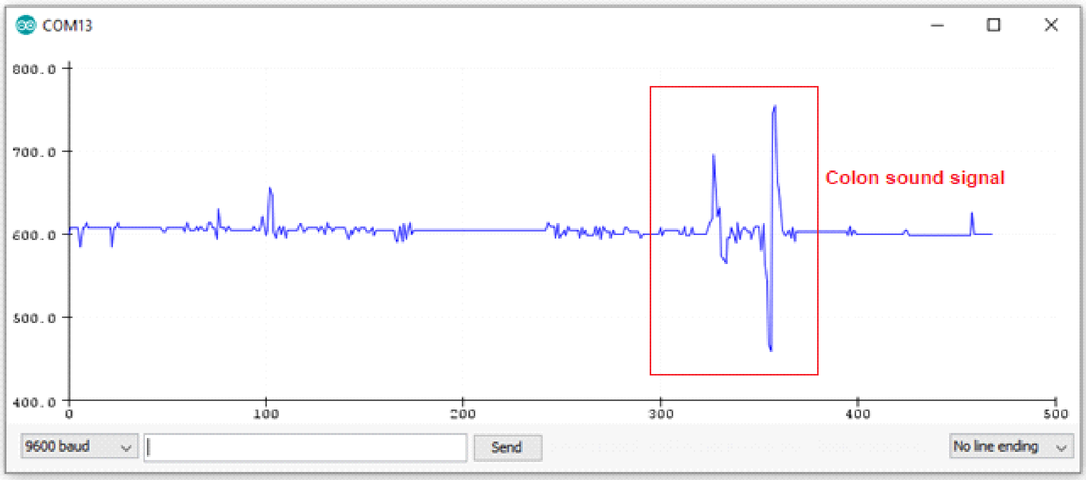


Figure 5. 3 Serial plotter of colon sound signal after filtration.

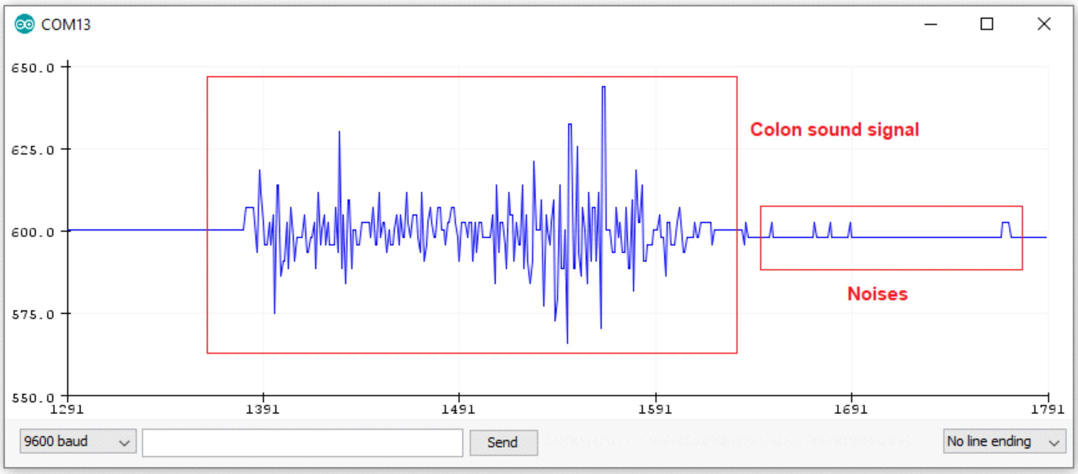


Figure 5. 4 Serial plotter of colon signal with artifact

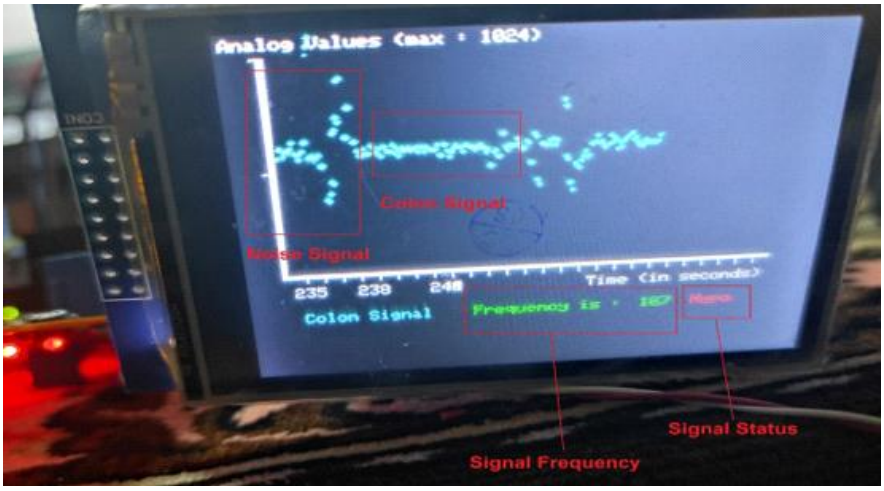


Figure 5. 5 Colon signal, frequency and status on TFT LCD

Figure 5. 6 Colon signal, frequency and status on TFT LCD

Chapter six

Result and conclusion

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Chapter six

Result and conclusion

This chapter presents the results of the system implemented, and the conclusions of the project described in the document. The idea description and objectives of the research, outlined in chapter one, are reviewed. Thenindicates extra suggestion for future work.

• System result

After the project is installed, its readings are examined on ten persons and then compared with the doctor result. The result of all readings is approximately close to the real readings. Table 6.1 shows these readings, also the signal of colon for normal person shows in figure 6.1.

#	Frequency	Result	State

1	192	Hypo	Normal
2	311	Hypo	Normal
3	389	Hypo	Normal
4	252	Hypo	Normal
5	589	Hyper	Abnormall (Injured(
6	288	Hypo	Normal
7	159	Hypo	Normal
8	355	Hypo	Normal
9	201	Hypo	Normal
10	316	Hypo	Normal

Table 6. 1 The Result of the System

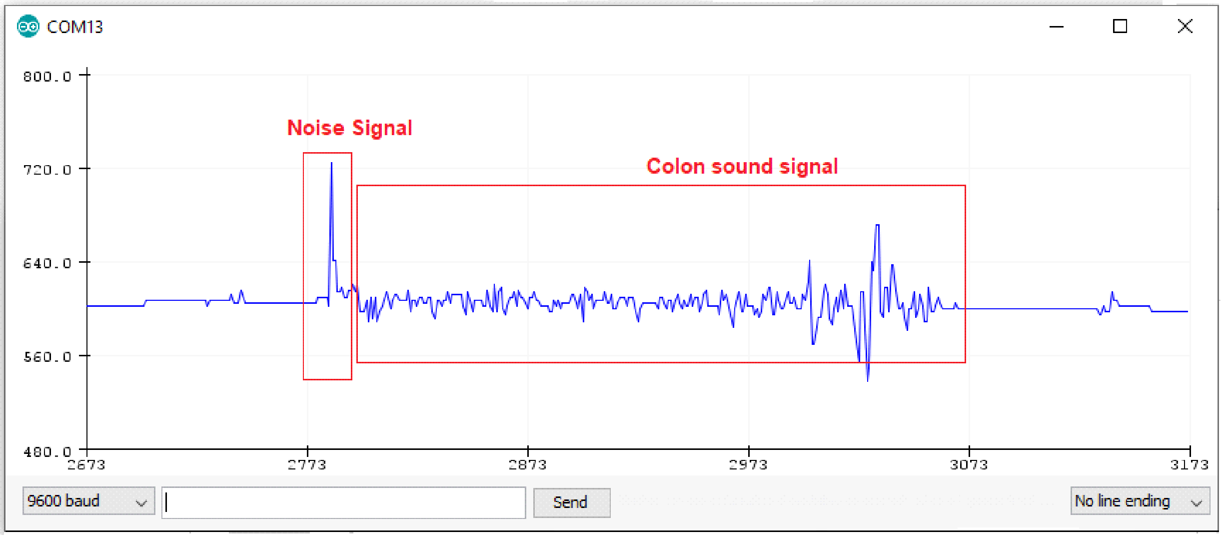

Figure 6. 1 colon signal for normal person

• Conclusion

A special microphone is used to collect a colon sound that helps a patients and doctors to detect the status of the patient and then displaying it. After designing, processing, implementing and testing the system, the overall system can provide the following features: In this project a diagnostic system has been built to examine the patient statues. The colon sound examine system are designed to displaying the signal continuously. This diagnose gives comfortability for patient and doctor since it is non-invasive, not costly. In IBS the movement of the bowel is hyperactive

The objectives of the project were listed in chapter one, all of them done through our work. Moreover, the results obtained through meeting these objectives are stated. We conclude that we have the ability to diagnose IBS in non-invasive way via movement of the bowel.

• Recommendations

In this project, the system was designed to examine the colon sound by recording the signal and then displaying on the Arduino Microcontroller plotter and TFT LCD, but this examine are not sufficient to give the exact total diagnostic, so this project needs more research time to improve its efficiency and some features could be added like store a colon sound and then displaying it on headphone with less noise, if it possible to detect the amplitude of the bowel sound that may be useful.

• Challenges

While designing the system, there are many challenges have been faced, such as:

- If the amount of fat in the abdomen and around the colon is high, the possibility of hearing the voice and assessing the situation becomes difficult.
- Any noise that occurs near the patient or moving the microphone during the examination greatly effects on the result and the examination process.
- Calculating the frequency of the sound wave that produced by the colon sound was complicated and needed further refinement to obtain the exact frequency.

Arduino Coad:

final

```
#include <Elegoo_GFX.h>
#include <Elegoo_TFTLCD.h>

#define LCD_CS A3
#define LCD_CD A2
#define LCD_WR A1
#define LCD_RD A0
#define LCD_RESET A4

#define BLACK   0x0000
#define BLUE    0x001F
#define RED     0xF800
#define GREEN   0x07E0
#define CYAN    0x07FF
#define MAGENTA 0xF81F
#define YELLOW  0xFFE0
#define WHITE   0xFFFF
#define GREY      0xCE79
#define LIGHTGREY 0xDEDB



// regions used for touch detection
int TopBtnArea[] = {0, 0, 0, 0};
int CenterBtnArea[] = {0, 0, 0, 0};
int BottomBtnArea[] = {0, 0, 0, 0};
int DataArea[] = {0, 0, 0, 0};
int DoneBtnArea[] = {220, 35, 65, 30};
```

final

```
// arrow buttons
int LeftArrowArea[] = { 33, 181, 41, 27}; // touch region for left arrow
int RightArrowArea[] = { 76, 181, 42, 27 }; // touch region for right arrow



Elegoo_TFTLCD tft(LCD_CS, LCD_CD, LCD_WR, LCD_RD, LCD_RESET);

int incrementation = 24;

int scale1 = 1;
int scale2 = 2;
int scale4 = 4;
int scale8 = 8;

float x1=0;
float a1;
float y1=0;
float m1;
float t=0;
int r=0;
int menuState;


int high_time;
int low_time;
float time_period;
```

final

```
float frequency;




int x=0;
int a;
float y=0;
int m;

void setup(void) {


Serial.begin(9600);
tft.reset();
tft.begin(0x9341);
tft.fillScreen(BLACK);
tft.setRotation(1);
tft.fillRect(20,15,3,145,WHITE);
tft.fillRect(20,160,272,3,WHITE);




tft.setCursor(30,190);
tft.setTextColor(CYAN);
```

final

```
tft.setTextSize(1);
tft.println("Colon Signal");







tft.drawLine(33,160,33,166,WHITE);
tft.drawLine(43,160,43,166,WHITE);
tft.drawLine(53,160,53,166,WHITE);
tft.drawLine(63,160,63,166,WHITE);
tft.drawLine(73,160,73,166,WHITE);
tft.drawLine(83,160,83,166,WHITE);
tft.drawLine(93,160,93,166,WHITE);
tft.drawLine(103,160,103,166,WHITE);
tft.drawLine(113,160,113,166,WHITE);
tft.drawLine(123,160,123,166,WHITE);
tft.drawLine(133,160,133,166,WHITE);
tft.drawLine(143,160,143,166,WHITE);
tft.drawLine(153,160,153,166,WHITE);
tft.drawLine(163,160,163,166,WHITE);
tft.drawLine(173,160,173,166,WHITE);
tft.drawLine(183,160,183,166,WHITE);
tft.drawLine(193,160,193,166,WHITE);
tft.drawLine(203,160,203,166,WHITE);
tft.drawLine(213,160,213,166,WHITE);
tft.drawLine(223,160,223,166,WHITE);
tft.drawLine(233,160,233,166,WHITE);
```

final

```
tft.drawLine(243,160,243,166,WHITE);
tft.drawLine(253,160,253,166,WHITE);
tft.drawLine(263,160,263,166,WHITE);
tft.drawLine(273,160,273,166,WHITE);
tft.drawLine(283,160,283,166,WHITE);
tft.drawLine(17,87,20,87,WHITE);
tft.drawLine(17,15,20,15,WHITE);
```

```
tft.drawLine(33,160,33,166,WHITE);
tft.drawLine(43,160,43,166,WHITE);
tft.drawLine(53,160,53,166,WHITE);
tft.drawLine(63,160,63,166,WHITE);
tft.drawLine(73,160,73,166,WHITE);
tft.drawLine(83,160,83,166,WHITE);
tft.drawLine(93,160,93,166,WHITE);
tft.drawLine(103,160,103,166,WHITE);
tft.drawLine(113,160,113,166,WHITE);
```

final

```
tft.drawLine(113,160,113,166,WHITE);
tft.drawLine(123,160,123,166,WHITE);
tft.drawLine(133,160,133,166,WHITE);
tft.drawLine(143,160,143,166,WHITE);
tft.drawLine(153,160,153,166,WHITE);
tft.drawLine(163,160,163,166,WHITE);
tft.drawLine(173,160,173,166,WHITE);
tft.drawLine(183,160,183,166,WHITE);
tft.drawLine(193,160,193,166,WHITE);
tft.drawLine(203,160,203,166,WHITE);
tft.drawLine(213,160,213,166,WHITE);
tft.drawLine(223,160,223,166,WHITE);
tft.drawLine(233,160,233,166,WHITE);
tft.drawLine(243,160,243,166,WHITE);
tft.drawLine(253,160,253,166,WHITE);
tft.drawLine(263,160,263,166,WHITE);
tft.drawLine(273,160,273,166,WHITE);
tft.drawLine(283,160,283,166,WHITE);
tft.drawLine(17,87,20,87,WHITE);
tft.drawLine(17,15,20,15,WHITE);




tft.setCursor(3,3);
tft.setTextColor(WHITE);
tft.setTextSize(1);
tft.println("Analog Values (max : 1024) ");
```

final

```
tft.setCursor(188,171);
tft.setTextColor(WHITE);
tft.setTextSize(1);
tft.println("Time (in seconds)");



tft.setCursor(10,164);
tft.setTextColor(WHITE);
tft.setTextSize(1);
tft.println("0");



tft.setCursor(31,170);
tft.setTextColor(WHITE);
tft.setTextSize(1);
tft.println(scale1);



tft.setCursor(41,170);
tft.setTextColor(WHITE);
tft.setTextSize(1);
```

final

```
tft.setTextSize(1);
tft.println(scale2);




tft.setCursor(61,170);
tft.setTextColor(WHITE);
tft.setTextSize(1);
tft.println(scale4);




tft.setCursor(101,170);
tft.setTextColor(WHITE);
tft.setTextSize(1);
tft.println(scale8);








}
void loop(void) {
```

final §

```
}
void loop(void) {

unsigned long start = micros();

//int vala = analogRead(A15);
//int valab = map(vala,0,1024,159,15);
//tft.fillCircle(incrementation,valab,1,CYAN);


xl= analogRead(A15);
yl=xl-al;



if (yl == 1 || yl == -1){

  xl=al;

 }

t=abs(yl);
```

final §

```
ml=(2.3*xl);
Serial.println(ml);
al=xl;
int valab = map(ml,0,1024,159,1);

tft.fillCircle(incrementation,valab,1,CYAN);






high_time=pulseIn(xl,HIGH);
low_time=pulseIn(xl,LOW);


time_period=high_time+low_time;
time_period=time_period/1000;
frequency=1000/time_period;


if (frequency > 500){



 tft.setCursor(125,190);
  tft.setTextColor(GREEN);
  tft.setTextSize(1);
```

final §

```
if (frequency > 500){



 tft.setCursor(125,190);
  tft.setTextColor(GREEN);
  tft.setTextSize(1);
  tft.println("Frequency is :");
  tft.fillRect( 220, 190, 50, 50, BLACK ); // Clear the text area
  tft.setCursor(220,190);
  tft.setTextColor(GREEN);
  tft.setTextSize(1);
  tft.print(frequency);

  tft.setCursor(250,190);
  tft.setTextColor(RED);
  tft.setTextSize(1);
  tft.println("Hyper");

//   Serial.print("Frequency");
//   Serial.print(r);
//   Serial.print("   The Status : Hypo");
```

final §

```
if (frequency < 500){



   tft.setCursor(125,190);
  tft.setTextColor(GREEN);
  tft.setTextSize(1);
  tft.println("Frequency is :");
  tft.fillRect( 220, 190, 50, 50, BLACK ); // Clear the text area
  tft.setCursor(220,190);
  tft.setTextColor(GREEN);
  tft.setTextSize(1);
  tft.print(frequency);

  tft.setCursor(250,190);
  tft.setTextColor(RED);
  tft.setTextSize(1);
  tft.println("Hypo");






  }
```

final §

```
  }
//int x = analogRead(A15);
//y=x-a;
//if (y == 1 || y == -1){

  //x=a;

// }

//m=(5*x);


//a=x;
//int valab = map(m,0,1024,159,1);

//tft.fillCircle(incrementation,valab,1,CYAN);
//tft.drawFastHLine(incrementation,valab,2,CYAN);
//tft.drawLine(incrementation,valab,incrementation+0.1,valab+0.1,CYAN);
//int valc = analogRead(A13);
//int valcb = map(valc,0,1024,159,15);
//tft.fillCircle(incrementation,valcb,1,GREEN);

incrementation++;

//delay(50);

if(scale1==27){
tft.fillRect(3,120,16,60,BLACK);
}
```

final §

```
#ifdef DEBUG

      // TFT Calibration
      Serial.print("Raw X = "); Serial.print(p.x);
      Serial.print(" Raw Y = "); Serial.println(p.y);
      Serial.print("Pressure = "); Serial.println(p.z);
      Serial.print("Screen XX: " );
      Serial.print(XX);
      Serial.print("  Screen YY:");
      Serial.println(YY);
      Serial.print("Raw Sensor 1 = "); Serial.println(sensor1Val);
      Serial.print("Raw Sensor 2 = "); Serial.println(sensor2Val);
      Serial.print("Loop counter "); Serial.println(loopCounter);

#endif // DEBUG ////////////////////////////////////////////////////////////


if(incrementation>282){
tft.fillRect(10,166,100,12,BLACK);
scale1 = scale1+26;
scale2 = scale2+26;
scale4 = scale4+26;
scale8 = scale8+26;
tft.setCursor(26,170);
tft.setTextColor(WHITE);
tft.setTextSize(1);
tft.println(scale1);
```

final §

```
tft.setTextSize(1);
tft.println(scale1);
tft.setCursor(41,170);
if(scale2>10){
tft.setCursor(39,170);
}
```

```
// the raw value can be used, but this can range from 0-1023 so some adjustments may be needed
      // here to make the graph more readable, otherwise values will easily go off the screen
      //int sensor1Transposed = sensor1Val;

      // the value for this sensor is different so it needs to be adjusted to fit nice on the display
      // the more division used the less granular the data becomes
      // the raw data was too variable and higher than the other sensor
      // so to get them to fit together nicely, one or both sensor needs to be adjusted.
```

```
tft.setCursor(61,170);
tft.setTextColor(WHITE);
tft.setTextSize(1);
```

final §

```
tft.setTextSize(1);
tft.println(scale4);
tft.setCursor(101,170);
tft.setTextColor(WHITE);
tft.setTextSize(1);
tft.println(scale8);
tft.fillRect(23,14,269,146,BLACK);

incrementation = 24;
}
return micros() - start;
}




void showMenuOptions() // shows buttons and sets options
{

  int borderSize = 30; // pixels
  int marginSize = 10;

  tft.setTextColor( YELLOW);
  tft.fillRect(borderSize, borderSize,  tft.width() - (borderSize * 2), tft.height() - (borderSize * 2), LIGHTGREY);

  tft.drawRect(borderSize, borderSize,  tft.width() - (borderSize * 2), tft.height() - (borderSize * 2), RED);
  tft.setCursor((tft.width() / 2) - borderSize,  borderSize + marginSize);
```

final §

```
  tft.setCursor((tft.width() / 2) - borderSize,  borderSize + marginSize);
  tft.setTextSize(3);
  tft.println("Menu");

  int indentRight = 40;
  int indentTop = 60; // where to start the text block
  int lineHeight = 30;
  int buttonSize = 83;

  tft.setCursor(  indentRight, indentTop = indentTop + 20);

  // set the button region so a press can be determined
  TopBtnArea[0] = indentRight - 5;
  TopBtnArea[1] = indentTop - 5;
  TopBtnArea[2] = buttonSize;
  TopBtnArea[3] = lineHeight + 7;



  if (menuState == 1) // top
  {
    // change button
    tft.fillRect(TopBtnArea[0], TopBtnArea[1], TopBtnArea[2], TopBtnArea[3], GREEN);
    tft.drawRect(TopBtnArea[0], TopBtnArea[1], TopBtnArea[2], TopBtnArea[3], RED);
//    setDirectionButtons();
//    setColorOptions();
//    fillCurrentColor(TopGraphColor);
```

final §

```
tft.drawLine(33,160,33,166,WHITE);
tft.drawLine(43,160,43,166,WHITE);
tft.drawLine(53,160,53,166,WHITE);
tft.drawLine(63,160,63,166,WHITE);
tft.drawLine(73,160,73,166,WHITE);
tft.drawLine(83,160,83,166,WHITE);
tft.drawLine(93,160,93,166,WHITE);
tft.drawLine(103,160,103,166,WHITE);
tft.drawLine(113,160,113,166,WHITE);
tft.drawLine(123,160,123,166,WHITE);
tft.drawLine(133,160,133,166,WHITE);
tft.drawLine(143,160,143,166,WHITE);
tft.drawLine(153,160,153,166,WHITE);
tft.drawLine(163,160,163,166,WHITE);
tft.drawLine(173,160,173,166,WHITE);
tft.drawLine(183,160,183,166,WHITE);
tft.drawLine(193,160,193,166,WHITE);
tft.drawLine(203,160,203,166,WHITE);
tft.drawLine(213,160,213,166,WHITE);
tft.drawLine(223,160,223,166,WHITE);
tft.drawLine(233,160,233,166,WHITE);
tft.drawLine(243,160,243,166,WHITE);
tft.drawLine(253,160,253,166,WHITE);
tft.drawLine(263,160,263,166,WHITE);
tft.drawLine(273,160,273,166,WHITE);
tft.drawLine(283,160,283,166,WHITE);
tft.drawLine(17,87,20,87,WHITE);
```

final §

```
  }

  else
  {
    //reset button
    tft.fillRect(TopBtnArea[0], TopBtnArea[1], TopBtnArea[2], TopBtnArea[3], WHITE);
    tft.drawRect(TopBtnArea[0], TopBtnArea[1], TopBtnArea[2], TopBtnArea[3], RED);
  }
  tft.setTextSize(2);
  tft.setTextColor( BLACK);
  tft.setCursor( indentRight + 5, indentTop + 7 );
  tft.print(" TOP ");

  CenterBtnArea[0] = indentRight - 5 + buttonSize;
  CenterBtnArea[1] = indentTop - 5;
  CenterBtnArea[2] = buttonSize;
  CenterBtnArea[3] = lineHeight + 7;

  if (menuState == 2)
  {

    tft.fillRect(CenterBtnArea[0], CenterBtnArea[1], CenterBtnArea[2], CenterBtnArea[3], GREEN);
    tft.drawRect(CenterBtnArea[0], CenterBtnArea[1], CenterBtnArea[2], CenterBtnArea[3], RED);
//    setDirectionButtons();
//    setColorOptions();
//    fillCurrentColor(CenterGraphColor);
```

final §

```
tft.drawLine(33,160,33,166,WHITE);
tft.drawLine(43,160,43,166,WHITE);
tft.drawLine(53,160,53,166,WHITE);
tft.drawLine(63,160,63,166,WHITE);
tft.drawLine(73,160,73,166,WHITE);
tft.drawLine(83,160,83,166,WHITE);
tft.drawLine(93,160,93,166,WHITE);
tft.drawLine(103,160,103,166,WHITE);
tft.drawLine(113,160,113,166,WHITE);
tft.drawLine(123,160,123,166,WHITE);
tft.drawLine(133,160,133,166,WHITE);
tft.drawLine(143,160,143,166,WHITE);
tft.drawLine(153,160,153,166,WHITE);
tft.drawLine(163,160,163,166,WHITE);
tft.drawLine(173,160,173,166,WHITE);
tft.drawLine(183,160,183,166,WHITE);
tft.drawLine(193,160,193,166,WHITE);
tft.drawLine(203,160,203,166,WHITE);
tft.drawLine(213,160,213,166,WHITE);
tft.drawLine(223,160,223,166,WHITE);
tft.drawLine(233,160,233,166,WHITE);
tft.drawLine(243,160,243,166,WHITE);
tft.drawLine(253,160,253,166,WHITE);
tft.drawLine(263,160,263,166,WHITE);
tft.drawLine(273,160,273,166,WHITE);
tft.drawLine(283,160,283,166,WHITE);
tft.drawLine(17,87,20,87,WHITE);
tft.drawLine(17,15,20,15,WHITE);
```

final §

```
  tft.drawRect(DataArea[0], DataArea[1], DataArea[2], DataArea[3], RED);

  tft.setTextSize(1);
  tft.setTextColor( YELLOW); // converts the pressure reading to a color
  tft.setCursor(  indentRight, indentTop = indentTop + lineHeight);

  tft.println("DATA CAPTURE");
  tft.setCursor(  indentRight, indentTop = indentTop + lineHeight);

  tft.setTextColor( WHITE);
  tft.print("Raw X = "); tft.print(x);
  tft.print(" Raw Y = "); tft.println(y);
  tft.setCursor(  indentRight, indentTop = indentTop + lineHeight);

  tft.print("Pressure = "); tft.println(z);
  tft.setCursor(  indentRight, indentTop = indentTop + lineHeight);

  tft.print("ScreenX: " ); tft.print(XX);
  tft.print("  ScreenY:"); tft.println(YY);
  tft.setCursor(  indentRight, indentTop = indentTop + lineHeight);

//  tft.print("Raw Sensor 1 "); tft.println(sensor1Val);
  tft.setCursor(  indentRight, indentTop = indentTop + lineHeight);

//  tft.print("Raw Sensor 2 "); tft.println(sensor2Val);
  tft.setCursor(  indentRight, indentTop = indentTop + lineHeight);
```

final §

```
/////////////////////

void drawDoneButton()
{
  tft.fillRect(DoneBtnArea[0], DoneBtnArea[1], DoneBtnArea[2], DoneBtnArea[3], BLACK);
  tft.drawRect(DoneBtnArea[0], DoneBtnArea[1], DoneBtnArea[2], DoneBtnArea[3], WHITE);

  tft.setCursor(DoneBtnArea[0] + 10, DoneBtnArea[1] + 7);
  tft.setTextColor(WHITE);
  tft.print("Done");




  tft.drawLine(33,160,33,166,WHITE);
tft.drawLine(43,160,43,166,WHITE);
tft.drawLine(53,160,53,166,WHITE);
tft.drawLine(63,160,63,166,WHITE);
tft.drawLine(73,160,73,166,WHITE);
tft.drawLine(83,160,83,166,WHITE);
tft.drawLine(93,160,93,166,WHITE);
tft.drawLine(103,160,103,166,WHITE);
tft.drawLine(113,160,113,166,WHITE);
tft.drawLine(123,160,123,166,WHITE);
tft.drawLine(133,160,133,166,WHITE);
tft.drawLine(143,160,143,166,WHITE);
tft.drawLine(153,160,153,166,WHITE);
tft.drawLine(163,160,163,166,WHITE);
```

final §

```
tft.drawLine(103,160,103,166,WHITE);
tft.drawLine(113,160,113,166,WHITE);
tft.drawLine(123,160,123,166,WHITE);
tft.drawLine(133,160,133,166,WHITE);
tft.drawLine(143,160,143,166,WHITE);
tft.drawLine(153,160,153,166,WHITE);
tft.drawLine(163,160,163,166,WHITE);
tft.drawLine(173,160,173,166,WHITE);
tft.drawLine(183,160,183,166,WHITE);
tft.drawLine(193,160,193,166,WHITE);
tft.drawLine(203,160,203,166,WHITE);
tft.drawLine(213,160,213,166,WHITE);
tft.drawLine(223,160,223,166,WHITE);
tft.drawLine(233,160,233,166,WHITE);
tft.drawLine(243,160,243,166,WHITE);
tft.drawLine(253,160,253,166,WHITE);
tft.drawLine(263,160,263,166,WHITE);
tft.drawLine(273,160,273,166,WHITE);
tft.drawLine(283,160,283,166,WHITE);
tft.drawLine(17,87,20,87,WHITE);
tft.drawLine(17,15,20,15,WHITE);



}
//////////////////////////////////////////////////////////////////////////////////////////////////////
//   drawDoneButton();

//}
```

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APPENDIX

Datasheets

Appendix A

CMA-4544PF-W mic datasheet

Appendix B

LM 358

Appendix B

Arduino Mega 2560 Datasheet