Palestine Polytechnic University

College of Engineering

Design of a Closed Loop Nebulizer System and Study its Effect on ECG.

By

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الاهداء

أيام مضت من عمرنا بدأناها بخطوة وها نحن اليوم نقطف ثمار مسيرة أعوام كان هدفنا فيها واضح وكنا نسعى في كل يوم لتحقيقه والوصول له مهما كان صعبا وها نحن اليوم نقف أمامكم وها نحن وصلنا وبيدينا شعلة علم وسنحرص كل الحرص عليها حتى لا تنطفئ ونشكر الله أولا وأخير على أن وفقنا وساعدنا على ذلك.

ثم نتقدم بالشكر إلى القلب الحنون من كانت بجانبنا بكل المراحل التي مضت من تلذذت بالمعاناه وكانت شمعه تحترق لتنيردربنا. **الى أمهاتنا الحبيبات**.

والى من علمنا أن نقف وكيف نبدأ الألف ميل بخطوة إلى يدنا اليمنى إلى من علمنا الصعود وعيناه تراقبنا.**الى والدنا**.

لمن كان يتحملنا بأخطائنا وكانوا عوناً لنا.**الى أخوتنا واخواتنا**.

الى من انجب اهالينا وفخروا لوصولنا الى هنا ، نهدي نجاحنا اليهم ،الى من تحت التراب منهم وكنا نتمنى ان يروا انجازنا هذا.**الى اجدادنا وجداتنا الأحياء منهم والأموات**.

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ولن ننسى وطننا المعبق بأريج الحب لن ننساه وسنقدم كل مابوسعنا له وسنجعل كل ركن به يشهد بما سنقدم وسنكون كالمطر ولن نبخل بما تعلمنا وسنكون كالماء أينما وقعنا نفعنا.

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Abstract

Nebulizers are classic pulmonary drug delivery devices that convert liquid medication into a mist. The mist is easy to inhale, making it useful for treating infants, children, and others who may have difficulty using respiratory inhalers properly. At present all commercially available nebulizers are open loop system. Hence, giving an excess amount of mist to the patient may lead to barns or suffocation of the patient, specially the children whom cannot express about the feeling.

The project aimed to explore the impacts of nebulisation process on respiratory change and ECG signals by monitoring them, before and after treatment. Furthermore, A light weight, closed loop nebulizer system is designed in the project to control nebulisation rate according to the measured respiratory change ; If the respiratory is abnormal during treatment, then the amount of mist reduced. If there still abnormal, the nebulizer will be turned off and alarm system will be activated.

ملخص المشروع

البخاخات هي أجهزة تقوم بإيصال الأدوية المستخدمة في الأمراض الرئوية التي تحول الأدوية السائلة إلى بخار. من السهل استنشاق الرذاذ ، مما يجعله مفيدًا لعلاج الرضع والأطفال وغيرهم ممن قد يجدون صعوبة في استخدام أجهزة الاستنشاق التنفسي بشكل صحيح. في الوقت الحاضر جميع البخاخات المتاحة تجاريا هي نظام حلقة مفتوحة. وبالتالي ، فإن إعطاء كمية كبيرة من البخار للمريض قد يؤدي إلى الحاق الضرر أو اختناق المريض ، وخاصة الأطفال الذين لا يستطيعون التعبير عن هذا الشعور.

يهدف المشروع إلى استكشاف آثار عملية البخاخات على التنفس وإشارات تخطيط القلب عن طريق مراقبتها ، قبل وبعد العلاج. علاوة على ذلك ، تم تصميم نظام البخاخات ذات الحلقة المغلقة خفيفة الوزن في المشروع للتحكم في معدل البخاخات وفقًا لـ تنفس المريض المحسوس؛ إذا انخفض النفس أثناء العلاج ، فإن كمية البخار تنخفض. إذا كان هناك انخفاض حاد في النفس ، سيتم إيقاف تشغيل البخاخات وسيتم تنشيط نظام الإنذار.

Contents

List of Table

List of Figures.

Chapter one

Introduction

Respiratory diseases are leading causes of death and disability in the world. About 65 million people suffer from chronic obstructive pulmonary disease (COPD) and 3 million die from it each year, making it the third leading cause of death worldwide. About 334 million people suffer from asthma, the most common chronic disease of childhood affecting 14% of all children globally. Pneumonia kills millions of people annually and is a leading cause of death among children under 5 years old. Over 10 million people develop tuberculosis and 1.4 million die from it each year, making it the most common lethal infectious disease.

A lot of progress has been made in increasing life expectancy and reducing the burden of many diseases such as polio. Hence, medical engineering was launched to design a medical device for treating respiratory diseases. Open-loop nebulizer is a drug delivery device used to administer medication in the form of a mist inhaled into the lungs. asthma, cystic fibrosis, COPD and other respiratory diseases or disorders. It uses oxygen, compressed air or ultrasonic power to break up solutions and suspensions into small aerosol droplets that can be directly inhaled from the mouthpiece of the device, and it is worth mentioning that Nebulizers may not be ideal devices to generate a therapeutically effective aerosol from a novel drug formulation. This could lead to overdosing or underdosing of the lung as nebulizer performance can vary widely when used to aerosolize a drug either not intended to be delivered in an aerosolized form, or designed to be used in a different nebulizer. Off-label use of drug and/or delivery devices with a failure to match the drug to the delivery device can lead to problems**.** The idea of this project is to overcome the preceding problems by designed a closed-loop nebulizer that can automatically change the patient nebulization dose depending on his respiratory rate.[1]

1.1 Project motivation.

Nebulizers may not be ideal devices to generate a therapeutically effective aerosol from a novel drug formulation. This could lead to overdosing or underdosing of the lung as nebulizer performance can vary widely when used to aerosolize a drug either not intended to be delivered in an aerosolized form, or designed to be used in a different nebulizer. Off-label use of drug and/or delivery devices with a failure to match the drug to the delivery device can lead to problems.

The idea of this project was to overcome the dose problems by designed a closed-loop nebulizer system, that has the capability to measure the respiration chang during the administration of medicine, and automatically control the dose of administration.

1.2 Project aims.

- Design a Portable closed loop nebulizer system.
- Design Respiratory change monitoring system and apply the feedback to the nebulizer system.
- Design an ECG system.
- Study the effects of nebulizer on ECG waveform.

1.3 Project Importance.

Design a portable device with light weight device, relatively low cost, safe, and comfortable medical device that can be used in home.

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1.4 Time schedule of the semester.

Table 1.1 Time schedual of the semester.

Week / Activities	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Finding Project Idea	■	■													
Proposal		■	■	■											
Collecting data		■	■	■	■	■	■	■	■						
Documentation			■	■	■	■	■	■	■	■	■	■	■	■	
Preparing for presentation													■	■	■
Print documentation															■

Table 2.2 Time schedual of the second semester.

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

1.5 List of Abbreviations.

Abbreviations	Full Word
COPD	Chronic obstructive pulmonary disease
WHO	World Health Organization
SVC	Superior Vena Cava
Bpm	beats per minute
SA node	A stands for sinoatrial
AV node	atrioventricular
CO_2	Carbon dioxide
O_2	Oxygen
pMDI	Pressurized Metered Dose Inhale
ECG	Electrocardiography
Input/output	I/O
PWM	Pulse Width Modulation

Chapter Two

Anatomy and Physiology of Cardiovascular and Respiratory Systems.

2.1 Cardiovascular system.

The cardiovascular system is sometimes called the blood-vascular, or simply the circulatory, system. It consists of the heart, which is a muscular pumping device, and a closed system of vessels called arteries, veins, and capillaries. As the name implies, blood contained in the circulatory system is pumped by the heart around a closed circle or circuit of vessels as it passes again and again through the various "circulations" of the body.[3]

2.1.1 Structure of Cardiovascular System

1. **Heart**

The heart is a muscle about the size of a fist, and is roughly cone-shaped, it is about 12cm long, 9cm across the broadest point and about 6cm thick. The pericardium is a fibrous covering which wraps around the whole heart. It holds the heart in place but allows it to move as it beats. The wall of the heart itself is made up of a special type of muscle called cardiac muscle, the heart has two sides, the right side and the left side. The heart has four chambers. The left and right side each have two chambers, a top chamber and a bottom chamber. The two top chambers are known as the left and right atria (singular: atrium). The atria receive blood from different sources. The left atrium receives blood from the lungs and the right atrium receives blood from the rest of the body. The bottom two chambers are known as the left and right ventricles. The ventricles pump blood out to different parts of the body. The right ventricle pumps blood to the lungs while the left ventricle pumps out blood to the rest of the body. The ventricles have much thicker walls than the atria which allows them to perform more work by pumping out blood to the whole body as shown in figure 2.1. [3]

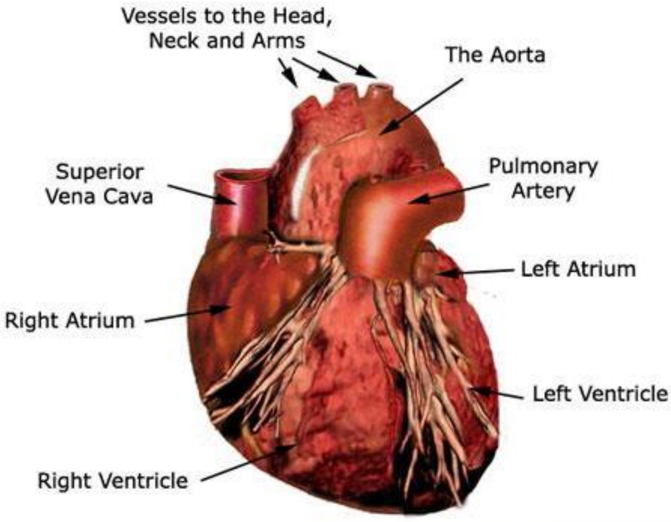

Figure2.1 Structure of heart. [4]

2. Blood Vessels

Blood Vessels are tubes which carry blood. Veins are blood vessels which carry blood from the body back to the heart. Arteries are blood vessels which carry blood from the heart to the body. There are also microscopic blood vessels which connect arteries and veins together called capillaries. There are a few main blood vessels which connect to different chambers of the heart. The aorta is the largest artery in our body. The left ventricle pumps blood into the aorta which then carries it to the rest of the body through smaller arteries. The pulmonary trunk is the large artery which the right ventricle pumps into. It splits into pulmonary arteries which take the blood to the lungs. The pulmonary veins take blood from the lungs to the left atrium. All the other veins in our body drain into the inferior vena cava (IVC) or the superior vena cava (SVC). These two large veins then take the blood from the rest of the body into the right atrium. [5]

3. Valves

Valves are fibrous flaps of tissue found between the heart chambers and in the blood vessels. They are rather like gates which prevent blood from flowing in the wrong direction. They are found in a number of places. Valves between the atria and ventricles are known as the right and left atrioventricular valves, otherwise known as the tricuspid and mitral valves respectively. Valves between the ventricles and the great arteries are known as the semilunar valves. The aortic valve is found at the base of the aorta, while the pulmonary valve is found the base of the pulmonary trunk. There are also many valves found in veins throughout the body. However, there are no valves found in any of the other arteries besides the aorta and pulmonary trunk. [6]

2.1.3 The Circulatory System and Blood Flow

The circulatory system is an organ system that permits blood and lymph circulation to transport nutrients (such as amino acids and electrolytes), oxygen, carbon dioxide, hormones, blood cells, etc. to and from cells in the body to nourish it and help to fight diseases, stabilize body temperature and pH, and to maintain homeostasis. [7]
The circulatory system divided in two types:

1. **Pulmonary Circulation**

The pulmonary circulatory system shown in figure 2.2 is the portion of the cardiovascular system in which deoxygenated blood is pumped away from the right ventricle via the pulmonary artery, to the lungs and returned, oxygenated, to the left atrium via the pulmonary vein, Deoxygenated blood from the superior and inferior vena cava, enters the right atrium of the heart and flows through the tricuspid valve (right atrioventricular valve)into the right ventricle, from which it is then pumped through the pulmonary semi lunar valve into the, pulmonary artery to the lungs. Gas exchange occurs in the lungs, whereby CO_2 is released from the blood, and oxygen is absorbed, pulmonary vein returns the now oxygen-rich blood to the left atrium. [8]

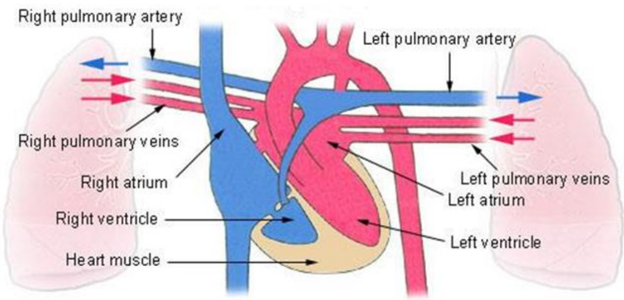

Figure2.2 Pulmonary circulations. [9]

2. Systemic Circulation

Systemic circulation as shown in figure 2.3 is the circulation of the blood to all parts of the body except the lungs. Systemic circulation is the portion of the cardiovascular system which transports oxygenated blood away from the heart through the aorta from the left ventricle where the blood has been previously deposited from pulmonary circulation, to the rest of the body, and returns deoxygenated blood back to the heart. Systemic circulation is, distance-wise, much longer than pulmonary circulation, transporting blood to every part of the body. [9]

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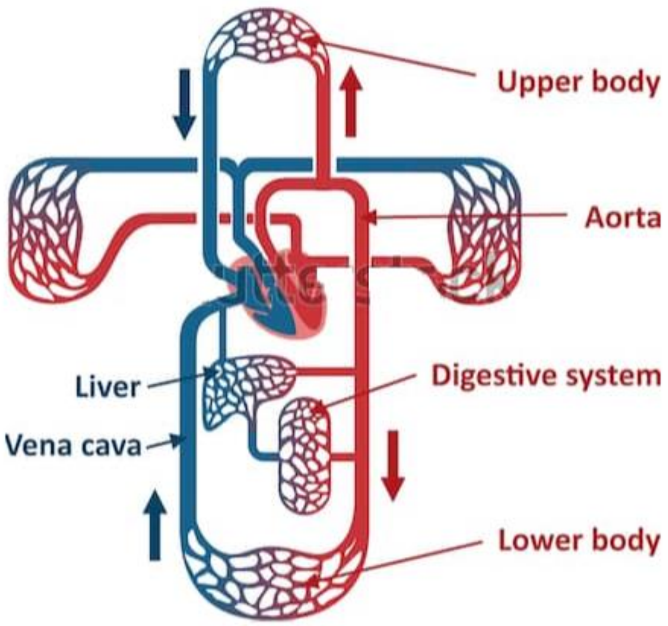


Figure2.3 Systemic circulation. [10]

2.2 Electrocardiogram (ECG).

An electrocardiogram records the electrical signals in your heart. It's a common test used to detect heart problems and monitor the heart's status in many situations. Electrocardiograms — also called ECGs or EKGs — are often done in a doctor's office, a clinic or a hospital room. And they've become standard equipment in operating rooms and ambulances, See Figure 2.4.

An ECG is a noninvasive, painless test with quick results. During an ECG, sensors (electrodes) that can detect the electrical activity of your heart are attached to your chest and sometimes your limbs. These sensors are usually left on for just a few minutes.[11]

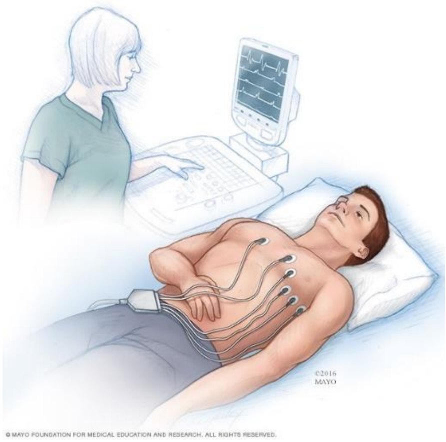


Fig 2.4 ECG.[12]

2.3 Respiratory System

The respiratory system consists of all the organs involved in breathing. These include the nose, pharynx, larynx, trachea, bronchi and lungs. The respiratory system does two very important things: it brings oxygen into our bodies, which we need for our cells to live and function properly; and it helps us get rid of carbon dioxide, which is a waste product of cellular function. The nose, pharynx, larynx, trachea and bronchi all work like a system of pipes through which the air is funneled down into our lungs. There, in very small air sacs called alveoli, oxygen is brought into the bloodstream and carbon dioxide is pushed from the blood out into the air. When something goes wrong with part of the respiratory system, such as an infection like pneumonia, it makes it harder for us to get the oxygen we need and to get rid of the waste product carbon dioxide. Common respiratory symptoms include breathlessness, cough, and pain, See Figure 2.5.

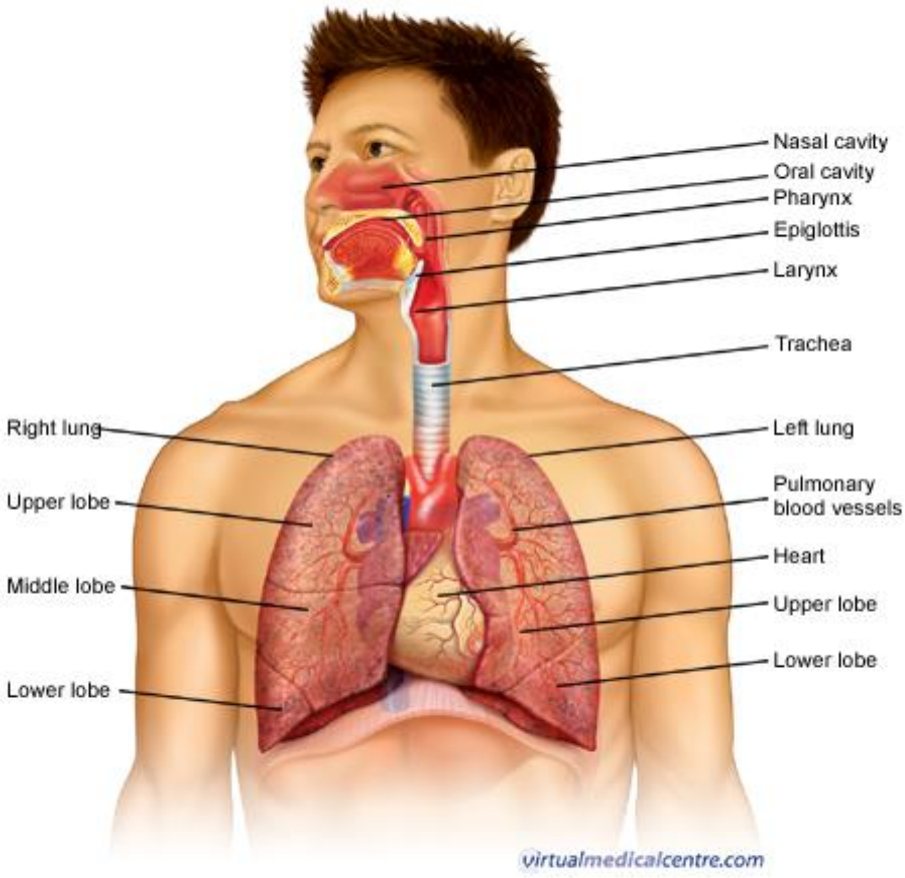


Fig 2.5 Structure of Respiratory System. [13]

The Upper Airway and Trachea

When you breathe in, air enters your body through your nose or mouth. From there, it travels down your throat through the larynx (or voice box) and into the trachea (or windpipe) before entering your lungs. All these structures act to funnel fresh air down from the outside world into your body. The upper airway is important because it must always stay open for you to be able to breathe. It also helps to moisten and warm the air before it reaches your lungs.

2.3.1 Structure of The Lungs

The lungs are paired, cone-shaped organs which take up most of the space in our chests, along with the heart. Their role is to take oxygen into the body, which we need for our cells to live and function properly, and to help us get rid of carbon dioxide, which is a waste product. We each have two lungs, a left lung and a right lung. These are divided up into 'lobes', or big sections of tissue separated by 'fissures' or dividers. The right lung has three lobes but the left lung has only two, because the heart takes up some of the space in the left side of our chest. The lungs can also be divided up into even smaller portions, called 'bronchopulmonary segments, see Figure 2.6.

These are pyramidal-shaped areas which are also separated from each other by membranes. There are about 10 of them in each lung. Each segment receives its own blood supply and air supply.

2.3.2 Principle of Lungs Work

Air enters your lungs through a system of pipes called the bronchi. These pipes start from the until they eventually form little thin-walled air sacs or bubbles, known as the alveoli. The alveoli are where the important work of gas exchange takes place between the air and your blood. Covering each alveolus is a whole network of little blood vessel called capillaries, which are very small branches of the pulmonary arteries. It is important that the air in the alveoli and the blood in the capillaries are very close together, so that oxygen and carbon dioxide can move (or diffuse) between them. So, when you breathe in, air comes down the trachea and through the bronchi into the alveoli. This fresh air has lots of oxygen in it, and some of this oxygen will travel across the walls of the from the blood in the capillaries into the air in the alveoli and is then breathed out. In this way, you bring in to your body the oxygen that you need to live, and get rid of the waste product carbon dioxide. Alveoli into your bloodstream. Travelling in the opposite direction is carbon dioxide, which crosses bottom of the trachea as the left and right bronchi and branch many times throughout the lungs,

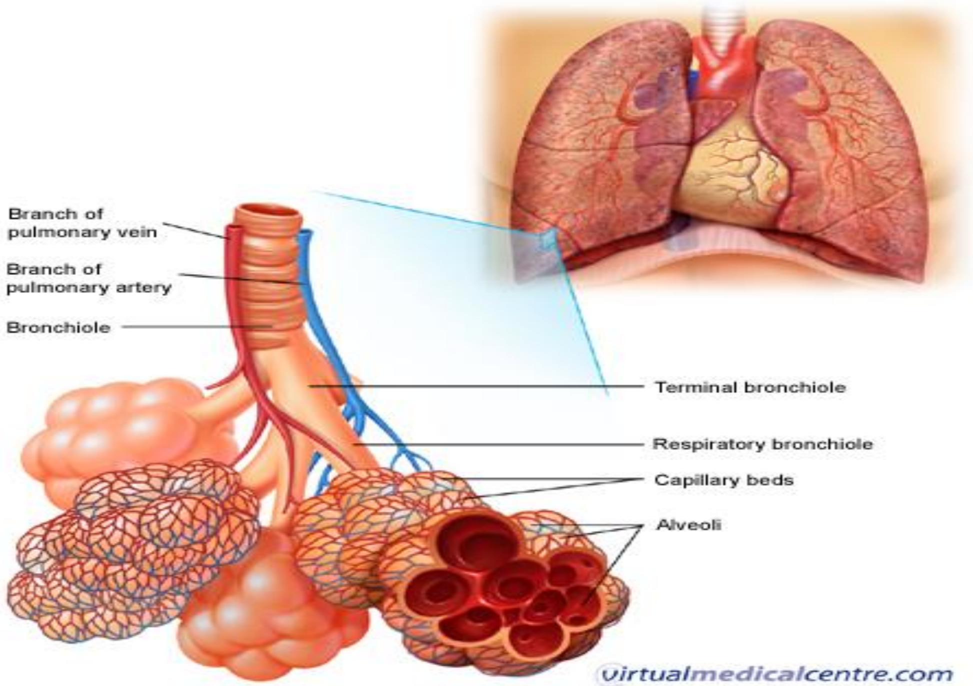


Figure 2.6 Structures of Lungs. [14]

2.3.3 The Work of Breathing

The lungs are covered by smooth membranes that we call pleurae. The pleurae have two layers, a 'visceral' layer which sticks closely to the outside surface of your lungs, and a 'parietal' layer which lines the inside of your chest wall (ribcage). The pleurae are important because they help you breathe in and out smoothly, without any friction. They also make sure that when your ribcage expands on breathing in, your lungs expand as well to fill the extra space.[14]

2.3.4 Respiratory Changes

Breathing patterns change during sleep. In awake condition, breathing is usually quite irregular, since it is affected by speech, emotions, exercise, posture, and other factors. As progress from wakefulness through the stages of non-REM sleep, breathing rate slightly decreases and becomes very regular. During REM sleep, the pattern becomes much more variable again, with an overall increase in breathing rate. The normal respiration rate for an adult at rest is 12 to 20 breaths per minute. A respiration rate under 12 or over 25 breaths per minute while resting is considered abnormal.

Among the conditions that can change a normal respiratory rate are asthma, anxiety, pneumonia, congestive heart failure, lung disease, use of narcotics or drug overdose.

2.3.5 The Normal Range of Respiration Rate.

Children have faster respiratory rates than adults, and the "normal" respiratory rate can vary significantly by age according to the table (2.1).

Table 2.1 Pediatric Respiration Rate [15]

Pediatric Respiration Rate	
Age	Rate (breath per minute)
Infant(birth-1year)	30-60
Toddler(1-3years)	24-40
Preschooler(3-6years)	22-34
School age(6-12years)	18-30
Adolescent	12-16

2.2.6 The Diseases of Respiratory System.

Diseases and conditions of the respiratory system fall into two categories: Infections, such as influenza, bacterial pneumonia and enterovirus respiratory virus, and chronic diseases, such as asthma and chronic obstructive pulmonary disease (COPD).

Asthma is a chronic inflammation of the lung airways that causes coughing, wheezing, chest tightness or shortness of breath, according to Tonya Winders, president of the Allergy & Asthma Network. These signs and symptoms may be worse when a person is exposed to their triggers, which can include air pollution, tobacco smoke, factory fumes, cleaning solvents, infections, pollens, foods, cold air, exercise, chemicals and medications. According to the CDC, more than 25 million people (or 1 in 13 adults and 1 in 12 children) in the United States have asthma.

COPD, sometimes called chronic bronchitis or emphysema, is a chronic and progressive disease where the air flow in and out of the lungs decreases, making it harder to breathe. Over time, the airways in the lungs become inflamed and thicken, making it harder to get rid of waste carbon dioxide, according to the American Lung Association. As the disease progresses, patients experience a shortness of breath, and it can limit activity. More than 15 million Americans are affected by COPD, according to the CDC.[16]

2.4 The Relationship between Cardiovascular and Respiratory System.

The overall goal of the cardiorespiratory system is to provide the organs and tissues of the body with an adequate supply of oxygen in relation to oxygen consumption. An understanding of the complex physiologic interactions between the respiratory and cardiac systems is essential to optimal patient management. Alterations in intrathoracic pressure are transmitted to the heart and lungs and can dramatically alter cardiovascular performance, with significant differences existing between the physiologic response of the right and left ventricles to changes in intrathoracic pressure. In terms of cardiorespiratory interactions, the clinician should titrate the mean airway pressure to optimize the balance between mean lung volume (ie, arterial oxygenation) and ventricular function (ie, global cardiac output), minimize pulmonary vascular resistance, and routinely monitor cardiorespiratory parameters closely. Oxygen delivery to all organs and tissues of the body should be optimized, but not necessarily maximized. The heart and lungs are, obviously, connected anatomically but also physiologically in a complex relationship.[17]

Chapter Three

Theoretical background

This chapter includes the theoretical background of each system in the project. systems are: Nebulizer, respiration rate and ECG, each system will be illustrated in simplified ways.

In the following section, techniques for converting liquid to steam in the Nebulizer device will be simplified, with an explanation of the disadvantages and advantages of each method.

3.1 Liquid to Steam Transfer Systems.

The most important part of the device is the tool that works to convert the added liquid in the device into steam, and as indicated in the previous paragraph, the technologies for this part used for conversion, will be defined. which includes different types, whether mechanical or electrical.

1. **Mechanical Soft Mist Inhaler**

This technology provides a metered dose to the user, as the liquid bottom of the inhaler is rotated clockwise 180 degrees by hand, adding a buildup tension into a spring around the flexible liquid container. When the user activates the bottom of the inhaler, the energy from the spring is released and imposes pressure on the flexible liquid container, causing liquid to spray out of 2 nozzles, thus forming a soft mist to be inhaled. The device features no gas propellant and no need for battery/power to operate. The average droplet size in the mist was measured to 5.8 micrometers, which could indicate some potential efficiency problems for the inhaled medicine to reach the lungs(slow). Due to the very low velocity of the mist, the Soft Mist Inhaler in fact has a higher efficiency compared to a conventional PMDI., Figure 3.1 shows the components of this type. [18]

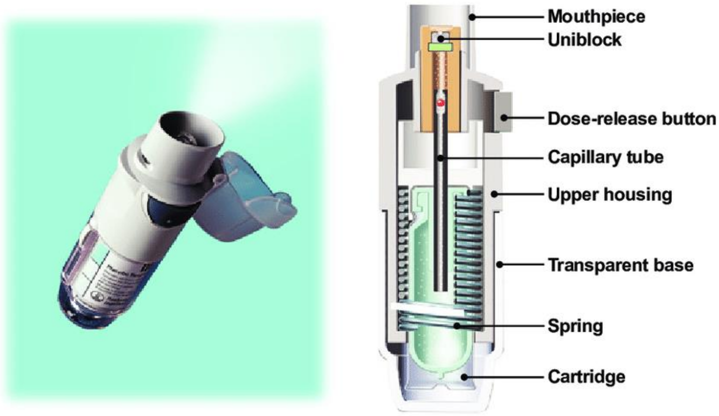


Fig 3.1 Mechanical Soft Mist Inhaler [19]

2. Pneumatic Jet Nebulizer

The most commonly used nebulizers are jet nebulizers, which are also called "atomizers". Jet nebulizers are connected by tubing to a compressor, that causes compressed air or oxygen to flow at high velocity through a liquid medicine to turn it into an aerosol, which is then inhaled by the patient, Figure 3.2 shows the components of jet nebulizer . jet nebulizers are commonly used for patients in hospitals who have difficulty using inhalers, such as in serious cases of respiratory disease, or severe asthma attacks. The main advantage of the jet nebulizer is related to its low operational cost. However, Compared to all the competing inhalers and nebulizers, the noise.[20]

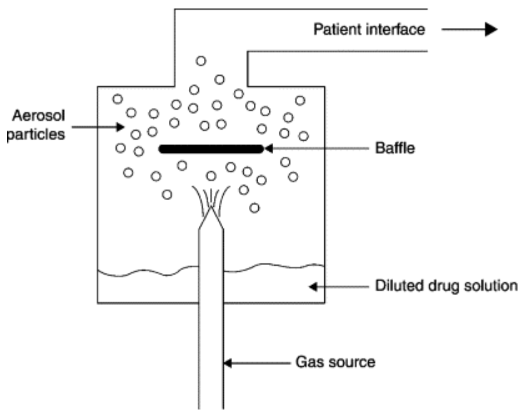


Fig 3.2 Jet nebulizer and its components [20]

3. Electrical

Electrical technology is the latest innovative method, which includes two types and they are Ultrasonic wave nebulizer and Vibrating mesh technology.

Ultrasonic nebulizers do not employ compressed gas; instead, a piezoelectric crystal is used to create energy within the stagnant aqueous formulation to convert the solution into small droplets for inhalation .The ultrasonic nebulizer consists of a piezoelectric crystal, a baffle system and a fan that may assist inhalation by patient (Figure 3.3). The medication solution is placed in the nebulizer chamber and the system is connected to a power supply. This electric current causes the piezoelectric crystal to produce vibrations with a high frequency, thus allowing the solution to form fountain-like structures. Large particles are produced at the apex of the fountain while smaller droplets are generated at the bottom .The larger droplets remain in the reservoir because they are deflected by the baffles and are then fragmented into smaller droplets to be ready for nebulization as inhalable aerosols. As they create aerosols from ultrasonic vibration instead of using a heavy air compressor, they only have a weight around 170 grams. Another advantage is that the ultrasonic vibration is almost silent. [21]

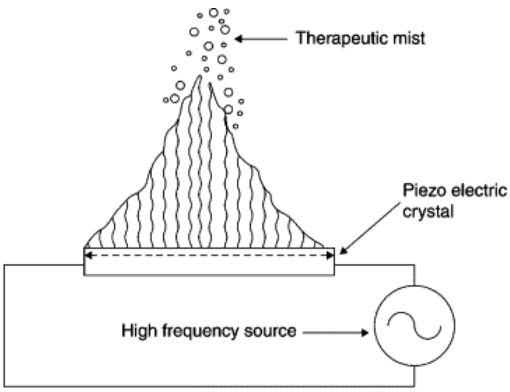


Fig 3.3 Schematic presentation of an ultrasonic nebulizer [22]

Vibrating mesh technology a mesh/membrane with 1000–7000 laser drilled holes vibrates at the top of the liquid reservoir, and thereby pressures out a mist of very fine droplets through the holes. This technology is more efficient than having a vibrating piezoelectric element at the bottom of the liquid reservoir, and thereby shorter treatment times are also achieved. The old problems found with the ultrasonic wave nebulizer, having too much liquid waste and undesired heating of the medical liquid, have also been solved by the new vibrating mesh nebulizers. Vibrating-mesh nebulizers are either passively vibrating-mesh or actively vibrating-mesh nebulizers.[23]

Passively vibrating-mesh nebulizers, the vibrations produced by a piezoelectric crystal are transferred via a transducer horn to the mesh that drives the medication through the holes. Passive and silent movement of the mesh produces a smaller droplet size and high aerosol output. [24]

Active vibrating-mesh nebulizer, the vibrating-mesh is a cone-shaped perforated plate having 1000 small holes, surrounded by a piezoceramic vibrational element that causes the mesh to generate aerosols by using a 'micropump' action. The size of droplets can be controlled by controlling the aperture size of the mesh. [25]

At the end of this section and after viewing all the techniques table 3.1 shows the advantages and disadvantages for each technique.

Table 3.1 Advantages and Disadvantages for Nebulizer's Techniques

Techniques	Advantages	Disadvantages
Mechanical Soft Mist Inhaler	- The device features no gas propellant and no need for battery/power to operate. - has a higher efficiency compared to a conventional pMDI.	very low velocity of the mist to reach the Lungs.
Pneumatic Jet Nebulizer	- low operational cost.	- noise

Electrical Ultrasonic nebulizers	- only have a weight around 170 grams . - the ultrasonic vibration is almost silent. - No desired heating of the medical liquid .	- Low efficient compared with Vibrating technique - having too much liquid waste
Electrical Vibrating mesh	- more efficient - No wasted liquid - thereby shorter treatment times are also achieved	Expensive

3.2 Microcontrollers

A microcontroller is a small computer on a single metal-oxide-semiconductor integrated circuit chip. Microcontrollers are used in automatically controlled products and devices, such as automobile engine control systems, implantable medical devices, remote controls, office machines, appliances, power tools, toys and other embedded systems. By reducing the size and cost compared to a design that uses a separate microprocessor, memory, and input/output devices, microcontrollers make it economical to digitally control even more devices and processes. Mixed signal microcontrollers are common, integrating analog components needed to control non-digital electronic systems. In the context of the internet of things, microcontrollers are an economical and popular means of data collection, sensing and actuating the physical world as edge devices. There are many types of controllers, but in this section, we will explain the two most popular types, PIC and Arduino.

PIC Microcontroller is a family of microcontrollers made by Microchip Technology, derived from the PIC1650x, originally developed by General Instrument's Microelectronics Division. The name PIC initially referred to Peripheral Interface Controller, and is currently expanded as Programmable Intelligent Computer.

Arduino boards are widely used in robotics, embedded systems, and electronic projects where automation is an essential part of the system. These boards were introduced for the students and people who come with no technical background. there are two types of Arduino chip, Arduino Nano and Arduino Mega.

Arduino Nano is a small, compatible, flexible and breadboard friendly Microcontroller board, developed by Arduino.cc in Italy. The power source is automatically selected to the highest voltage source, each of the 14 digital pins on the Nano can be used as an input or output. They operate at 5 volts and each pin can provide or receive a maximum of 40 mA.

Arduino mega have been used because of its bigger memory than memory in the Arduino nano, MP3 shield easily connected to the Arduino mega .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 as shown in figure (3.4), 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

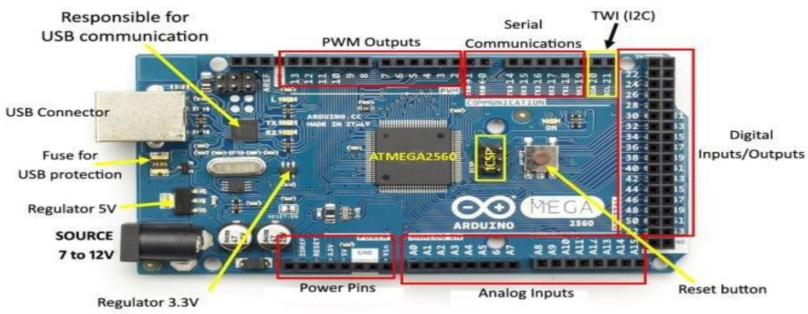


Fig 3.4 Arduino mega

3.3 Respiration Rate Monitoring Methods.

Breathing is an important physiological task in living organisms. For humans, this process results in air containing oxygen being inhaled into the lungs, where gas exchange occurs across the alveolar-capillary membrane. Carbon dioxide is excreted as part of the process, in the air released through the nose or mouth. The entire process from the inhalation to exhalation is known as a breathing (or respiration) cycle.

Respiration rate is an important indicator of a person's health, and thus it is monitored when performing clinical evaluations. There are different approaches for respiration monitoring, but generally they can be classed as contact or noncontact. For contact methods, the sensing device (or part of the instrument containing it) is attached to the subject's body. For noncontact approaches the monitoring is performed by an instrument that does not make any contact with the subject .In this section of respiration monitoring approaches (both contact and noncontact) .

3.3.1 Contact Based Respiration Rate Monitoring Methods.

Contact respiration rate monitoring instruments are usually based on measuring one of the following parameters: respiratory sounds (acoustic based methods), respiratory airflow (airflow-based methods), respiratory related chest or abdominal movements (abdominal movement detection), respiratory CO_2 emission and oximetry probe SpO_2(transcutaneous CO_2 monitoring,). Respiration rate can also be derived from the electrocardiogram (ECG), see fig 3.5.

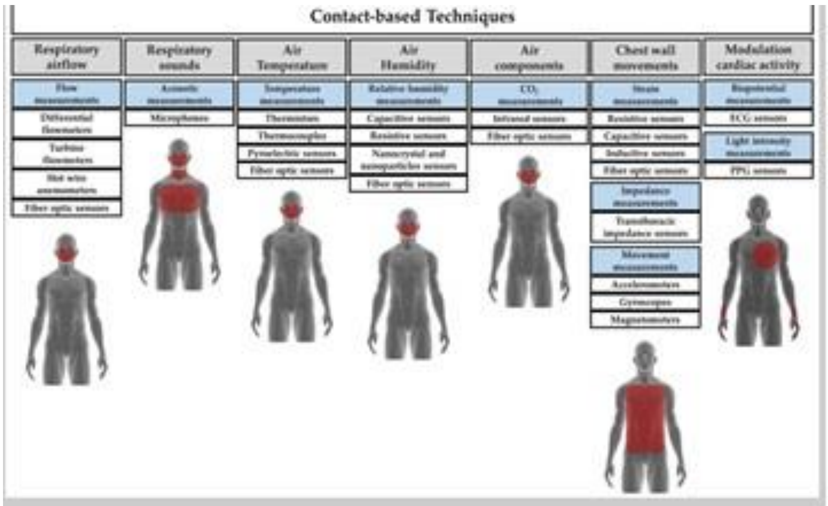


Fig. 3.5 Most popular contact-based techniques for measuring respiration rate.

Acoustic based methods (respiratory sound) can be measured using a microphone placed either close to the respiratory airways or over the throat to detect the variation of sound. Then a frequency analysis and estimation of the loudness of the sound can be carried out [25]. reported a respiratory sounds measurement system to detect sleep apnea in infants. The system depended on recording a signal derived from breathing sounds from the nose. This method was applied to eight premature infants. Snorting, speaking, crying, coughing, etc. had a negative effect on the operation of the system. Corbishley and Rodriguez-Villegas proposed a miniaturized and wearable respiration monitoring respiration system. It used a microphone mounted on the neck to obtain the largest breathing acoustic.[26],[27]

Airflow based methods, airflow can be detected because exhaled air is warmer, has higher humidity and contains more CO_2 than inhaled air. These variations can be used for indicating the respiratory rate. Most airflow-sensing methods need a sensor, attached to the airways. The measurement of the airflow can be achieved by using a nasal or oronasal thermistor which detects changes in temperature between the inhaled and exhaled air. This gives a semi-quantitative estimate of airflow, but the method is limited due to a high incidence of thermistor displacement. The nasal pressure transducer is another sensor used to measure respiration rate. Nasal pressure is a more accurate measure of airflow than others as it based on the actual volume of the air exhaled. It can be measured via nasal cannula, mouthpiece, or facemask. A problem with airflow measurement is that some patients may not feel comfortable with the sensor. The collector can also affect respiratory activity by increasing dead space. have reported a CO_2 sensor to measure respiration rate. [28]

Chest and abdominal movement detection**,** chest and abdominal wall movements can best be measured by either mercury strain gauges or impedance methods. Respiratory inductance plethysmography is a non-invasive technique whereby two bands measure the respiration rate, the thoracic band which is placed around the rib cage and the abdominal band which is placed over the abdomen at the level of the umbilicus. The bands are made from an extendible/deformable conducting material, either a very fine wire or thin foil such that the conductivity can be maintained during the stretching process. The principle of the strain gauge sensor is based on increase in the resistance of a conductor when the area of the conductor is increased during the respiration process. Normally the inspiratory thoracic and abdominal expansion is almost synchronous. However, if the upper airway is partially obstructed, there may be a change in the phase angle and timing of the movements of the thorax and abdomen. The movements become asynchronous, that is, the thorax moves inwards, and the abdomen outwards. During expiration this pattern is then reversed. Thoraco-abdominal asynchrony is a normal finding in infants in whom chest wall compliance is greater and is exacerbated by respiratory disease or respiratory muscle weakness. Studied the abdominal strain gauge transducer for measuring respiration rate. The strain gauge was strapped around the patient's chest and changes in thoracic or abdominal circumference during breathing were measured. The method involved a classification algorithm to separate respiratory signals as apnea, respiration, or respiration with motion, by using a second order autoregressive modeling and zero cross algorithm.[29]

In transcutaneous CO_2 monitoring a heated electrode (about 428C) is applied to the skin (usually an arm). This method relies on the diffusion of gas to the skin and provides an overall estimate of change in CO_2 level rather than minute by minute readings. The electrode is surrounded by a solution to provide conductivity. Care needs to be taken to avoid skin burning on sensitive and neonatal skin .Transcutaneous CO_2 monitoring therefore allows measurements of consequences of abnormal ventilation rather than a measure of the respiratory rate itself.[30]

Oximetry probe (SpO_2) based**,** blood oxygen saturation (SpO_2) measurement is another technique for monitoring the consequences of abnormal ventilation. When air enters the lungs its oxygen binds to the hemoglobin in red blood cells. The oxygen is then transported throughout the body in arterial blood. A pulse oximeter uses the red and infrared frequencies to determine the percentage of hemoglobin in the blood that is saturated with oxygen. This percentage is called blood saturation, or SpO_2. An oximeter simultaneously displays the SpO_2 level as well as the pulse rate and plethysmogram. There have been studies indicating that respiration rate can be extracted from plethysmogram. Plethysmogram from ten healthy adults were processed using wavelet transforms. Respiration waveform was observed in the plots of the wavelet transforms. In another study involving infants, of median age 2 days, the feasibility of extracting respiratory information from the plethysmogram traces was also demonstrated. The magnitude frequency spectra of the plethysmogram traces showed peaks associated with respiration rate.[31],[32]

Electrocardiogram (ECG) derived respiration rate, this method is based on the fact that respiration has a modulating effect on the ECG. In this respiration rate monitoring approach, ECG electrodes are attached to the subject in order to record an ECG. By measuring the fluctuation in ECG, the respiration rate can be derived. This technique is called ECG-Derived Respiration (EDR) and is based on a process known as sinus arrhythmia, that is, the modulation of ECG by the breathing process. EDR is believed to be based on small ECG morphology changes during the respiratory cycle caused by movement of the heart position relative to the electrodes and the change in lung volume. Principal component analysis has been used to identify which ECG lead was most effective before extracting the respiration rate.EDR monitoring has also been performed by using a single-channel that did not have to be a precordial lead. In contrast to a number of other studies that used ECG characteristic waves (e.g., QRS complex), this study used the higher order statistics of ECG recording .A study carried out a quantitative comparison of EDR monitoring techniques based on direct measurement of the modulation components versus techniques based on calculation of the mean electrical axis variation. The study concluded that single lead respiration rate estimates are more robust than the methods based on the mean electrical axis.

looked at three methods: The EDR, the electrical impedance pneumography (IP) signal across the chest, and the ECG or the changes in light absorption which is known as photoplethysmgrame (PPG) across a finger. They obtained estimates of the breathing rate by adding the individual estimated outputs for both the IP and PPG channels after applying the Kalman filters for both waveforms. A limitation of these methods is that movement artefacts introduce errors in estimating the breathing rates.[33]

3.3.2 Noncontact Based Respiration Rate Monitoring Methods.

Noncontact respiration rate monitoring instruments are usually based on measuring one of the following parameters: radar-based respiration rate monitoring, optical based respiration rate monitoring and thermal sensor and thermal imaging-based respiration rate monitoring.

The system was called the Radar Vital Signs Monitor (RVSM). It was developed to monitor the performance of Olympic athletes at distances exceeding 10 m. The RVSM detected breathing–induced movements of the chest using the Doppler phenomenon. A limitation of this method was motion artefact which corrupted the breathing signals. There have been no published studies describing the use of this method in children.[34]

Optical based respiration rate monitoring a non-restrictive visual sensing method to detect the respiration pattern by using a fiber grating (FG) vision sensor and processor unit. Their system consisted of two parts. The first was the FG projecting device. This provided an array of invisible infra-red-light spots (wavelength 810 nm). The second part was a Charge-Coupled Device (CCD) camera with an optical band-pass filter. Infrared light was used to project a set of bright spots on the subject, while the CCD camera was used to capture the scene of bright spots. The moving distances of bright spots in each image were extracted and analyzed to monitor respiration. used a static camera to detect thoracic movements to determine respiration rate. The projection of the surface of the thorax was represented as a region with a range of brightness intensities. Respiration was monitored by quantifying the variations of the locations of the image intensities over time. Non-invasive optical methods have not previously been described in children, however, in a study carried out , a high speed desktop computer connected to a video camera (webcam) was used to record respiration related chest and abdominal movements in children in a sleep unit. The video consisted of a series of sequential images, each marked with an individual time stamp (t), corresponding to the time of the recording. An algorithm was designed to subtract the current image at time t (i.e., imgt) and the image a few time frames before at time t- td (i.e., imgt   td). The value of td was determined practically. An increase in the value of td caused faster algorithm operation, but decreased the resolution of the algorithm in detecting movements. The sum of pixel values in each binary image was determined to produce a set of data values (x). The magnitude of each data value in x represented the movement between the time tand t td. These values were then plotted against time to obtain a respiration signal. A plot of the values of x during exhalation and inhalation is provided in Figure 3.6 . The vertical axis of the plot represents chest and abdominal movements.

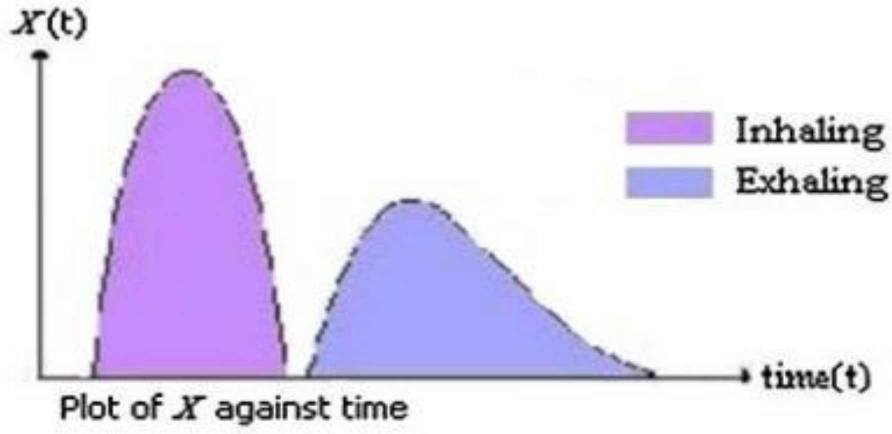


Fig. 3.6 A plot of values of x during inhalation and exhalation.

Two lobes were observed, the lobe representing inhalation being larger. During exhalation, the chest's wall initially moves slowly inward, its movement increases with time, reaching a peak and then, the amount of movement decreases. A similar process occurs during inhalation, but this time the chest's wall moves outward. Figure 3.7 shows the plot of x(t) during three respiration cycles. An algorithm was developed to extract the respiration rate from the recorded signal in real-time.

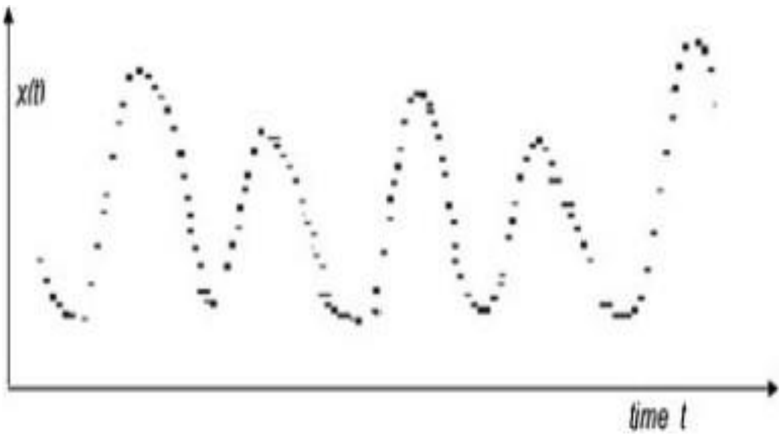


Fig.3.7 Plot x(t) against time during three respiration cycles.

Thermal sensor-based respiration rate monitoring system. In this approach there was no contact with the child's skin. The sensor could detect temperature changes induced by respiration and then the data were corrected and analyzed simultaneously by a personal computer that was linked to a central nursery room. To avoid missing the breathing signals, an ellipsoid shaped mask was made and the thermo sensors were placed on the mask so that breathing could be detected when the child's head turned. The problem with this method was that a mask had to be placed close to the child's face. developed an infrared imaging-based respiration rate monitoring method. They designed a tracking algorithm that could follow facial features related to respiration. These features were selected manually from a reference image (i.e., the first image in the video) by specifying three windows. Two of these windows covered the areas between the bridge of nose and the inner corner of the eyes (i.e., the periorbital regions) and represented the warmest facial areas. Another window was placed on the apex of nose to represent the coolest facial area. Their algorithm tracked these three windows in the following recorded images. The respiration signal was obtained from a rectangular region under the nose. Instead of using a focal plane array of mid-wave infrared sensors, used a thermal camera consisting of a focal plane array for a long-wave infra-red (6–15 mm) sensor. They measured the temperature changes around the neck region, carotid vessel complex, and the nasal region. The selection of these regions was carried out manually. A wavelet analysis technique was developed to extract the ECG and the respiration rate. The chosen area was divided into eight equal concentric segments as shown in Figure 3.8 .

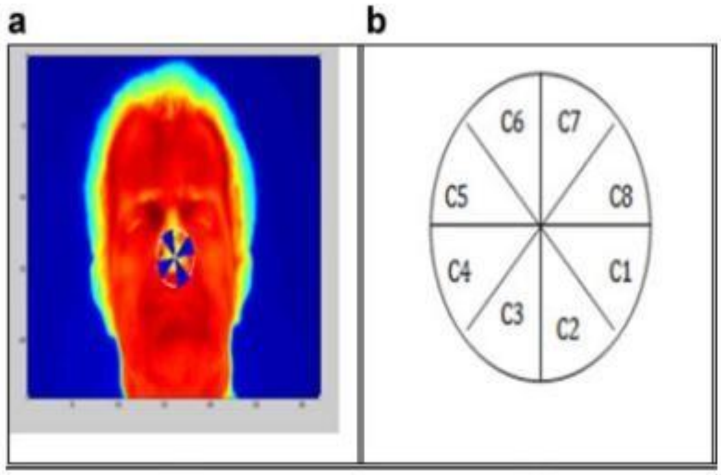


Fig. 3.8(a) A thermal image with tip of the nose represented by a circle, (b) the eight segments of the selected respiration region.

The pixel values within each of the eight segments were averaged to obtain a single value representing the skin temperature in that segment. The process was repeated for each image. Plots of the average temperature against time for the Fig 3.6 . A plot of values of x during inhalation and exhalation. segments were obtained (see Fig. 3.9)

These plots represented the respiration signal associated with the segments. The respiration signal reduces in amplitude during inhalation and increases in amplitude during exhalation. The clarity of the signals varied, with segments 3 and 7 providing the clearest signals and segment 1 providing the least clear signal. This result indicated that for respiration monitoring, it would be advisable to consider all the eight segments and the clearest respiration signals. An algorithm then to select the segments that provide was produced to automatically extract the respiration rate from the recorded signal.

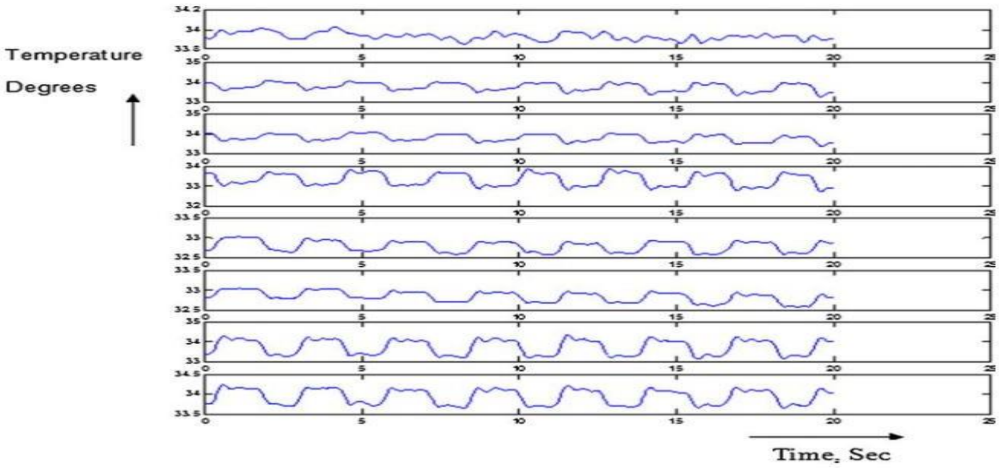


Fig.3. 9 Respiration signals obtained from segments 1 to 8 (from top to bottom respectively)

Monitoring respiration rate is an important task when evaluating a subject's health. Respiration rate monitoring devices can be classified by a number of ways depending on the manner of their use and their operation. In this section, they were grouped into contact and noncontact. This review has highlighted the advances made to improve the effectiveness of respiration monitoring. The potential for noncontact respiration monitoring is emphasized. Noncontact respiration rate monitoring devices have a distinct advantage over contact methods, especially in children, as they cause least disturbance to the patient. Studies are still ongoing to produce more effective respiration monitoring devices .Several techniques are available for measurement of respiratory rate via nasal prongs, masks, thermistor or respiratory impedance plethysmography. These methods all involve some contact with the child. A pneumotachograph has the advantage that it gives quantitative assessments of flows, from which respiratory rate can be derived, and may be important in a research setting. The thermistor is a commonly used technique to detect temperature changes breath by breath at the nostril, thereby giving the number of breaths per minute. This technique has been formally validated in the measurement of respiratory rate for the purposes of sleep studies. The technique has been demonstrated to work well in measuring tidal volume in infants.

However, from a clinical perspective the main disadvantage of these methods is that they require connection to the child, some to the facial area, which disturbs many children and may be poorly tolerated. In addition, in infants and children, the added dead space of the equipment required for some of these techniques may have an influence on breathing patterns. Currently noncontact respiration monitoring methods have not yet reached the level of maturity that can be used routinely in clinical environments. Concerns related to patient safety, electromagnetic interference with existing medical equipment's, complexity of using the systems have been factors in their slow take up in clinical environments. With further development, noncontact methods will gradually become more and more viable and will effectively complement contact-based respiration rate monitoring methods.

Table 3.2: Advantages and Disadvantages For Contact and Noncontact Based Respiration Monitoring Methods

Methods	**Advantages**	**Disadvantages**
Acoustic Based Methods	-very simple -using microphone to measurement respiration sound to detect sleep apnea in infants.	-Influence of environmental factor. - Snorting, speaking, crying, coughing, etc. had a negative effect on the operation of the system
Airflow Based Methods	a) Thermistor - The measurement of the airflow can be achieved by using a nasal or oronasal thermistor which detects changes in temperature between the inhaled and exhaled air, this gives a semi-quantitative estimate of airflow. b)The nasal pressure -Nasal pressure is a more accurate measure of airflow than others as it based on the actual volume of the air exhaled	- the method is limited due to a high incidence of thermistor displacement. -A problem with airflow measurement is that some patients may not feel comfortable with the sensor. The collector can also affect respiratory activity by increasing dead space.
Chest and Abdominal Movement Detection	-Noninvasive technique. -Good accurate. -Measuring device.	-Indirect measuring. -Influence of environmental factor. -Sensitivity to body motion artifact (movement and motion not related to breathing that negatively affect the output signal.
Transcutaneous CO_2 Monitoring	-This method relies on the diffusion of gas to the skin and provides an overall estimate of change in CO_2 level rather than minute by minute Readings.	-Care needs to be taken to avoid skin burning on sensitive and neonatal skin. Transcutaneous CO_2 monitoring therefore allows measurements of consequences of abnormal ventilation rather than a measure of the respiratory rate itself.

Oximetry Probe (SpO2) Based	- Noninvasive technique. -Simple and can be used to evaluate trands.	- cannot be used to assess oxygen delivery (anemia) or adequacy of ventilation and that accuracy is lessened in the presence of elevated dysfunctional hemoglobin levels.
Electrocardiogram (ECG) Derived Respiration Rate	-Noninvasive technique. -Good accurate.	-Indirect measuring. -Influence of environmental factor. -Sensitivity to body motion artifact.
Radar Based Respiration Rate Monitoring	-Good accurate. -Monitor the performance of Olympic athletes at distances exceeding 10 m,and the RVSM detected breathing–induced movements of the chest using the Doppler phenomenon.	-A limitation of this method was motion artifact which corrupted the breathing signals. - There have been no published studies describing the use of this method in children.
Optical Based Respiration Rate Monitoring	-Reliability. -Non intrusive nature of fiber optics combined with the possibility making small and simple.	-Influence of environmental factor.
Thermal Sensor	-Noncontact with child's skin.	-Poor performance of the oral sensor. -Patient tolerance and comfort should be explored in larger studies to determine the usability of the device in a clinical setting. -The performance of this device in several pathological conditions needs to be explored in further studies.

3.4 ECG System.

An electrocardiogram — abbreviated as EKG or ECG — is a test that measures the electrical activity of the heartbeat. With each beat, an electrical impulse (or “wave”) travels through the heart. This wave causes the muscle to squeeze and pump blood from the heart. A normal heartbeat on ECG will show the timing of the top and lower chambers.

3.4.1 ECG Electrodes.

In order to measure and record potentials and current in the body, it is necessary to provide some interface between the body and the electronic measuring apparatus, bio-potential electrodes carry out this interface function. Because current in the body is carried by ions, where as in leads wire and measuring circuitry by electrons, thus the electrode must serve as a transducer which convert the ionic current into electrical current. There is two type of ECG electrode disposable electrodes and reusables electrodes.

3.4.2 Disposable ECG Electrode.

A disposable electrocardiogram electrode template for simultaneously, quickly and correctly placing a plurality of sensors on a human chest, the template comprising, and Disposable ECG electrodes for use with snap-connect lead wires and this electrode are the interface with body surface. There are many types of disposable ECG electrode like Metal-Plate Electrodes, Suction Electrode and Silver-Silver Chloride Electrode and will discussed in the next paragraph.

Metal-Plate Electrodes: It is the simplest form, it consists of a metallic conductor in contact with the skin, an electrolyte soaked pad or gel is used to establish and maintain the contact, figure 3.10 illustrate the structure of metal-plate electrode, it consists of a flat metal plate that has been bent into a cylindrical segment, a terminal is placed on its outside surface near one end, this terminal is used to attach the lead wire to the electrocardiograph, the electrode is made of a nickel silver alloy, before it attach to the body its concave surface is covered with electrolyte gel. [37]

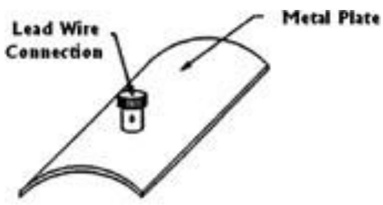


Fig 3.10: Metal-Plate Electrode.

Suction Electrode: is a modification of the metal plate electrode, it easier to attach this electrode to the skin to make a measurement and then move it to another point to repeat the measurement. These types of electrodes are used primarily for diagnostic recordings of bio- potentials such as the electrocardiogram.

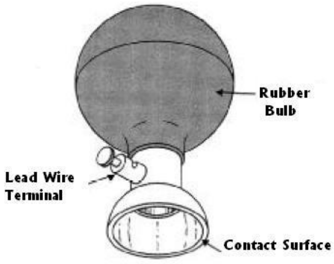


Fig 3.11: Suction Electrode.

They consist of a hallow metallic cylindrical electrode that makes contact with the skin at its base, a terminal for the lead wire is attached to the metal cylinder and a rubber suction bulb fits over its other base, electrolyte gel is placed over the contracting surface of the electrode, the bulb is squeezed, and the electrode is then placed on the chest wall, the bulb is released and applies suction against the skin, this electrode can be used for short periods of time, it cause irritation, although the electrode itself is quite large and the contacting area is relatively small, thus, the electrode impedance is relatively higher than the metal-plate electrode. [37]

Silver-Silver Chloride Electrode (Ag-AgCl): electrode shown in figure 3.12. It is relatively stable in biological application. They are composed of a metal (Ag), coated with a salt of the metal (AgCl), this material (AgCl) is only very slightly soluble in water, so it remain stable, in addition some form of electrode paste or jelly is applied between the electrode and the skin, which the principal anions of this electrolyte is the Cl^-, for best result, the electrolyte solution should be saturated with AgCl so that there is little chance for the surface layer to dissolve. [37]

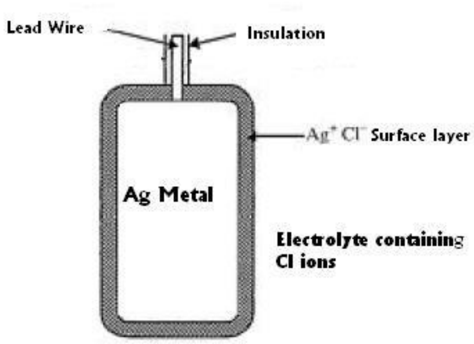


Fig 3.12: Ag-AgCl electrode shown in cross sectio

Chapter Four

System Design

This chapter includes the hardware and software stages that contribute to the identification of the optimal design layout and nominal operating conditions of industrial processes. The conceptual design of the system, shown in figure 4.1, comprises three main parts; nebulizer system, respiratory rate system, and ECG system.

The nebulizer will be designed as closed loop device that detect the respiration continuously, helping patients to take the drugs as a mist easily and safely. Respiration will be detecting continuously during nebulization, and sent to controller for processing; If the respiration become abnormal, the controller will decrease the nebulization rate. ECG system will be designed and connected to controller to study the effect of nebulization on ECG signal.

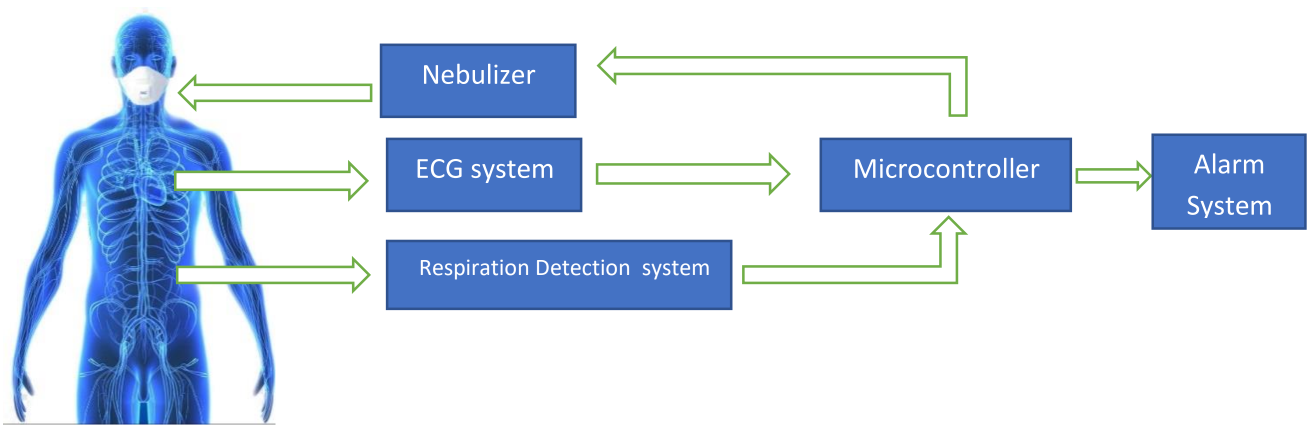


Figure 4.1 Main Block Diagram of the system

Components of each stage will be further explained in the following sections; the selection of more adequate integrated circuits (IC_s) and other components to accomplish each stage function and achieve the desired response of the electronics circuit connection is employed in the design.

4.1 Nebulizer System

Nebulizer system is required in this project to convert the drug from liquid to mist. At present all commercially available nebulizers can be categorized into two basic types: (i) jet (or pneumatic) small-volume nebulizers and (ii) ultrasonic nebulizers. Jet nebulizers are based on the venturi principle, whereas ultrasonic nebulizers use the converse piezoelectric effect to convert alternating current to high-frequency acoustic energy (Rau, 2002). The major features of both types of nebulizer are duration of treatment at each time of use, particle size distributions produced, and aerosol drug output.

ultrasonic nebulizer technique is chosen in this project according to its vibration that is almost silent., no heating of the medical liquid and its Possibility to be designed as portable. Traditional ultrasonic Nebulizer device consist of oscillation circuit and ultrasonic disc only.in this project we developed the traditional system by added a DC motor , Figure 4.2 depicts the block diagram of the Developer Ultrasonic nebulizer. It has three main stages which are DC motor, delivery system and ultrasonic nebulizer cup. moreover As the Nebulizer is a closed loop system, so if the respiration become abnormal the nebulizer decrease the nebulization rate by control the motor's speed, The motor's speed will be controlled by the driver chip as will be discussed in the following sections.

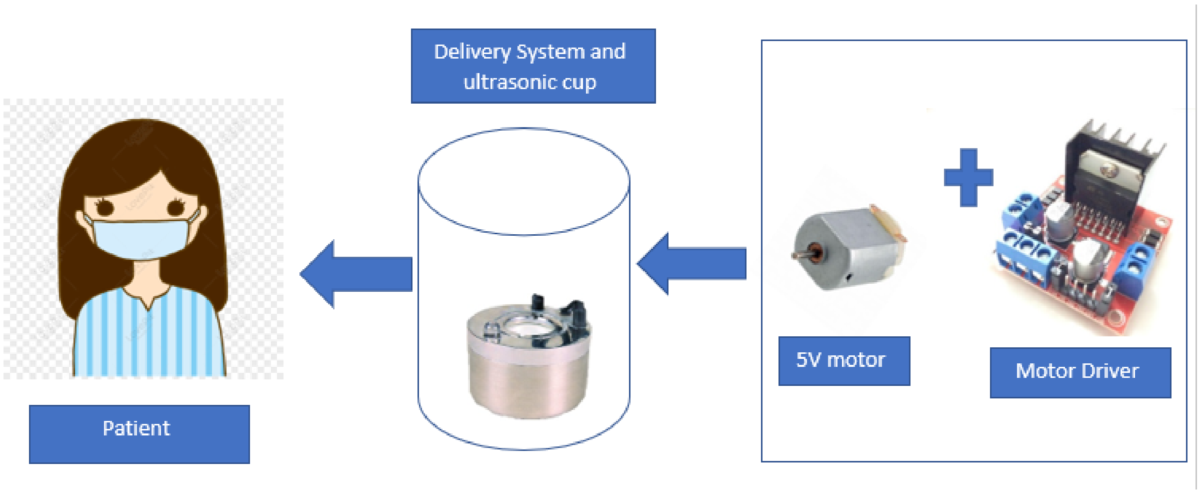


Fig 4.2 Developer Ultrasonic Nebulizer block diagram

4.1.1 Developer Ultrasonic Nebulizer

Developer Ultrasonic Nebulizer ,see Figure 4.2, which is an device that consist of ultrasonic mist maker system and DC motor .

ultrasonic system were provided by using mist fogger ,shown in Fig 4.3, which its internal connection is and oscillation circuit – provides 1.7 KHz – and ultrasonic disc .Our mist machine produces negative ion smoke through electronic and ultrasonic technology, which has the effect of filtering unpleasant odors,sterilizing,and humidifying the air.In the absence of any heat or chemicals. Can be safely used and easy to operate at 24V.

Fig 4.3 Mist fogger [38]

The Fogger that used in this design has the following specification:

- Mist Maker Size: 4.6 cm diameter.
- Material:aluminum
- Aerosolized amount:≥400mL/H
- Disc: 2.4cm.
- Operating Voltage: 24V.
- Operating Frequency : 1.7 KHz

DC Motor were used in the Developer system to accelerate the mist , and help us to control the mist quantity that goes to patient according to respiration change during the operation . is any of a class of rotary electrical motors that converts direct current electrical energy into mechanical energy. The most common types rely on the forces produced by magnetic fields. Nearly all types of

DC motors have some internal mechanism, either electromechanical or electronic, to periodically change the direction of current in part of the motor.

Motor specification :

1 .Rated Voltage: 4.5v, 5v ,6v ,9v, 12v

2.Speed:10-2000RPM

3 .Shaft dimension can be customized

4 .Motor diameter with 10mm

5 .Direction: CW CCW

6 .Long life, low noise

7. torque and shaft can be customized after evaluation.

4.1.2 Driver Motor And Relay Connection

According to the motor’s specification that mentioned before, the Arduino cannot be connect to the motor directly because the motor needs a current equal to 1A and the Arduino can give just 40-60mA, so L298N chip used to connect between motor and Arduino.

The L298N, shown in figure 4.4, is an integrated monolithic circuit in a 15- lead Milliwatt and PowerSO20 packages. It is a high voltage , high o/p current (equal to 3A) dual full-bridge driver de-signed to accept standard TTL logic level sand drive inductive loads such as relays, solenoids, DC and stepping motors. Two enable inputs are provided to enable or disable the device independently of the in-put signals .The emitters of the lower transistors of each bridge are connected together rand the corresponding external terminal can be used for the connection of an external sensing resistor. [40]

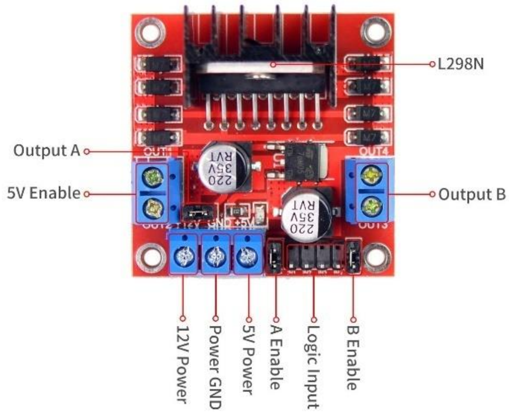


Fig 4.4 L298N Driver [40]

L298N Easy Driver connection with Arduino UNO and DC motor , shown in Following figure 4.5.

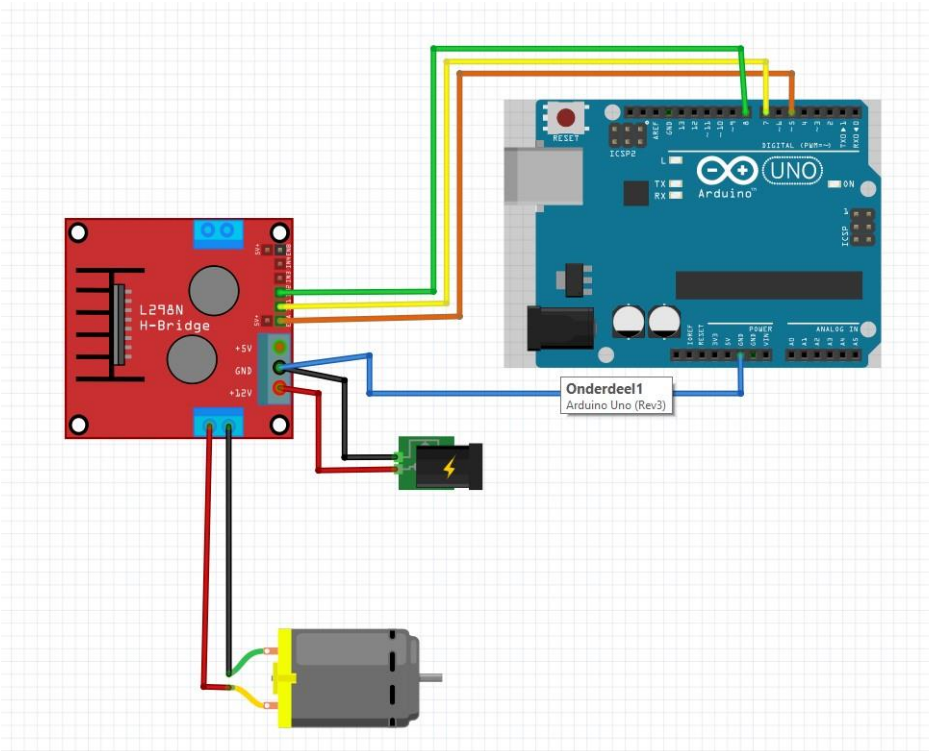


Fig 4.5 Arduino connect to DC motor [41]

The motor speed will be controlled by PWM , whenever the respiration become abnormal the motor's speed become slower than before , as a result the drug dose become lower and if the Respiration still abnormal for a while the motor and ultrasonic fogeer will be OFF, we use a relay to control the ultrasonic fogger by Arduino according to the respiration changing.

Fig 4.6 5V relay

5V Relay used , Fig 4.6 , is a relay interface board, it can be controlled directly by a wide range of microcontrollers such as Arduino, AVR, PIC, ARM and so on. It uses a low level triggered control signal (3.3-5VDC) to control the relay. Triggering the relay operates the normally open or normally closed contacts. It is frequently used in an automatic control circuit. To put it simply, it is an automatic switch to control a high-current circuit with a low-current signal.5V relay signal input voltage range, 0-5V. VCC power to the system.

Our connection were normally open ,fig 4.7 , the fogger is on until the Arduino Give a 5V (HIGH) to the relay so it will be OFF.

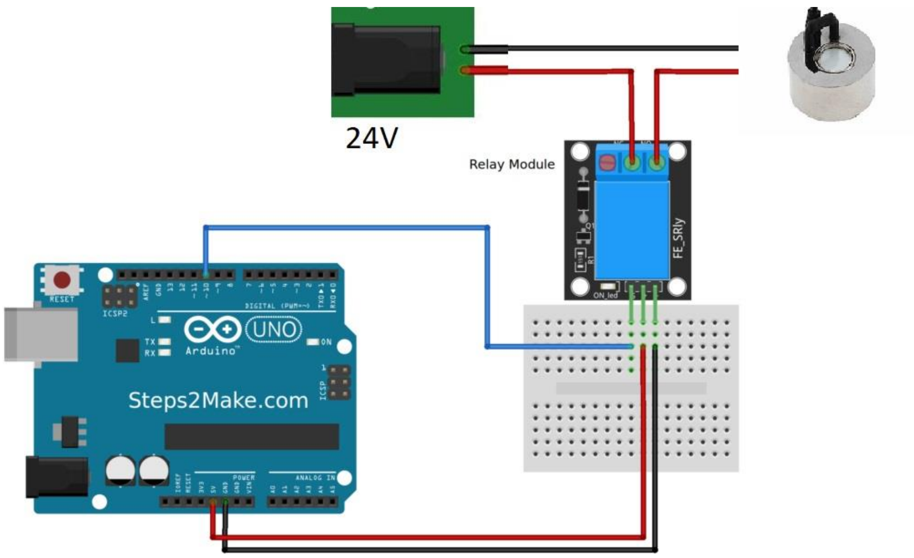


Fig 4.7 Relay Connection to Arduino

4.1.3 Nebulizer Delivery System

.

After converting the liquid into mist, it's the time to deliver it to the patient by a delivery system which is chosen to be mouth piece or mask and a tubes , Figure 4.8 .

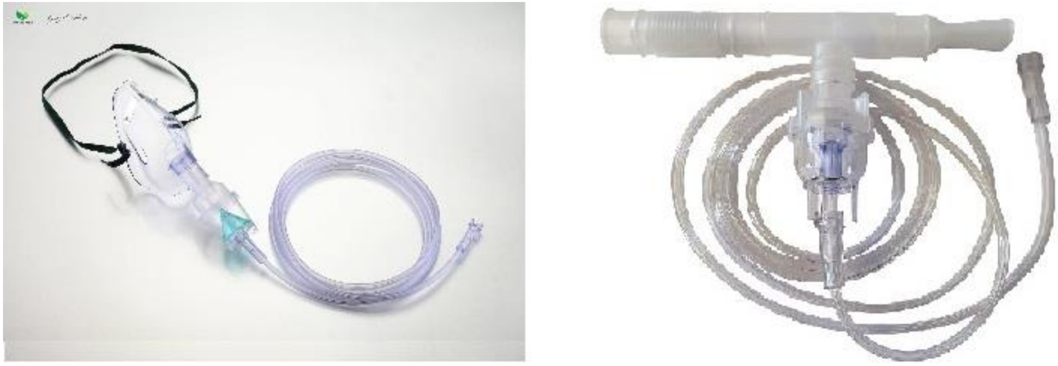


Fig 4.8 Final connect of tube and mouth piece or mask

4.2 Respiration Detection System

Respiratory detection is an important physiological parameter whose abnormality has been regarded as an important indicator of serious illness. Hence, it is required in this project to extract, and characterize the patient respiration rhythm throughout the treatment (nebulization process). In order to make respiratory detection monitoring simple to perform, reliable and accurate, many different methods have been proposed for such automatic monitoring. According to the theory of respiratory detection extraction, methods are categorized into three modalities: extracting respiratory detection from other physiological signals, respiratory detection based on respiratory movements, and respiratory detection based on airflow. In this project, respiratory detection based on respiratory movements is chosen due to its simplicity, accuracy, and relatively low price. A reflective object sensor based belt, shown in figure 4.9, to measure the patient thoracic expansion.

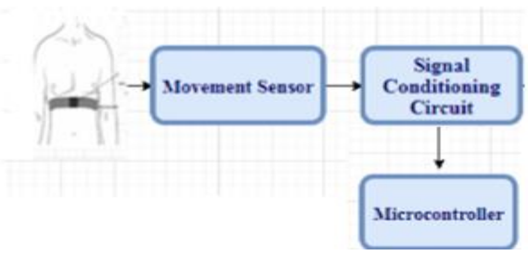


Fig 4.9 Block Diagram of Respiration Detection System

When the patient’s chest movement changes that consequently changes that sensor deformation. The Flexiforce sensor then converts this change in movement to change in resistance .The signal conditioning circuit convert the resistance change into voltage change.

4.2.1 Movement Sensor

Monitoring respiration change is an important task when evaluating a human's health and the method of measuring breathing is many. This process is depend on chest movement using strap around patient's chest contains a Flexiforce sensor. Chest moving distance ranges from 1.5 cm to as much as 7 cm with deep inspiration.

The FlexiForce sensor single element force sensor acts as a force sensing resistor in an electrical circuit. Force Range of the 406 FlexiForce sensor is available in a 0.1-10 N range. Force Range can be increased in custom sensors, Interlink Electronics have designed and manufactured sensors with operating force larger than 50Kg. When the force sensor is unloaded, its resistance is very high. When a force is applied to the sensor the output resistance decreasing, shown in figure 4.10, the resistance can be read by connecting a multimeter to the two sensor's pins then applying a force to the sensing area. The conductance for this sensor distinguishes that it has a linear relationship, shown in figure 4.11, with the applied force Linearity (Error) < ±3% of full scale, see table (4.1 and 4.2). [42]

Table 4.1 Force-Resistance Relation

Force(lbs)	Resistance(KΩ)
0.5	924.57
1	711.21
5	390.24
10	206.16
20	103.08
30	68.72
34	59.8
40	51.42

Note, 1lb=0.45kg And1lb=4.448N

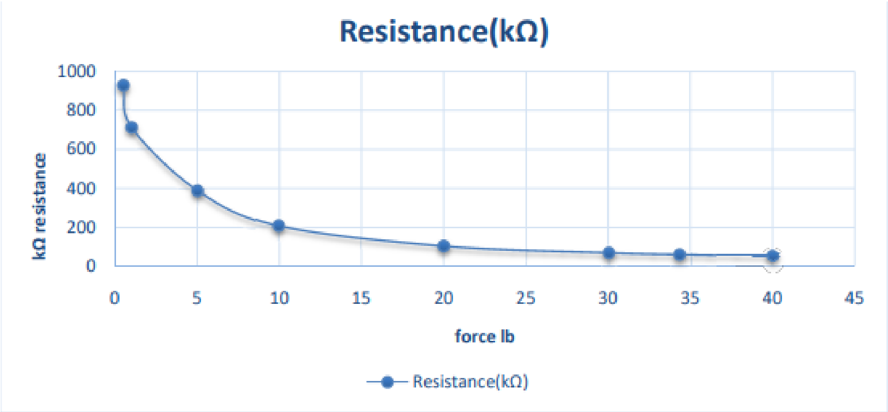


Fig 4.10 Force-Resistance Relation**.**

Table 4.2 Force-Conductance Relation

Force(lbs)	Conductance(μS)
0.5	1.08
1	1.41
5	2.56
10	4.85
20	9.70
30	14.55
34	16.72
40	19.45

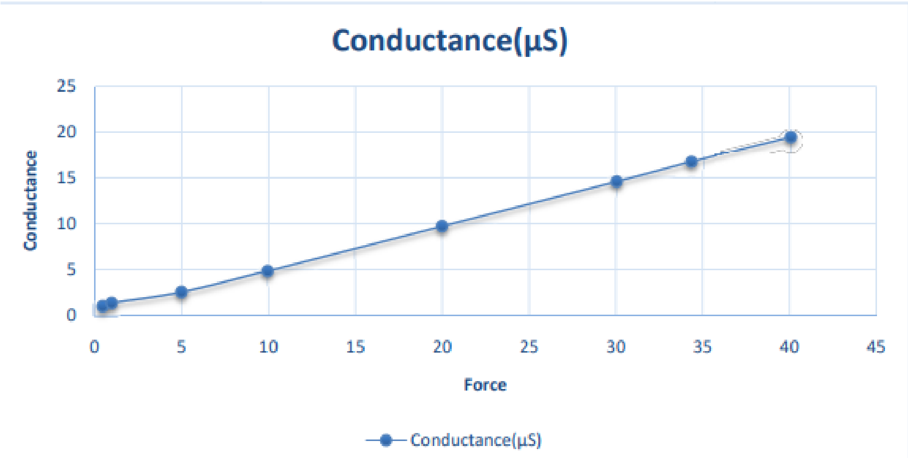


Fig 4.11 Force-Conductance Relation

4.2.2 Signal Conditioning Circuit

According to the performance of the FlexiForce sensor and since it's a variable that changes in accordance with input applied force. The force to voltage circuit it used to deal with force to another signal type which is voltage that easy to use, the circuit that shown in figure 4.12 contains of AD820AN op-amp, this amplifier is chosen because of its advantages, Rs is a FlexiForce sensor resistance. At first to amplify the output voltage from the sensor the maximum and suitable output voltage from the sensor will be calibrated at 5 DC voltage since it is a valid voltage input to the Arduino.

AD820AN is chosen for its wide input voltage range (3-36 V) and a several acceptable features as power supply rejection ratio, common mode rejection ratio, one of its application is medical instrumentation and other characteristics as illustrate in Appendix A.

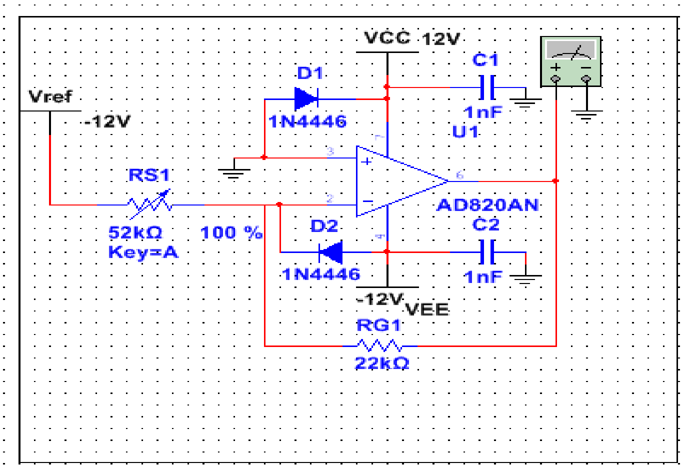


Fig 4.12 Signal Conditioning Circuit

AD820AN was connected as inverting op-amp to produce more linear output voltage than non-inverting op-amp, to obtain 5 volt as maximum output voltage, feedback resistance should be adjusted as (RG= 22KΩ) , see equation 4.1.
To calibrate 5 output voltage at maximum load (40Ib)with an input of (-12V) , the sensor resistance will reach approximately (52KΩ) as illustrate in table 4.1.

<u>Calculation</u>

For inverting op-amp

$Vout = -Vin * RG/Rs$ ………………4.1

$RG = Vout * RS / -Vin$

$RG = 5\ V * 52K\Omega / -(-12V)$

$RG = \sim 22K\Omega$

Where Vin=-12 volt, RG= 22KΩ, and Rs as shown in table 4.1, the output voltage can be calculated shown in figure 4.13 , see table 4.3

Table 4.3 Force-Output Voltage Relation

Force(lbs)	Vout (volt)
0.5	0.26
1	0.37
5	0.67
10	1.28
20	2.56
30	3.84
34	4.41
40	5

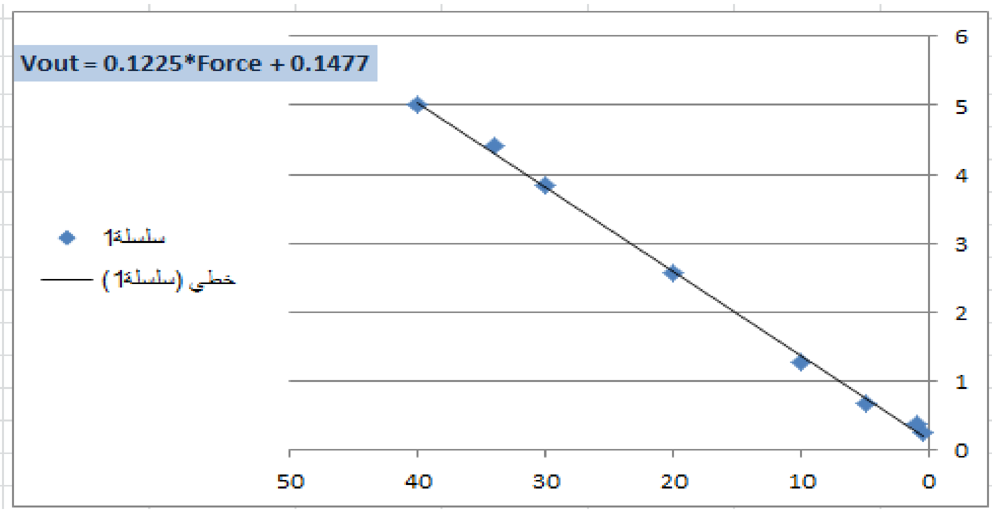


Fig 4.13 Force-Output Voltage Relation

4.3 ECG system

An electrocardiogram is a picture of the electrical conduction of the heart. By examining changes from normal on the ECG, clinicians can identify a multitude of cardiac disease processes. it is required in this project to extract, characterize and study the patient heart action during the nebulizer operation.in order to make ECG monitoring simple to perform accurate, many types of electrodes have been proposed for monitoring. According to the theory of ECG electrodes, types are categorized into three: Metal-Plate electrode, Suction Electrode and Silver-Silver Chloride Electrode (Ag-AgCl). In this project Ag-AgCl electrodes used to extract the ECG signal due to its low noise level it generates during biological signals recording and the non-polarizable nature of Ag/AgCl electrodes allows the charges to cross the electrode-electrolyte interface unlike stainless steel electrodes.

The purpose of this topic is to develop an ECG monitoring system using an ECG module.

4.3.1 ECG module (AD8232).

The AD8232 Spark Fun Single Lead Heart Rate Monitor is a cost-effective board used to measure the electrical activity of the heart. This electrical activity can be charted as an ECG or Electrocardiogram and output as an analog reading. ECGs can be extremely noisy, the AD8232 Single Lead Heart Rate Monitor acts as an op amp to help obtain a clear signal from the PR and QT Intervals easily.

The AD8232 is an integrated signal conditioning block for ECG and other biopotential measurement applications. It is designed to extract, amplify, and filter small biopotential signals in the presence of noisy conditions, such as those created by motion or remote electrode placement.

The AD8232 Heart Rate Monitor breaks out nine connections from the IC that you can solder pins, wires, or other connectors to. SDN, LO+, LO-, OUTPUT, 3.3V, GND provide essential pins for operating this monitor with an Arduino or other development board. Also provided on this board are RA (Right Arm), LA (Left Arm), and RL (Right Leg) pins to attach and use your own custom sensors. Additionally, there is an LED indicator light that will pulsate to the rhythm of a heartbeat. Biomedical Sensor Pads and Sensor Cable are required to use the heart monitor[44].

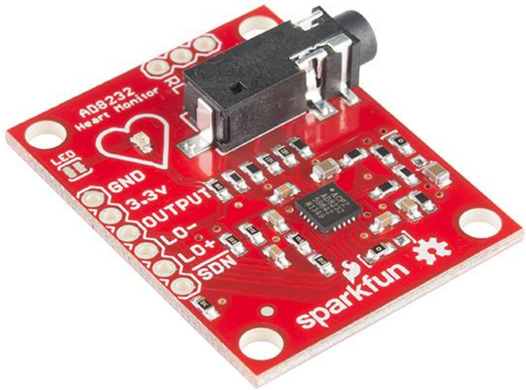


Fig4.14 ECG module (AD8232) .

4.3.2 Module connection to Arduino .

The AD8232 Heart Rate Monitor breaks out nine connections from the IC. We traditionally call these connections "pins" because they come from the pins on the IC, but they are actually holes that you can solder wires or header pins . We connected five of the nine pins on the board to Arduino. The five pins we needed are labeled GND, 3.3v, OUTPUT, LO-, and LO+, Figure 4.15 .

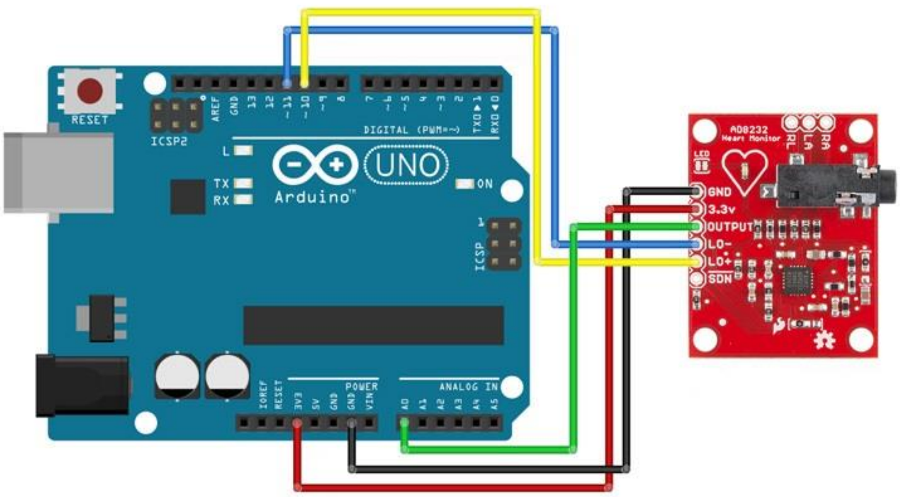


Fig4.15 AD8232 pins connection[45].

4.4 Power Supply

The system intended to operate using rechargeable 24 Volt battery (two 12V Buttary) to power the Arduino, motor's driver and other systems. because system is portable, we need a battery that has the following characteristics:

1. Has relatively long life and have 8595.72 mAh (see Table 4.5)
2. Provide needed power
3. Small and not heavy

As we use a dual supply Op-Amp ,We provide -12 and +12 volt from 24 volt Buttary , Fig 4.16.

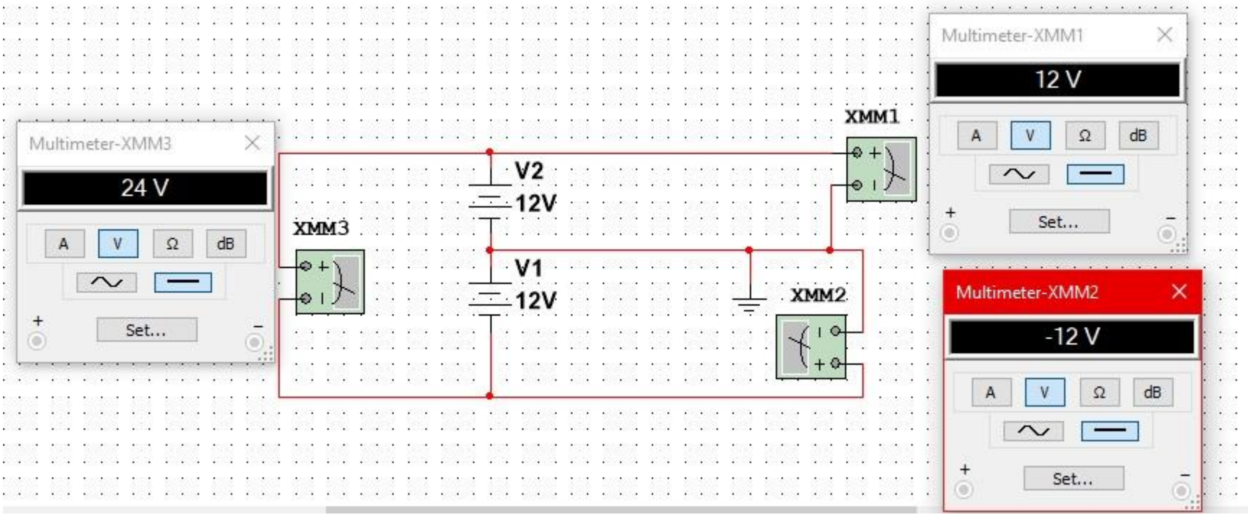


Fig4.16 -12V and +12 V from 24V.

Table 4.4 Current Consumption

item	Number	Quiescent Current
Ad820	1	620 µA
Arduino	1	19 ma
Mist Fogger	1	500mA
DC Motor	1	mA
L298N	1	13mA
Total current =		A 1.43262

4.5 Alarm System

Alarms are intended to draw attention to a problem before it becomes harmful. Most stand-alone monitors can generate an alarm when a monitored variable cross fixed or adjustable limits Alarms with this design are used to warn people that a patient is experiencing a non-breathing requiring resuscitation. In our project we will use Buzzer as an alarm system and it is an audio signaling device which may be mechanical, electromechanical, or piezoelectric. Typical uses of buzzers and beepers are as alarm devices. A buzzer, shown in figure 4.17, is an integrated structure of electronic transducers, a DC power supply. Here it is used when the respiration rate stays abnormal after decreasing the drug dose, the buzzer is chosen to work by Arduino pin’s output which equal the 5 V.

Fig 4.17 Active Buzzer 5V

4.6 Arduino Interfacing

Arduino is an open-source prototyping platform used for building electronics projects. It consists of both a physical programmable circuit board and a software, or IDE (Integrated Development Environment) that runs on your computer, where you can write and upload the computer code to the physical board ,The Arduino Nano as illustrate in figure 4.28, can be powered via 12V (pin 27). The power source is automatically selected to the highest voltage source, each of the 14 digital pins on the Nano can be used as an input or output., they operate at 5 volts. Each pin can provide or receive a maximum of 40 mA and has an internal pull up resistor (disconnected by default) of (20-50) KOhms.

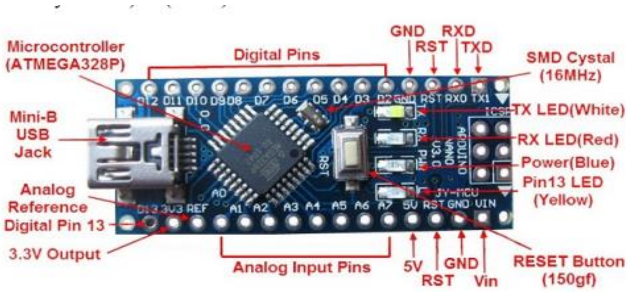
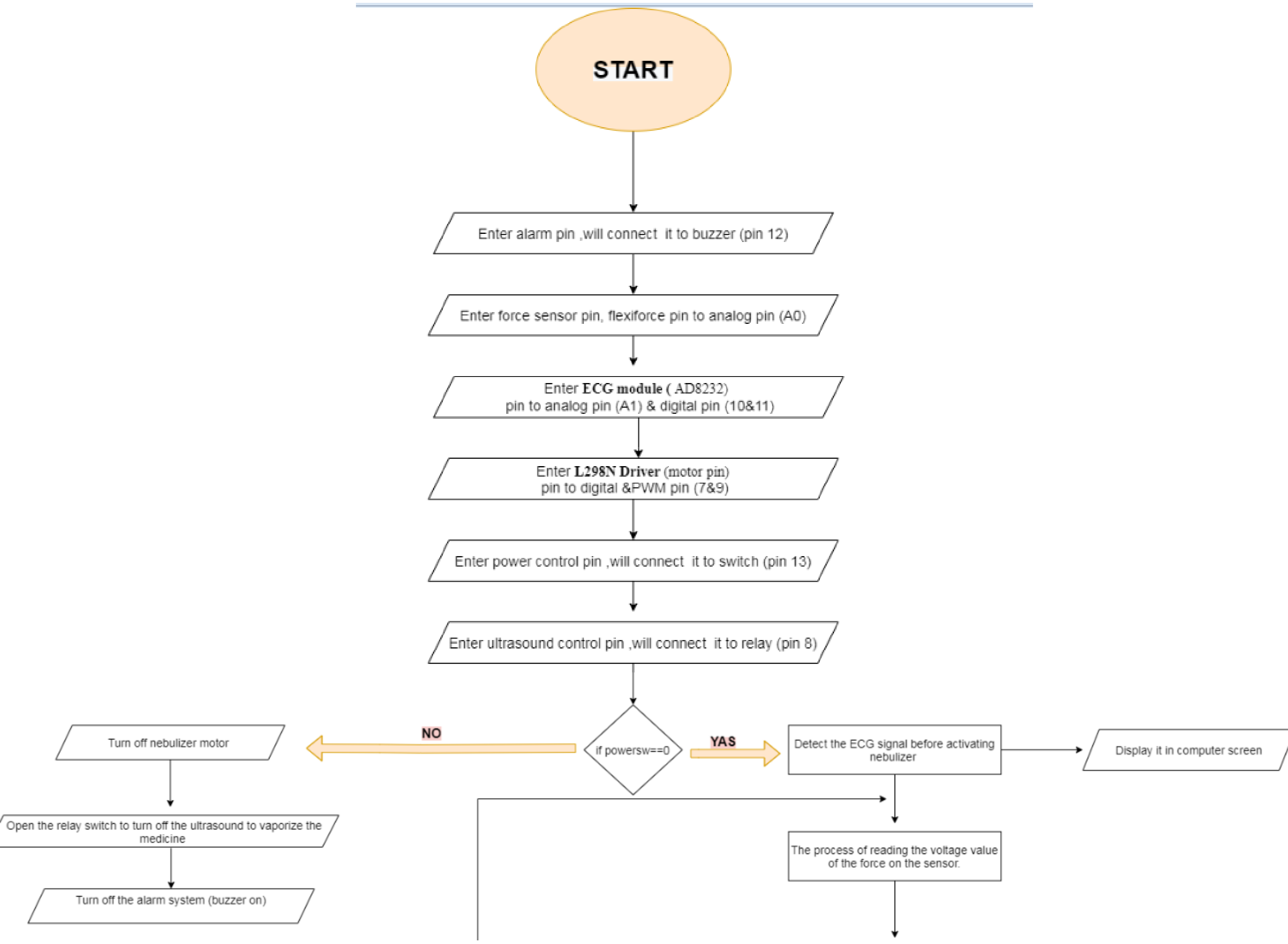
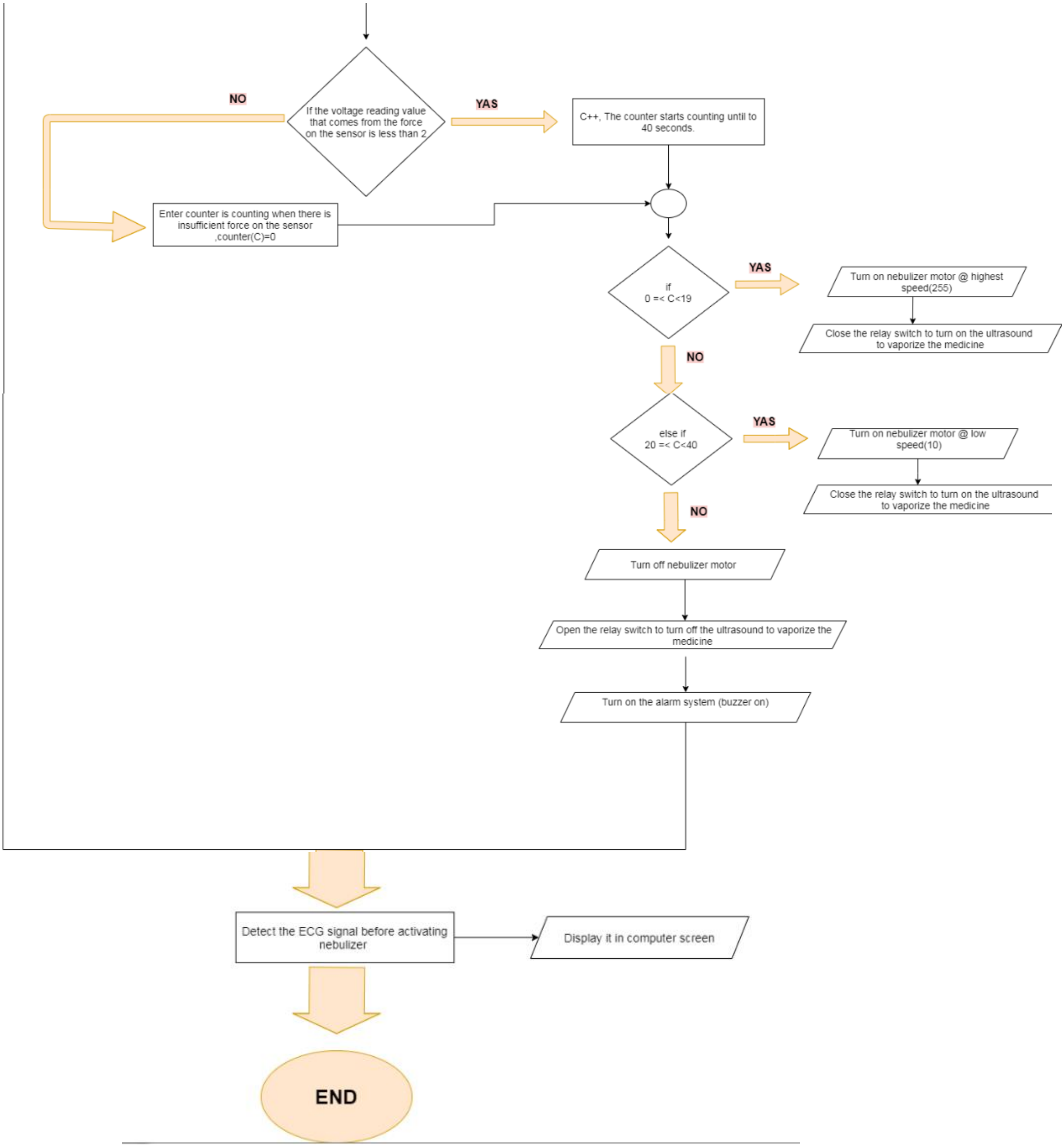


Fig 4.18 Microcontroller board, Arduino Nano

4.7 Flow Chart

After the process of reading the voltage value from the force on the sensor, this value will enter the Arduino hardware to check the respiration change in specific time, this value which represent the respiration change had to be compared with a reference value that measured before start the nebulizer operation. If the voltage value during the nebulizer operation is lower than the normal value (ref value) ,after few second if it still abnormal situation a programming code will define this as an dangerous situation and start to decrease the drug dose by decrease the DC motor's speed or off the operation if it exceeded the specified time as a very dangerous situation . else the nebulizer operation will be completed normally .additionally ECG signal were took from the patient before and after the operation and then enter it to the Arduino to travel it to computer and study the effect of the nebulizer operation on the ECG signal .


START
Enter alarm pin ,will connect it to buzzer (pin 12)
Enter force sensor pin, flexiforce pin to analog pin (A0)
Enter ECG module (AD8232)
pin to analog pin (A1) & digital pin (10&11)
Enter L298N Driver (motor pin)
pin to digital &PWM pin (7&9)
Enter power control pin ,will connect it to switch (pin 13)
Enter ultrasound control pin ,will connect it to relay (pin 8)
if powersw==0
NO
YAS
Turn off nebulizer motor
Open the relay switch to turn off the ultrasound to vaporize the medicine
Turn off the alarm system (buzzer on)
Detect the ECG signal before activating nebulizer
Display it in computer screen
The process of reading the voltage value of the force on the sensor.


If the voltage reading value that comes from the force on the sensor is less than 2
NO
YAS
C++, The counter starts counting until to 40 seconds.
Enter counter is counting when there is insufficient force on the sensor ,counter(C)=0
if 0 =< C<19
YAS
Turn on nebulizer motor @ highest speed(255)
Close the relay switch to turn on the ultrasound to vaporize the medicine
NO
else if 20 =< C<40
YAS
Turn on nebulizer motor @ low speed(10)
Close the relay switch to turn on the ultrasound to vaporize the medicine
NO
Turn off nebulizer motor
Open the relay switch to turn off the ultrasound to vaporize the medicine
Turn on the alarm system (buzzer on)
Detect the ECG signal before activating nebulizer
Display it in computer screen
END

4.8 Project Circuit

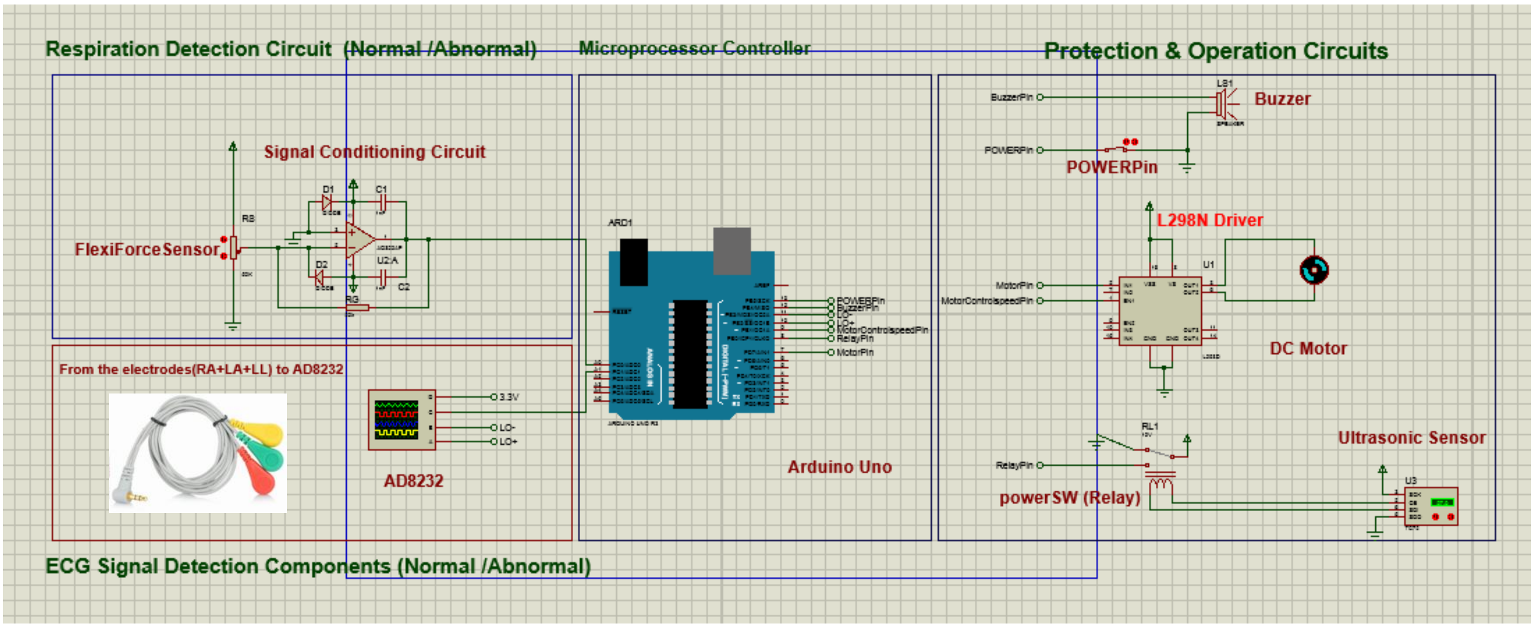


Fig 4.19: Closed Loop Nebulizer System Circuit

Chapter Five

Test and Implementation

Throughout a chapter the implementation working will discuss although the test for used sensor and the reference value that depended, ECG module (AD8232) and nebulizer system components.

5.1 System Implementation

This implementation of this system for the project and its external design of four parts:

5.1.1 Strap

Is a first stage is near the patient, that is placed around a patient's chest, fitted with a sensor to sensitivity the movement of the chest. The strap must has important properties, which it must be biocompatible with the body so we used antibacterial cloth type and comfortable, this cloth is put on the beds in hospitals. As it does not harm the patient, even if he sleeps for hours on end. Show in fig5.1.

The circumference of the strap is customized according to the patient's circumference to suit it. For a term baby, the average circumference of the chest is 30–33 cm (12–13 inches).[46] And according to these data in table 5.1.

Table 5.1 Baby Size chest [47]

Baby's size	cm
3 months	40.5
6 months	43
12 months	45.5
18 months	48
24 months	50.5

Fig 5.1 The strap contains Flexiforce sensor

5.1.2 Hardware Module

The second part of the project is a box as shown in fig 5.2 and 5.3 contains conditional electrical circuit for processing data that comes from the strap, this data is a resistance signal converted from chest force on the sensor during breathing. Then the microcontroller controlled the ultrasound disc , the DC motor ,and turned buzzer on if the situation critical.

Fig 5.2 Box Designing

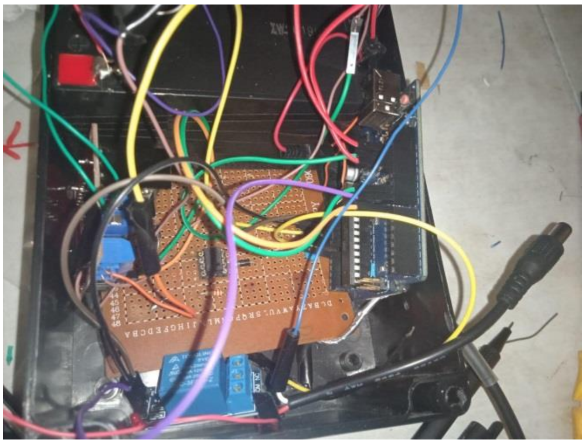


Fig 5.3 Box components

5.1.3 ECG module

The third part of the project is an AD8232 Heart Monitor used to measure the electrical activity of the heart before and during operation. This electrical activity can be charted as an ECG or Electrocardiogram and output as an analog reading on a computer screen.

AD8232 ECG Sensor Placement on Body, see Figure 5.4 .

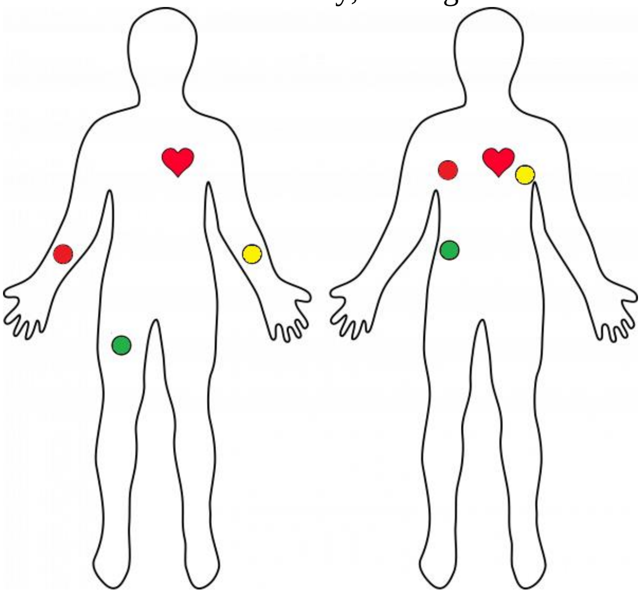


Fig 5.4 Electrodes connection to the body

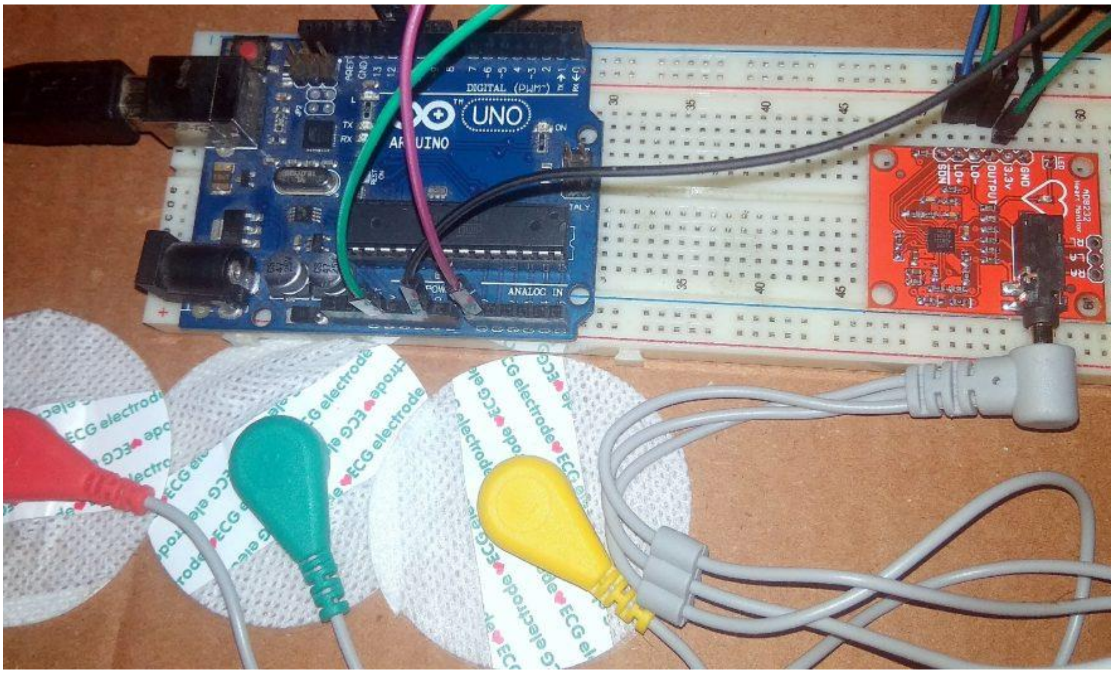


Fig 5.5 ECG Monitoring with AD8232 ECG Sensor & Arduino

5.1.4 Nebulizer System

The fourth part of the project is a nebulizer device components consist of ultrasonic Fogger for vaporize the medicine and DC motor to control amount of mist according to Respiration, shown in figure 5.6.

The nebulizer designed as closed loop device that detect the respiration change continuously, helping patients to take the drugs as a mist easily and safely. Respiration change will be measured continuously during nebulization, and sent to controller for processing.

5.6 Nebulizer Device Components

5.2 FlexiForce Sensor Test

At no load the sensor impedance measurement is described open loop “high impedance”. While applying the sensor on patient it has been observed that in the inhalation, the sensor is affected by a certain force and shows a change in resistance and then show a change in voltage and then return of the sensor to its natural state as if there is no effect in the exhalation. And it has been found that when the force increases his resistance decrease and the value of voltage is increase gradually.

5.3 Reference Value Test

When the device was tested on a patients , it was found that the voltage from the force on the sensor varies according to the strength of breathing for each person.

When the nebulizer device turn on ,may suddenly the respiration decrease occurs in patient so gradually decrease chest movement, and then the resistance become high impedance and the voltage will decrease, as show in table 4.1 and 4.3.

Therefore the reference voltage value is set to be less than 2, show in fig5.7.

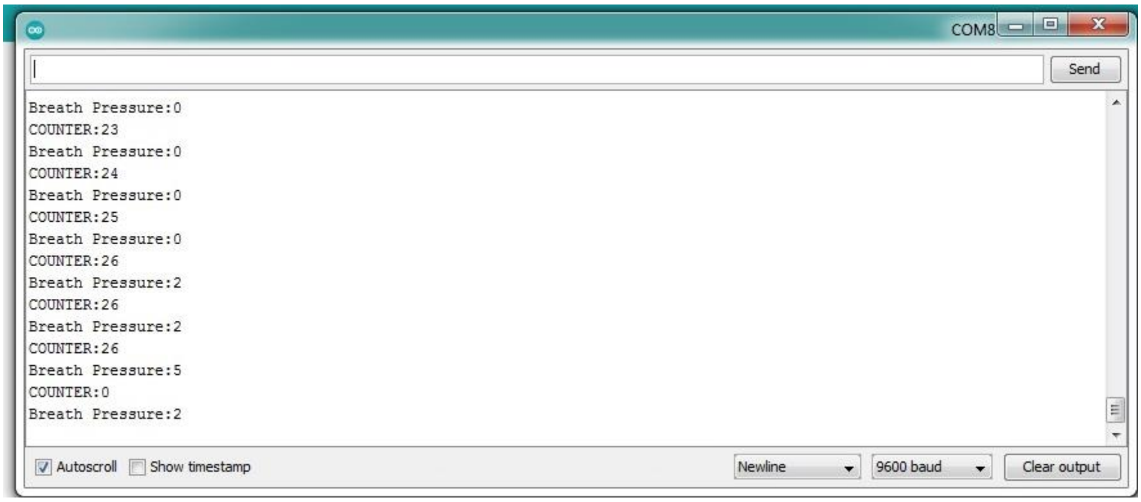


Fig 5.7 Tested to determine Vref

5.4 AD8232 Heart Rate Monitor Test

The electrode pads are large sticky pads that can be used several times. It is easiest to snap the pads to the sensor cable before applying the pad. When the pads are removed, the liner should be reapplied to keep the adhesive side as clean as possible, and to minimize noise in the signal, the subject should remain seated and as still as possible in order to get a reasonably stable reading. Applying light pressure to the electrodes may help with signal acquisition.

The LED on the module will blink when electrical activity is detected. With a fairly stable reading, the LED will blink at the heart rate and can be used as a general indication of whether the device is picking up the electrical signals.

This module is intended to provide an easy way to experiment with ECG technology. When the module was tested, the ECG signal detected in a normal state as shown in fig 5.8.

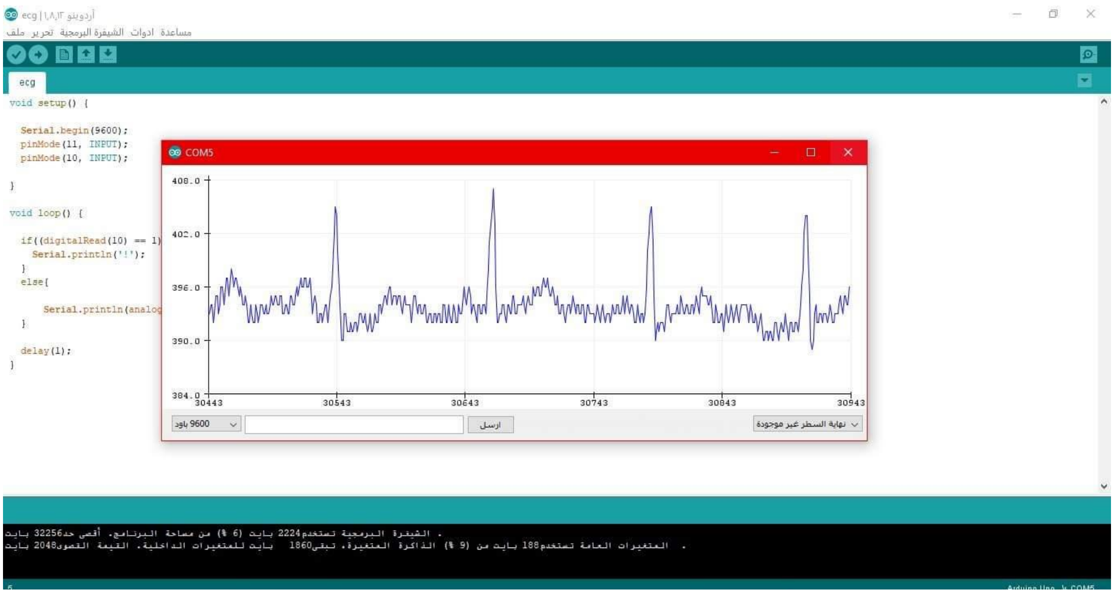


Fig 5.8 ECG signal

5.5 Ultrasound Disc and DC Motor Test

By placing the ultrasound piece inside the water and applying a 24 volts to it, evaporation was observed, and by applying the programming code to the motor, its speed was controlled by respiration , fig 5.9, and if the respiration still upnormal for more than 20 sec the Arduino will give a 5V to the relay so the Fogger stoped , also the motor fig 5.10.

```
volatile byte state2 = LOW;
int Value ;
 const byte  powerSW=8;
 volatile byte state3 = HIGH;
int motorValue = 0;


void setup()
{
pinMode(MotorPin,OUTPUT);
pinMode(MotorControlspeed,OUTPUT);
  pinMode(POWERPin,INPUT_PULLUP);
  pinMode(powerSW,OUTPUT);
}
void loop() {
    Value = digitalRead(POWERPin);
   if (Value == 0)
   {
  // put your main code here, to run repeatedly:
  digitalWrite(MotorPin,HIGH);
 analogWrite(MotorControlspeed, 255);
  delay(1000);
  analogWrite(MotorControlspeed, 10);
   delay(500);}

     else  {
  digitalWrite(MotorPin,state1);}

  }
```

Fig 5.9 Arduino programming to control the motor

```
else if (c>=20 && c<40)
{

  digitalWrite(powerSW,!state3);
 digitalWrite(MotorPin,!state1);
  analogWrite(MotorControlspeed,10);
  digitalWrite(BuzzerPin,state2);
 //OPEN ALARM SYSTEM,&LOW SPEED MOTOR
Serial.println("Danger Situation");
}
```

Fig 5.10 Fogger OFF code

Chapter Six

Result and conclusion

This chapter presents the results of impacts of nebulization process on respiration detection, ECG signals, controlled the nebulization process by respiration detection, and the conclusions of the project described in the document. The idea description and objectives of the research, outlined in chapter one, are reviewed. Then indicates extra suggestion for future work.

6.1 System Result

Project results are the changes or effects expected to take place after implementing the project. The results are generally positive improvements to the lives of the beneficiaries. This project contain three types of result before nebulization process,during and after it for the patient, when the patient breathing good and no suffocation happen during nebulization process , the smart strap that contain the Flexiforce sensor detecting chest movement that makes circuit box giving an normal output and detect normal ECG signal , then the motor moves at highest speed and the medicine evaporated by ultrasound.

At the end of the project, the following results achieved:

6.1.1 Before Nebulization Operation

During this stage of the project, the ECG signal was recorded by a serial monitor in Arduino before vaporization operation , and the sensor reading was detected in the normal state, as shown in fig 6.1 and 6.2 .

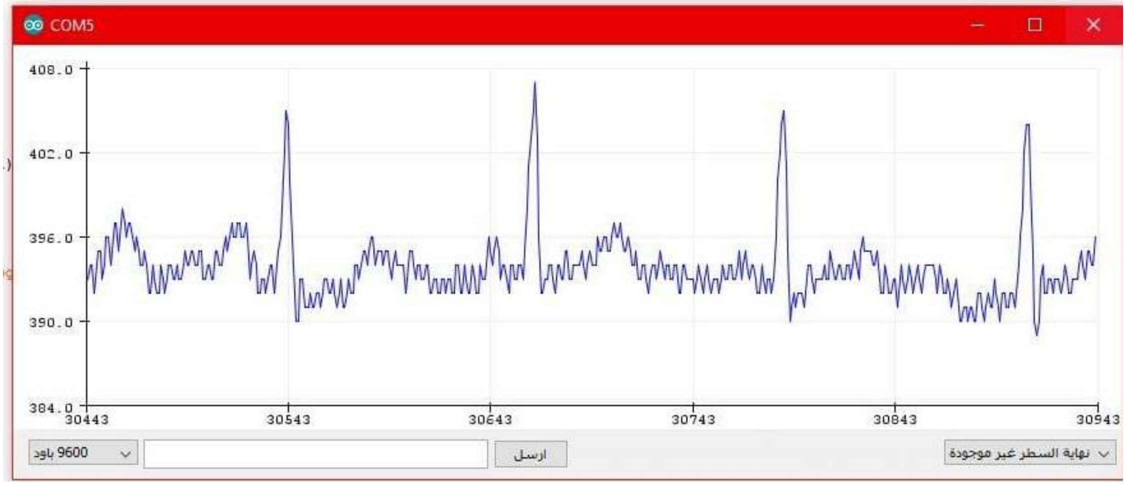


Fig 6.1 ECG Signal Before Nebulization Process

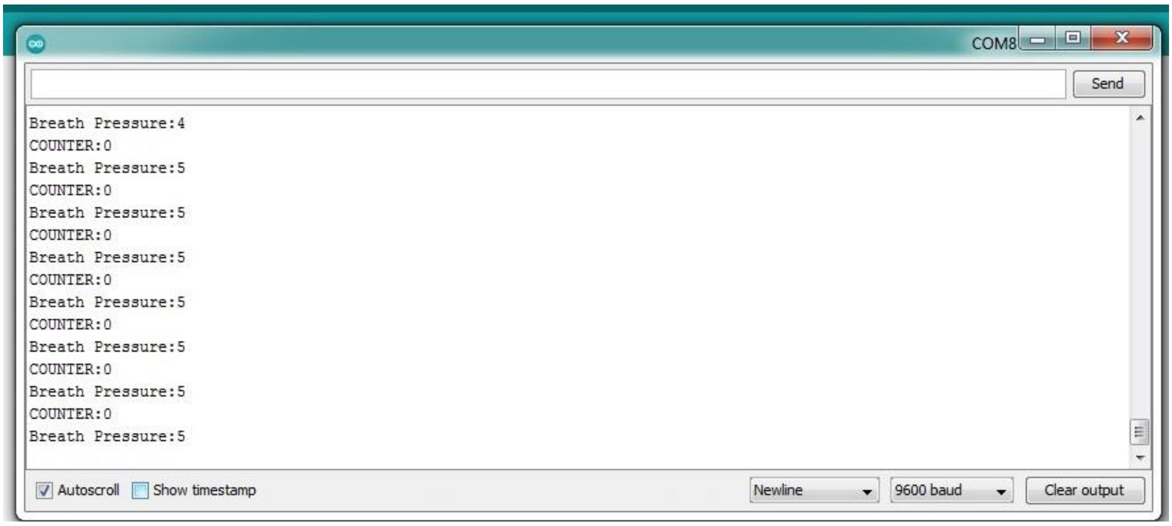


Fig 6.2 Normal Breath Pressure

6.1.2 During Nebulization Operation

When sensor reading was detected in normal state then the ultrasonic Fogger and DC motor(at high speed) were ON, and the ECG signal was recorded by a serial monitor in Arduino during this stage, as shown in fig 6.3 .and then the sensor reading was detected from normal to abnormal state , as shown in fig 6.4 and 6.5 ,then the motor speeds down until 20 second from abnormal situation , and the abnormal situation continue more than 20sec so the motor stopped, also ultrasonic Fogger ,and buzzer was turned on.

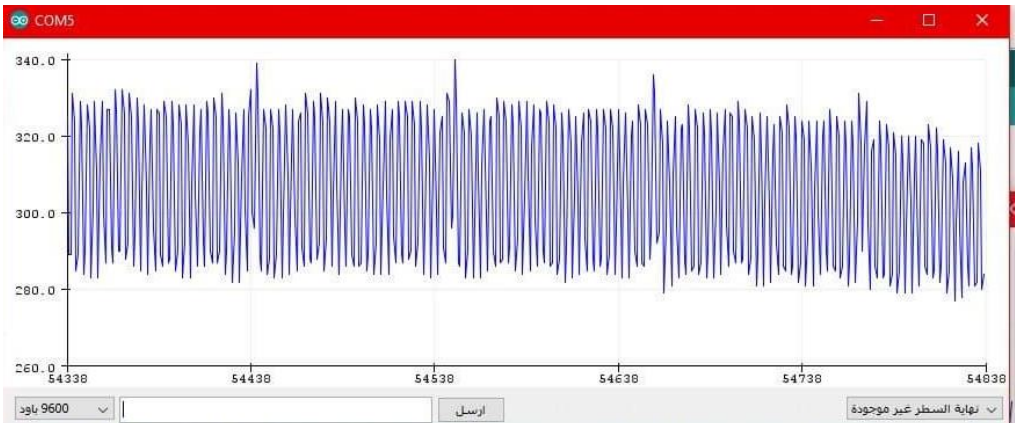


Fig 6.3 ECG Signal During Nebulization Process

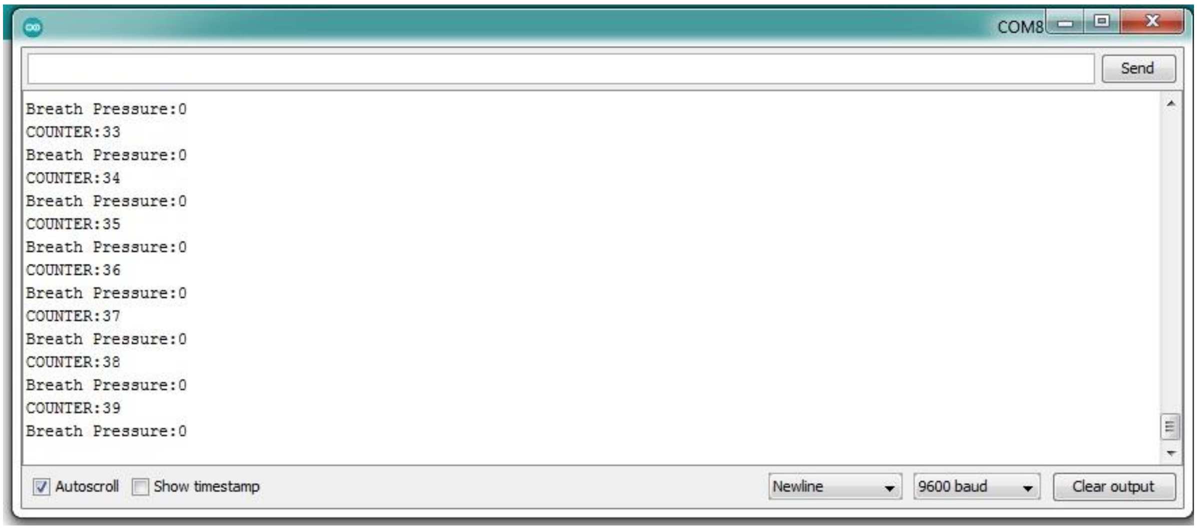


Fig6.4 Abnormal Breath Pressure

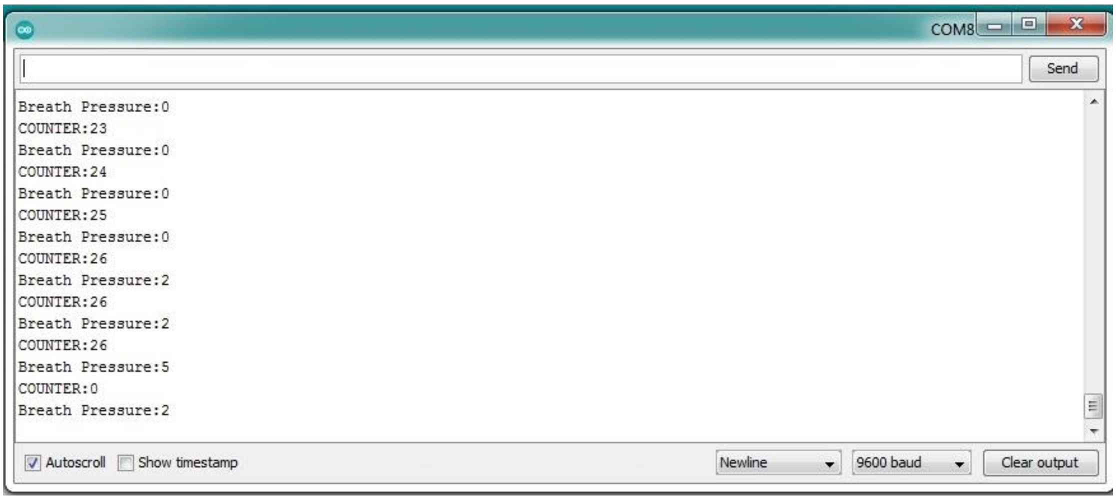


Fig 6.5 From Abnormal To Normal Breath Pressure

6.1.3 After Nebulization Operation

After the nebulization operation ,the ultrasonic Fogger and DC motor are turned off , and the ECG signal was recorded by a serial monitor, this result show the interval before the nebulization stopped and when it stopped (back normal situation), fig 6.6.

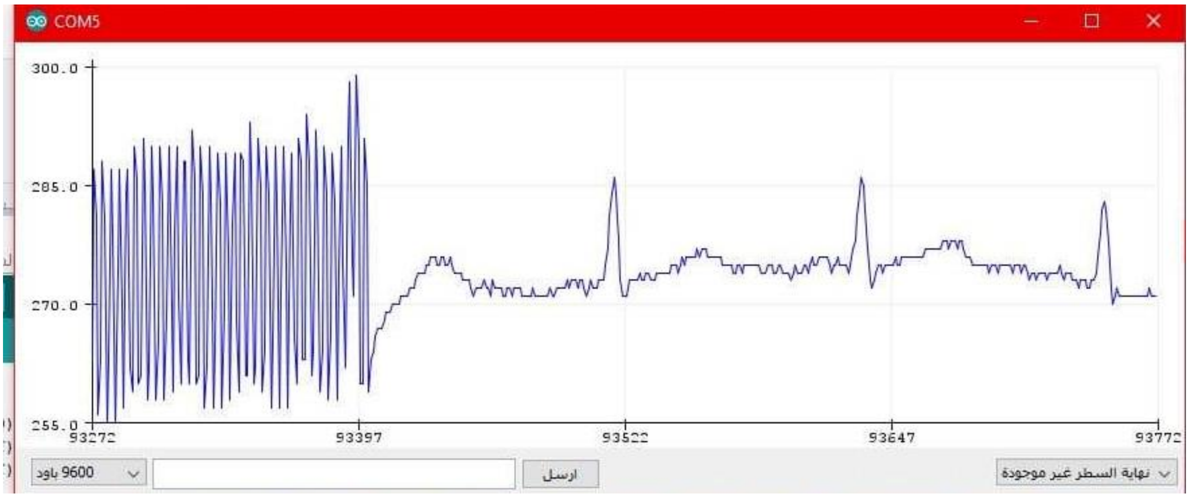


Fig 6.6 ECG Signal

6.2 Conclusion

Our hypothesis was that through designing and implementing this project ,a system could be set up to explore the impacts of nebulization process on respiratory change and ECG signal, by monitoring them before , through and after nebulization operation , and the idea of this project was to overcome the dose problems by design closed-loop nebulizer system, that has the capability to measure the respiration change during the administration of medicine, and automatically control the dose of mist.

. Furthermore ,this project provided a more complete understanding of the physiological processes occurring during nebulization process , And a light weight , closed loop nebulizer system is designed to control nebulization rate according to the detected respiratory change ; If the respiratory is abnormal during treatment, then the amount of mist reduced. If it still abnormal, the nebulizer will be turned off and alarm system will be activated.

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 control nebulization process for patients in an easy and convenient way by designing a non-invasive portable smart strap, Developer ultrasonic nebulizer and alarm system to warn people in case of an emergency, benefitting and protecting patients from respiration change in abnormal way.

6.3 Future Work

Interesting future studies might involve:

1- Sending SMS messages to the patient in order to provide information of time to take the drug, dosage of drug and ECG signal before, during and after the operation.

2- Developing another technical circuit to display more vital parameters on the LCD monitor.

3-Including a selection key for the reference value for various age groups, this is requires a Changing the construction and design.

4- Developing another technical circuit to detect the respiration rate along the process and provide this information for patient.

6.4 Challenges

Many challenges have been faced while designing the project:

1. Not all required components are available in the Palestinian

Market, some of the components were imported from the outside of Palestine and late to arrive due to COVID-19 , so we changed many things in the project according to the component that we had , like :

- In the first we’ve chosen the jet nebulizer to design , but the specific suction motor we request didn’t arrive yet , and we did not find the same one here , so we’ve chosen ultrasonic nebulizer.
- We designed an oscillation circuit to give a specific frequency to the ultrasonic disc , but the disc didn’t available in west bank or in 48 Palestine ,for luck we find the ultrasonic fogger , so we have been replaced the circuit and disc by Fogger.

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APPENDIX

Code

Programming Code

```
define Force sensor pin //
int flexiForcePin = A0; //analog pin 0


؛int c =0
؛const byte POWERPin = 13
؛const byte MotorPin = 7
؛const byte MotorControlspeed = 9
؛volatile byte state1 = LOW
؛const byte BuzzerPin = 12
؛volatile byte state2 = LOW
؛ int Value
```

```
؛const byte  powerSW=8
؛volatile byte state3 = HIGH
؛int motorValue = 0


()void setup
}
؛(pinMode(MotorPin,OUTPUT
؛(pinMode(MotorControlspeed,OUTPUT
؛(pinMode(BuzzerPin, OUTPUT
؛(pinMode(POWERPin,INPUT_PULLUP
؛(pinMode(powerSW,OUTPUT
؛(Serial.begin(9600
؛(Serial.begin(9600
؛(pinMode(10, INPUT
؛(pinMode(11, INPUT
{


()void loop
}
```

```
؛(Value = digitalRead(POWERPin
(if (Value == 0
}
(++for(int i=0;i<=500;i
}
؛(digitalWrite(powerSW,LOW
}((if((digitalRead(10) == 1)||(digitalRead(11) == 1
؛('!')Serial.println
{
}else

؛((Serial.println(analogRead(A1
{

؛(delay(1
{

؛(int flexiForceReading =(5.0/1023)* analogRead(A0

؛(":Serial.print("COUNTER
؛(Serial.println(c
؛(":Serial.print("Breath Pressure
؛(Serial.println(flexiForceReading
```

```
(if (flexiForceReading<2

؛++c

(else if (flexiForceReading>2

؛c=0


(if (c>=0 && c<19

}

؛(digitalWrite(powerSW,!state3

؛(digitalWrite(MotorPin,!state1

؛(analogWrite(MotorControlspeed, 255

؛(digitalWrite(BuzzerPin,state2


؛("Serial.println("Normal Situation

{

(else if (c>=20 && c<40

}


؛(digitalWrite(powerSW,!state3

؛(digitalWrite(MotorPin,!state1

؛(analogWrite(MotorControlspeed,10

؛(digitalWrite(BuzzerPin,state2

OPEN ALARM SYSTEM,&LOW SPEED MOTOR//
```

```
؛("Serial.println("Danger Situation

{

}(else if (c>=40

؛(digitalWrite(MotorPin,state1

digitalWrite(BuzzerPin, !state2); //STOPE THE MOTOR & ALARM STILL
OPEND

؛("Serial.println("VERY Danger Situation

؛(digitalWrite(powerSW,state3

{


{

}  else

؛(digitalWrite(MotorPin,state1

؛(digitalWrite(BuzzerPin,state2

؛(digitalWrite(powerSW,state3


{

(++for(int j=0;j<=500;j

}

؛(digitalWrite(powerSW,LOW

}((if((digitalRead(10) == 1)||(digitalRead(11) == 1

؛('!')Serial.println

{
```

```
}else

؛((Serial.println(analogRead(A1
{

؛(delay(1
{
  {
```

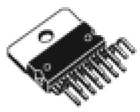
Datasheets

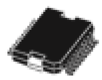
Appendix A

Driver L288

DUAL FULL-BRIDGE DRIVER

- OPERATING SUPPLY VOLTAGE UP TO 46 V
- TOTAL DC CURRENT UP TO 4 A
- LOW SATURATION VOLTAGE
- OVERTEMPERATURE PROTECTION
- LOGICAL "0" INPUT VOLTAGE UP TO 1.5 V (HIGH NOISE IMMUNITY)


Multiwatt15

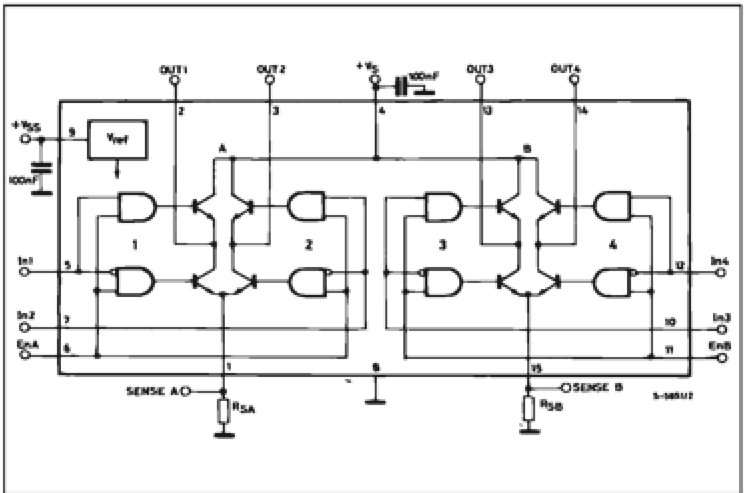

PowerSO20

ORDERING NUMBERS : L298N (Multiwatt Vert.)
L298HN (Multiwatt Horiz.)
L298P (PowerSO20)

DESCRIPTION

The L298 is an integrated monolithic circuit in a 15 lead Multiwatt and PowerSO20 packages. It is a high voltage, high current dual full-bridge driver designed to accept standard TTL logic levels and drive inductive loads such as relays, solenoids, DC and stepping motors. Two enable inputs are provided to enable or disable the device independently of the input signals. The emitters of the lower transistors of each bridge are connected together and the corresponding external terminal can be used for the connection of an external sensing resistor. An additional supply input is provided so that the logic works at a lower voltage.

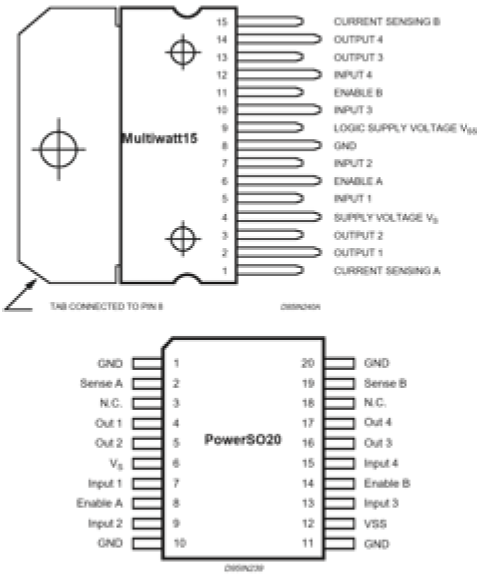
BLOCK DIAGRAM



ABSOLUTE MAXIMUM RATINGS

Symbol	Parameter	Value	Unit
V_S	Power Supply	50	V
V_{SS}	Logic Supply Voltage	7	V
V_I,V_{en}	Input and Enable Voltage	–0.3 to 7	V
I_O	Peak Output Current (each Channel) – Non Repetitive (t = 100μs) –Repetitive (80% on –20% off; t_{on} = 10ms) –DC Operation	 3 2.5 2	 A A A
V_{sens}	Sensing Voltage	–1 to 2.3	V
P_{tot}	Total Power Dissipation (T_{case} = 75°C)	25	W
T_{op}	Junction Operating Temperature	–25 to 130	°C
T_{stg}, T_j	Storage and Junction Temperature	–40 to 150	°C

PIN CONNECTIONS (top view)



THERMAL DATA

Symbol	Parameter		PowerSO20	Multiwatt15	Unit
$R_{th\ j\text{-}case}$	Thermal Resistance Junction-case	Max.	–	3	°C/W
$R_{th\ j\text{-}amb}$	Thermal Resistance Junction-ambient	Max.	13 (*)	35	°C/W

(*) Mounted on aluminum substrate

Appendix B

Flexiforce sensor Datasheet

INTERLINK ELECTRONICS
Sensor Technologies

Features and Benefits

- Actuation Force as low as 0.1N and sensitivity range to 10N.
- Easily customizable to a wide range of sizes
- Highly Repeatable Force Reading; As low as 2% of initial reading with repeatable actuation system
- Cost effective
- Ultra thin; 0.45mm
- Robust; up to 10M actuations
- Simple and easy to integrate

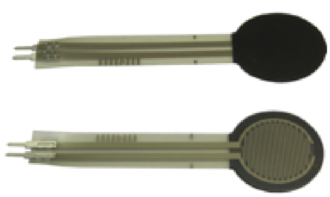
Industry Segments

- Game controllers
- Musical instruments
- Medical device controls
- Remote controls
- Navigation Electronics
- Industrial HMI
- Automotive Panels
- Consumer Electronics

FSR 402 Data Sheet

Description

Interlink Electronics FSR™ 400 series is part of the single zone Force Sensing Resistor™ family. Force Sensing Resistors, or FSRs, are robust polymer thick film (PTF) devices that exhibit a decrease in resistance with increase in force applied to the surface of the sensor. This force sensitivity is optimized for use in human touch control of electronic devices such as automotive electronics, medical systems, and in industrial and robotics applications.



The standard 402 sensor is a round sensor 18.28 mm in diameter. Custom sensors can be manufactured in sizes ranging from 5mm to over 600mm. Female connector and short tail versions can also be ordered.

FSR 402
P/N: 30-81794

INTERLINK ELECTRONICS
Sensor Technologies

Detect liquid blockage Detect tube or pump occlusion or blockage by measuring back pressure

Detect proper tube positioning

r other force measurement applications

Figure 1 - Force Curve

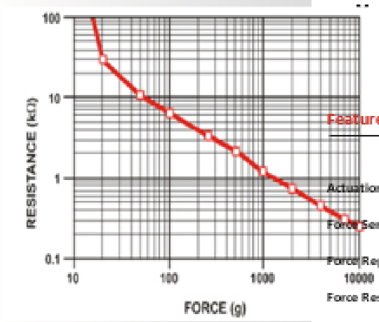
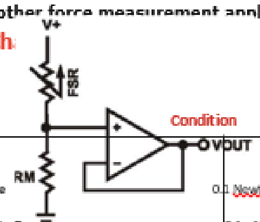


Figure 2 - Schematic



Ch

Feature	Condition	Value*	Notes
Actuation Force		0.1 Newtons	
Force Sensitivity Range		0.1 - 10.0 [2] Newtons	
Force Repeatability [3]	(Single part)	± 2%	
Force Resolution [3]		continuous	
Force Repeatability [3]	(Part to Part)	±6%	
Non-Actuated Resistance		10M W	
Size		18.28mm diameter	
Thickness Range		0.2 - 1.25 mm	
Stand-Off Resistance		>10 M ohms	Unloaded, unbent
Switch Travel	(Typical)	0.05 mm	Depends on design
Hysteresis [3]		+10%	$(R_{F+} - R_{F-})/R_{F+}$
Device Rise Time		<3 microseconds	measured w/steel ball
Long Term Drift		<5 % per $\log_{10}$ (time)	35 days test, 1kg load
Temp Operating Range	(Recommended)	-30 - +70 ºC	
Number of Actuations	(Life time)	10 Million tested	Without failure

* Specifications are derived from measurements taken at 1000 grams, and are given as one standard deviation / mean, unless otherwise noted.

1. Max Actuation force can be modified in custom sensors.
2. Force Range can be increased in custom sensors. Interlink Electronics have designed and manufactured sensors with operating force larger than 50Kg.
3. Force sensitivity dependent on mechanics, and resolution depends on measurement electronics.

Interlink Electronics - Sensor Technologies

Applications

Detect & qualify press Sense whether a touch is accidental or intended by reading force

Use force for UI feedback Detect more or less user force to make a more intuitive interface

Enhance tool safety Differentiate a grip from a touch as a safety lock

Find centroid of force Use multiple sensors to determine centroid of force

Detect presence, position, or motion Of a person or patient in a bed, chair, or medical device

INTERLINK ELECTRONICS
Sensor Technologies

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Application Information

FSRs are two-wire devices with a resistance that depends on applied force.

For specific application needs please contact Interlink Electronics support team.

An integration guide is also available.

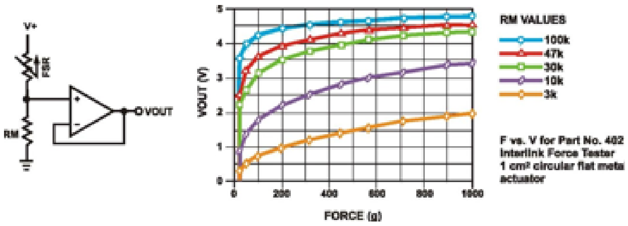
For a simple force-to-voltage conversion, the FSR device is tied to a measuring resistor in a voltage divider configuration (see Figure 3). The output is described by the equation:

$$V_{OUT} = \frac{R_M V+}{(R_M + R_{FSR})}$$

In the shown configuration, the output voltage increases with increasing force. If R_{FSR} and R_M are swapped, the output swing will decrease with increasing force.

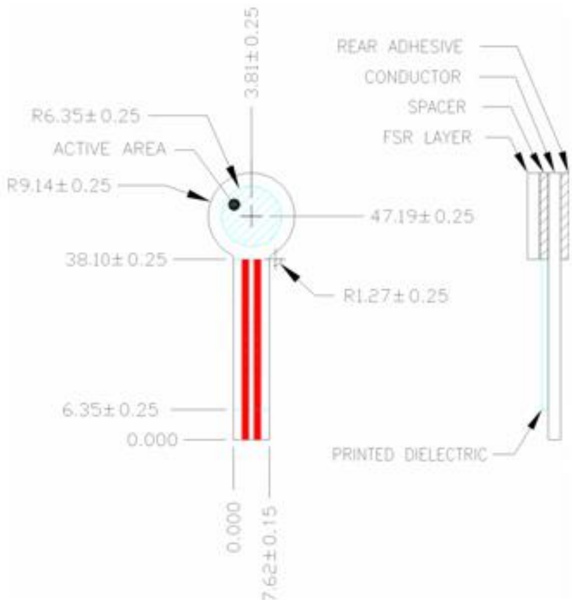
The measuring resistor, R_M, is chosen to maximize the desired force sensitivity range and to limit current. Depending on the impedance requirements of the measuring circuit, the voltage divider could be followed by an op-amp. A family of force vs. V_{OUT} curves is shown on the graph below for a standard FSR in a voltage divider configuration with various R_M resistors. A (V+) of +5V was used for these examples.

Figure 3



INTERLINK ELECTRONICS
Sensor Technologies

Mechanical Data



Part No. 402

- Active Area: 12.7mm
- Nominal thickness: 0.55 mm

Appendix C

5V Relay datasheet

SONGLE RELAY

松乐继电器 ® SONGLE RELAY	RELAY ISO9002	SRD

1. MAIN FEATURES

- ☐ Switching capacity available by 10A in spite of small size design for highdensity P.C. board mounting technique.
- ☐ UL,CUL,TUV recognized.
- ☐ Selection of plastic material for high temperature and better chemical solution performance.
  - ☐ Sealed types available.
- ☐ Simple relay magnetic circuit to meet low cost of mass production.

2. APPLICATIONS

☐ Domestic appliance, office machine, audio, equipment, automobile, etc.

(Remote control TV receiver, monitor display, audio equipment high rushing current use application.)

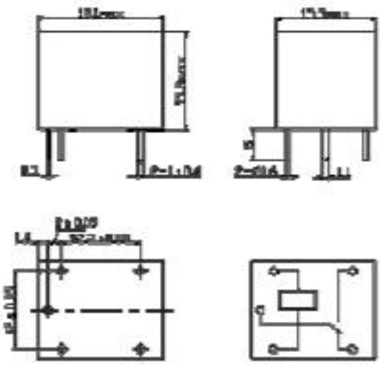
3. ORDERING INFORMATION

SRD	XX VDC	S	L	C
Model of relay	Nominal coil voltage	Structure	Coil	Contact form
SRD	03、05、06、09、12、24、48VDC	S:Sealed type	L:0.36W	A:1 form A
				B:1 form B
		F:Flux free type	D:0.45W	C:1 form C

4. RATING

CCC	FILE NUMBER:CQC03001003729	7A/240VDC
CCC	FILE NUMBER:CQC03001003731	10A/250VDC
UL /CUL	FILE NUMBER: E167996	10A/125VAC 28VDC
TUV	FILE NUMBER: R50056114	10A/250VAC 30VDC

5. DIMENSION(unit:mm) DRILLING(unit:mm) WIRING DIAGRAM



6. COIL DATA CHART (AT20° C)

Coil Sensitivity	Coil Voltage Code	Nominal Voltage (VDC)	Nominal Current (mA)	Coil Resistance (Ω) □ 10%	Power Consumption (W)	Pull-In Voltage (VDC)	Drop-Out Voltage (VDC)	Max-Allowable Voltage (VDC)
SRD (High Sensitivity)	03	03	120	25	abt. 0.36W	75%Max.	10% Min.	120%
	05	05	71.4	70				
	06	06	80	100				
	09	09	40	225				
	12	12	30	400				
	24	24	15	1600				
	48	48	7.5	6400				
SRD (Standard)	03	03	150	20	abt. 0.45W	75% Max.	10% Min.	110%
	05	05	89.3	55				
	06	06	75	80				
	09	09	50	180				
	12	12	37.5	320				
	24	24	18.7	1280				
	48	48	10	4500	abt. 0.51W			

7. CONTACT RATING

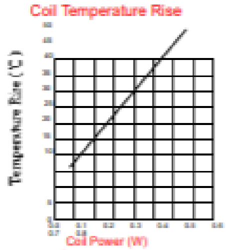
Item \ Type	SRD FORM C	SRD FORM A
Contact Capacity Resistive Load (cosΦ=1)	7A 30VDC 10A 125VAC 10A 250VAC	10A 30VDC 10A 240VAC
Inductive Load (cosΦ=0.4 L/R=7msec)	3A 120VAC 3A 28VDC	5A 120VAC 5A 28VDC
Max. Allowable Voltage	250VAC/110VDC	250VAC/110VDC
Max. Allowable Power Force	800VAC/240W	1200VA/300W
Contact Material	AgCdO	AgCdO

8. PERFORMANCE (at initial value)

Item \ Type	SRD
Contact Resistance	100mΩ Max.
Operation Time	10msec Max.
Release Time	5msec Max.
Dielectric Strength	
Between coil & contact	1500VAC 50/60HZ (1 minute)
Between contacts	1000VAC 50/60HZ (1 minute)
Insulation Resistance	100 MΩ Min. (500VDC)
Max. ON/OFF Switching	
Mechanically	300 operation/min
Electrically	30 operation/min
Ambient Temperature	-25℃ to +70 C
Operating Humidity	45 to 85% RH
Vibration	
Endurance	10 to 55Hz Double Amplitude 1.5mm
Error Operation	10 to 55Hz Double Amplitude 1.5mm
Shock	
Endurance	100G Min.
Error Operation	10G Min.
Life Expectancy	
Mechanically	10^7 operations. Min. (no load)
Electrically	10^5 operations. Min. (at rated coil voltage)
Weight	abt. 10grs.

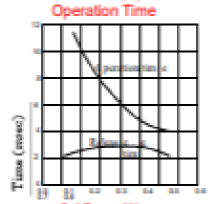
9.REFERENCE DATA

Coil Temperature Rise



Coil Power (W)

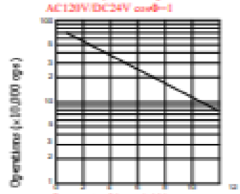
Operation Time



Coil Power (W)

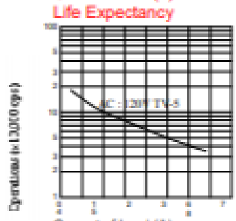
Life Expectancy

AC120V/DC24V cosΦ=1



Current of Load (A)

Life Expectancy



Current of Load (A)

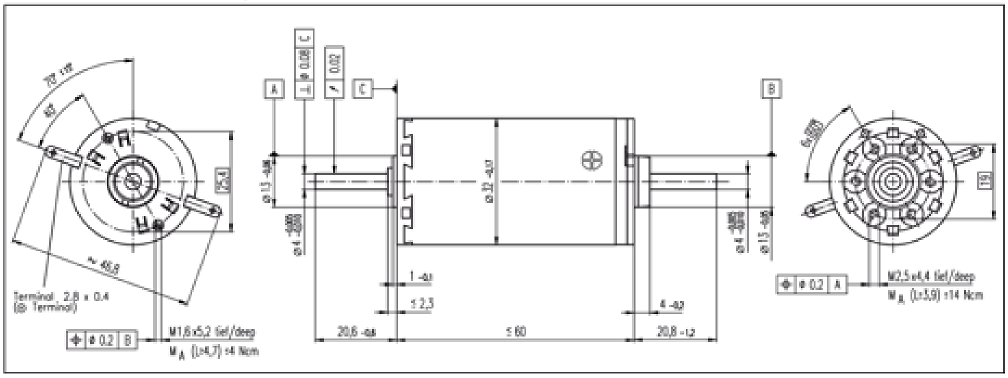
Appendix D

5 v DC motor

maxon DC motor

A-max 32
∅32 mm, Escobillas de grafito, 20 Vatios

HIGH Power

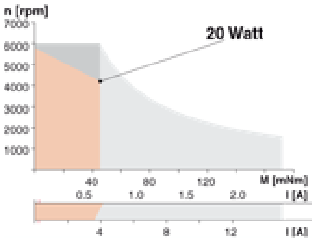


Datos del motor: Números de Referencia

sin CLL

1	Potencia nominal asignada	W	20	20	20	20	20	20	20
2	Tensión nominal	Volt	6.0	9.0	12.0	24.0	30.0	36.0	42.0
3	Velocidad en vacío	rpm	4780	4920	4610	6420	6130	5820	5620
4	Par de arranque	mNm	121	130	131	206	194	187	178
5	Relación velocidad/par	rpm/mNm	41.0	39.0	36.0	31.7	32.1	31.6	32.1
6	Corriente en vacío	mA	242	165	115	81	62	49	40
7	Corriente de arranque	mA	10500	7670	5430	5860	4220	3220	2530
8	Resistencia en bornas	Ohm	0.573	1.17	2.21	4.09	7.11	11.2	16.6
9	Máx. velocidad permitida	rpm	6000	6000	6000	6000	6000	6000	6000
10	Máx. corriente en continuo	mA	3610	2520	1840	1350	1020	817	671
11	Máx. par permanente	mNm	41.7	42.7	44.5	47.3	47.1	47.5	47.1
12	Máx. potencia útil a tensión nominal	mW	14100	16000	15300	33900	30500	28000	25700
13	Máx. rendimiento	%	69	71	72	77	77	77	76
14	Constante de par	mNm/A	11.5	17.0	24.2	35.1	46.0	58.1	70.2
15	Constante de velocidad	rpm/V	827	563	394	272	208	164	136
16	Constante de tiempo mecánica	ms	18	16	15	14	14	14	14

Rango de funcionamiento



Leyenda

Detalles en página 36

Rango recomendado de funcionamiento

Funcionamiento continuo
Teniendo en cuenta los valores de resistencia térmica antes mencionados (líneas 19 y 20). El rotor alcanzará la máxima temperatura durante funcionamiento continuo a 25°C de temperatura ambiente = límite térmico.

Funcionamiento intermitente.
El motor puede ser sobrecargado durante cortos periodos (cíclicamente).

110854 Motor con bobinado de alta resistencia

110848 Motor con bobinado de baja resistencia

Programa Stock
Programa Estándar
Programa Especial (¡previo encargo!)

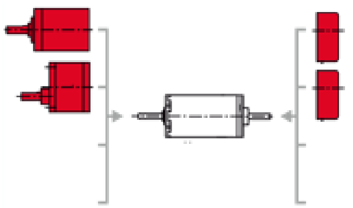
- Juego axial 0.12 - 0.22 mm
- Carga máx. en el **rodamiento a bolas**
  axial (dinámica) 7.6 N
  radial (a 5 mm de la brida) 32.0 N
  Máx. fuerza montaje a presión (estática) 110 N
  idem, con eje sostenido 2000 N
- Carga máx. en el **cojinete sinterizado**
  axial (dinámica) 5 N
  radial (a 5 mm de la brida) 10.5 N
  Máx. fuerza montaje a presión (estática) 110 N
  idem, con eje sostenido 2000 N
- Juego radial
  en **rodamiento a bolas** 0.025 mm
  en **cojinete sinterizado** 0.012 mm
- Rango de temperatura ambiente -20/+85°C
- Máx. temperatura del rotor +125°C
- Número de delgas del colector 13
- Peso del motor 242 g
- Los datos de la tabla son valores nominales. Para las tolerancias aplicables (ver página 33) y para detalles adicionales, por favor solicite nuestra impresión por ordenador.

- Opciones: Cojinetes sinterizados en lugar de rodamientos a bolas y cablecillos en vez de terminales.

Sistema Modular maxon

Reductor Planetario
∅32 mm
0.75-4.5 Nm
Detalles página 161

Reductor engranaje recto
∅38 mm
0.1-0.6 Nm
Detalles página 164



Encoder Digital
HP HEDS 5540
500 ppv., 3 canales
Detalles página 177

Encoder Digital
HP HEDL 5540
500 ppv., 3 canales
Detalles página 179

Appendix C

AD8232

ANALOG DEVICES

Single-Lead, Heart Rate Monitor Front End

FUNCTIONAL BLOCK DIAGRAM

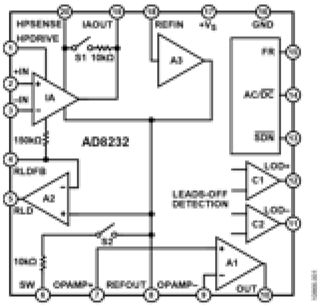


Figure 1.

Data Sheet **AD8232**

FEATURES

Fully integrated single-lead ECG front end
Low supply current: 170 µA (typical)
Common-mode rejection ratio: 80 dB (dc to 60 Hz)
Two or three electrode configurations
High signal gain (G = 100) with dc blocking capabilities
2-pole adjustable high-pass filter
Accepts up to ±300 mV of half cell potential
Fast restore feature improves filter settling
Uncommitted op amp
3-pole adjustable low-pass filter with adjustable gain Leads off detection: ac or dc options
Integrated right leg drive (RLD) amplifier
Single-supply operation: 2.0 V to 3.5 V
Integrated reference buffer generates virtual ground Rail-to-rail output
Internal RFI filter
8 kV HBM ESD rating
Shutdown pin
20-lead 4 mm × 4 mm LFCSP package

APPLICATIONS

Fitness and activity heart rate monitors
Portable ECG
Remote health monitors
Gaming peripherals
Biopotential signal acquisition

SPECIFICATIONS

V_S = 3 V, V_{REF} = 1.5 V, V_{CM} = 1.5 V, T_A = 25°C, $\overline{FR}$=low, SDN=high, AC/DC = low, unless otherwise noted.

Table 1.

Parameter	Symbol	Test Conditions/Comments	Min	Typ	Max	Unit
INSTRUMENTATION AMPLIFIER						
Common-Mode Rejection Ratio, DC to 60 Hz	CMRR	V_{CM} = 0.35 V to 2.85 V, V_{DIFF} = 0 V	80	86		dB
		V_{CM} = 0.35 V to 2.85 V, V_{DIFF} = ±0.3 V		80		dB
Power Supply Rejection Ratio	PSRR	V_S = 2.0 V to 3.5 V	76	90		dB
Offset Voltage (RTI)	V_{OS}					
Instrumentation Amplifier Inputs				3	8	mV
DC Blocking Input[1] Average				5	50	μV
Offset Drift						
Instrumentation Amplifier Inputs				10		μV/°C
DC Blocking Input[1]				0.05		μV/°C
Input Bias Current	I_B			50	200	pA
		T_A = 0°C to 70°C		1		pA
Input Offset Current	I_{OS}			25	100	pA
		T_A = 0°C to 70°C		1		pA
Input Impedance						
Differential				10||7.5		GΩ||pF
Common Mode				5||15		GΩ||pF
Input Voltage Noise (RTI)						
Spectral Noise Density		f = 1 kHz		100		nV/√Hz
Peak-to-Peak Voltage Noise		f = 0.1 Hz to 10 Hz		12		μV p-p
		f = 0.5 Hz to 40 Hz		14		μV p-p
Input Voltage Range		T_A = 0°C to 70°C	0.2		$+V_S$	V
DC Differential Input Range Output	V_{DIFF}		−300		+300	mV
Output Swing		R_L = 50 kΩ	0.1		$+V_S$ − 0.1	V
Short-Circuit Current	I_{SHT}			6.3		mA
Gain	A_V			100		V/V
Gain Error		V_{DIFF} = 0 V		0.4		%
		V_{DIFF} = −300 mV to +300 mV		1	3.5	%
Average Gain Drift		T_A = 0°C to 70°C		12		ppm/°C
Bandwidth	BW			2		kHz
RFI Filter Cutoff (Each Input)				1		MHz
OPERATIONAL AMPLIFIER (A1)						
Offset Voltage	V_{OS}			1	5	mV
Average TC		T_A = 0°C to 70°C		5		μV/°C
Input Bias Current	I_B			100		pA

THEORY OF OPERATION

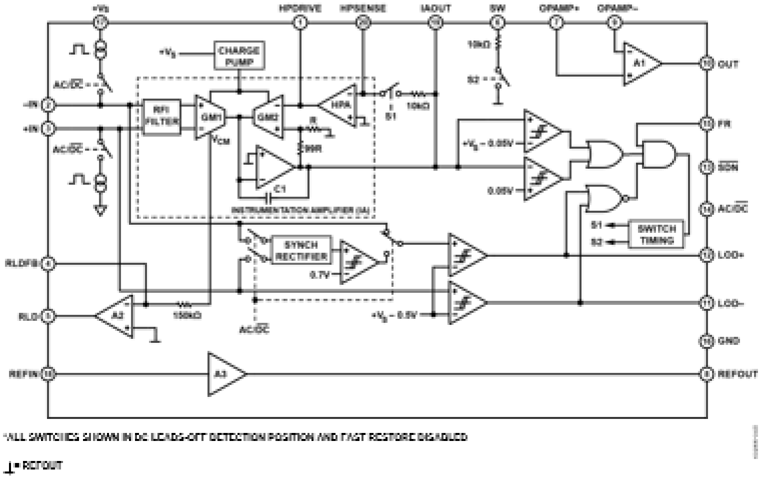


Figure 45. Simplified Schematic Diagram

ARCHITECTURE OVERVIEW

The AD8232 is an integrated front end for signal conditioning of cardiac biopotentials for heart rate monitoring. It consists of a specialized instrumentation amplifier (IA), an operational amplifier (A1), a right leg drive amplifier (A2), and a midsupply reference buffer (A3). In addition, the AD8232 includes leads off detection circuitry and an automatic fast restore circuit that brings back the signal shortly after leads are reconnected.

The AD8232 contains a specialized instrumentation amplifier that amplifies the ECG signal while rejecting the electrode half-cell potential on the same stage. This is possible with an indirect current feedback architecture, which reduces size and power compared with traditional implementations.

INSTRUMENTATION AMPLIFIER

The instrumentation amplifier is shown in Figure 45 as comprised by two well-matched transconductance amplifiers (GM1 and GM2), the dc blocking amplifier (HPA), and an integrator formed by C1 and an op amp. The transconductance amplifier, GM1, generates a current that is proportional to the voltage present at its inputs. When the feedback is satisfied, an equal voltage appears across the inputs of the transconductance amplifier, GM2, thereby matching the current generated by

The feedback of the amplifier is applied via GM2 through two separate paths: the two resistors divide the output signal to set an overall gain of 100, whereas the dc blocking amplifier integrates any deviation from the reference level. Consequently, dc offsets as large as ±300 mV across the GM1 inputs appear inverted and with the same magnitude across the inputs of GM2, all without saturating the signal of interest.

To increase the common-mode voltage range of the instrumentation amplifier, a charge pump boosts the supply voltage for the two transconductance amplifiers. This further prevents saturation of the amplifier in the presence of large common-mode signals, such as line interference. The charge pump runs from an internal oscillator, the frequency of which is set around 500 kHz.

OPERATIONAL AMPLIFIER

This general-purpose operational amplifier (A1) is a rail-to-rail device that can be used for low-pass filtering and to add additional gain. The following sections provide details and example circuits that use this amplifier.

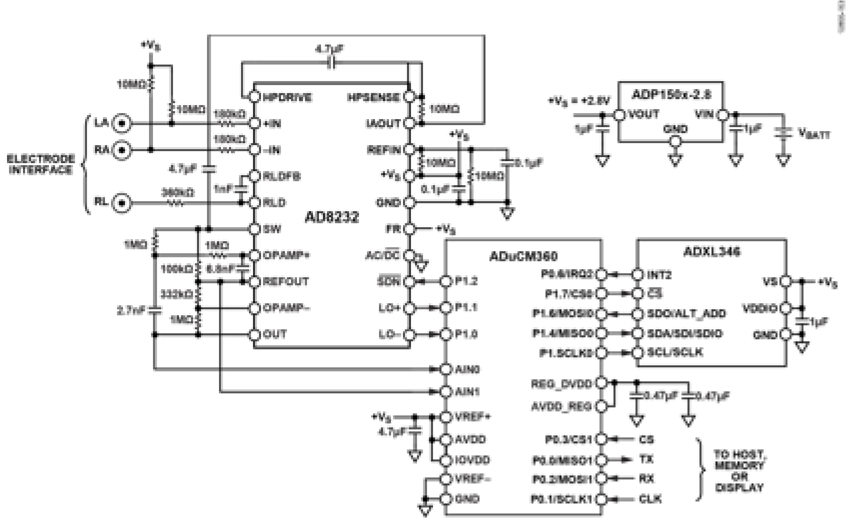


Figure 68. Low Power Portable Cardiac Monitor