Palestine Polytechnic University

College of Engineering

Design and Development of a Full Automated Contrast Injector Device for CT-Scan

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﴿الْحَمْدُ لِلَّهِ الَّذِي هَدَانَا لِهَذَا وَمَا كُنَّا لِنَهْتَدِيَ لَوْلَا أَنْ هَدَانَا اللَّهُ﴾

الحمد لله رب العالمين ....

نهدي تخرجنا إلى من اسمعنا اول اذان في حياتنا ... وسخر كل قواه عوناً لنا... كي نصل الى ما نحن عليه الان ... الى من جرع الكأس فارغاً ليسقينا قطرة حب ... إلى من حصد الأشواك عن دربنا ليمهد لنا طريق العلم ... الى ملاكنا في الحياة ... إلى من حوتنا في احشائها تسعة أشهر... وسقتنا من دمها وقوت يومها.. إلى من سهرت الليالي من أجل ... إلى من علمتنا معنى المحبة والصبر والحب والحنان والعطف ... إليكِ يا نبع الحنان وفيروزة الأيام ... الى من ساروا معنا الدروب يضيئونها ... يساعدوننا على النهوض كلما تعثرنا... يدفعون بنا نحو القمة ... أساتذتنا... إلى من ركبوا معنا قطار العمر وكانوا لنا سنداً على نوائب الدهر... اخوتنا واخواتنا رفقاء دربنا واصدقائنا... في غمضة عين مرت ايامنا وها نحن اليوم نجني قطافنا كل الشكر والامتنان لكم ...

الملخص

حاقن وسائط التباين ، هو عبارة عن جهاز طبي مخصص للاستخدام من قِبل متخصصي التصوير الطبي والتشخيصي ،يستخدم كمرفق لأجهزة التصوير المقطعي وأجهزة الرنين المغناطيسي لحقن وسائط التباين الإشعاعي والمحلول الملحي في نظام الأوعية الدموية للمريض أثناء فحوصات الأشعة المقطعية ، الذي يمكن برمجته لتقديم كميات محددة من عامل التباين بمعدلات تدفق محددة ، يتم حقنها قبل إجراء فحص التصوير ، تساعد مواد التباين على تمييز أو "تباين" المناطق محددة من الجسم. من خلال تحسين وضوح أعضاء معينة ، أو الأوعية الدموية أو الأنسجة ، تساعد مواد التباين الأطباء على تشخيص الحالات الطبية .

يقدم هذا المشروع تصميم حاقن التباين وتطبيقه بشكل بسيط ،وتطويره بتقنيات إضافية ، وتمكن هذه التقنيات في حل العديد من مشاكل الأجهزة الموجودة في المستشفيات ومراكز الأشعة ، وهي تصميم نظام تحكم لاسلكي باستخدام تقنية البلوتوث ، تصميم نظام وحدة الإنذار لتأمين المريض من انتفاخ الذراع والكشف عنه, وكما يمتاز المشروع بانخفاض التكلفة القائمة عليه مقارنة بأسعار الأجهزة الموجودة في السوق .

Abstract

Contrast Injector is a medical device intended for use by medical and diagnostic imaging specialists, used as a facility for CT and MRI devices to inject the radiation contrast media and saline solution into the patient's vascular system during CT scans, which can be programmed to provide specific amounts of agent Contrast at specific flow rates, injected before imaging, contrast materials help distinguish or "contrast" specific areas of the body. By improving the clarity of certain organs, blood vessels or tissues, contrast materials help doctors diagnose medical conditions.

This project introduces the design of the Injector Incompatibility and its simple application, and developed by additional technologies. These techniques enable the solution of many problems of devices in hospitals and radiology centers, namely design of wireless control system using Bluetooth technology, design of the alarm system to secure the patient from swelling of the arm and detection, The project is also characterized by lower cost based on comparable hardware prices found in the market.

List of Contents

List of Figure

List of Table

List of Abbreviations

Abbreviations	Full Word
IVC	Inferior Vena Cava
SVC	Superior Vena Cava
CT	Computed Tomography
MRI	Magnetic Resonance Imaging
NS	Normal Saline
PI	Power Injector
FSR	Force Sensing Resistors
PTF	Polymer Thick Film
SPP	Serial Port Protocol
AFH	Adaptive Frequency Hopping Feature
RAM	Random Access Memory
PM	Permanent Magnet
VR	Variable Reluctance
PSI	Pound Per Square Inch
IN	Inches
IBF	Pound Of Force
IB.IN	Pounds.Inches
N.M	Newton Meter

Chapter One

Introduction

1.1 Project Idea

1.2 Project Objectives

1.3 Project Importance

1.4 Field Study

1.5 Economical Study

1.6 The Project Timeline

Stephen Heilman an emergency room physician saw an early coronary arteriogram during the early 1960s and immediately realized the need for better tools to deliver contrast media. He teamed up with Mark Wholey, who had visited Sweden and had trained with some of the pioneers of angiography in the early 1960s as well. Together, they invented and developed the first flow-controlled angiographic injector in Dr. Heilman's home outside of Pittsburgh, Pennsylvania. The Heilman-Wholley Injector was commercialized in 1967, and was initially distributed by Picker X-Ray Company and manufactured by the new company, Medrad, Inc. Medical devices employed for injecting radio-opaque contrast media and normal saline solution into the body to enhance the visibility of tissues for a medical imaging procedure are known as contrast injectors. Over the years, with ever-increasing technological sophistication, these contrast injectors have evolved from manual injectors, providing added accuracy and advantages. These automated versions are known as auto injectors, Auto injectors are capable of controlling the amount of contrast media and normal saline solution injected, utilization rate, and are also able to increase dosage to keep pace with fast medical imaging scanners. [1], [2]

1.1 Project idea

This project will handle two main ideas; the first idea is designing the contrast injector and applying it with a simple form. The second one is solving many problems of the device in hospitals and radiology centers which are available in our country. And developing it with an additional technique, this technique is replacing the control wires that connect the device and the control room together with a wireless control by using Arduino microcontroller with Bluetooth technique. Moreover, the device will be provided with an isolation cover to be saved of contrast solution which might be spilled into the device due to technical errors, the third one is design Alarm module system to safe the patient from the arm bulge and detection by using strain gauge sensor Finally, the project will give a chance to have a device that is cheaper, but it does the same functions with more professional techniques.

1.2 Project Objectives

The objective of the project is to:

1- Design a wireless control system using Bluetooth technology.
2- Control the amount of the injected contrast and normal saline using stepper motor.
3- The system will be controlled using Arduino microcontroller.
4- Design Alarm module system to safe the patient from the arm bulge and detection.

1.3 Project Importance

The importance of the project is summarized as following:

1- More economic.
2- User friendly.
3- High sensitivity.
4- Fewer problems.
5- More safety.

1.4 Field study

Mohammad Abu Mayalah operator of radiology department at AL-Ahli Hospital has requested technical of contrast injector device that replace the wire of device with wireless technical to easily use of application interface , it available to more safe device from leaking of contrast media solution entire device because of Technical errors by operators , so design an isolation cover device that project neglect any button or monitor display on cover by substituted it of application interface control and display .

Osama Makhamreh will get Master's degree , main operator of Ibn Rushd Radiology Center Hospital has requested technical of contrast injector device that make solution of bulge because of Technical errors by operator or random error of needle spill contrast media solution out of artery then a bulge it occur , so in this project Design Alarm module system to safe the patient from the arm bulge and detection it .

1.5 Economical Study

This section lists the overall cost of the project components that are considered in implementing this system.

The **Table 1.1** contains the main required hardware components of the project design and its prices

Table 1.1: The Total Price

No	Types	Price	Quantity
1	Stepper Motors	100 $	2
2	Actuator, Connectors and Stands	80 $	2
3	Drivers	30 $	2
4	Rechargeable Batteries and Chargers	150 $	2
5	Dc-Dc boost converter	6 $	1
6	Battery Voltage Tester	6 $	1
7	Microcontrollers	80 $	2
8	Bluetooth Modules	60 $	3
9	Switches	5 $	2
10	Micro switches	5 $	4
11	Resistors	3 $	8
12	LEDs	3 $	4
13	Copper Board	5 $	2
14	Syringes	50 $	2
15	Project Cover	200$	1
16	Cuff	25 $	1
The Total Price		805 $	

1.6 The Project Timeline

Table 1.2 Activities Schedule of the First 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 1.3 Activities Schedule of the Second Semester .

Weeks / Activities	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Full Designing	■	■	■	■	■										
Purchasing components						■	■	■	■	■	■	■			
System Implementation													■	■	
System Analysis													■	■	
Print documentation															■

Chapter Two

Anatomy and Physiology of Cardiovascular and Urinary Systems

2.1 Cardiovascular system

2.1.1 Introduction of Cardiovascular System

2.1.2 Structure of Cardiovascular System

2.1.3 The circulatory system and Blood flow

2.1.4 Contrast media and saline solution flow in the body

2.2 The urinary system

2.2.1 Introduction of urinary system

2.2.2 Structure of urinary system

2.2.3 Contrast media and normal saline removal

2.1 Cardiovascular system

2.1.1 Introduction of Cardiovascular System

The heart has four separate compartments or chambers. The upper chamber on each side of the heart, which is called an atrium, receives and collects the blood coming to the heart. The atrium then delivers blood to the powerful lower chamber, called a ventricle, which pumps blood away from the heart through powerful, rhythmic contractions. [3]

2.1.2 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. [4]

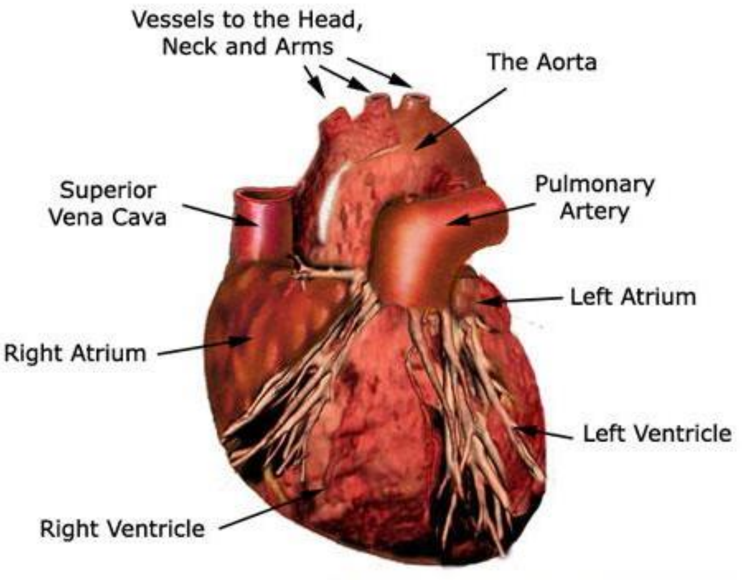

Figure 2.1 Structure of heart. [5]

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. [6]

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. [7]

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. [8]

The circulatory system divided in two types:

1. **Pulmonary circulation**

The pulmonary circulatory system shown in figure2.2 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 is released from the blood, and oxygen is absorbed, pulmonary vein returns the now oxygen-rich blood to the left atrium. [9]

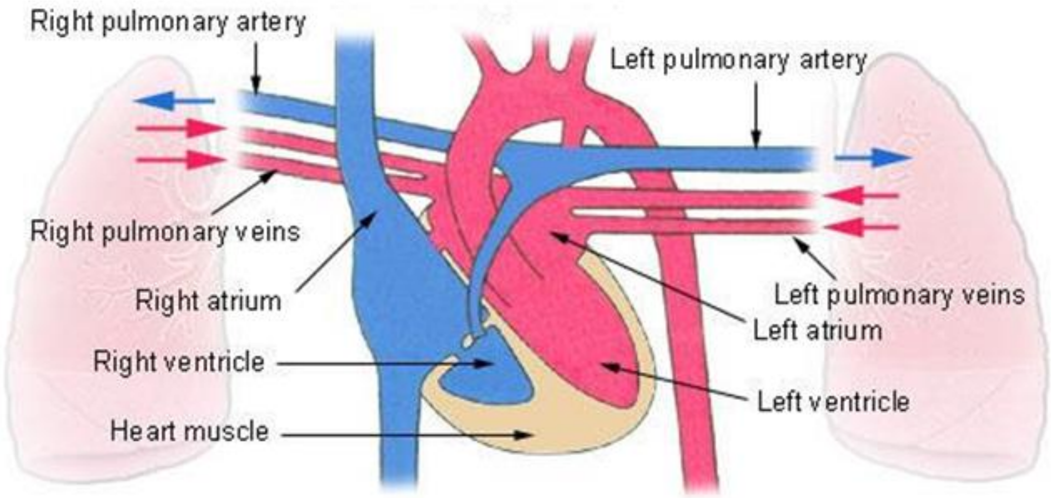

Figure 2.2 Pulmonary circulations. [10]

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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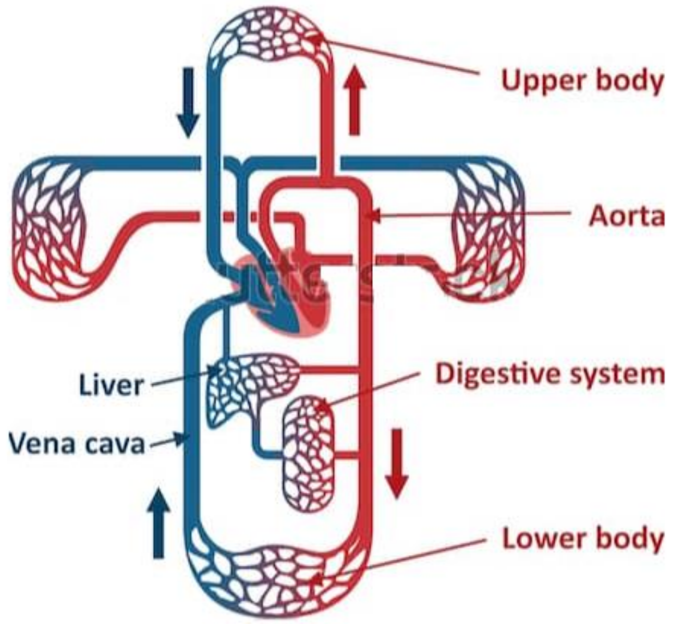


Figure 2.3 Systemic circulation. [11]

2.1.4 Contrast media and saline solution flow in the body

After peripheral intravenous injection, contrast medium travels to the right heart, the pulmonary circulation, and the left heart before reaching the central arterial system. Its circulation throughout the body is regulated by the cardiovascular system. Contrast medium rapidly redistributes from the vascular to the interstitial spaces of the organs. Because contrast media consist of relatively small molecules that are highly diffusible, the transport of contrast media is predominantly "flow limited" and far less "diffusion limited." In a flow-limited process, the delivery of contrast medium through the circulatory system to an organ. Well-perfused organs such as the kidney, the spleen, and the liver show high contrast enhancement during the initial circulation (first pass) of contrast medium to the organs, As contrast medium circulates in the body, it is diluted by the blood, and the bolus disperses as it moves downstream through the circulatory system. The effect of dilution is greater in organs more distal from the injection site progressively broadened contrast enhancement profile with a more flattened peak. For very long injections, the recirculation can even occur during the infusion of the contrast material. Recirculated contrast-does not reach a target organ simultaneously because of multiple circulatory pathways in the body. For example, blood in the cerebral circulation returns to the right heart and recirculates faster than blood in the portal circulation. The transit time for normal recirculation may range 15–40 seconds depending on circulatory paths (faster for shorter paths). The recirculated contrast medium is further diluted by intravascular and extracellular volume, and the bolus dispersion is largely governed by blood flow and tissue perfusion. He most important patient-related factor affecting the timing of contrast enhancement is cardiac output and cardiovascular circulation. When cardiac output decreases, the circulation of contrast medium slows. Contrast material bolus arrives slowly and clears slowly, resulting in delayed contrast material bolus arrival and delayed peak arterial and parenchymal enhancement. The time of contrast material bolus arrival and the time to peak enhancement in all organs are highly correlated with, and linearly proportional to, the reduction in cardiac output. [12]

2.2 The urinary system

2.2.1 Introduction of urinary system

The urinary system, also known as the renal system or urinary tract, consists of the kidneys, ureters, bladder, and the urethra. The purpose of the urinary system is to eliminate waste from the body, regulate blood volume and blood pressure, control levels of electrolytes and metabolites, and regulate blood PH; urinary tract is the body's drainage system for the eventual removal of urine. [13]

2.2.2 Structure of urinary system

1. Kidneys

The human body has two kidneys, one on either side of the middle back, just under the ribs. Each kidney contains thousands of small filters called nephrons. Each nephron has a mesh of capillaries, connecting it to the body's blood supply, Around 180 liters of blood sieve through the kidneys every day. The main functions of the kidney include:

1. Regulating the amount of water and salts in the blood
2. Filtering out waste products
3. Making a hormone that helps to control blood pressure. [14]

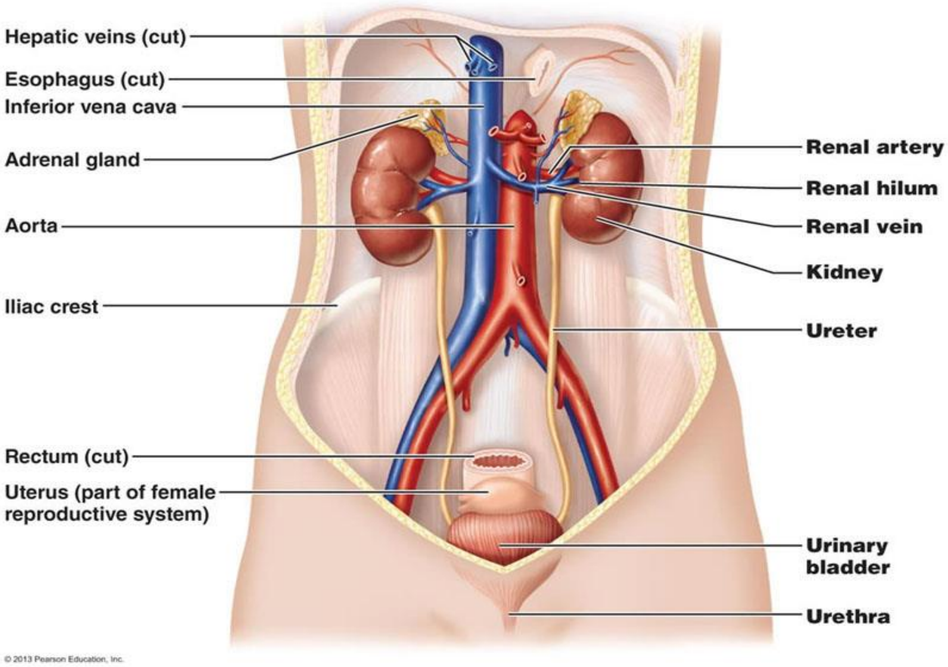


Figure 2.4 Structure of urinary system. [15]

2. Ureters

Each kidney has a tube called a ureter. The filtered waste products (urine) leave the kidneys via the ureters and enter the bladder. [14]

3. Bladder

The bladder is a hollow organ that sits inside the pelvis. It stores the urine, When a certain amount of urine is inside the bladder, the bladder 'signals' the urge to urinate, Urine contains water and waste products like urea and ammonia. [14]

4. Urethra

The urethra is the small tube connecting the bladder to the outside of the body. The male urethra is about 20 centimeters long, while the female urethra is shorter, about four centimeters. At the urethra's connection to the bladder is a small ring of muscle, or sphincter. This stops urine from leaking out. [14]

2.2.3 Contrast media and normal saline removal

Contrast media is mainly excreted by our kidneys and that's a physiological process which the kidney will go anyway, contrast media are excreted mainly by glomerular filtration. There is thus, a significant correlation between both body and renal clearances of contrast media and glomerular filtration rate, and their renal excretion will be delayed in patients with renal insufficiency. Contrast media can be efficiently removed from blood by hemodialysis. Contrast media begin the process of removing almost immediately, can quite clearly see a great deal of contrast already in the patient's bladder, waiting to be urinated out. There are trace amounts in the body for several hours, but it's pretty much gone within 12 hours without have severely poor kidney function, But in some patients the contrast media cause a reversible renal impairment due to constriction of the renal vessels and hypo perfusion of the kidneys, So in order to avoid such condition, good hydration is advised which will dilute the contrast media in our blood and improvements the perfusion of our kidneys by increasing the blood volume. [16]

Chapter Three

Characteristics of Contrast Media Used in Medical Imaging

3.1 Contrast media

3.1.1 Principle of imaging

3.1.2 Types of contrast media used in CT- scan

3.1.3 Ways contrast media enter the body

3.2 Normal saline solution

3.2.1 Saline solution

3.2.2 Medical purposes

3.2.3 Normal saline solution

3.2.4 Normal saline and Contrast Media flow

3.3 The biocompatibility of material

3.3.1 Biomaterials

3.3.2 Classes of Materials Using in contrast injector

3.3.3 Blood compatibility

3.1 Contrast media

To visualize anatomic detail, the area of interest must differ in radiographic density from its surrounding tissue .The ability to distinguish between radiographic densities enables differences in anatomic tissues to be visualized. Factors that affect the degree of radiographic density differences include absorption characteristics of the tissues that comprise the anatomic part, technical factors utilized, characteristics of the image receptor, automatic image processing, and the use of contrast media agents. Radiographic images of anatomic areas low in subject and are more difficult to visualize. Instilling a contrast medium into the area of interest will change the absorption classified as contrast result in few density differences characteristics of the anatomic area and alter its subject contrast and the radiographic density differences. Enhancing the density differences within the area of interest will improve visualization of the anatomic detail. [17]

3.1.1 Principle of imaging

Contrast materials, also called contrast agents or contrast media, are used to improve pictures of the inside of the body produced by x-rays, computed tomography (CT), magnetic resonance (MR) imaging, and ultrasound. Often, contrast materials allow the radiologist to distinguish normal from abnormal conditions; Contrast materials are not dyes that permanently discolor internal organs. They are substances that temporarily change the way x-rays or other imaging tools interact with the body. When introduced into the body prior to an imaging exam, contrast materials make certain structures or tissues in the body appear different on the images than they would if no contrast material had been administered, Contrast materials help distinguish or "contrast" selected areas of the body from surrounding tissue. By improving the visibility of specific organs, blood vessels or tissues, contrast materials help physicians diagnose medical conditions. [18]

3.1.2 Types of contrast media used in CT- scan:

1. Barium sulfate

The clement barium has an atomic number of 56; thus, it is radiopaque. Barium sulfate is an inert powder composed of crystals that is used for examination of the digestive system. The chemical formula is BaSO, which indicates a ratio of one atom of barium to one atom of sulfur to four atoms of oxygen, thus it is a compound. Because barium sulfate is not soluble in water, it must be mixed or shaken into a suspension in water. Depending on the environment of the barium sulfate, such as acid within the stomach, the powder has a tendency to clump and come out of suspension. This is called flocculation. Stabilizing agents such as sodium carbonate or sodium citrate usually are used to prevent flocculation. These ingredients are listed as suspending agents on the container labels. Other ingredients used in orally administered barium sulfate include vegetable gums, flavoring, and sweeteners to increase palatability Barium sulfate suspensions must be concentrated enough so that x-rays are absorbed. These suspensions must flow easily and yet coat the lining of organs , recommended that barium sulfate be mixed with cold tap water to reduce irritation to the colon and to aid the patient in holding the enema during the examination. The cold tap water reduces spasm and cramping. Although mixing the barium sulfate with room temperature water has also been recommended for maximum patient comfort. [19]

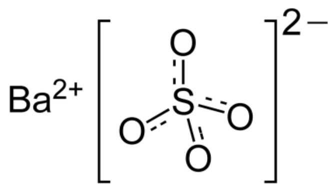


Figure 3.1 The Barium sulfate structure. [20]

Table 3.1 The Barium sulfate contrast using. [21]

Area	Concentration (wt/vol %)	Method Of Administration	Patient Preparation	Patient Instructions and Care During Procedure
Esophagus: esophagram	30-50	Oral	None	Provide supportive communication. For esophageal varices, the patient should exhale, swallow barium, and then hold his or her breath on that exhalation for that exposure.
Stomach: upper gastrointesti-nal series	30-50	Oral	Nothing to eat or drink after midnight before examination	Provide supportive communication. Provide explanation of reasons for various positions.
Small intestine: small bowel series	40-60 if included with stomach examination	Oral	If included with a stomach examination, low-residue diet eaten for 2 days before examination	Provide supportive communication. Provide explanation for length of procedure. In most patients, the transit time of the barium sulfate suspension through the small intestine is approximately 1 hr.
Large intestine: colon or barium enema	12-25	Rectal	Large amount of fluid or fluid diet day before examination Nothing to eat or drink after midnight before examination Cleansing enema before examination	Provide supportive communication so that the patient does not lose control. Watch patient for changes in mental status that may indicate fluid overload.
Stomach: computed tomography*	12-25	Oral	Nothing to eat or drink after midnight before examination	Provide supportive communication. The patient should believe that the radiogra-pher is constantly watching the procedure.

2. Iodinated contrast media

Are contrast agents that contain iodine atoms used for x-ray-based imaging modalities such as computed tomography (CT), The ability to distinguish between tissues of different x-ray attenuation (image contrast) depends upon two types of interactions between photons and matter: Compton scattering and photoelectric absorption. Both these interactions depend upon physical density, but the latter also depends upon atomic number of the matter. As iodine has a high atomic number, 53, compared to most tissues in the body, the administration of iodinated material produces image contrast due to differential photoelectric absorption. [22]

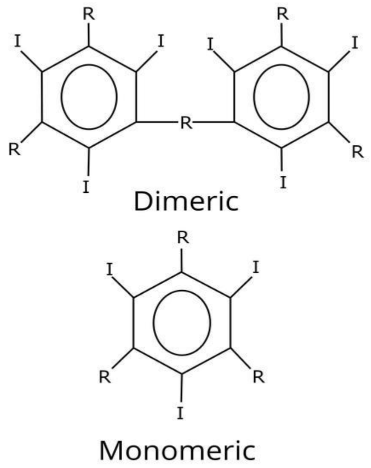


Figure 3.2 The Iodinated contrast structure. [23]

Iodine has a particular advantage as a contrast agent because the k-shell binding energy (k-edge) is 33.2 Kev, similar to the average energy of x-rays used in diagnostic radiography. When the incident x-ray energy is closer to the k-edge of the atom it encounters, photoelectric absorption is more likely to occur, Differences in photoelectric absorption across different x-ray energies is harnessed in dual-energy CT, in which patients are scanned with two different x-ray spectra. Material decomposition techniques allows the creation of virtual images in which iodine is preferentially increased in intensity (iodine map) or removed altogether (virtual non-contrast), which can hold additional diagnostic value. [22]

3.1.3 Ways contrast enter the body

1. swallowed (taken by mouth or orally)
2. Administered by enema (given rectally)
3. Injected into a blood vessel (vein or artery; also called given intravenously or intra arterially). [18]

Table 3.2 The Iodinated contrast using. [19]

AREA	CONTRAST AGENT	METHOD OF ADMINISTRATION	PATIENT PREPARATION	PATIENT INSTRUCTIONS/CARE DURING PROCEDURE
Brain: cerebral angiography, computed tomography	Usually nonionic	Injection into vein or artery	Usually liquid diet to minimize nausea Premedication for sedation Intravenous fluids to aid hydration	Supportive communication Tell the patient that he or she may feel warm and sense a metallic taste on injection. Explain what is being done as it is being done. Watch the patient for adverse reactions. Apply pressure to injection site after procedure is completed.
Thorax: thoracic angiography or four-vessel study	Usually nonionic	Injection into vein or artery	Usually liquid diet to minimize nausea Premedication for sedation Intravenous fluids to aid hydration	Supportive communication Tell the patient that he or she may feel warmth and sense a metallic taste on injection. Explain what is being done as it is being done. Watch the patient for adverse reactions. Apply pressure to injection site after procedure is completed.
Lower limbs: venography	Usually nonionic	Injection into vein	Sometimes premedication for sedation Intravenous fluids for hydration	Supportive communication Tell the patient that he or she may feel warmth and sense a metallic taste on injection. Explain what is being done as it is being done; there may be some pain. Watch the patient for adverse reactions. Apply pressure to injection site after procedure is completed.
Spinal canal: myelography	Only nonionic	Injection into subarachnoid space	Usually liquid diet Usually premedication for sedation	Supportive communication Explain the use of shoulder braces and that the table will be tilted but the patient's head must be kept in extension. Explain what is being done as it is being done. Watch the patient for adverse reactions. Advise nursing staff and patient that patient should remain in bed with the head up for 24 hr to prevent headache and nausea.
Kidneys, ureters, and bladder: excretory urography, renal angiography, cystography	Usually nonionic	Injection into vein or artery For cystography, usually through catheter in urinary bladder	Liquid diet day before examination to reduce gas formation Laxatives or a cleansing enema may be given Bladder should be emptied before the examination begins	Supportive communication Tell the patient that he or she may feel warmth and sense a metallic taste during and just after injections; several injections may be done. Explain the timing of the radiographs and the x-ray tube movement if tomography is done. Watch the patient for adverse reactions. Angiography: apply pressure to the injection site after procedure is completed.

Table 3.3 Patient history factors in Iodinated contrast examination. [19]

FACTORS	IMPORTANCE
Age	↑ Risk with increased age
Allergies or asthma	↑ Risk of allergic-like reactions
Diabetes	Insulin usually given before procedure; these patients should be scheduled before others
Coronary artery disease	↑ Risk of tachycardia, bradycardia, hypertension, myocardial infarction (heart attack)
Hypertension	Hypertension with tachycardia
Renal disease	Inform radiologist if creatinine level is above 1.4 mg/dl
Multiple myeloma	Abnormal protein binds with contrast and can cause renal failure Patients must be hydrated
Confusion or dizziness	Blood-brain barrier effects
Sickle cell anemia or family history of chronic obstructive pulmonary disease	↑ Risk of blood clots ↑ Risk of dyspnea (difficulty in breathing)
Previous iodine contrast examinations	Did the patient have difficulties with procedure?
Pregnancy	Inform radiologists before proceeding
History of blood clots	↑ Risk of blood clots
Use of beta blockers	↑ Risk of anaphylactoid reactions
Use of calcium channel blockers	↑ Risk of heart block
Use of metformin (Glucophage)	↑ Risk of lactic acidosis if renal failure occurs

Table 3.4 Patient history factors in barium sulfate examination. [19]

FACTOR	IMPORTANCE
Age	Ability to communicate, hear, and follow directions ↑ Risk of colon perforation due to loss of tissue tone
Diverticulitis or ulcerative colitis	↑ Difficulty in holding an enema ↑ Risk of colon perforation
Long-term steroid therapy	↑ Risk of colon perforation
Colon biopsy within previous 2 wks	Lower gastrointestinal series is contraindicated
Pregnancy	Inform radiologist before proceeding with examination
Mental retardation, confusion, or dizziness	↑ Risk of aspiration during upper gastrointestinal series
Recent onset of constipation or diarrhea	↑ Risk of colon perforation or tumor rupture
Nausea and vomiting	↑ Risk of aspiration during upper gastrointestinal series

3.2 Normal Saline solution

3.2.1 Saline solution

Saline, also known as saline solution is a mixture of sodium chloride in water and has a number of uses in medicine. Applied to the affected area it is used to clean wounds, help remove contact lenses, and help with dry eyes. By injection into a vein it is used to treat dehydration such as from gastroenteritis and diabetic ketoacidosis. It is also used to dilute other medications to be given by injection. Large amounts may result in fluid overload, swelling, acidosis, and high blood sodium. In those with long-standing low blood sodium, excessive use may result in osmotic demyelination syndrome. Saline is in the crystalloid family of medications. It is most commonly used as a sterile 9 g of salt per liter (0.9%) solution, known as normal saline. Higher and lower concentrations may also occasionally be used. Saline has a pH of 5.5 making it acidic. The medical use of saline began around 1831. It is on the World Health Organization's List of Essential Medicines, the most effective and safe medicines needed in a health system. [24]

3.2.2 Medical purposes

Saline is often used to flush wounds and skin abrasions. Normal saline will not burn or sting when applied, Saline is also used in I.V. therapy, intravenously supplying extra water to rehydrate patients or supplying the daily water and salt needs ("maintenance" needs) of a patient who is unable to take them by mouth. Because infusing a solution of low osmolality can cause problems such as hemolysis, intravenous solutions with reduced saline concentrations typically have dextrose (glucose) added to maintain a safe osmolality while providing less sodium chloride. The amount of normal saline infused depends largely on the needs of the patient (e.g. ongoing diarrhea or heart failure). [25]

3.2.3 Normal saline solution

Normal saline (NSS, NS or N/S) is the commonly used phrase for a solution of 0.90% w/v of NaCl, 308 mOsm/L or 9.0 g per liter. Less commonly, this solution is referred to as physiological saline or isotonic saline (because it closely approximates isotonic, that is, physiologically normal, solution); although neither of those names is technically accurate (because normal saline is not exactly like blood serum), they convey the practical effect usually seen: good fluid balance with minimal hypertonicity or hypertonicity. NS is used frequently in intravenous drips (IVs) for patients who cannot take fluids orally and have developed or are in danger of developing dehydration or hypovolemia. NS is also used for aseptic purpose. NS is typically the first fluid used when hypovolemia is severe enough to threaten the adequacy of blood circulation, and has long been believed to be the safest fluid to give quickly in large volumes. However, it is now known that rapid infusion of NS can cause metabolic acidosis. [26]

3.2.4 Normal saline and Contrast Media flow

A saline flush pushes the tail of the injected contrast medium bolus into the central blood volume and makes use of contrast medium that would otherwise remain unused in the injection tubing and peripheral veins. A saline flush therefore increases both the efficiency of contrast medium utilization and the level of contrast enhancement. Additional advantages of a saline flush include:

1. Improved bolus geometry due to reduced intravascular contrast medium dispersion.
2. Reduced streak artifact from dense contrast medium in the brachiocephalic vein. and superior vena cava on thoracic CT studies.
3. Increased hydration to reduce contrast-induced nephrotoxicity.
4. Elimination of the need for injecting a small amount of saline at the end of CT scan to wash out any residual contrast medium which is highly viscous and may clog the vascular access catheter.

The injection of a saline bolus while injecting the contrast medium, rather than after the completion of contrast medium injection, would result in a dilution of contrast medium, as demonstrated in the biphasic-concentration injection technique. Furthermore, the saline flush may be injected at rates different from contrast medium to modify the level of enhancement during the late phase of contrast enhancement. In general, higher enhancement with a faster saline injection or a prolonged lower enhancement with a lower saline injection would be achieved. However, two recent studies suggested that the injection of saline faster than that of contrast medium may not result in further increase in the degree of contrast enhancement. [27]

3.3 The biocompatibility of material

3.3.1 Biomaterials

Any material of natural or of synthetic origin that comes in contact with tissue , blood of biological fluid , and intended for use in prosthetic ,diagnostic therapeutic of storage application. A biocompatibility that a material, device of construct can be brought into direct contact with living tissue without causing a harmful tissue reaction (pain , swelling or necrosis) that could compromise function, causing a systemic toxic reaction or having tumorigenic potential. Biomaterials and medical devices are now commonly used as prostheses in cardiovascular, orthopedic, dental, ophthalmological, and reconstructive surgery, in interventions such as angioplasty (stents) and hemodialysis (membranes), in surgical sutures or bio adhesives, and as controlled drug release devices. Most implants serve their recipients well for extended periods by alleviating the conditions for which they were implanted. [28]

3.3.2 Classes of Materials Using in contrast injector

1. Polymer

Many types of polymers as shown in table 3.5 are widely used in biomedical devices that include orthopedic, dental, soft tissue, and cardiovascular implants. Polymers represent the largest class of biomaterials. In this section, we will consider the main types of polymers, their characterization, and common medical applications. Polymers may be derived from natural sources, or from synthetic organic processes. [29]

Table 3.5 Patient history factors in Iodinated contrast examination. [30]

Polymer	Water absorption (%)	Bulk modulus (GPa)
Polyethylene	0.001–0.02	0.8–2.2
Polypropylene	0.01–0.035	1.6–2.5
Polydimethyl-siloxane	0.08–0.1	
Polyurethane	0.1–0.9	1.5–2
Polytetrafluoro-ethylene	0.01–0.05	1–2
Polyvinyl-chloride	0.04–0.75	3–4
Polyamides	0.25–3.5	2.4–3.3
Polymethyl-methacrylate	0.1–0.4	3–4.8
Polycarbonate	0.15–0.7	2.8–4.6
Polyethylene-terephthalate	0.06–0.3	3–4.9

a) Polyethylene

Is used in its high-density form in biomedical applications because low-density material cannot withstand sterilization temperatures. It is used as tubing for drains and catheters, and in ultrahigh-MW form as the acetabular component in artificial hips and other prosthetic joints. The material has good toughness and wears resistance and is also resistant to lipid absorption. Radiation sterilization in an inert atmosphere may also provide some covalent cross-linking that strengthens the PE. [31]

b) Polyurethanes

Are tough elastomers with good fatigue and blood-containing properties, they are used in pacemaker lead insulation, catheters, vascular grafts, heart assist balloon pumps, artificial heart bladders, and wound dressings. [31]

c) Polypropylene

Is an isotactic crystalline polymer with high rigidity, good chemical resistance, and good tensile strength, its stress cracking resistance is excellent, and it is used for sutures and hernia repair. [31]

2. Metals

Have been used as implants since more than 100 years ago such as surgical stainless steel is a grade of stainless steel used in biomedical applications. Although several types of stainless steels are available for implant use , in practice the most common is 316L This steel has less than 0.030% (wt.%) carbon in order to reduce the possibility of in vivo corrosion. another notable micro structural feature of 316L as used in typical implants is plastic deformation within grains .The metal is often used in a 30% cold-worked state because cold-worked metal has a markedly increased yield, ultimate tensile, and fatigue strength relative to the annealed state. [32]

3.3.3 Blood compatibility

Can be defined as the property of a material or device that permits it to function in contact with blood without inducing adverse reactions. Unfortunately, this simple definition offers little insight into what a blood compatible material is. More useful definitions become increasingly complex. This is because there are many mechanisms we can also view blood compatibility from a different perspective by considering a material that is not blood compatible, i.e., a thrombogenic material. Such a material would produce specific adverse reactions when placed in contact with blood: formation of clot or thrombus composed of various blood elements; shedding or nucleation of emboli (detached thrombus); the destruction of circulating blood components, the most blood compatible material is the natural, healthy, living lining of our blood vessels. This "material" functions well by a combination of appropriate surface chemistries, good blood flow characteristics, and active biochemical processes involving removal of prothrombotic substances and secretion of natural anticoagulants. [33]

1. Red Cells

Red cells are usually considered as passive participants in processes of hemostasis and thrombosis, although under some conditions (low shear or venous flows) red cells may form a large proportion of total thrombus mass. The concentration and motions of red cells have important mechanical effects on the diffusive transport of blood elements. For example, in flowing blood, red-cell motions may increase the effective discursivity of platelets by several orders of magnitude. Under some conditions, red cells may also contribute chemical factors that influence platelet reactivity .The process of direct attachment of red cells to artificial surfaces has been considered to be of minor importance and has therefore received little attention in studies of blood–materials interactions. [34]

2. White Cells

The various classes of white cells perform many functions in inflammation, infection, wound healing, and the blood response to foreign materials. White-cell interactions with artificial surfaces may proceed through as-yet poorly defined mechanisms related to activation of the complement, coagulation, fibrinolytic, and other enzyme systems, resulting in the expression by white cells of procoagulant, fibrinolytic, and inflammatory activities. [35]

Chapter Four

Project Design

In this chapter, the design of the system is described including: illustration, definition, principle of operation and electrical circuit’s connection. All parts of the system and components are selected and built to achieve the project objectives. An Arduino microcontroller with Bluetooth technology is used to control the contrast media and normal saline flow rate. Bluetooth electronic application interface is then used for entering the amount and flowrate of the solution.

The block diagram will be described in details as follows:

5.1 Main Block diagram

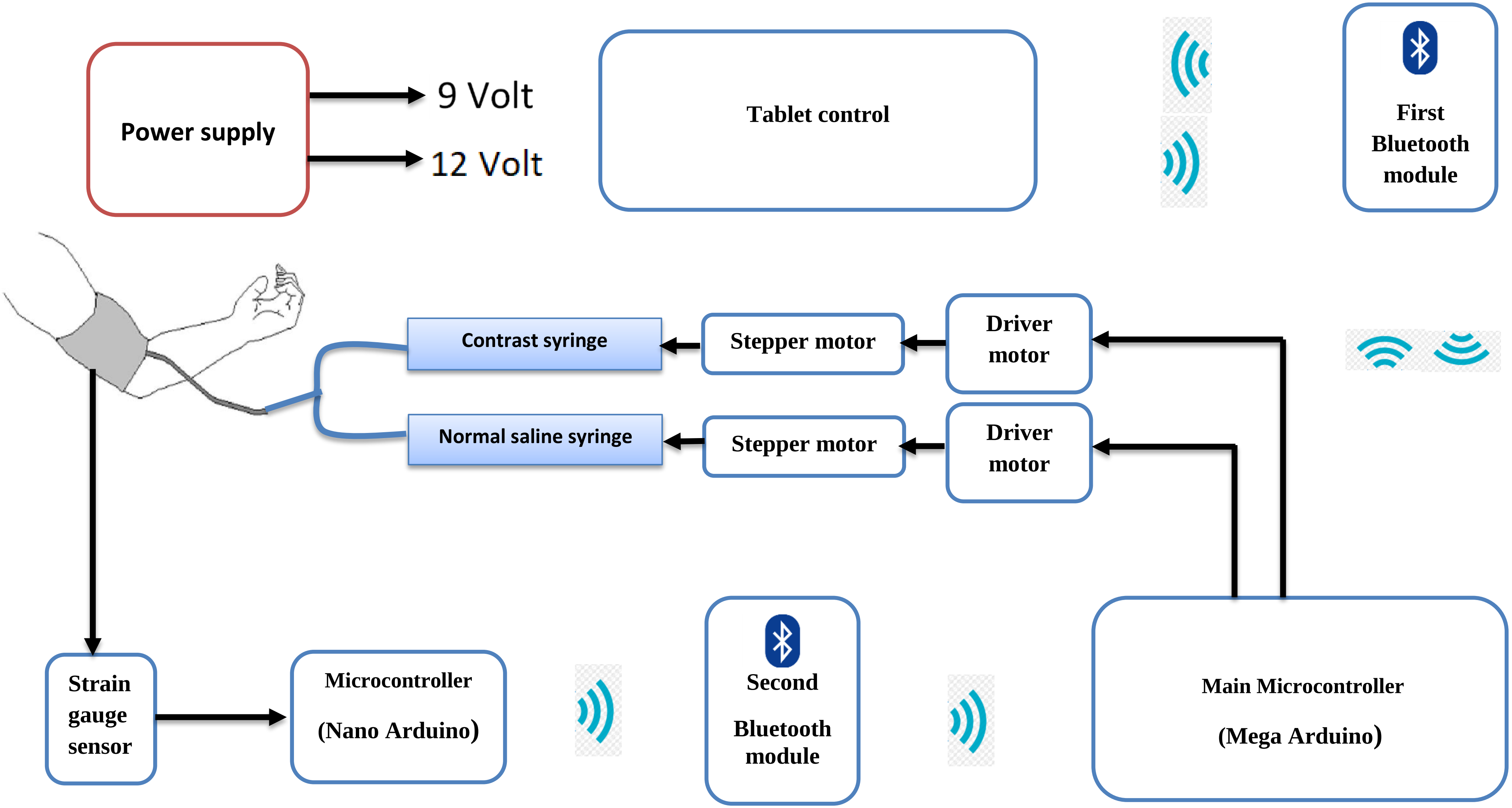


Figure 5.1 Main block diagram.

4.1.1 Description of block diagram

The system Block diagram, shown in figure consists of three main stages the first stage Mega Arduino microcontroller receive signals from the android application inputs by Bluetooth module that transfer order data from application to main Arduino to control of stepper motors motion by transmitted the appropriate signals to drivers motors, the second stage represent of injection contrast media and normal saline by use Driver motor able to handle larger amounts of current and higher voltages from a microcontroller pin, allow you to control a Stepper motors, from a small signal , rotation motion that converting to horizontal motion , this mean that a digital signal receive from drivers motor are used to drive the motor , and every time receives a digital pulse it rotate a specific number of degrees in rotation , so syringes connect with stepper motor , the solutions flow from the syringe to tubes finally flow inside the body throw of the cannula ,the third stage Nano Arduino receive signal from the strain gauge sensor, process it to safe the patient from the arm bulge and detection by using strain gauge sensor , then make alarm system by send signal for main Arduino using Bluetooth module connection to stop injection , after that show alarm in the application interface.

4.2 Alarm module system

4.2.1 System block diagram

Nano Arduino receive signal from the strain gauge sensor, process it to safe the patient from the arm bulge and detection by using strain gauge sensor , then make alarm system by send signal for main Arduino using Bluetooth module connection to stop injection , after that show alarm in the application interface as shown in figure 4.2.

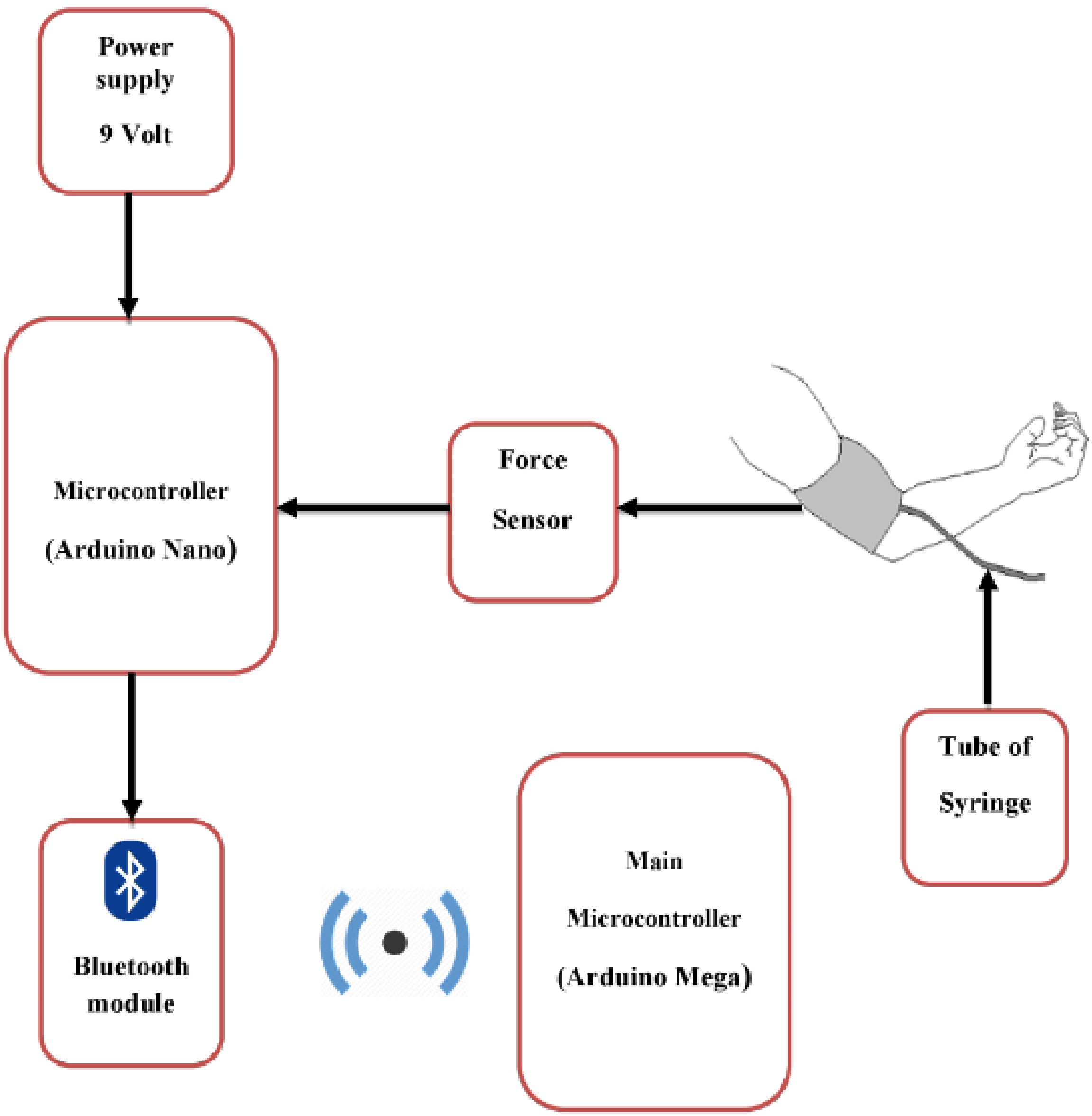


Figure 4.2 Block diagram of alarm module.

4.2.2 Force Sensing Resistors

(FSR) are a polymer thick film (PTF) device which exhibits a decrease in resistance with an increase in the force applied to the active surface. Its force sensitivity is optimized for use in human touch control of electronic devices such as automotive electronics, medical systems and industrial PCs. FSRs are not a load cell or strain gauge, though they have similar properties. FSRs are not suitable for precision measurements. [36]

4.2.2.1 Strain gauge

A Strain gauge (sometimes referred to as a Strain gage) is a sensor whose resistance varies with applied force; It converts force, pressure, tension, weight, etc., into a change in electrical resistance which can then be measured. When external forces are applied to a stationary object, stress and strain are the result. Stress is defined as the object's internal resisting forces, and strain is defined as the displacement and deformation as shown in figure 4.3. [36]

The strain gauge is one of the most important sensors of the electrical measurement technique applied to the measurement of mechanical quantities. As their name indicates, they are used for the measurement of strain. As a technical term "strain" consists of tensile and compressive strain, distinguished by a positive or negative sign. Thus, strain gauges can be used to pick up expansion as well as contraction. [36]

The strain of a body is always caused by an external influence or an internal effect. Strain might be caused by forces, pressures, moments, heat, structural changes of the material. If certain conditions are fulfilled, the amount or the value of the influencing quantity can be derived from the measured strain value. In experimental stress analysis this feature is widely used. Experimental stress analysis uses the strain values measured on the surface of a specimen, or structural part, to state the stress in the material and also to predict its safety and endurance. Special transducers can be designed for the measurement of forces or other derived quantities, e.g., moments, pressures, accelerations, displacements, vibrations and others. The transducer generally contains a pressure sensitive diaphragm with strain gauges bonded to it. [36]

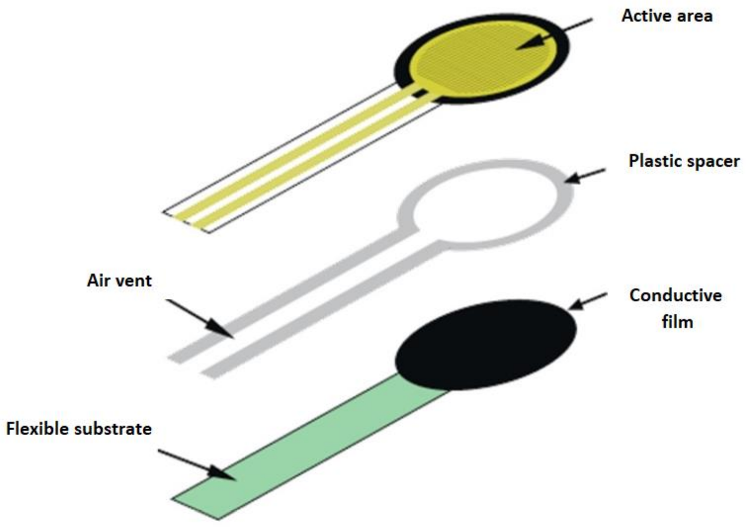


Figure 4.3 Strain gauge sensors. [36]

At the low force end of the force-resistance characteristic, a switch like response is evident. This turn-on threshold, or 'break force", that swings the resistance from greater than 100 kΩ to about 10 kΩ (the beginning of the dynamic range that follows a power-law) is determined by the substrate and overlay thickness and flexibility, size and shape of the actuator, and spacer-adhesive thickness (the gap between the facing conductive elements). Break force increases with increasing substrate and overlay rigidity, actuator size, and spacer adhesive thickness. Eliminating the adhesive, or keeping it well away from the area where the force is being applied, such as the center of a large FSR device, will give it a lower rest resistance as shown in Figure 4.4. [37]

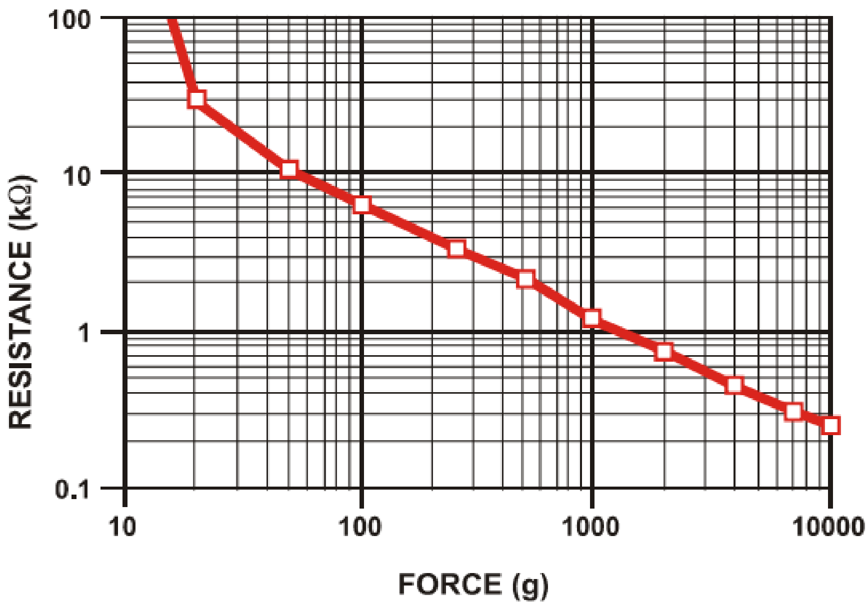


Figure 4.4 Resistances vs. Force for FSR. [37]

4.2.3 Force sensor connection

The FSR changes its resistance with force. It ranges from near infinite when not being touched, to under 300ohms when pressed really hard. So we can measure that change using one of the Arduino's analog inputs. But to do that we need a fixed resistor (not changing) that we can use for that comparison (We are using a 33K resistor). As shown in figure 4.5.

For a simple force-to-voltage conversion, the FSR device is tied to a measuring resistor R_M in a voltage divider configuration as shown in figure 4.6. The output is described by the equation:

$$V_{out}=\left(\frac{RM}{RM\ +RFSR}\right)*vin \quad \text{..........................(4.1)}$$

$$V_{out}=\left(\frac{33K}{33K\ +RFSR}\right)*5V$$

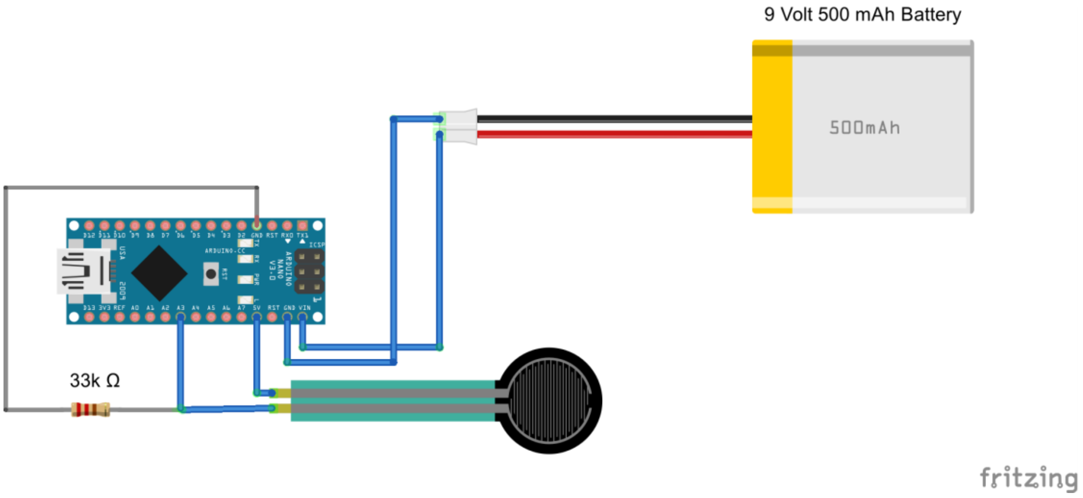


Figure 4.5 Connecting FSR with Arduino Nano.

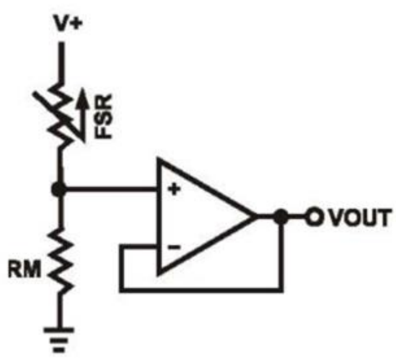


Figure 4.6 Voltage divider configuration.

4.2.4 Force sensor and Bluetooth connection

The analog read on Nano Arduino is basically a voltage meter. At 5V (its max) it will read 1023, and at 0v it will read 0. So we can measure how much voltage is on the FSR using the analog Read and we will have force reading, compare analog read from sensor with value represent the begin of arm bulge after that send alarm signal to main Arduino by using Bluetooth technique , stop device work and show alarm in tablet as shown in figure 4.7.

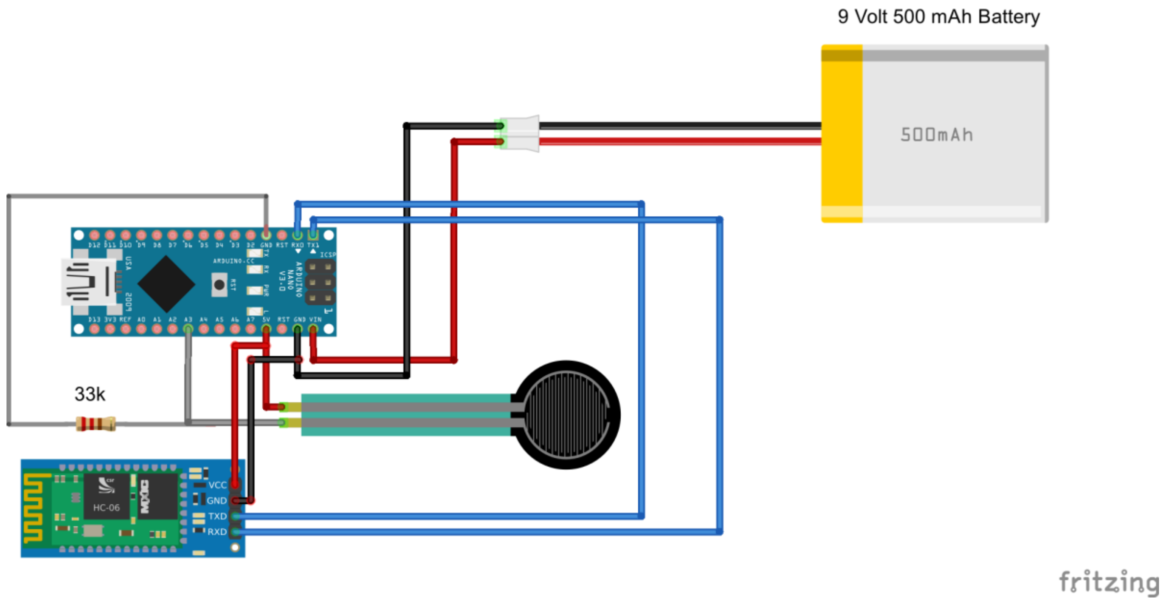


Figure 4.7 Force sensor and Bluetooth connection.

4.2.5 Alarm module connection

Battery 9 volt 500 mAh supplying voltage to module with switch On/Of that indicate by using green LED , Nano Arduino receive signal from the force sensor , if the analog reading between ** and ** then make indicate detection comfortable and suitable position of the cuff around patient arm using blue LED, when analog reading more ** then make indicate alarm using red LED in addition to , system will be send signal to main Arduino using Bluetooth module to stop injection as shown in figure 4.8.

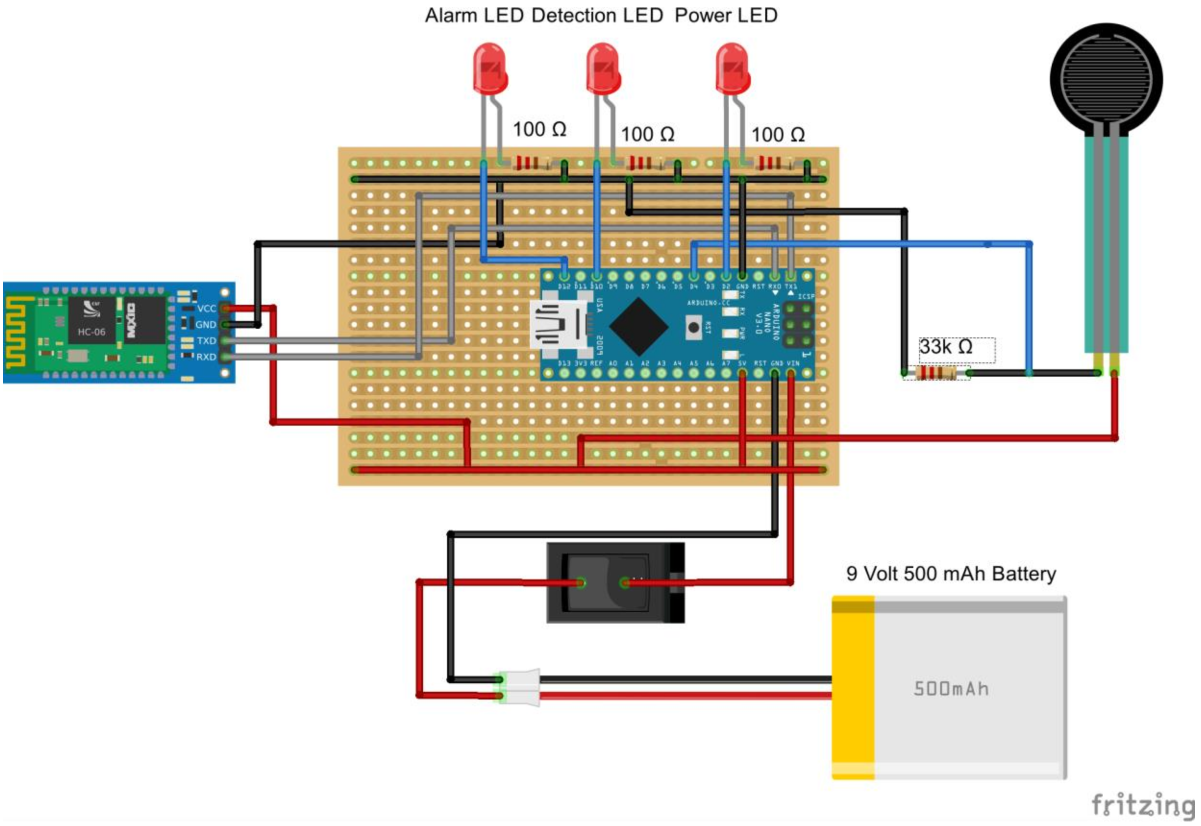


Figure 4.8 Alarm module connections.

4.3 Microcontroller unit

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

It contains memory, programmable input/output peripherals as well a processor. Microcontrollers are mostly designed for embedded applications and are heavily used in automatically controlled electronic devices such as cellphones, cameras, microwave ovens, washing machines, etc. [38]

Features of a microcontroller:

- Far more economical to control electronic devices and processes as the size and cost involved is comparatively less than other methods.
- Operating at a low clock rate frequency, usually use four bit words and are designed for low power consumption.

- Architecture varies greatly with respect to purpose from general to specific, and with respect to microprocessor, ROM, RAM or I/O functions.
- Has a dedicated input device and often has a display for output.
- Usually embedded in other equipment and are used to control features or actions of the equipment.
- Program used by microcontroller is stored in ROM.
- Used in situations where limited computing functions are needed. [38]

The Arduino software is easy to use and flexible enough for advanced users. It runs on mac, windows, and Linux. Teachers and students use it to build low cost scientific instruments, to prove chemistry and physics principles, or to get started with programming and robotics. Designers and architects build interactive prototypes, musicians and artists use it for installations and to experiment with new musical instrument. There are many other microcontrollers and microcontroller platforms available for physical computing. Parallax Basic Stamp, net media's BX-24, phi gets, MIT's handy board, and many others offer similar functionality. All of these tools take the messy details of microcontroller programming and wrap it up in an easy to use package. Arduino also simplifies the process of working with microcontrollers, but it offers some advantage for teachers, and interested amateurs over other systems. [39]

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

4.3.1 Arduino Nano

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. [39]

Arduino Nano is a small, compatible, flexible and breadboard friendly Microcontroller board, developed by Arduino.cc in Italy, as shown in figure 4.9. [39]

Can be powered via 9V regulated external power supply (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 and each pin can provide or receive a maximum of 40 mA. [39]

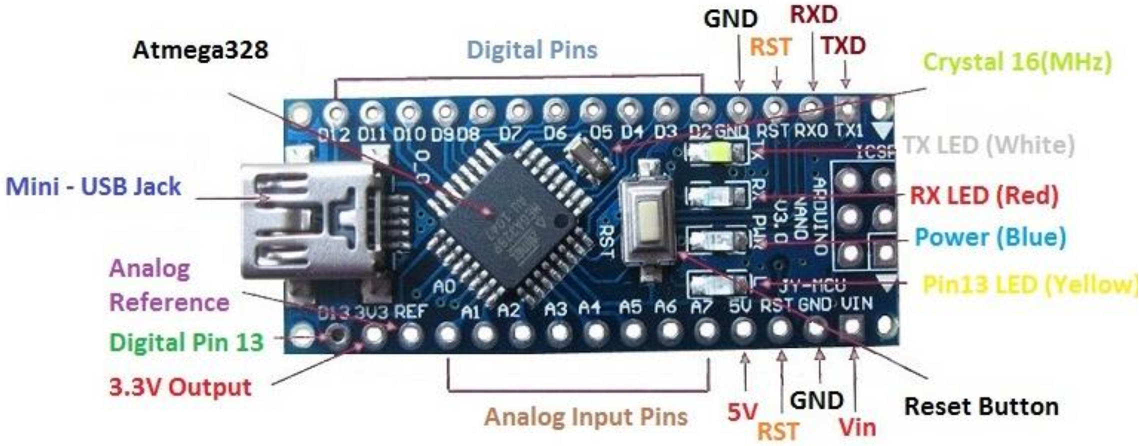


Figure 4.9 Arduino Nano. [39]

4.3.2 Arduino Mega

The reasons that Arduino mega have been used the memory bigger than memory in the Arduino Uno, 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 4.10 , 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. [40]

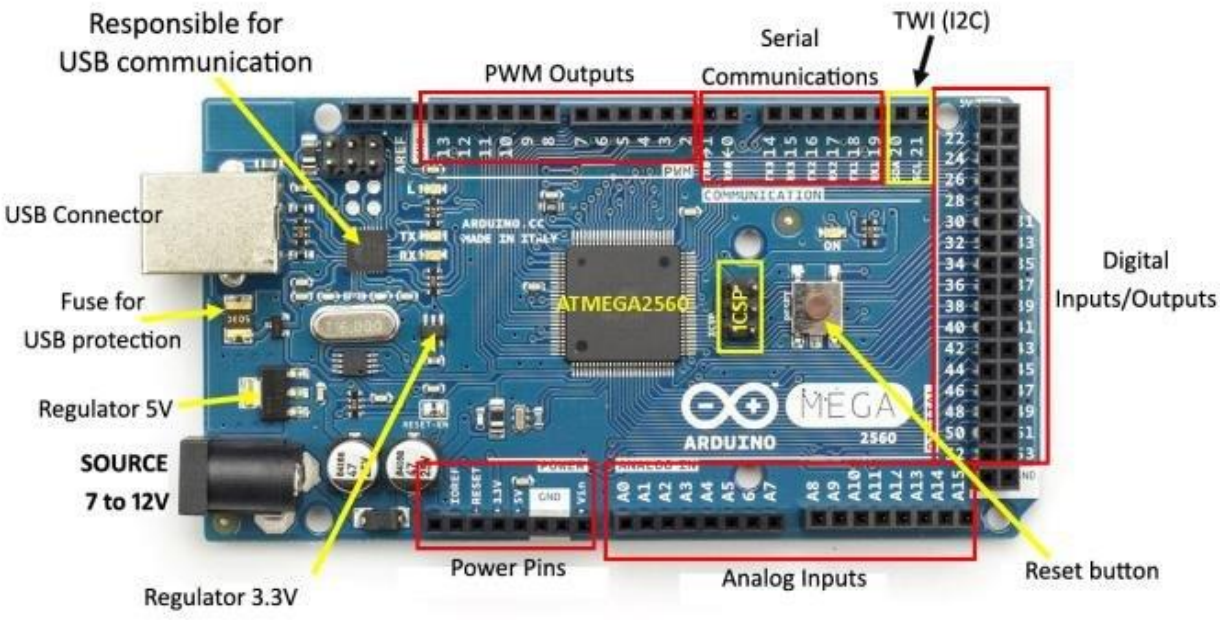


Figure 4.10 Arduino Mega. [41]

HC-05 module is an easy to use Bluetooth SPP (Serial Port Protocol) module as shown in figure 4.11, designed for transparent wireless serial connection setup.

Serial port Bluetooth module is fully qualified Bluetooth V2.0+EDR (Enhanced Data Rate) 3Mbps Modulation with complete 2.4GHz radio transceiver and baseband. It uses CSR Blue core 04-External single chip Bluetooth system with CMOS technology and with AFHIt has the footprint as small as 12.7mmx27mm. It used to connect the main Arduino mega with Arduino Nano placed in (Alarm module) in addition to connect the main Arduino mega with android application Bluetooth. [42]

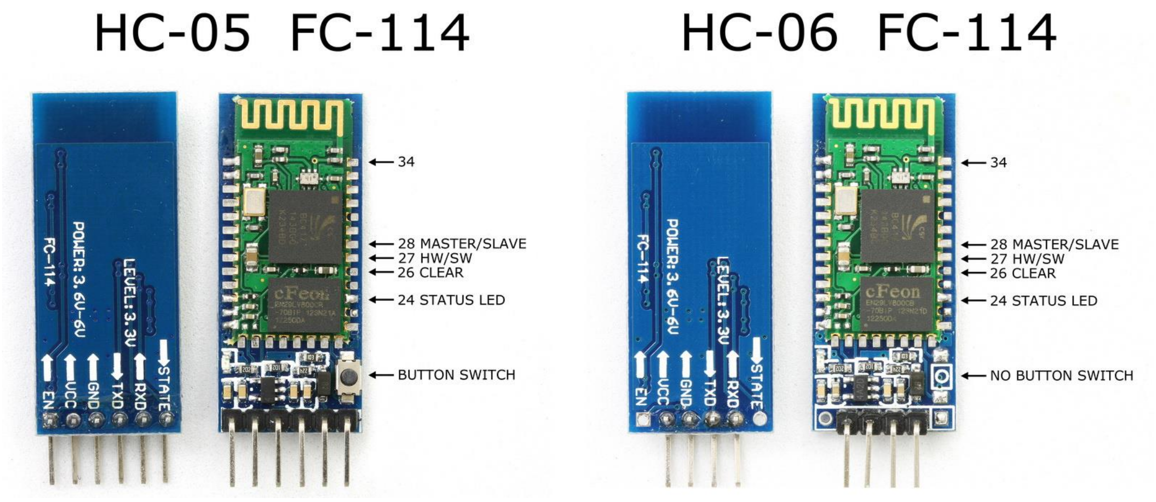


Figure 4.11 HC-05 and HC-06 Bluetooth modules. [43]

The following figure 4.12 shows the HC-05 connection with Arduino Mega and android application:

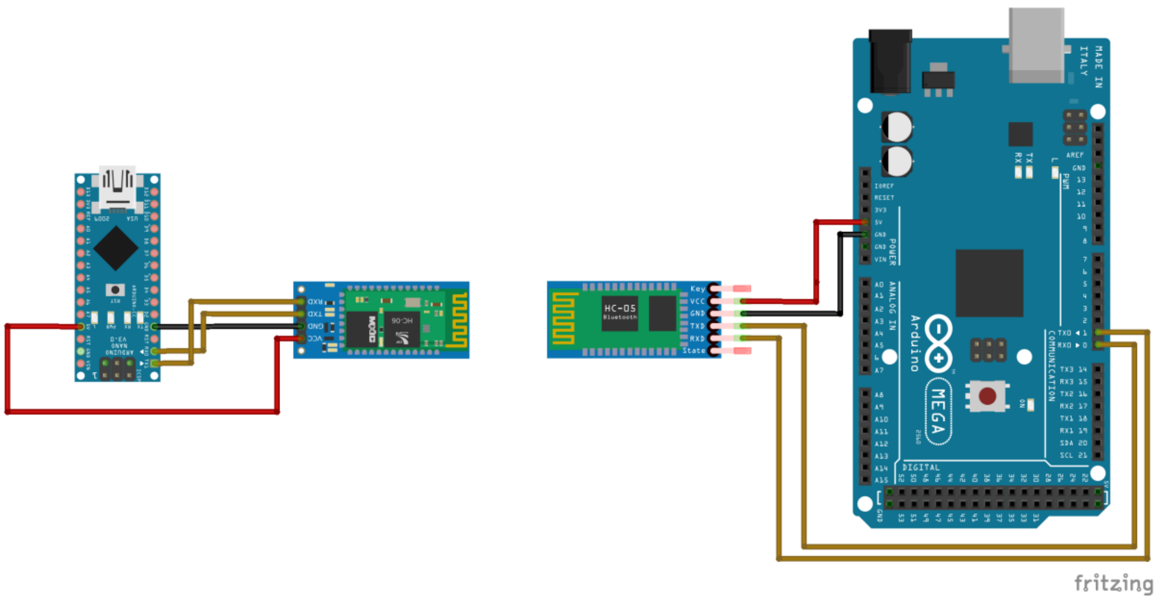


Figure 4.12 HC-05 and HC-06 Bluetooth with Mega and Nano Arduino connection.

The following figure 5.12 shows the HC-06 connection with Arduino Mega and android application:

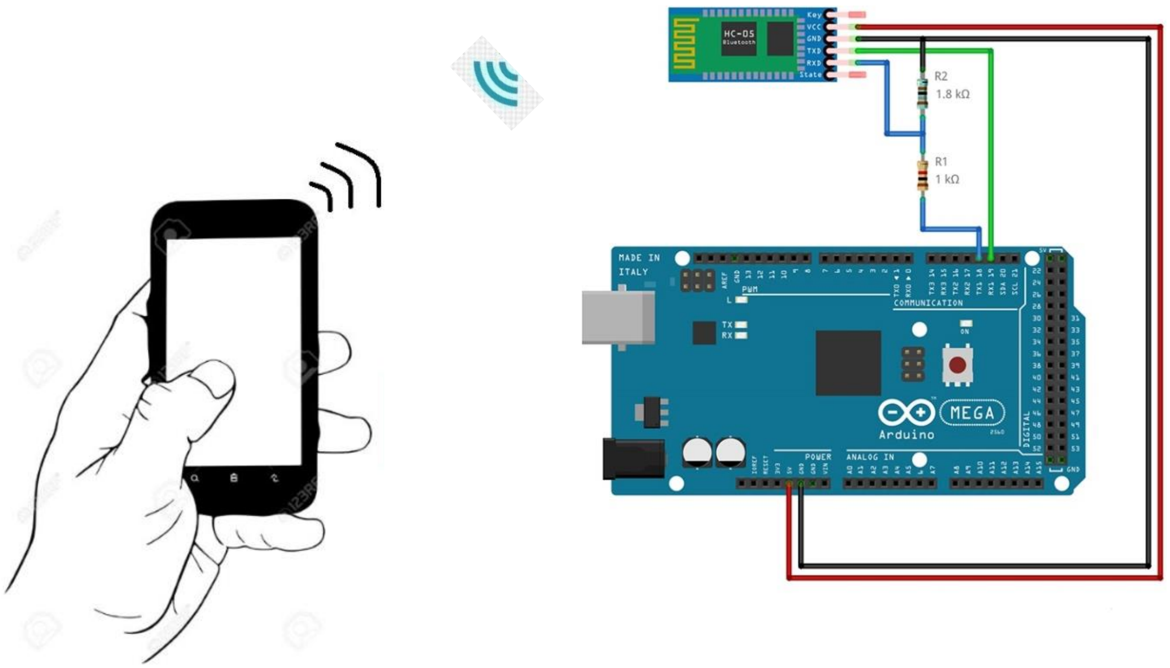


Figure 4.13 HC-06 connections with Arduino Mega and android application.

4.4 Android application remote control

Bluetooth Electronics application use to Control electronic projects with an Android device, this app communicates using Bluetooth to an HC-06 or HC-05 Bluetooth module in project ,

• Ideal for learning electronics in a fun way.

• Ideal for rapid prototyping a new idea.

• Ideal for exhibiting project.

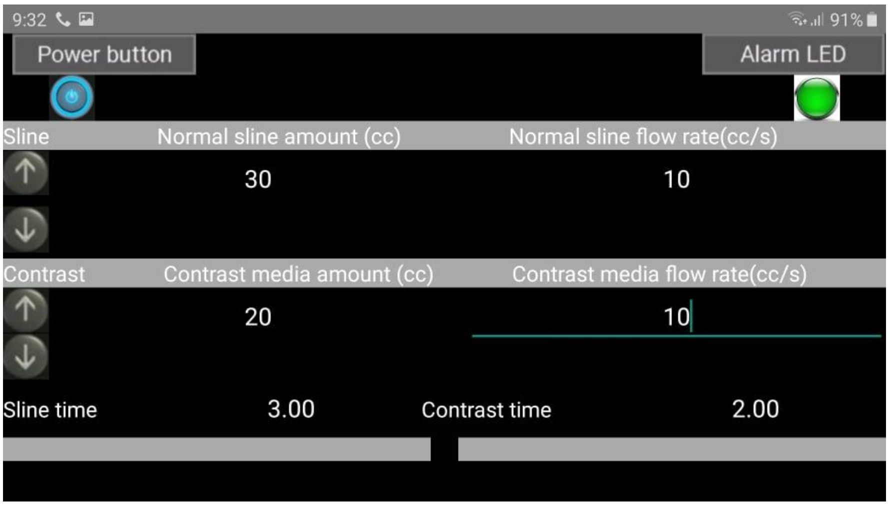
Some electronics skills required. Requires an Android device with Bluetooth capability enabled.

Large selection of controls available including buttons, switches, sliders, pads, lights, gauges, terminals, accelerometers and graphs, Drag and drop them onto the panel grid.

In project using Bluetooth Electronics application to control volume and flow rate of contrast and saline solution that will inject in arm of patient, volume unit in (cc) and unit of flow rate (cc/s) by using Power button , four button use to load and unload the syringe manually.

In addition to , application indicate many parameter such that , alarm detection by blinking LED , time operation of contrast and normal saline injection in a second and indicate the state of contrast and normal saline syringe quantities that if the syringes full it will be indicate " Contrast Syringe Full " or " Saline Syringe Full " , if the syringe empty it will be indicate " Contrast Syringe Empty " or " Saline Syringe Empty " , otherwise , it show " Contrast Syringe Ready " or " Saline Syringe Ready ".

Figure 4.14 represent Android application Login and remote interface :



(a) **(b)**

Figure 4.14 (a) Android application Login (b) Remote interface

4.5 Stepper motor drivers

Stepper motor drivers are specifically designed to drive stepper motors, which are capable of continuous rotation with precise position control, even without a feedback system. Our stepper motor drivers offer adjustable current control and multiple step resolutions, and they feature built-in translators that allow a stepper motor to be controlled with simple step and direction inputs. These modules are generally basic carrier boards for a variety of stepper motor driver ICs that offer low-level interfaces like inputs for directly initiating each step. An external microcontroller is typically required for generating these low-level signals. [44]

4.5.1 The L298N driver

The L298N is an integrated monolithic circuit in a 15- lead Multiwatt and PowerSO20 packages. It is a high voltage , high current 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. An additional Supply input is provided so that the logic works at a lower voltage.[45]

The main features of the L298n Module are:

- High working voltage – can reach up to 46v
- Large output current
    - Instantaneous peak current can reach 3A
    - Continuous working current can reach 2A
- 25W Rated Power
- High-Voltage and Current full-bridge driver with 2 H-bridges used to drive inductive loads like DC and Stepper Motors.
- Controlled with standard logic level signals
- 2 enable control terminals to enable or device without inputting signals.
- Able to drive a two-phase stepper motor, four-phase stepper motor or two DC motors.

- Has a high-capacity filter capacitor and freewheeling diode to protect devices from the reverse current of an inductive load.
- Built-in stabilivolt tube 78M05 can be used to obtain 5v from power supply. (Must be used with an external 5v logic supply when drive voltage is greater than 12v to protect the chip). [46]

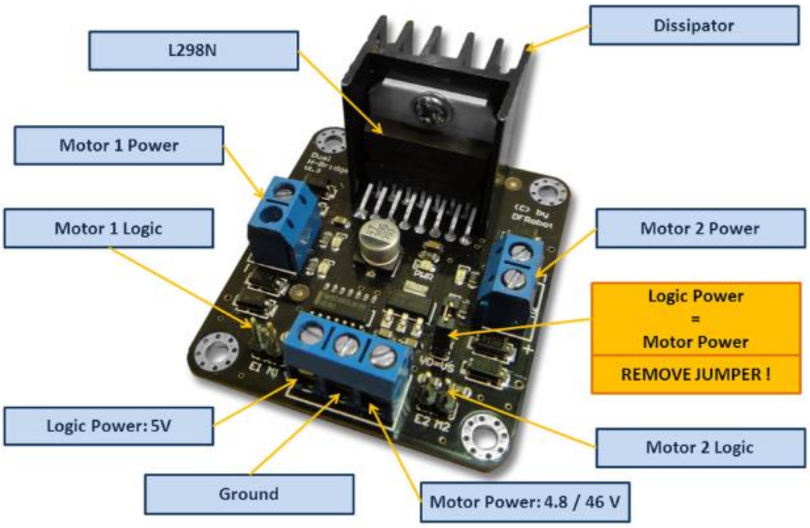


Figure 4.15 The L298N driver. [46]

Controlling a Stepper Motor with Arduino and L298N Stepper motors that has four wires, It has 200 steps per revolution, and can operate at at 60 RPM. If you don't already have the step and speed value for motor, find out now and will need it for the sketch, The key to successful stepper motor control is identifying the wires – that is which one is which. You will need to determine the A+, A-, B+ and B- wires. these are red, green, yellow and blue.[47]

4.6 Stepper motor

A stepper motor may be thought of as polyphase synchronous motor, having salient stator poles, the name stepper derives from the most common application for these machines, that is, rotating a fixed angular step in response to each input pulse received by their controller, when this type of motor is supplied from an electronic drive, accurate position control and precise rotational speeds are the natural consequences. In stepping motors rotation is produced by sequentially switching suitably connected windings to produce discrete angular steps of essentially uniform magnitude. Stepper motor is an electromagnetic actuator. It is an incremental drive (digital) actuator and is driven in fixed angular steps. This means that a digital signal is used to drive the motor and every time it receives a digital pulse it rotates a specific number degree in rotation. Figure 4.16 describe the basic construction of stepper motor. [48].

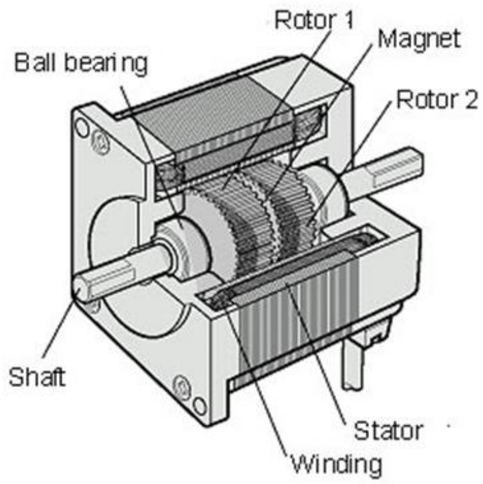


Figure 4.16 Describe the basic construction of stepper motor. [49]

4.6.1 Fundamentals of operation

Brushed DC motors rotate continuously when DC voltage is applied to their terminals. The stepper motor is known by its property to convert a train of input pulses (typically square wave pulses) into a precisely defined increment in the shaft position. Each pulse moves the shaft through a fixed angle. [50]

Stepper motors effectively have multiple "toothed" electromagnets arranged around a central gear-shaped piece of iron. The electromagnets are energized by an external driver circuit or a micro controller. To make the motor shaft turn, first, one electromagnet is given power, which magnetically attracts the gear's teeth. When the gear's teeth are aligned to the first electromagnet, they are slightly offset from the next electromagnet. This means that when the next electromagnet is turned on and the first is turned off, the gear rotates slightly to align with the next one. From there the process is repeated. Each of those rotations is called a "step", with an integer number of steps making a full rotation. In that way, the motor can be turned by a precise angle. [50]

There are three main types of stepper motors:

1. Permanent magnet stepper
2. Variable reluctance stepper
3. Hybrid synchronous stepper

Permanent magnet motors use a permanent magnet (PM) in the rotor and operate on the attraction or repulsion between the rotor PM and the stator electromagnets. Variable reluctance (VR) motors have a plain iron rotor and operate based on the principle that minimum reluctance occurs with minimum gap, hence the rotor points are attracted toward the stator magnet poles. Whereas hybrid synchronous are a combination of the permanent magnet and variable reluctance types, to maximize power in a small size. [51]

4.6.2 Hybrid Actuators with Stepper Motors

Hybrid actuators transfer the rotation movement of the stepper to the movement of a linear screw with the help of a special patented nut. The actuator contains a hybrid stepper motor, which utilizes both the advantages of a reluctance motor and a motor with permanent magnets. The construction is based on a reluctance motor and ensures a small step angle (up to 0.9°) and fine resolution. The use of permanent magnets on the other hand increases the turning moment and provides a stronger motor. The composition of these two technologies together with the movement nut into a single case creates an affordable compact linear drive – a hybrid stepper actuator. Hybrid actuators represent an affordable solution for all application requiring small and exact control of a linear movement. Actuators create large forces in small spaces. The actuator contains a standard stepper motor, which may be simply controlled in the same way as stepper motors. The core of the hybrid actuator is an exact trapezoidal movement screw and nut shaped for the corresponding load. Integration of the movement screw in the motor provides a compact and precise drive unit which simplifies the construction of the resulting machine. Actuators find applications in medicine, measuring technology, handling technology and in other areas. One type of such actuators is shown in Figure 4.17. [52]

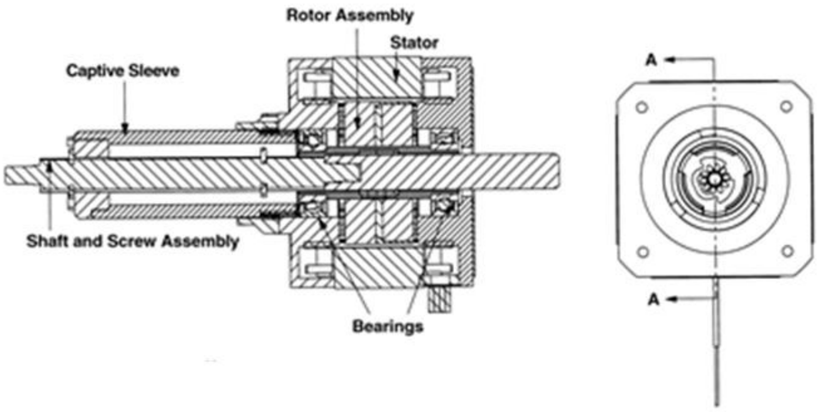


Figure 4.17 Schematic of a type captive linear stepping actuator. [53]

4.6.3 Driver circuits

On the first is turned off, the gear rotates slightly to align with the next one. From there the process is repeated. Each of those rotations is called a "step", with an integer number of steps making a full rotation. In that way, the motor can be turned by a precise angle. [54]

Stepper motor performance is strongly dependent on the driver circuit. Torque curves may be extended to greater speeds if the stator poles can be reversed more quickly, the limiting factor being a combination of the winding inductance. To overcome the inductance and switch the windings quickly, one must increase the drive voltage. This leads further to the necessity of limiting the current that these high voltages may otherwise induce. [54]

The medical device industry is considered a hub of innovation for good reason; with constantly improving designs and processes, the possibilities seem endless. Over the past 20 years, stepper motors from Lin Engineering have played a role in this innovation. In fact, you may find our stepper motors in applications such as plate readers, liquid and specimen handling systems, chromatography, and In Vitro diagnostic machines. Regardless of what the application may be, all devices in the medical industry require two main critical ingredients:

1. High Reliability.
2. Smooth Motion.

In the medical device industry, high reliability is crucial for obvious reasons; in most cases, steppers motors are being used in environments which help support human life. Using high quality components and maintaining strict manufacturing tolerances are essential for ensuring the reliability and longevity of stepper motors as shown in figure 4.18. [55]

Figure 4.18 Linear stepping actuator. [56]

Advantages of stepper motor:

1. Low cost for control achieved.
2. High torque at startup and low speeds.
3. Ruggedness.
4. Simplicity of construction.
5. Can operate in an open loop control system.
6. Low maintenance.
7. Less likely to stall or slip.
8. Will work in any environment.
9. Can be used in robotics in a wide scale.
10. High reliability
11. The rotation angle of the motor is proportional to the input pulse.
12. A wide range of rotational speeds can be realized as the speed is proportional to the frequency of the input pulses. [57]

Final design of linear stepper motor connect with syringe as shown in figure 4.19:

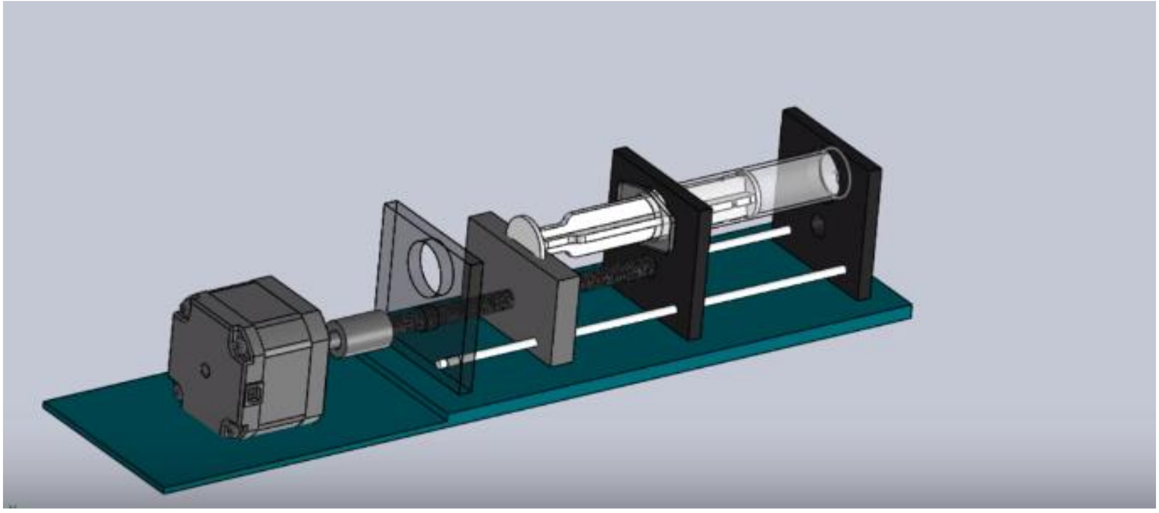


Figure 4.19 Stepper motor connect with syringe. [58]

4.6.4 Stepper motor calculation and analysis

- Force calculation that need to moving the syringes :

$$F = \frac{P\pi d}{4} \quad \text{......................................(4.2)}$$

Where :

F : Maximum force applied.

P : Maximum Pressure of syringe.

d : Diameter of syringe .

$$F = \frac{(300psi\ )(\pi)(2.67in)}{4}$$

$$F = 1766.25\ lpf$$

- Stepper motor torque calculation that need to moving the syringes :

$$T_R = \frac{Fd_m}{2}\left(\frac{l + \pi f d_m \sec\alpha}{\pi d_m - fl \sec\alpha}\right) \quad \text{..............................(4.3)}$$

Where :

T_R : The torque required to lift the load.

F : Maximum force applied.

d_m : Mean (pitch) diameter,

l : The distance through which the screw advances in one turn .

f : represents the coefficient of friction for the threads .

α : Thread angle.

$$TR = (794.8)(\frac{0.85}{2.762})/1000$$

$$TR = 0.2445\ ib.in$$

Convert ib.in to N.m:

$$TR = 0.02762\ \mathrm{N.m}$$

- To select a Suitable motor, must be used torque T_m higher than torque required.

  T_R to overcome friction:

$$T_m = 1.2\ T_R \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(4.4)$$

$$T_m = (1.2)(0.02762)$$

$$Tm = 0.033\ \mathrm{N.m}$$

Where :

Tm: The torque of the motor measurement. [59]

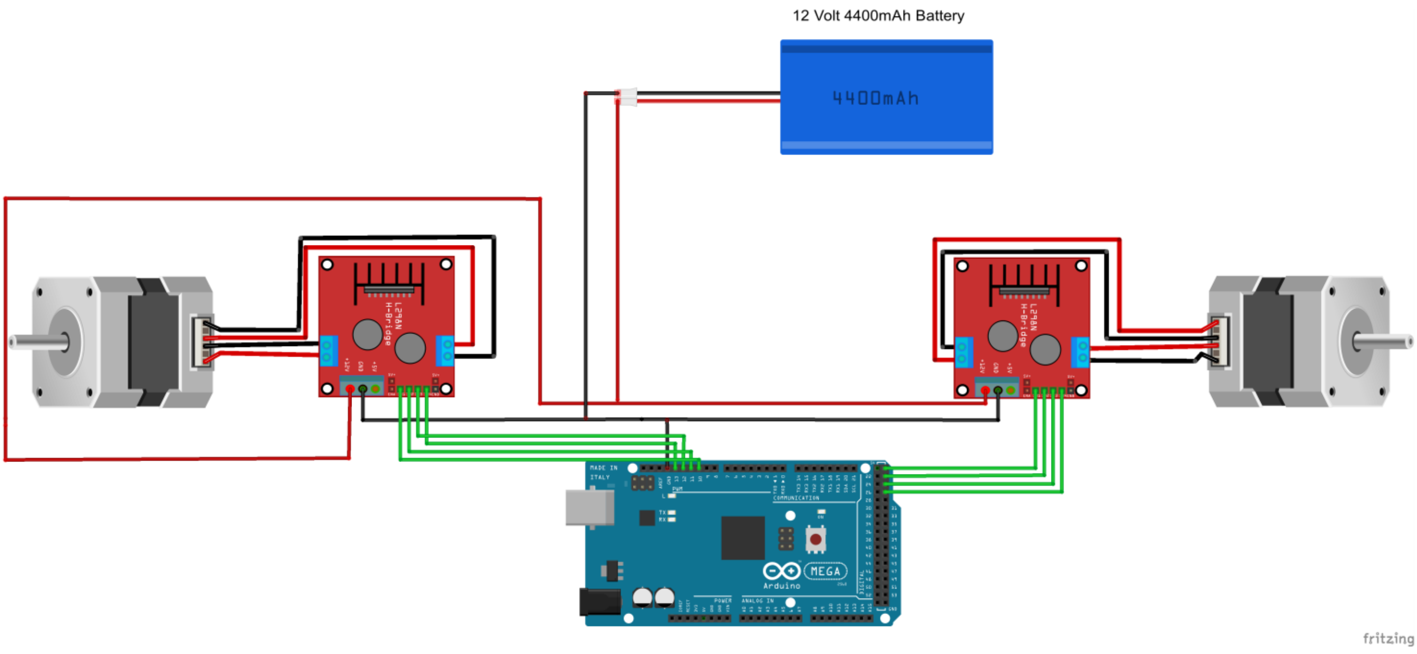


Figure 4.20 Stepper motor connect with driver and Arduino Mega.

4.7 Linear position control

Limit switches are types of automatic sensors that detect the position of an object through physical contact. An object moves the actuator that opens or closes a set of electrical contacts housed in the switch body, which are connected to equipment circuits by the connection terminals.[60]

The main components of a limit switch are the switch body, the connection terminals, and the actuator, the switch body, or contact block, includes the enclosure and electrical contacts, the connection terminals are where you connect the input and output wires. In most cases, a limit switch is connected to some sort of control circuit (e.g. relays or programmable logic controllers).[60]

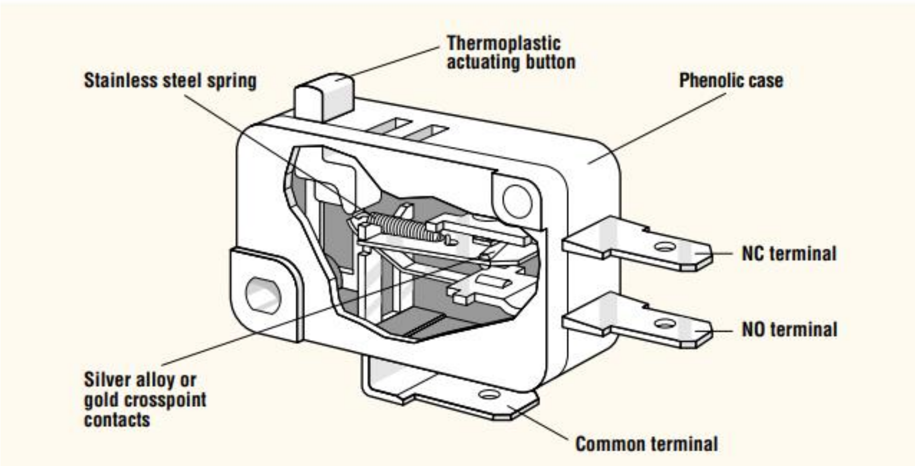


Figure 4.21 Micro switch. [61]

External limit switches are used to make or break an electrical connection. It can be designed in many forms, but to put simply, it's a device with a lever (or button or spring etc) that, once moved, will either close or open an electrical circuit. They are also designed in a variety of sizes and power to accommodate a wide range of motion control devices, from small electric linear actuators, to large high-power heavy-duty linear actuators.[61]

Micro switch is actually a trademarked name people use to refer to snap-action switches in general, much like how people use Kleenex as a general term for paper tissues. The term "snap-action" refers to the instant when the contacts suddenly change state, micro switches are widely used for a wide variety of applications. For example, most limit switches are snap-action.[61]

Specifications:

- Reliability, repeatability, accuracy.
- Impressive breadth of product offerings.
- Tested-tough, for industrial machinery.
- Supreme performance, through superior application understanding.
- Withstanding shock, vibration, wash downs and outdoor environments.[62]

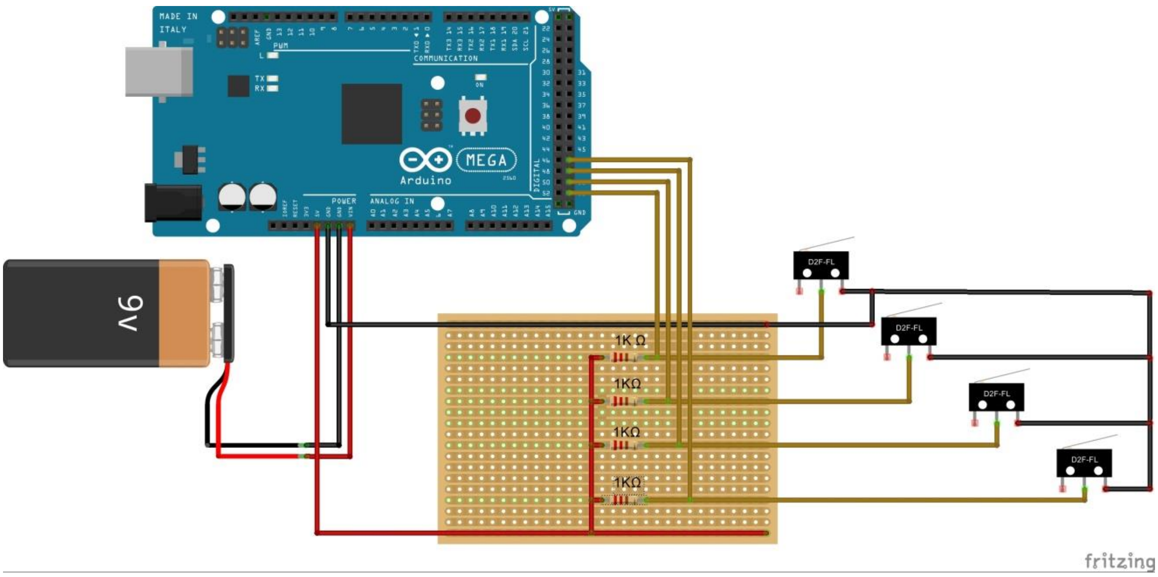


Figure 4.22 Micro switch connect with Arduino Mega

4.8 Lipo Battery Voltage Tester and Low Voltage Buzzer Alarm

Lipo Battery Voltage Tester And Low Voltage Buzzer Alarm is a simple, compact, 2-in-1 device that is perfect for 1-8S batteries, Just plug in battery's balance connector and know the pack voltage (both total pack and individual cell) instantly. The built-in low voltage alarm monitors the pack voltage and will automatically emit a buzzer sound and blink an LED light when the voltage drops below the threshold (can easily adjust the low voltage threshold by pressing the small button on the unit).[63]

This unit has high quality extra buzzer that you can hear from far away, high brightness LED digital display and push button selectable voltage detection level that. helps protect your battery cells 2S to 8S.

Specifications:

- Low voltage Buzzer alarm mode for 2-8S.
- With a push key by which you can change the value settings and save.
- When voltage is below the set value, it will buzzer very loudly with red LED light. (pre-set value is 3.3V)
- Mini shape, no larger than a common key.
- Compact, easy to carry.
- Really useful in flight if you can't see the lights.
- Use for 1-8s Lipo/Li-ion/LiMn/Li-Fe.
- Voltage detection precision: ±0.01V
- Unit voltage display range: 0.5-4.5V
- Total Voltage display Range: 0.5-36V
- 1S test mode voltage range: 3.7-30V
- 1S test mode detection precision: ±0.5%
- Alarm set value range: OFF 2.7-3.8V [64]

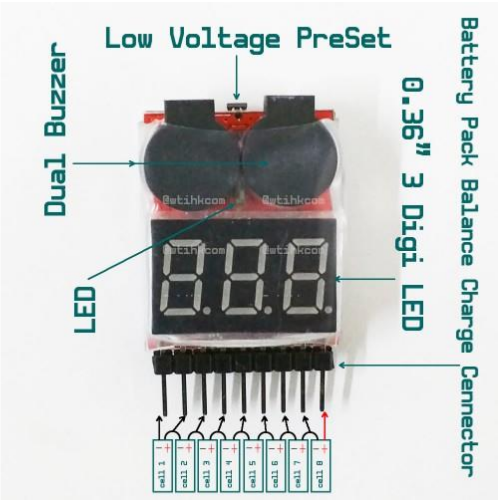


Figure 4.23 Lipo Battery Voltage Tester.[65]

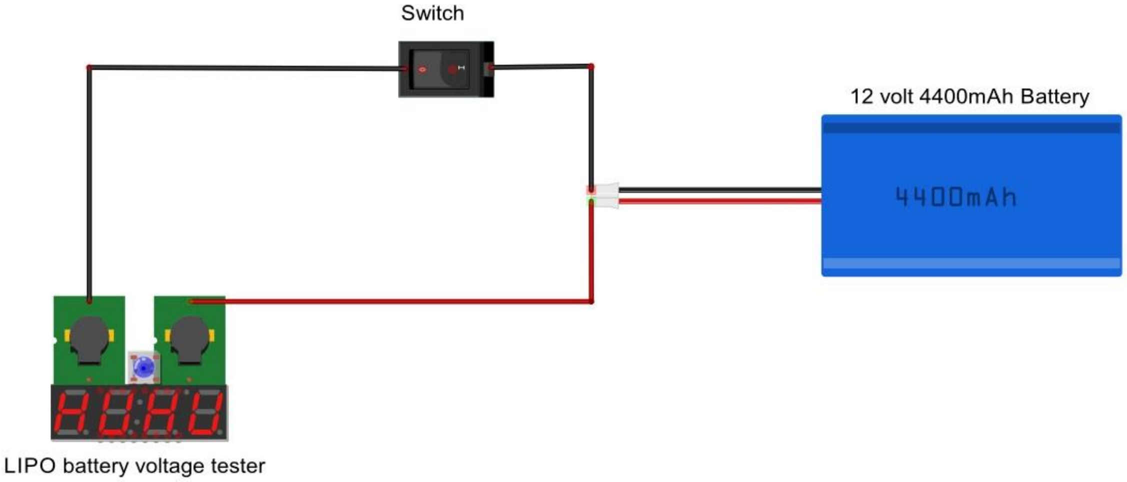


Figure 4.24 Lipo Battery Voltage Tester connect with 12 volt Li-ion rechargeable

Final System circuit connection as shown in figure

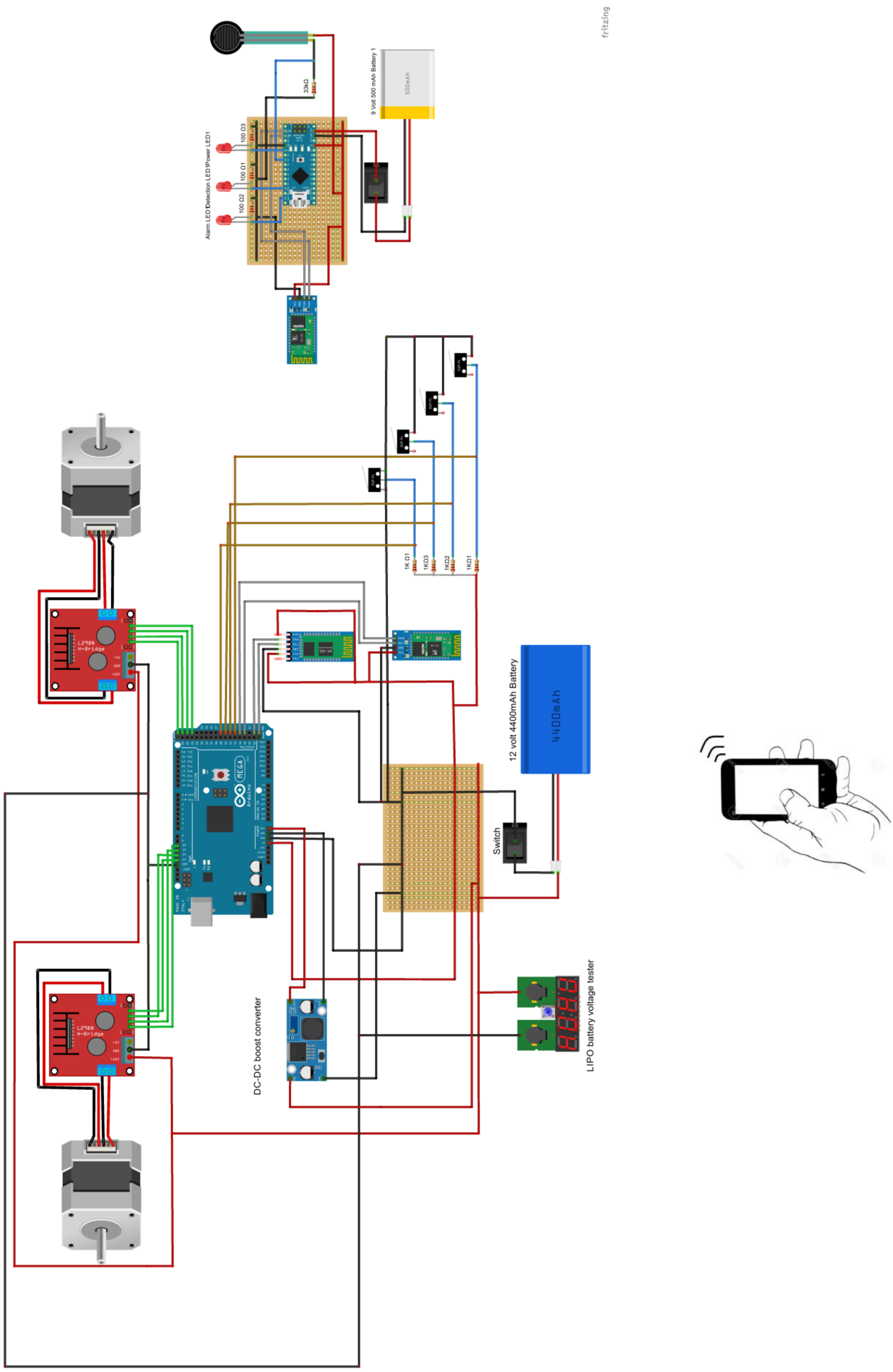


Figure 4.25 Represent System circuit connection.

4.9 Project cover design

A 3D design of project cover prepared by CATIA program , that dimensions :

X : 550.0 (mm)

Y: 293.661 (mm)

Z : 129.643 (mm)

As shown in figure 4.26 :

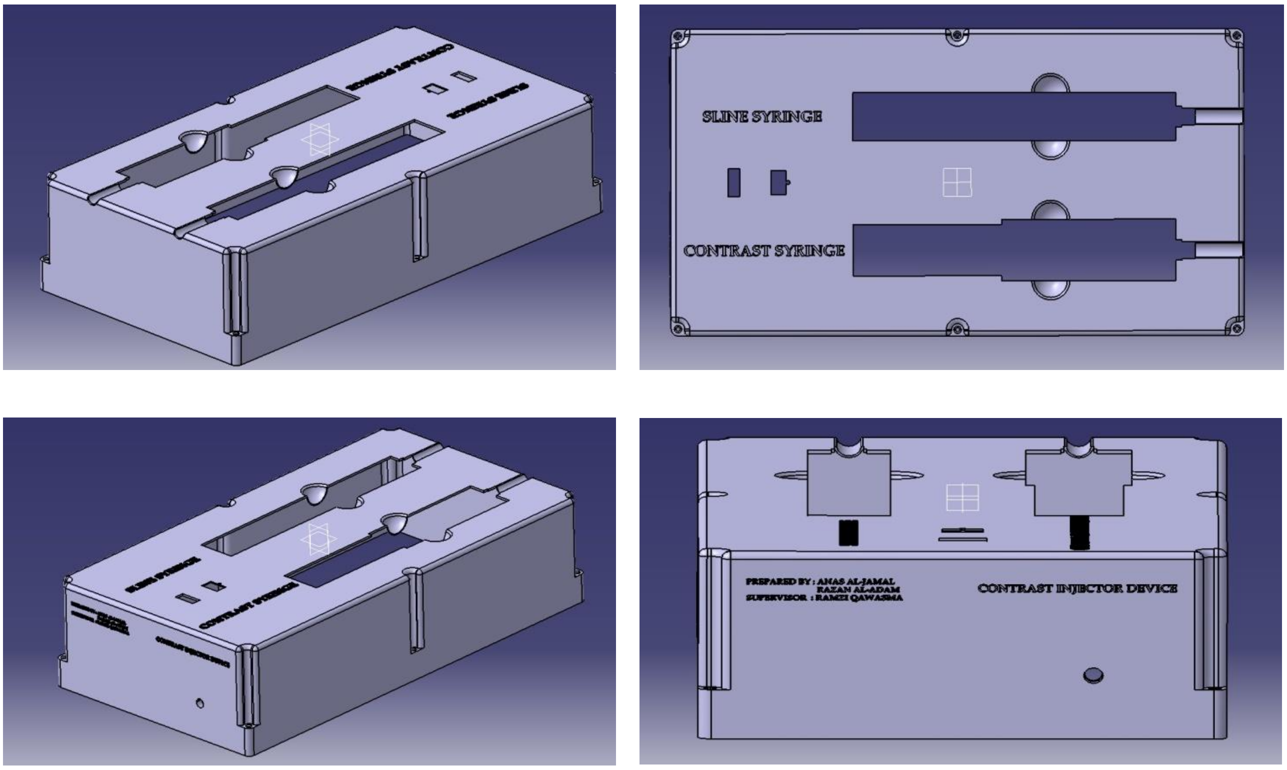


Figure 4.26 The design of the 3D cover plans and elevations of the project .

4.10 Fluid delivery system

Fluid delivery components use in injection system including:

1. Disposable syringes:

A feature of syringe injection system us Use 200 ml contrast syringe and 100 ml normal saline syringe as shown in figure 4.27. [66]

- Made from clarified polypropylene to allow optimal detection of air bubbles
- Dual-seal plunger designed to prevent air aspiration or leakage
- Tapered luer tip for bubble removal
- Sterile, Disposable, Latex-Free, Pyrogen-Free Syringes
- Non-stick luer eliminates syringe damage. [66]

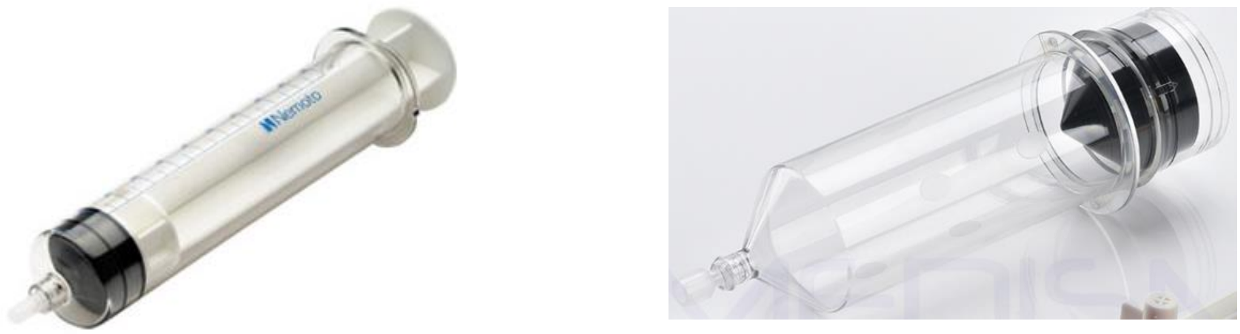


Figure 4.27 A 200 ml contrast syringe and 100 ml normal saline syringe. [66]

2. Transfer Sets:

Sterile transfer sets with various designs to fill syringes from multiple sizes and styles of containers syringe kit that includes a longer, vented spike to accommodate small volume single-use saline bags. It is offered in a kit which provides workflow convenience and may save money; figure 4.28 show Kit Includes 2 distinct spikes, also figure 4.29 show sterile transfers set. [67]

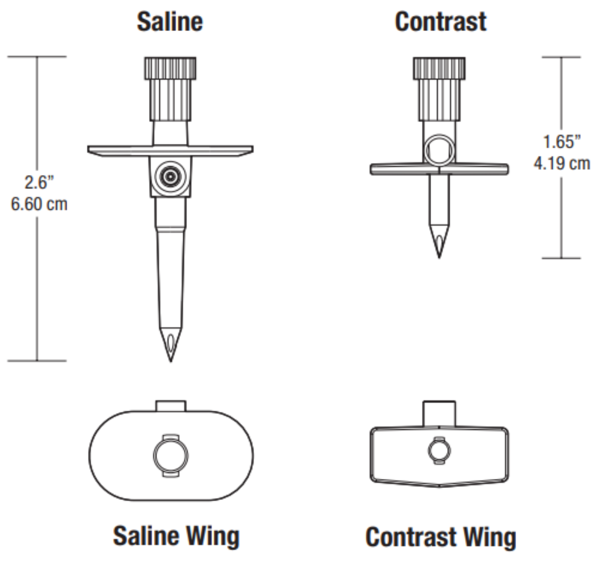


Figure 4.28 Kit includes 2 distinct spikes. [68]

Features of Transfer Sets tube:

- Contrast spike is available with ball check to prevent leakage.
- Long and short spikes available.
- Supports faster fill rates.
- Available with swayable valve. [69]

Figure 4.29 Sterile transfer sets. [70]

3. Straight Lines and Y-Lines connector

- Extension line suitable for low pressure applications
- For pressures upto 4.5 bar (65 psi)
- Also available with "Y" injection port (latex or latex free) for intermittent medication
- Available with or without clamp
- Tube dia : I Ø 3.0 mm. & O Ø 4.1 mm
- Male luer lock at one end & female luer lock at other end.
- Tube lengths : 25, 50, 100, 150 & 200 cm

Sterile, Clear, Flexible, Straight and Coiled Low Pressure Extension Line available in multiple lengths designed for use with multiple connections, including needleless valves, to help prevent sticking, breaking and overtightening; and to withstand pressures obtained during CT procedures as shown in figure 4.30. [70]

(a) **(b)**

Figure 4.30 Straight Lines and Y-Lines connector. [71]

4. Gauge cannula:

The gauge refers to the inner measurement or opening of the needle. Needles are routinely available in a variety of gauge sizes, including 18, 21, 23, and 25 gauge, as shown in the image. The needle gauge becomes a consideration when the vein of the patient is narrow, fragile, or superficial. In such cases, a gauge size with a larger number (eg, 25 G) may be preferred over a routine needle gauge (eg, 21 G) to minimize damage to the blood vessel, as well as minimize the associated pain with collection.[72]

The high flow rate necessary for adequate vascular delineation requires intravenous access with a catheter capable of administering iodinated contrast at a high injection rate using a power injector4. The rate and volume of contrast injection and the scan delay should be customized to the specific catheter and injection site utilized, preferably a 20-gauge or larger needle is placed in the vein reduces destabilizing risks that lead to extravasation as shown in table 4.1. [73]

Table 4.1 Flow rate different gauge cannulas. [73]

Color	Gauge	Catheter Length (in)	Catheter ID (mm)	Catheter OD (mm)	Extension Tube ID (mm)	Gravity Flow Rate (mL/min)	Max CT Flow Rate (mL/sec)	High Pressure Rating (psi)
Diffusics™ Closed IV Catheter System								
Yellow	24	0.75	0.53	0.71	1.22	21	3.0	325
Blue	22	1.00	0.67	0.90	1.65	45	6.5	325
Pink	20	1.00	0.83	1.10	1.65	68	10.0	325

Figure 4.31 show colors of different gauge cannulas:

Figure 4.31 Colors of different gauge cannulas. [73]

Stages of install fluid delivery on the contrast media injector:

1. Install the spike on the contrast injector.
2. Take the saline bag and contrast agents connect to the CT injector.
3. Press the button and absorb the contrast media and saline, then remove all of the bottles.
4. Expel the air bubble in the CT injector from the barrel to the extension line.
5. Connect the connecting tube to the patient, start injecting the contrast media.

4.11 Power supply

The project is portable system supply, by using 12 volt Li-ion rechargeable for device , battery have relatively long life and have 4400mAh Capacity, and 9v Li-ion rechargeable battery with 500mAh Capacity ,they are used to power supply each subsystems, electrical circuits, sensor, and motors.

The XL6009 automatic dc-dc boost converter is a adjustable voltage regulators, it is a popular kind for regulating and outputting positive voltage ,use to regulate 12 volt to 8 volt because of feeding the main microcontroller Arduino Mega as shown in figure 4.32.

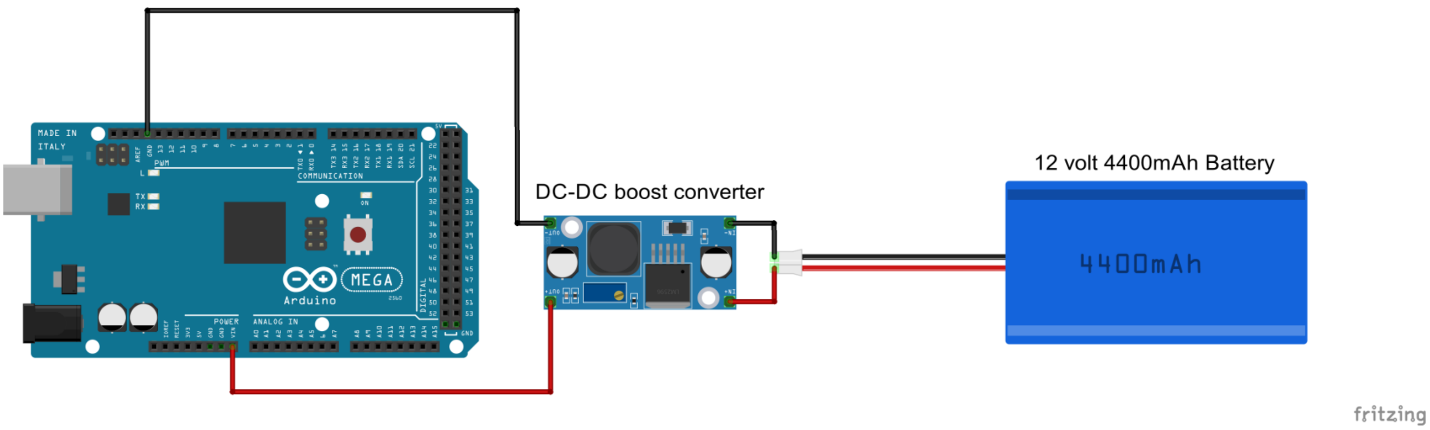


Figure 4.32 Dc-Dc boost converter connection.

The following table shows the total power consumption in device of project, can be determined by the following equation $P = I * V$ …………………………………..(4.5)

Where: P is the power (m Watt), I is the current (mA), V is the voltage (v).

Table 4.2 Power consumption of main part.

System component	Power consumption	Quantity	Total power consumption (Watt)
Arduino Mega	**12v * 20mA**	**1**	**0.24**
stepper Motor	**12v * 1700mA**	**2**	**40.8**
Bluetooth module	**5v * 40mA**	**2**	**0.4**
Lipo voltage tester	**12 * 10mA**	**1**	**0.12**
L298 Driver	**12 * 36mA**	**2**	**0.86**
Total power consumption = 42.42 Watt			

Run time in hour = $\frac{\text{(Battery Capacity in Amp Hours)}}{\text{Load power in Watts}} * \text{ voltage input}$ ……...(4.6)

Run time in hour = $\frac{4.4\text{Ah}}{42.42} * 12 \text{ v}$

Run time in hour = 1.24 hour.

The following table shows the total power consumption of alarm circuit:

Table 4.3 Power consumption of alarm circuit.

System component	Power consumption	Quantity	Total power consumption (mWatt)
Arduino Nano	**9v * 19mA**	**1**	**171**
Bluetooth module	**5v * 40mA**	**1**	**200**
Strain gauge sensor	**9v * 0.4mA**	**1**	**3.6**
Total power consumption = 374.6 mWatt			

Run time in hour = $\frac{\text{(Battery Capacity in Amp Hours)}}{\text{Load power in Watts}} * \text{ voltage input}$

Run time in hour = $\frac{500\text{mA}h}{374.6\text{mw}att} * 9$ v

Run time in hour = 12 hour.

The hours maximum run time is 1.24 before the battery of device is completely discharged, while 12 hour for alarm module completely discharged.

4.12 Flow Chart

The smartphone sets flow and amount of contrast media and normal saline transfer the data via Bluetooth module to the microcontroller, if the operator chooses the contrast media only one of steeper motors activate, if the operator chooses the normal saline the other motor activate, if the operator chooses both channel, both motor activate. The strain gauge detects if the arm bulges, sends the data to the microcontroller and display it on the smartphone alerts the operator as shown in figures 4.33 ,4.43

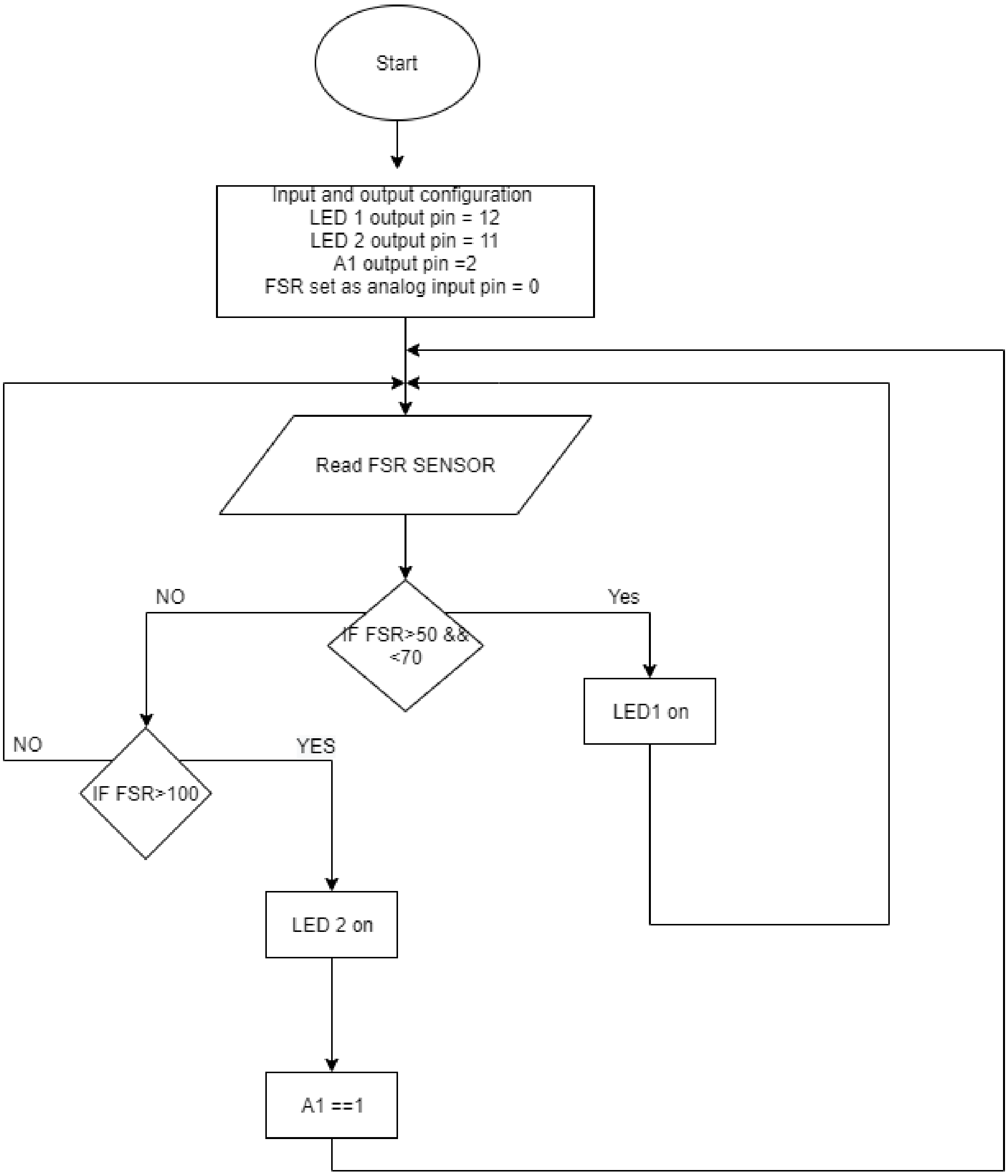


Figure 4.33 Flow chart of cuff circuit.

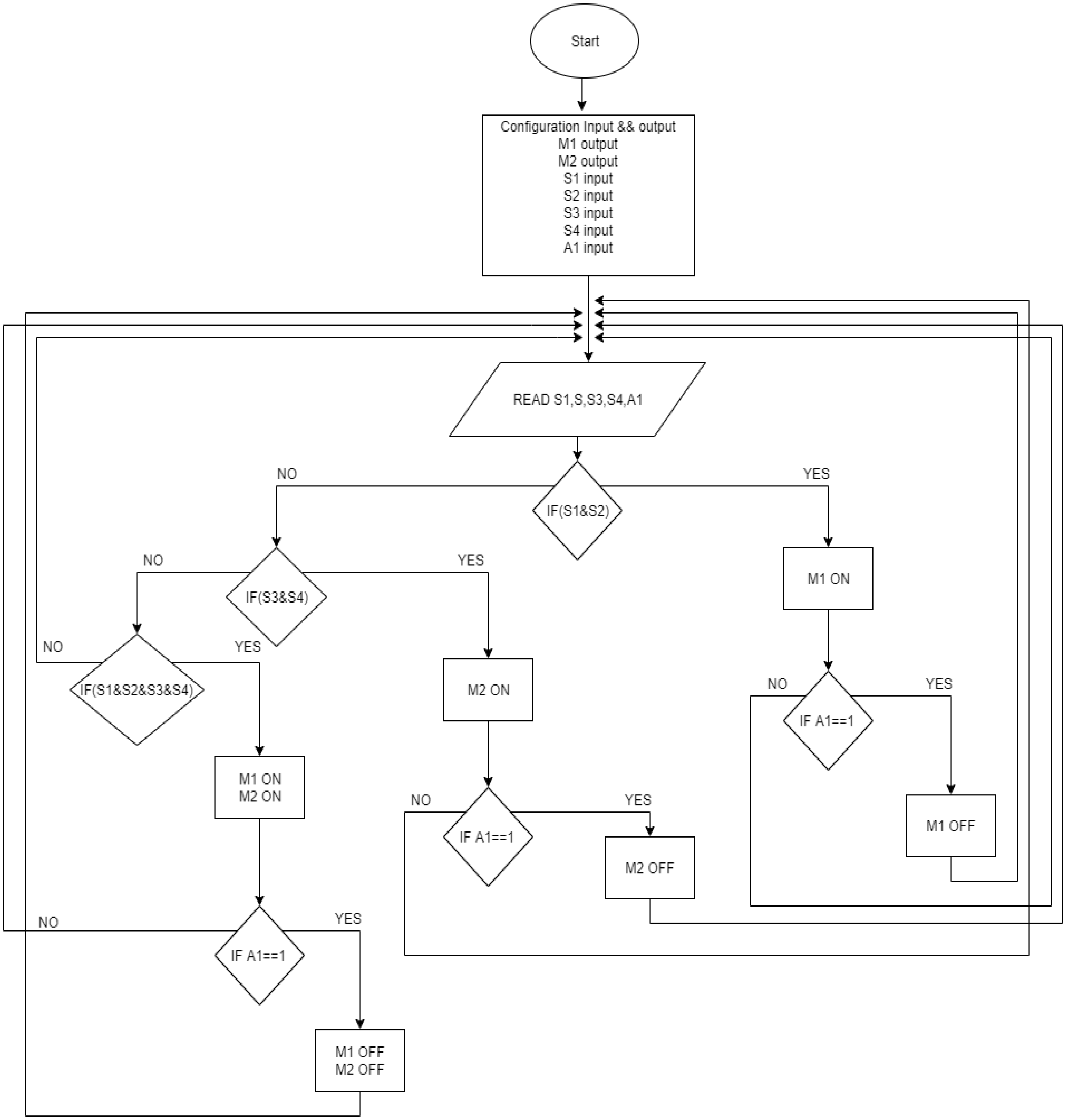


Figure 4.34 Flow chart contrast injector circuit.

Chapter Five

System Implementation and Testing

5.1 Cuff circuit

5.1.1 HC-06 Bluetooth

5.1.2 Force sensor

5.2 Main circuit of contrast Injector system

5.2.1 Bluetooth Hc-05 & Hc-06 circuit

5.2.2 Micro switch circuit

5.2.3 Lipo Battery Voltage Tester and Low Voltage Buzzer Alarm circuit

5.2.4 The L298N driver of motors circuit

5.3 Stepper Motors connection

5.4 Controlling circuits units

5.5 Power Supply

This chapter clarifies the results achieved through design the injector and cuff module have been build and used, which will perform several operations required to inject saline and contrast solution , indicate alarm condition , so that get the appropriate and correct position of the cuff around patient arm.

Each of the stages described in the previous chapter and the signal processing to get the desired signal will be briefly explain in this chapter.

5.1 Cuff circuit

This circuit is contains several electronic component , where suppling voltage to the Arduino Nano from 9v battery rechargeable ,the another electronic parts fed by 5 volts from Arduino Nano, which are:

- HC-06 Bluetooth.
- Force sensor.
- Power LED.
- Detection LED.
- Alarm LED.

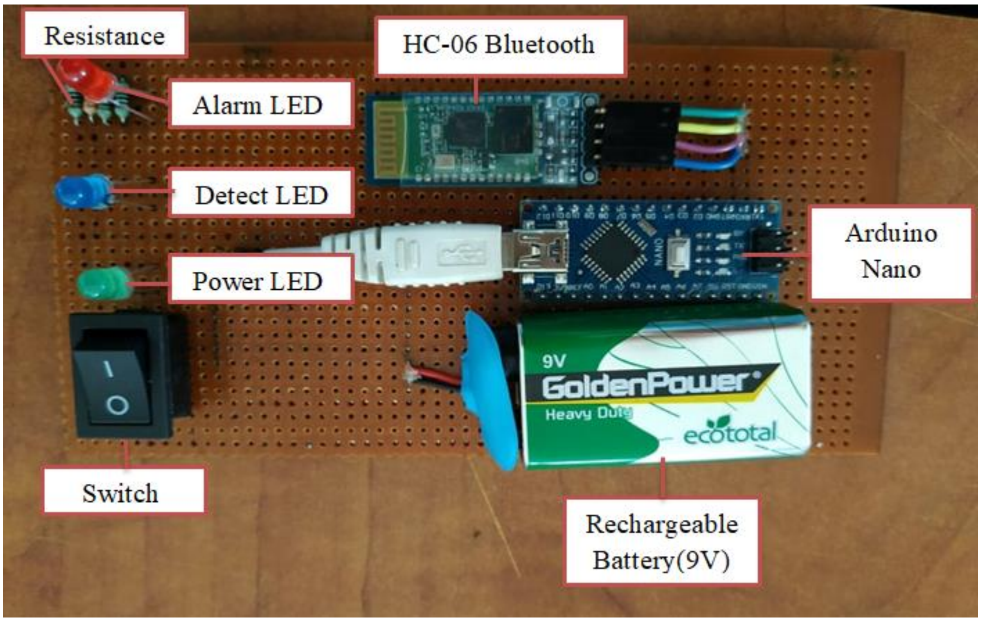


Figure 5.1 Cuff circuit

5.1.1 HC-06 Bluetooth

HC-06 used to send data from Arduino Nano to the Arduino Mega by HC-06 Bluetooth, and the figure 5.2 shows how was the HC-06 and another electrical component connected to the Arduino Nano

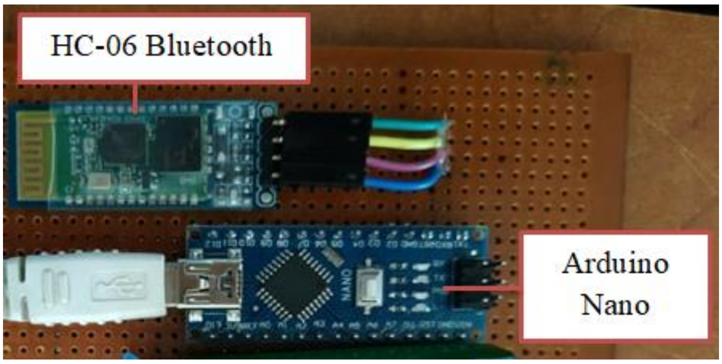


Figure 5.2 HC-06 Bluetooth connection

5.1.2 Force sensor:

The force sensor will receive a signal from the patient's arm and send it to Arduino Nano by using voltage driver with 33KΩ resistance .

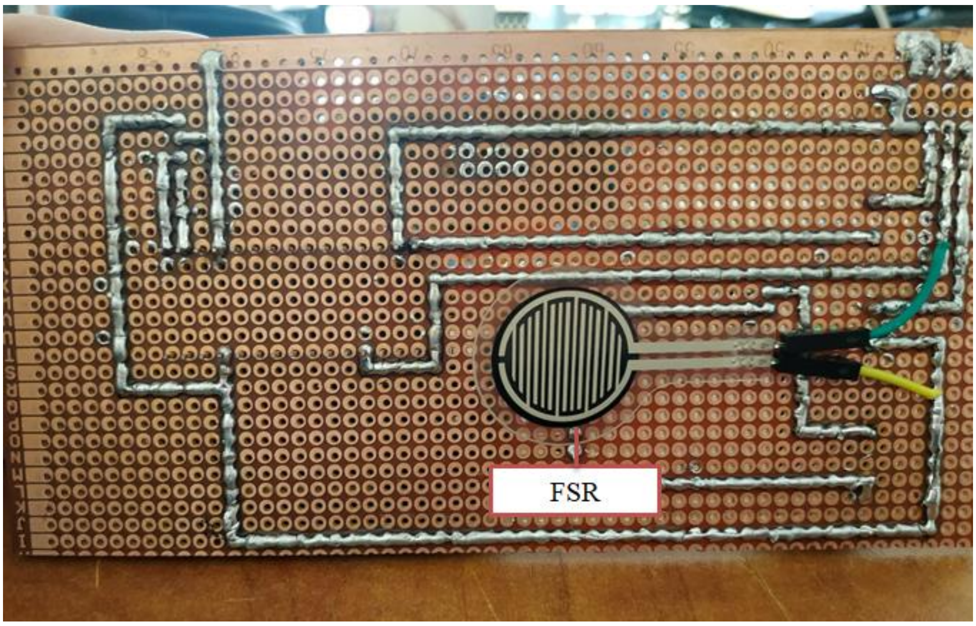
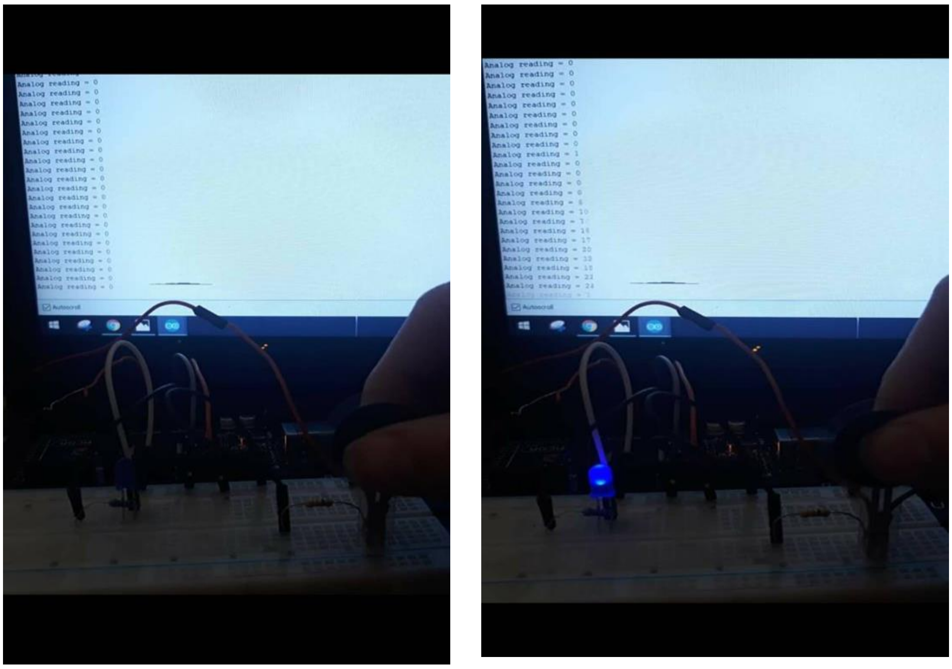


Figure 5.3 Force sensor connection

Force sensor simulation :

The force sensor simulation by using Arduino serial monitoring , applying the force on FSR the analog values display on monitor, in addition to blue LED (detection LED) on when the analog value greater 0.However , when the analog value equal 0 the LED will be off as shown in figure 5.4.



(a) (b)

Figure 5.4 Simulation of FSR sensor (a) Without force , (b) Applied force.

Table 5.1 Force sensor simulation:

Analog reading simulation	$V_{out(RM)}$	$R_{(FSR)}$	Force(g)	Force(N)
95	0.46 volt	325.69kΩ	5g	0.05 N
140	0.68 volt	209.65kΩ	6g	0.06 N
272	1.32 volt	92.00 kΩ	9g	0.09 N
496	2.42 volt	35.21 kΩ	40g	0.4 N
678	3.31 volt	16.84 kΩ	100g	1 N
888	4.32 volt	5.19 kΩ	200g	2 N
904	4.41 volt	4.4 kΩ	290g	2.9 N
973	4.75 volt	1.73 kΩ	900g	9 N

$$V_{out} = \frac{\text{Analog reading}}{1023} * Vin \quad \text{...(5.5)}$$

$$= \left(\frac{95}{1023}\right) * 5 = 0.46 \text{ volt}$$

$$R_{(FSR)} = \frac{(Vin - Vout) * RM}{Vout} \quad \text{...(5.6)}$$

$$= \frac{(5 - 0.46) * 33k}{0.46} = 325k\Omega$$

Force(N)= Force(Kg) * 10 ....(5.7)

=0.005 * 10 = 0.05N

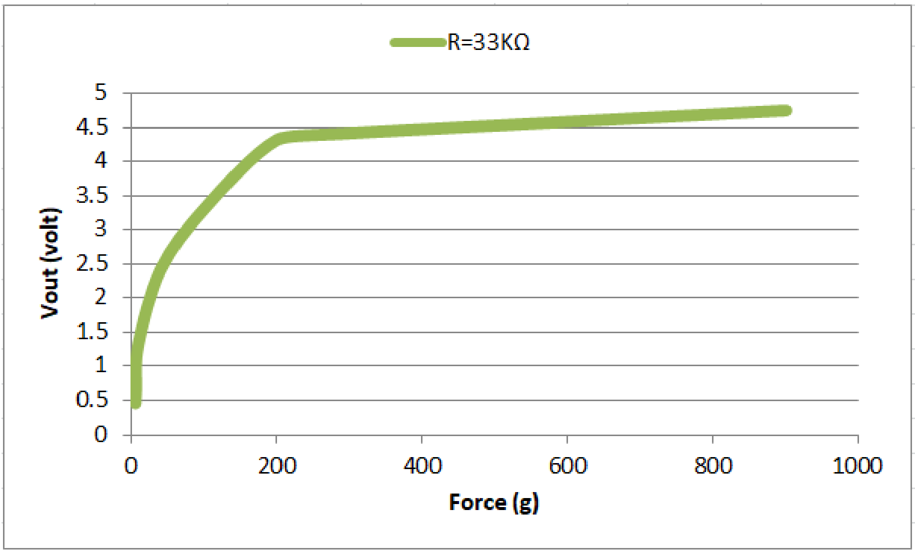


Figure 5.5 Voltage vs. force relationship of FSR

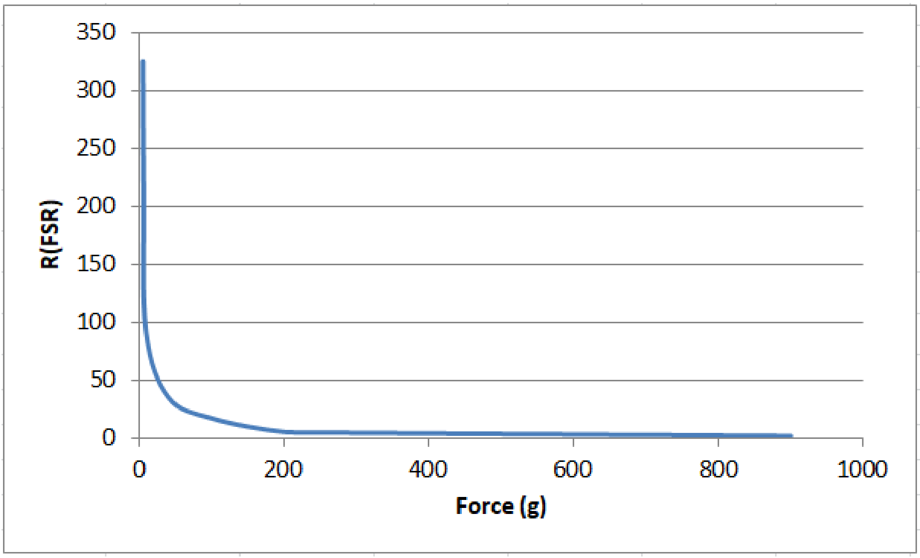


Figure 5.6 Resistance vs. force relationship of FSR

5.2 Main circuit of contrast Injector system

This circuit is contains several electronic and mechanical component , where 12 volt battery suppling voltage to:

- Arduino Mega.
- Drivers motor
- Stepper motors.
- Lipo indictor battery voltage.

The another electronic parts fed by 5 volts from Arduino Mega, which are:

- HC-05 Bluetooth
- HC-06 Bluetooth
- Micro switches

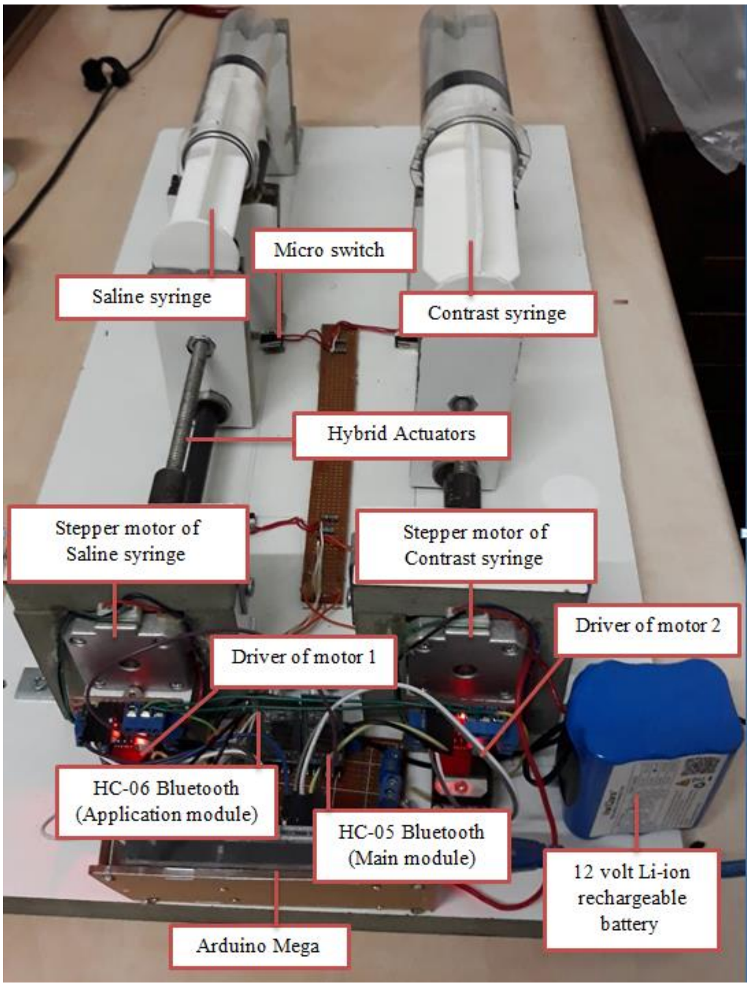


Figure 5.7 Main system circuit

5.2.1 Bluetooth Hc-05 & Hc-06 circuit

Bluetooth Hc-05 & Hc-06 connection , where are feeding supply from main Arduino Mega as shown in figure 5.8.

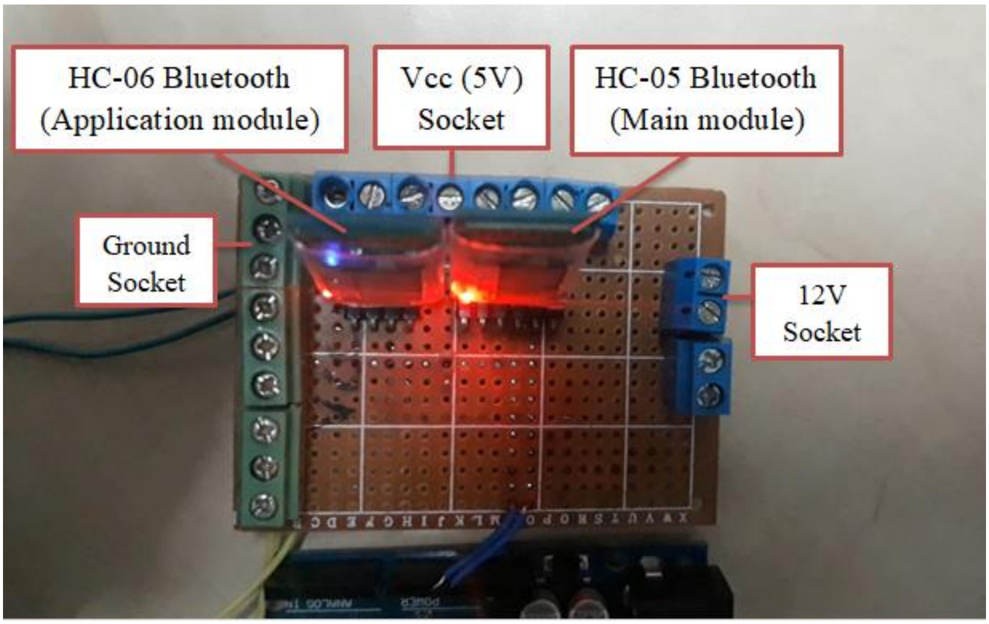


Figure 5.8 Bluetooth Hc-05 & Hc-06 connection

5.2.2 Micro switch circuit

There are 4 Micro switch as shown in figure 5.9. To indicate the condition of syringe if the syringes are empty or full. As shown in table 5.2

Table 5.2 Condition of syringes:

Micro switch 1	Contrast syringe empty
Micro switch 2	Contrast syringe full
Micro switch 3	Saline syringe empty
Micro switch 4	Saline syringe full

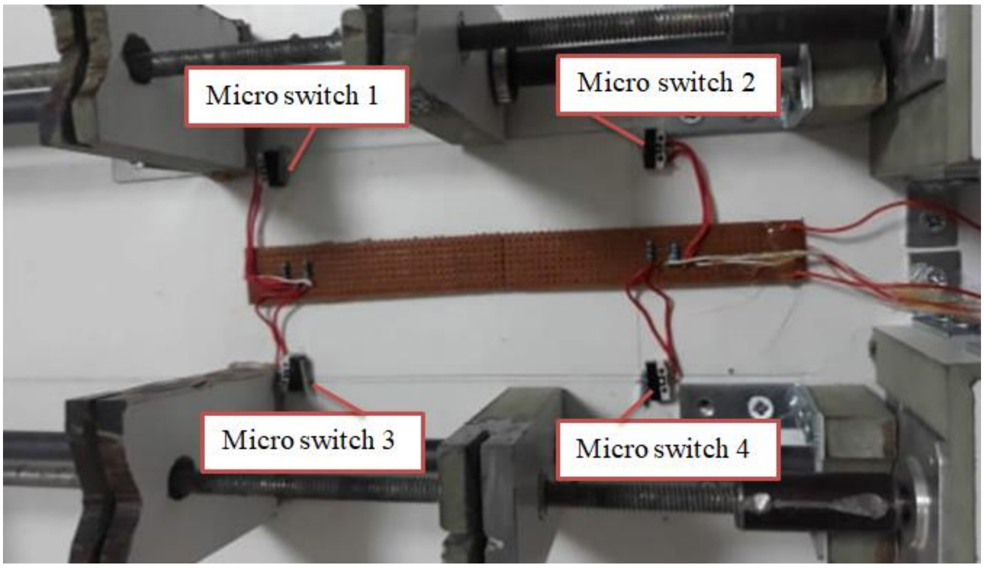


Figure 5.9 Micro switch circuit

Micro switch simulation :

The micro switch simulation by using LED (detection LED) on when the micro switch closed .However , when the micro switch open the LED will be off ,As shown in figure 5.10**.**

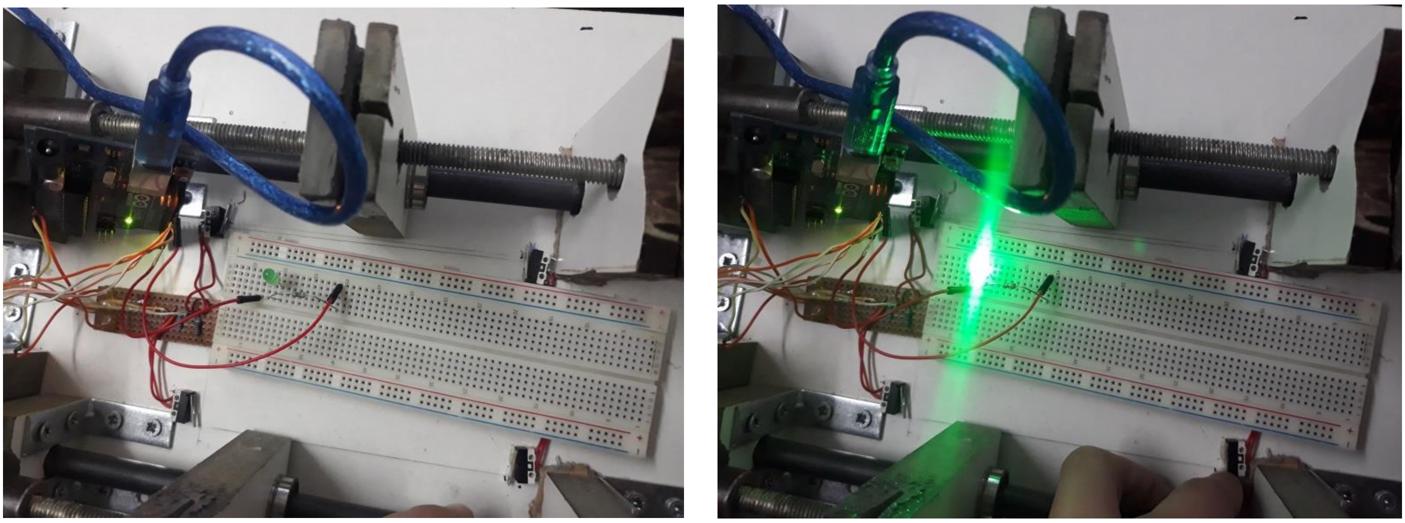


Figure 5.10 Micro switch simulation

5.2.3 Lipo Battery Voltage Tester and Low Voltage Buzzer Alarm circuit

Lipo Battery Voltage Tester connect with Li-ion rechargeable battery to know the pack voltage instantly as shown in figure 5.11.

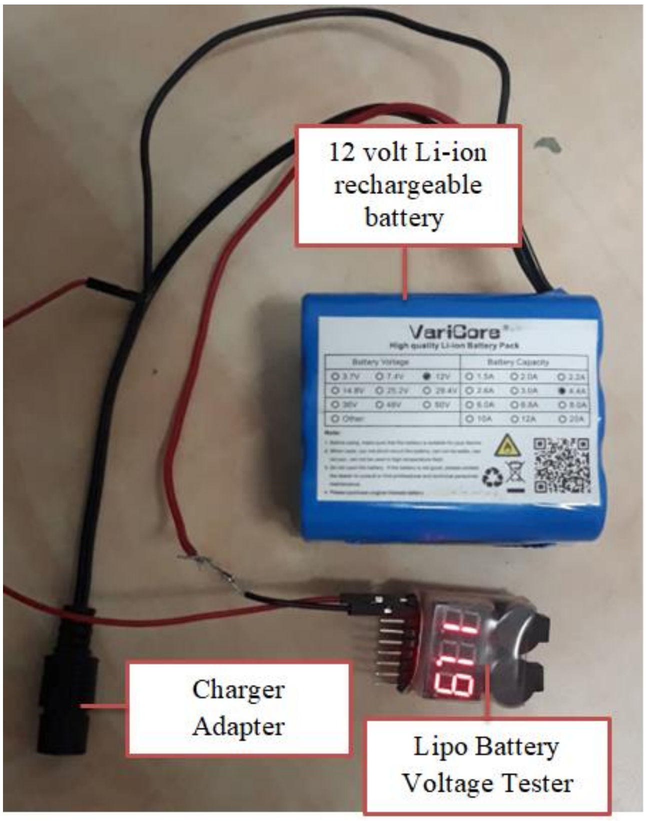


Figure 5.11 Lipo Battery Voltage Tester circuit

The minimum value of battery is 3v select by push button selectable low voltage. As shown in figure 5.12

Alarm monitors the pack voltage and will automatically emit a buzzer sound and blink an LED light when the voltage drops.

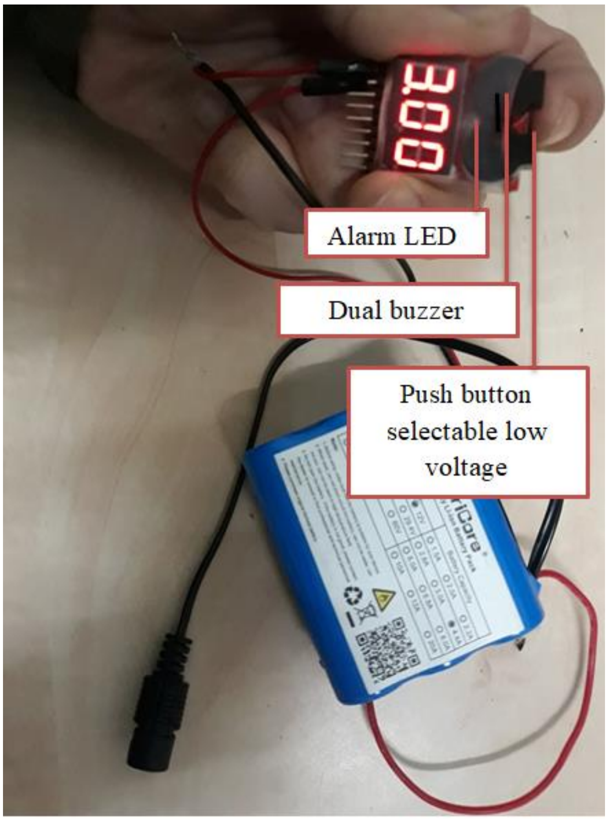


Figure 5.12 Adjustability of low voltage Lipo indicator

5.2.4 The L298N driver of motors circuit

The L298N drivers connect with Arduino Mega and two Stepper Motors , to Control a Stepper Motors by using Arduino coding , where are feeding supply from main 12V Li-ion rechargeable battery as shown in figure 5.13

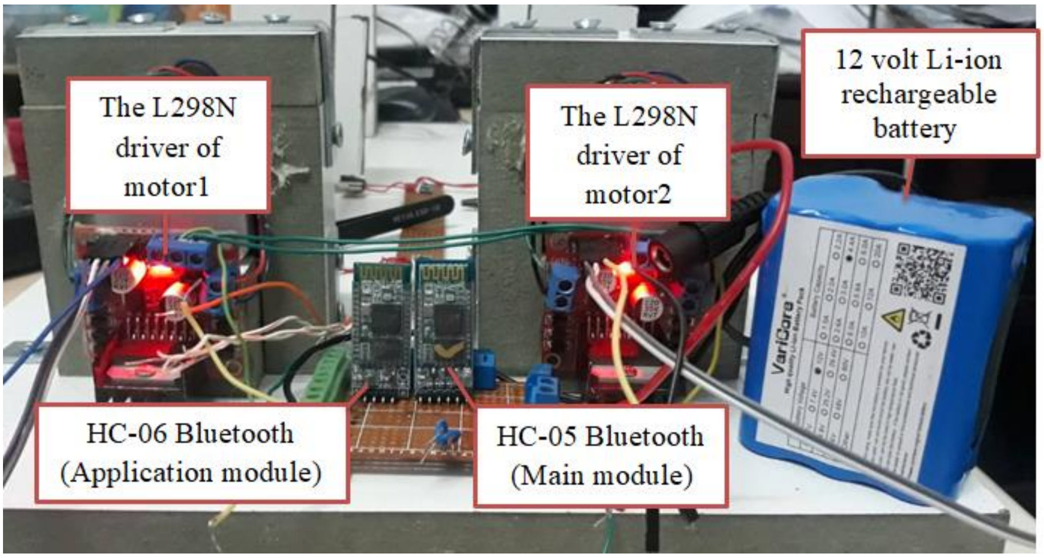


Figure 5.13 The L298N driver of motors circuit

5.3 Stepper Motors connection

Stepper Motors connect with Hybrid Actuators ,To facilitate movement of syringes forward or backward as shown in figure 5.14.

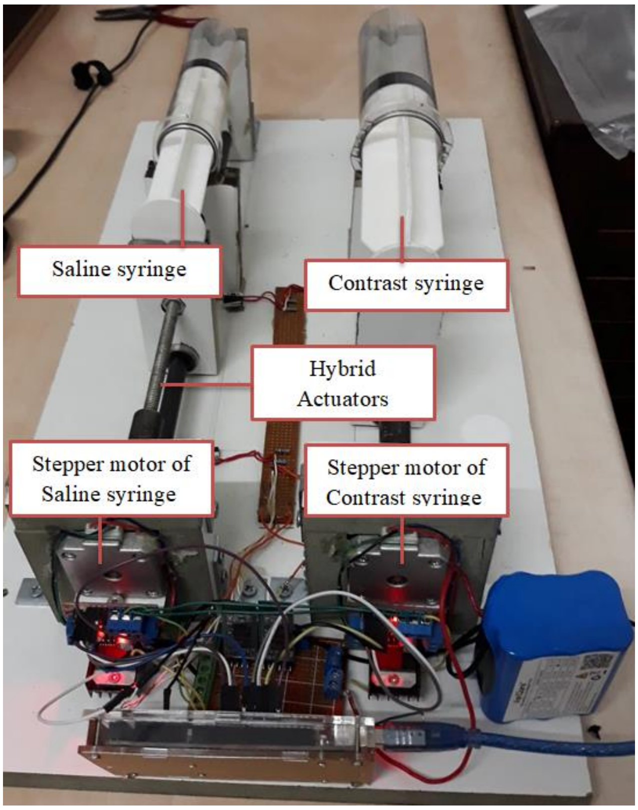


Figure 5.14 Stepper Motors connection

5.4 Controlling circuits units

The controlling circuit unit of contrast injector consists of Microcontroller Arduino Mega and L298N Motors Drivers. In microcontroller unit, the signal is taken from application remote and used to control the motors in order to move the syringes.

HC-05 & HC-06 Bluetooth, Drivers motor and Micro switches are connected with Arduino Mega Microcontroller as shown in figure 5.15.

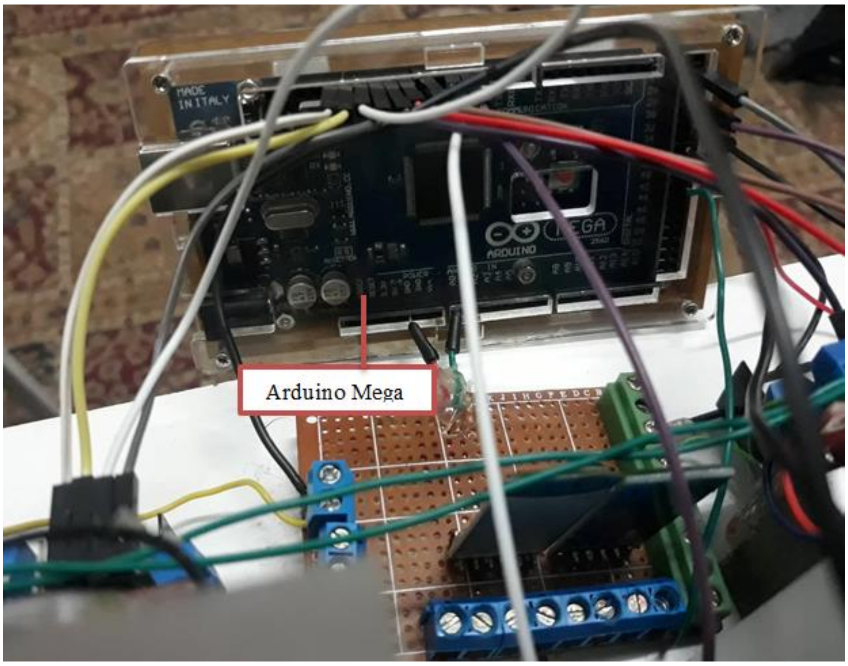


Figure 5.15 Controlling circuit unit of contrast injector system

The controlling circuit unit of cuff consists of Microcontroller Arduino Nano. In microcontroller unit, the signal is taken from force sensor and used to detect position of cuff and alarm signal .

HC-06 Bluetooth , Force sensor and LEDs are connected with Arduino Nano Microcontroller as shown in figure 5.16.

Figure 5.16 Controlling circuit unit of cuff modul

5.5 Power Supply

In this project we used two power supply systems, 9-volt battery was used to feed the cuff circuit as shown in figure , and 12-volt battery was used to feed the Main circuit of contrast Injector system. Voltage was divided into 5-V by a booster that used to provide a convenient voltage to feed Arduino mega as shown in figure 5.17.

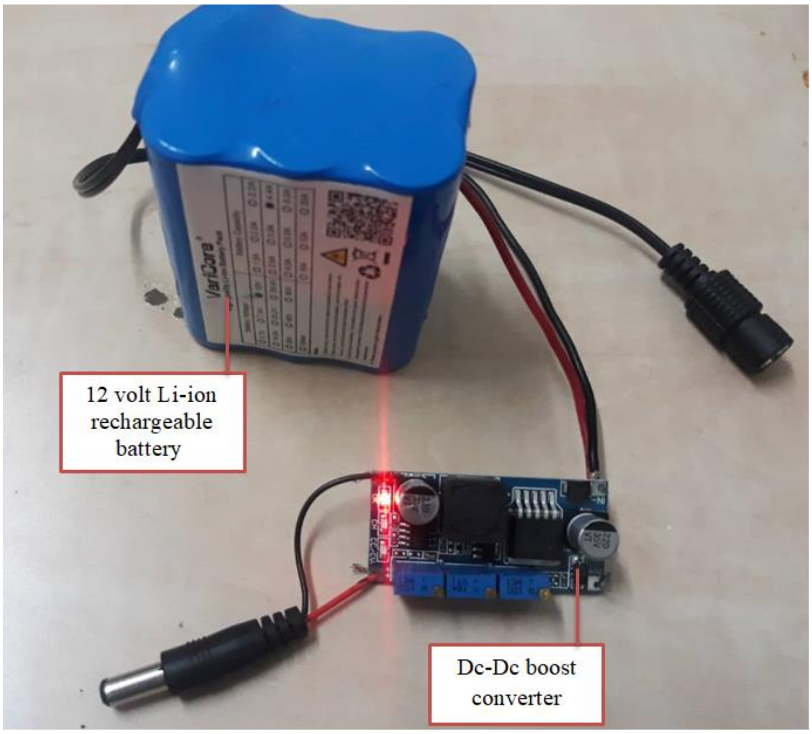


Figure 5.17 Connection of Dc-Dc boost convertor

Figure 5.18 Charger of the 12V battery

Figure 5.19 Charger of the 9V battery

Chapter Six

Result Analysis and Conclusion

6.1 Results

6.1.1 Calibration and simulation results

6.2 Challenges

6.3 Conclusions

6.4 Recommendation and Future Work

This chapter of the project presents the amount and flow rate of the contrast injector device that is used to inject contrast and saline solution to patient in CT-scan department , in addition to safety system during injection operation.

6.1 Results

The results of all measurements by using Graduated Cylinders that tabled at Table 6.1, 6.2, 6.3, 6.4,6.5,and 6.6 is been in several ranges of the contrast and normal saline solution .

6.1.1 Calibration and simulation results

The measurements of amount are taken by the device that construct in this project for two solution; a Contrast media and Normal Saline solution

The Table 6.1 represents a measurement amount of contrast media that is taken by the project system at fixed value from application . Then, the readings are drawn by the curve Figure 6.1

Table 6.1: Contrast syringe amount test

CONTRAST SYRINGE AMOUNT TEST	Samples Number	Actual amount (cc)	Measurement amount(cc)	Mean value (cc)	Error Percentage(%)
	1	10 cc	9.5cc	9.75cc	2.5%
	2	10 cc	9cc		
	3	10 cc	10cc		
	4	10 cc	10.5cc		

The mean value is equal to the sum of readings divided by its number:

$$\text{Mean} = \frac{\Sigma\, measurement}{no.of\ measurement} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (6.1)$$

Mean =9.75 cc

By comparing between the Measurement value and Actual value , the error for the contrast media injector is **:**

$$\text{Error} = \frac{difference\ between\ measurement\ and\ actual\ value}{actual\ value} * 100\ \% \ldots\ldots (6.2)$$

Error = 2.5%

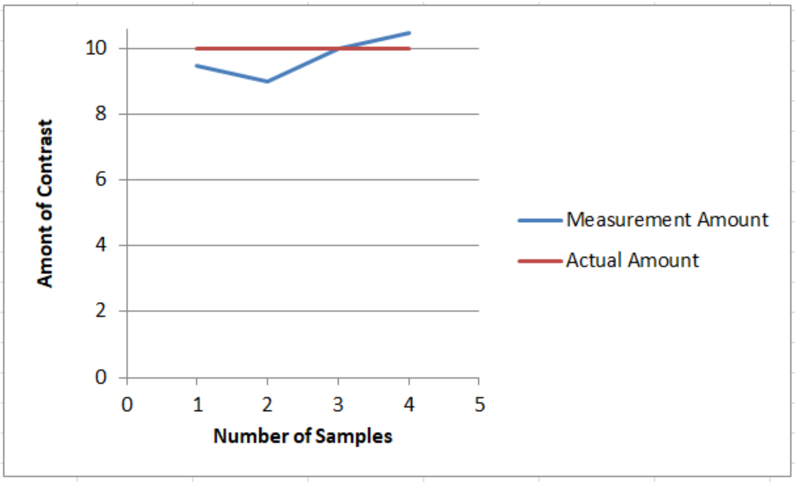


Figure 6.1 The Relations Between number of sample and Amount of Contrast

The Table 6.2 represents a measurement amount of normal saline solution that is taken by the project system at fixed value from application . Then, the readings are drawn by the curve Figure 6.2

Table 6.2: Normal Saline syringe amount test

SALINE SYRINGE AMOUNT TEST	Samples Number	Actual amount (cc)	Measurement amount(cc)	Mean amount (cc)	Error Percentage(%)
	1	10 cc	10cc	9.62cc	3.75%
	2	10 cc	9cc		
	3	10 cc	11cc		
	4	10 cc	8.5cc		

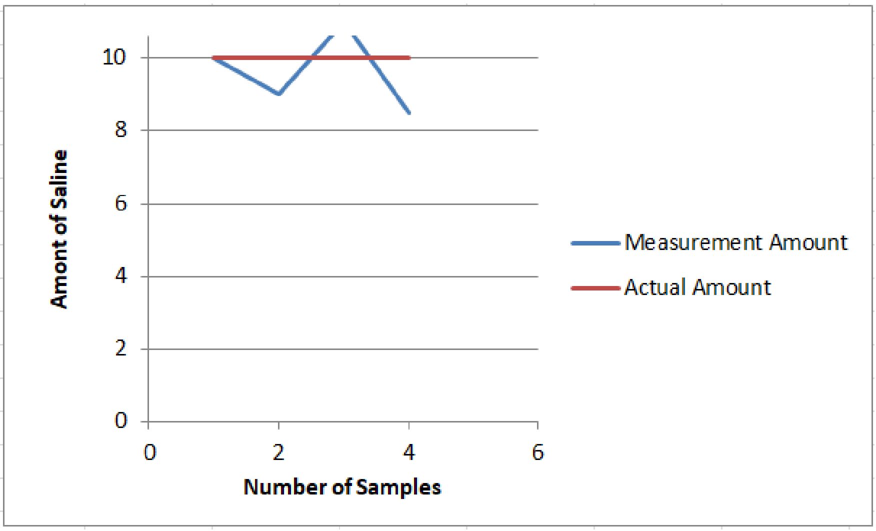


Figure 6.2 The Relations Between number of sample and Amount of Saline

The Table 6.3 represents a measurement value of contrast syringe injection time that is taken by the project system at fixed amount of contrast from application . Then, the readings are drawn by the curve Figure 6.3

Table 6.3: Contrast syringe injection time test

	Samples Number	Actual amount (cc)	Actual time (s)	Measurement time(s)	Mean time (s)	Error Percentage(%)
CONTRAST SYRINGE INJECTION TIME TEST	1	20 cc	2s	1.84s	2.028s	1.4%
	2	20 cc	2s	1.9s		
	3	20 cc	2s	2.1s		
	4	20 cc	2s	2.5s		
	5	20 cc	2s	1.8s		

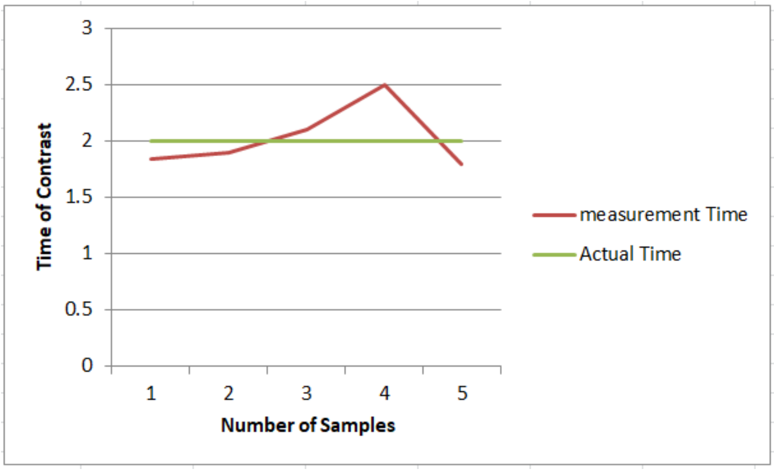


Figure 6.3 The Relations Between number of sample and Time of Contrast

The Table 6.4 represents a measurement value of normal saline injection time that is taken by the project system at fixed amount of normal saline from application . Then, the readings are drawn by the curve Figure 6.4

Table 6.4: Normal saline syringe injection time test

	Samples Number	Actual amount (cc)	Actual time (s)	Measurement t(s)	Mean value (s)	Error Percentage(%)
SALINE SYRINGE INJECTION TIME TEST	1	20 cc	2s	1.7s	2.068s	3%
	2	20 cc	2s	2.8s		
	3	20 cc	2s	2.1s		
	4	20 cc	2s	1.9s		
	5	20 cc	2s	1.8s		

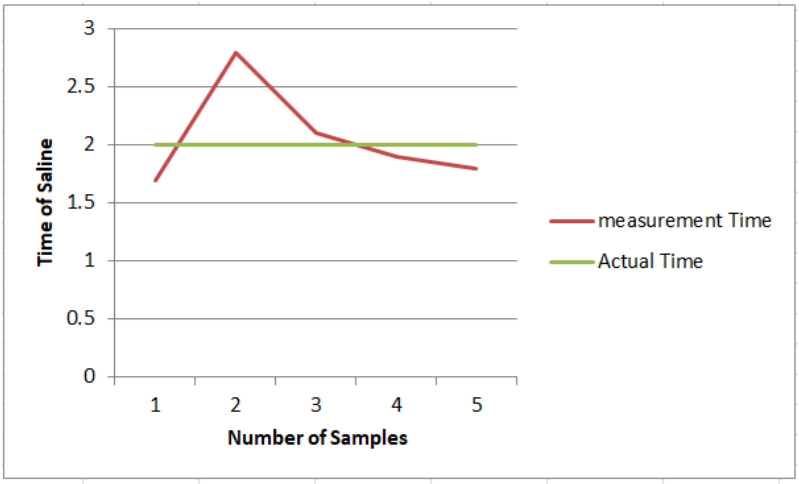


Figure 6.4 The Relations Between number of sample and Time of Saline

The Table 6.5 represents a measurement value of contrast flow rate that is taken by the project system at fixed amount of contrast equal 20cc and flow rate equal 10cc/s from application input with 2sec injection time . Then, the readings are drawn by the curve Figure 6.5

Table 6.5: Contrast syringe flow rate test

CONTRAST SYRINGE FLOW RATE TEST	Samples Number	Measurement amount (cc)	Measurement time (s)	Calculations flow rate (cc/s)	Mean flow rate (cc/s)	Error Percentage (%)
	1	20 cc	1.8s	11.1 cc/s	9.7 cc/s	2.88%
	2	19 cc	1.6s	11.87 cc/s		
	3	17 cc	2.3s	7.39 cc/s		
	4	23 cc	2.5s	9.2 cc/s		
	5	19 cc	2.1s	9.0 cc/s		

$$\text{Calculation flow rate} = \frac{measurement\ amount}{measurement\ time} \quad \text{..............................(6.3)}$$

$$\text{Calculation flow rate} = \frac{2}{1.8} = 11.1\ \text{cc/s}$$

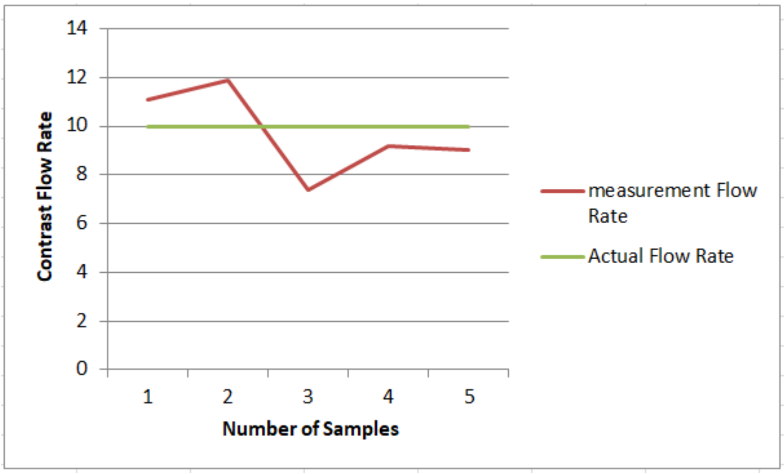


Figure 6.5 The Relations Between number of sample and Contrast flow rate

The Table 6.6 represents a measurement value of normal saline flow rate that is taken by the project system at fixed amount of normal saline equal 20cc and flow rate equal 10cc/s from application input with 2sec injection time. Then, the readings are drawn by the curve Figure 6.6

Table 6.6: Normal Saline syringe flow rate test

Saline SYRINGE FLOW RATE TEST	Samples Number	Measurement amount (cc)	Measurement time (s)	Calculations flow rate (cc/s)	Mean flow rate (cc/s)	Error Percentage (%)
	1	19cc	1.95s	9.7 cc/s	10.06 cc/s	0.6%
	2	20cc	1.8s	11.1 cc/s		
	3	18.5cc	2.1s	8.8 cc/s		
	4	22cc	2.05s	10.7 cc/s		
	5	21.5	2.1s	10 cc/s		

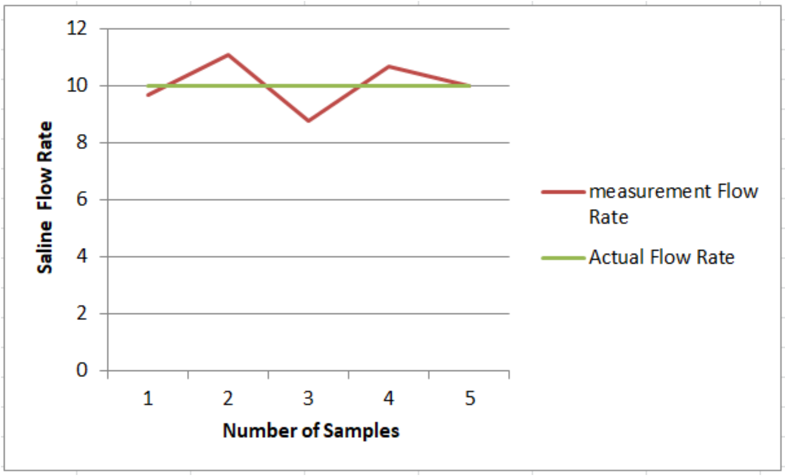


Figure 6.6 The Relations Between number of sample and Saline flow rate

The Table 6.7 represents a measurement value of FSR analog reading for detection and alarm LED, that is taken by the cuff system many person arms to make calibration for force sensor, the readings are drawn by the curve Figure 6.7 & 6.8

Table 6.7: Cuff test

	Samples Number	Analog Detection value	Analog alarm value
CUFF TEST	1	449	930
	2	580	902
	3	521	950
	4	497	911
	5	516	952

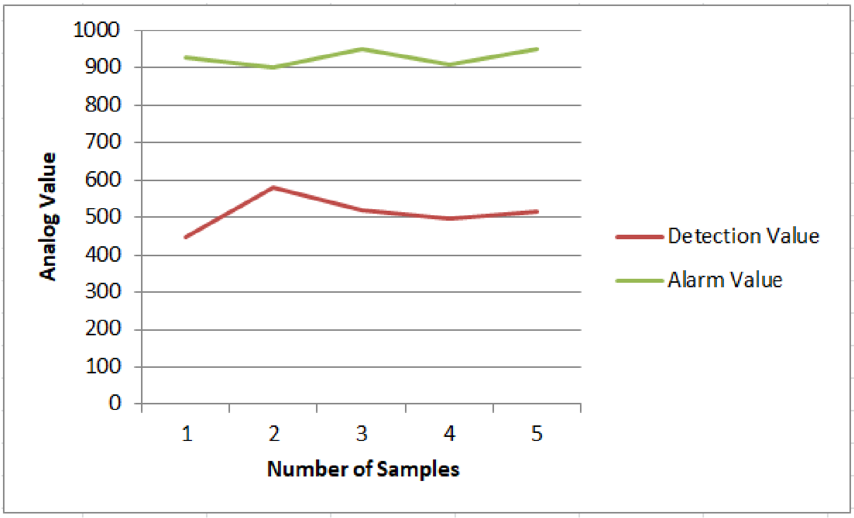


Figure 6.7 Relationship of analog reading for detection and alarm value

Figure 6.8 FSR analog reading for detection and alarm LED

6.2 Challenges

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

- Some of required components for the project are not available in the local market.
- Some of the project components are expensive.
- Project budget support was not appropriate as it should be.
- Mechanism of mechanical system much more hard to design as needed function .
- Programming the android application considered as Outside of the our specialty .
- The size of 3D printer cannot available in our country to print project case as complete piece.

6.3 Conclusions

After complete our project, we conclude that:

- Contrast injector device capable to injected precession amount and flow rate of contrast media or normal saline solution in specific time .
- The technical of moving syringe by using stepper motor, it has more special than other techniques to suitable perform function requirement.
- Safety of patient it more important part of system, that protect him from operator mismatch, by using alarm module to make operator attention .
- Control unit system depend on android application remote control that distinguish of user friendly interface , in addition to provide many parameter about information of injection operation condition and safety of patient .
- Bluetooth technical it characterized easily to connection between more than system with long distance and many of insulation walls , also immune of electrical interference .
- Portable system with rechargeable battery it allow the device move into any department of hospital without need of external power supply unit , so low voltage indicator using to rechargeable battery .

6.4 Recommendation and Future Work.

- Integrated application remote control of CT-scan imaging protocol with programmable injection of contrast media and normal saline depend to type of imaging.
- Measured of internal pressure of vein to make attention suitable condition to make injection by using pressure sensor , in addition to adjustable of pressure requirement for patients.
- Safety techniques by using of Automatic Air bubbles detector system for detect bubbles in tubes with alarm display to protect patients .
- Development of contrast injector device to appropriate MRI system, such that injection methods and parameter requirements .
- Using syringe less techniques to make injection by using roller pump without using disposable syringe .

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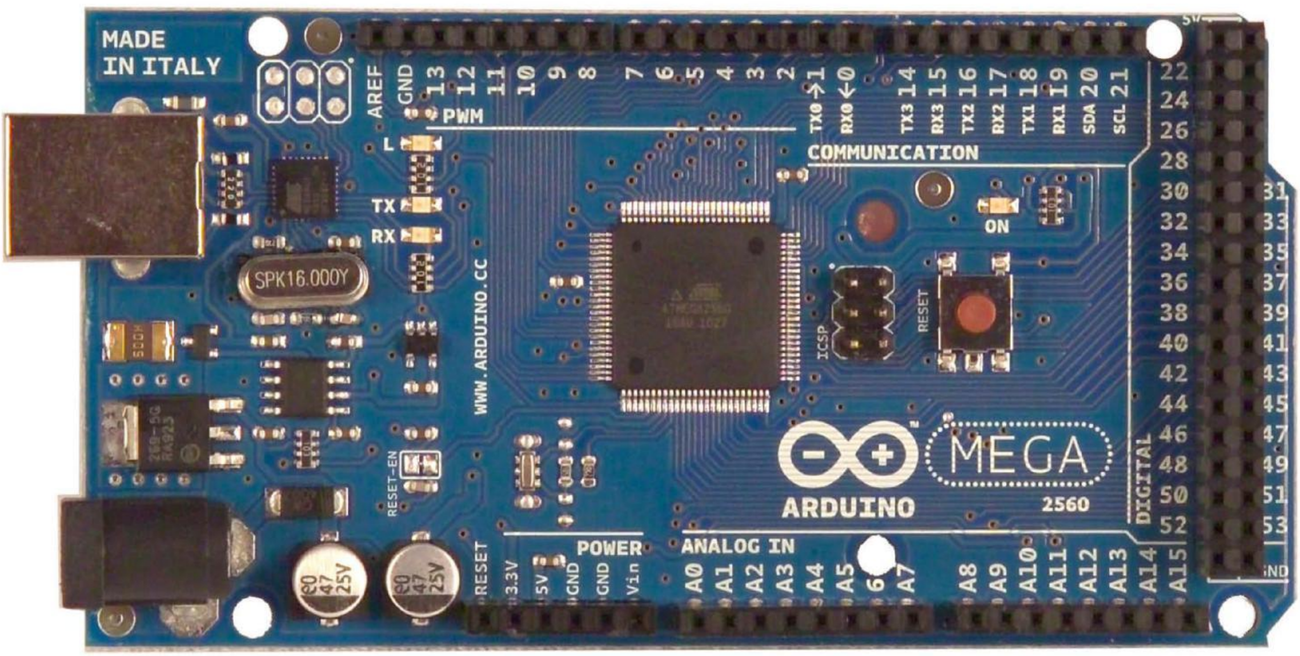
APPENDIX

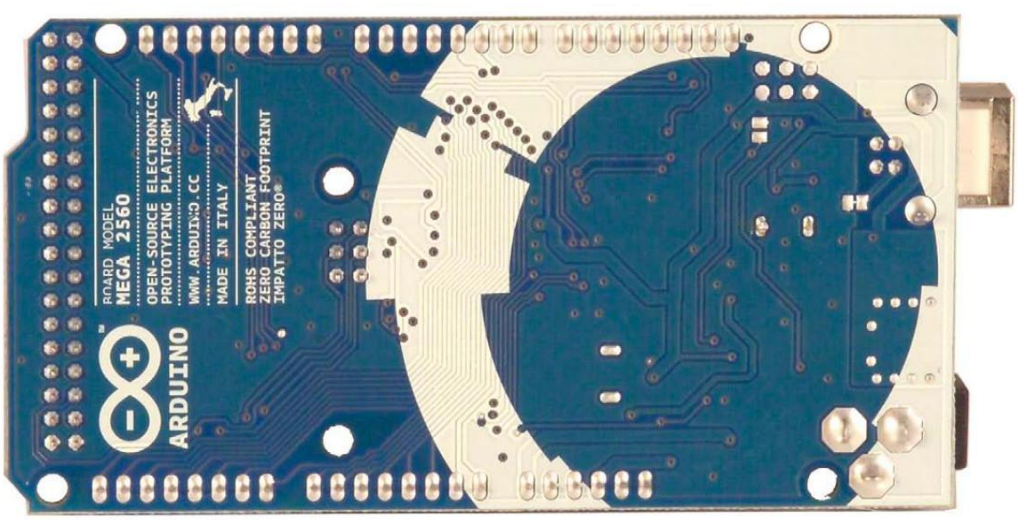
Datasheets

APPENDIX A

Mega Microcontroller

Arduino Mega 2560





Overview

The Arduino Mega 2560 is a microcontroller board based on the ATmega2560 (datasheet). It has 54 digital input/output pins (of which 14 can be used as PWM outputs), 16 analog inputs, 4 UARTs (hardware serial ports), a 16 MHz crystal oscillator, a USB connection, a power jack, an ICSP header, and a reset button. It contains everything needed to support the microcontroller; simply connect it to a computer with a USB cable or power it with a AC-to-DC adapter or battery to get started. The Mega is compatible with most shields designed for the Arduino Duemilanove or Diecimila.

Schematic & Reference Design

EAGLE files: arduino-mega2560-reference-design.zip

Schematic: arduino-mega2560-schematic.pdf

Summary

Microcontroller	ATmega2560
Operating Voltage	5V
Input Voltage (recommended)	7-12V
Input Voltage (limits)	6-20V
Digital I/O Pins	54 (of which 14 provide PWM output)
Analog Input Pins	16
DC Current per I/O Pin	40 mA
DC Current for 3.3V Pin	50 mA
Flash Memory	256 KB of which 8 KB used by bootloader
SRAM	8 KB
EEPROM	4 KB
Clock Speed	16 MHz

Power

The Arduino Mega can be powered via the USB connection or with an external power supply. The power source is selected automatically.

External (non-USB) power can come either from an AC-to-DC adapter (wall-wart) or battery. The adapter can be connected by plugging a 2.1mm center-positive plug into the board's power jack. Leads from a battery can be inserted in the Gnd and Vin pin headers of the POWER connector.

The board can operate on an external supply of 6 to 20 volts. If supplied with less than 7V, however, the 5V pin may supply less than five volts and the board may be unstable. If using more than 12V, the voltage regulator may overheat and damage the board. The recommended range is 7 to 12 volts.

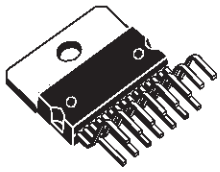
The Mega2560 differs from all preceding boards in that it does not use the FTDI USB-to-serial driver chip. Instead, it features the Atmega8U2 programmed as a USB-to-serial converter.

APPENDIX B

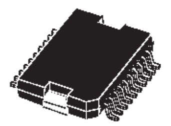
L298N Motor Driver

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



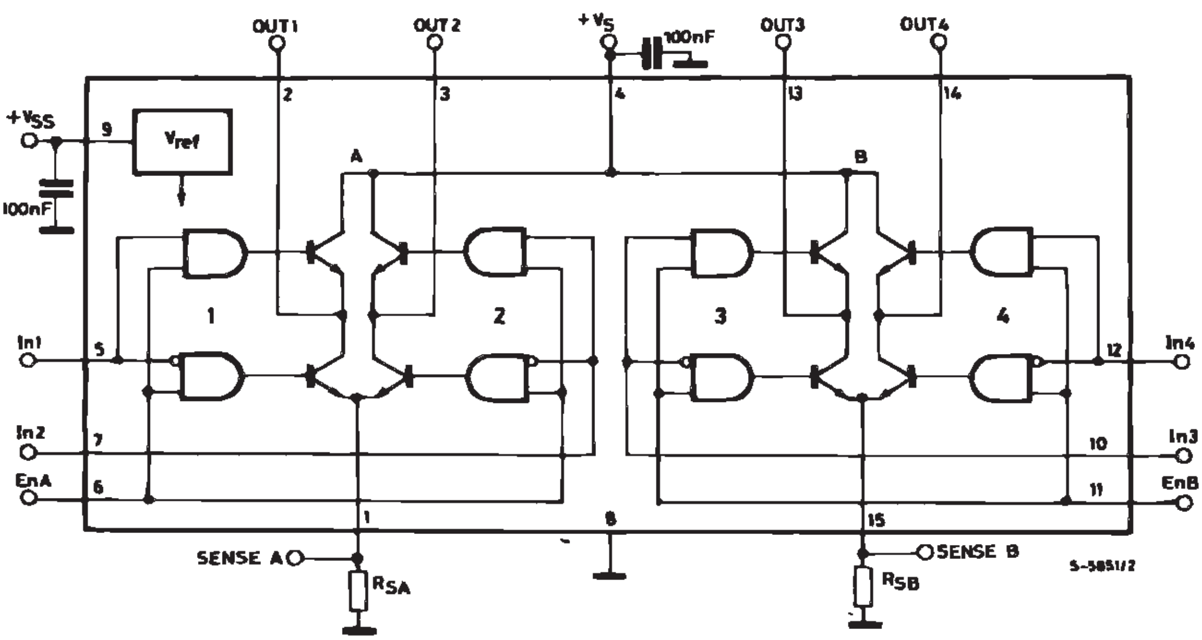
PowerSO20

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.

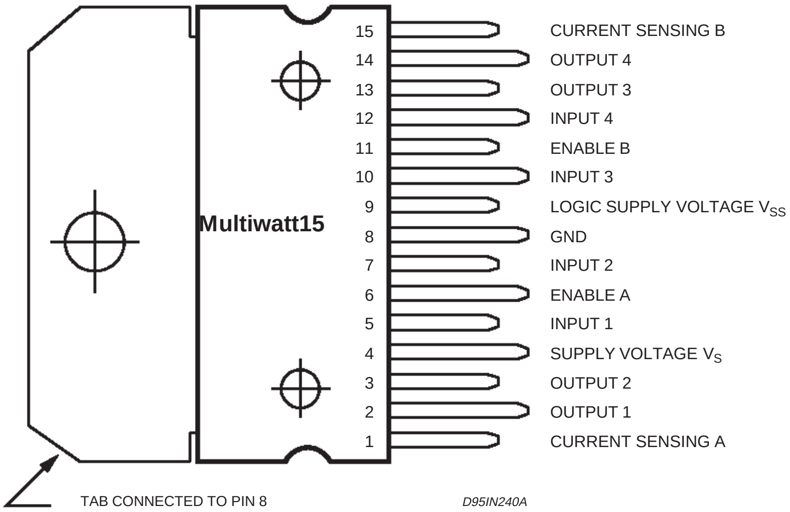
BLOCK DIAGRAM

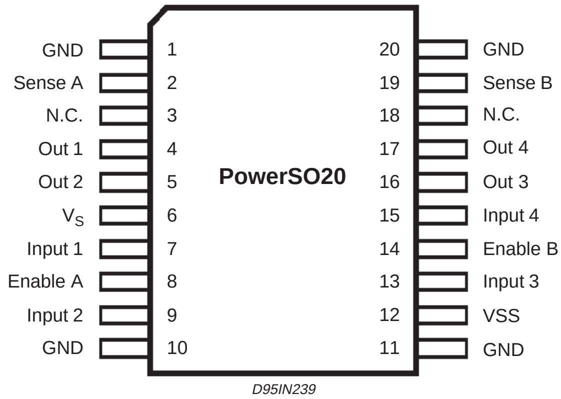


ABSOLUTE MAXIMUM RATINGS

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

PIN FUNCTIONS (refer to the block diagram)

MW.15	PowerSO	Name	Function
1;15	2;19	Sense A; Sense B	Between this pin and ground is connected the sense resistor to control the current of the load.
2;3	4;5	Out 1; Out 2	Outputs of the Bridge A; the current that flows through the load connected between these two pins is monitored at pin 1.
4	6	V_S	Supply Voltage for the Power Output Stages. A non-inductive 100nF capacitor must be connected between this pin and ground.
5;7	7;9	Input 1; Input 2	TTL Compatible Inputs of the Bridge A.
6;11	8;14	Enable A; Enable B	TTL Compatible Enable Input: the L state disables the bridge A (enable A) and/or the bridge B (enable B).
8	1,10,11,20	GND	Ground.
9	12	VSS	Supply Voltage for the Logic Blocks. A100nF capacitor must be connected between this pin and ground.
10; 12	13;15	Input 3; Input 4	TTL Compatible Inputs of the Bridge B.
13; 14	16;17	Out 3; Out 4	Outputs of the Bridge B. The current that flows through the load connected between these two pins is monitored at pin 15.
–	3;18	N.C.	Not Connected

ELECTRICAL CHARACTERISTICS (V_S = 42V; V_{SS} = 5V, T_j = 25°C; unless otherwise specified)

Symbol	Parameter	Test Conditions	Min.	Typ.	Max.	Unit
V_S	Supply Voltage (pin 4)	Operative Condition	V_{IH} +2.5		46	V
V_{SS}	Logic Supply Voltage (pin 9)		4.5	5	7	V
I_S	Quiescent Supply Current (pin 4)	V_{en} = H; I_L = 0 V_i = L V_i = H		13 50	22 70	mA mA
		V_{en} = L V_i = X			4	mA
I_{SS}	Quiescent Current from V_{SS} (pin 9)	V_{en} = H; I_L = 0 V_i = L V_i = H		24 7	36 12	mA mA
		V_{en} = L V_i = X			6	mA
V_{iL}	Input Low Voltage (pins 5, 7, 10, 12)		–0.3		1.5	V
V_{iH}	Input High Voltage (pins 5, 7, 10, 12)		2.3		VSS	V
I_{iL}	Low Voltage Input Current (pins 5, 7, 10, 12)	V_i = L			–10	μA
I_{iH}	High Voltage Input Current (pins 5, 7, 10, 12)	Vi = H ≤ V_{SS} –0.6V		30	100	μA
V_{en} = L	Enable Low Voltage (pins 6, 11)		–0.3		1.5	V
V_{en} = H	Enable High Voltage (pins 6, 11)		2.3		V_{SS}	V
I_{en} = L	Low Voltage Enable Current (pins 6, 11)	V_{en} = L			–10	μA
I_{en} = H	High Voltage Enable Current (pins 6, 11)	V_{en} = H ≤ V_{SS} –0.6V		30	100	μA
$V_{CEsat(H)}$	Source Saturation Voltage	I_L = 1A I_L = 2A	0.95	1.35 2	1.7 2.7	V V
$V_{CEsat(L)}$	Sink Saturation Voltage	I_L = 1A (5) I_L = 2A (5)	0.85	1.2 1.7	1.6 2.3	V V
V_{CEsat}	Total Drop	I_L = 1A (5) I_L = 2A (5)	1.80		3.2 4.9	V V
V_{sens}	Sensing Voltage (pins 1, 15)		–1 (1)		2	V

APPENDIX C

Datasheet of Force Sensor

FSR 406 Data Sheet

FSR 400 Series Square Force Sensing Resistor

Features and Benefits

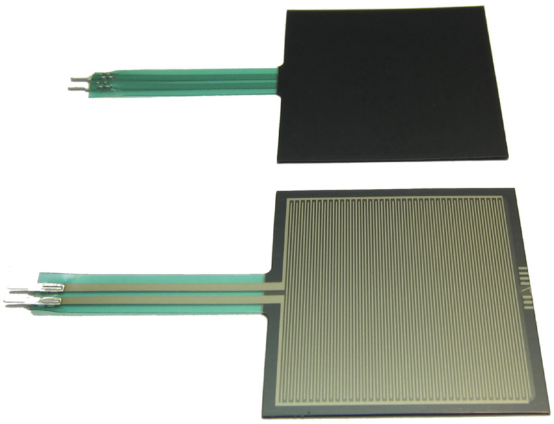
- Actuation Force as low as 0.1N and sensitivity range to 10N.
- Easily customizable to a wide range of sizes
- Highly Repeatable Force Reading; As low as 2% of initial reading with repeatable actuation system
- Cost effective
- Ultra thin; 0.45mm
- Robust; up to 10M actuations
- Simple and easy to integrate

Industry Segments

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

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 406 sensor is a square sensor 43.69mm in size. Custom sensors can be manufactured in sizes ranging from 5mm to over 600mm.

Figure 1 - Typical Force Curve

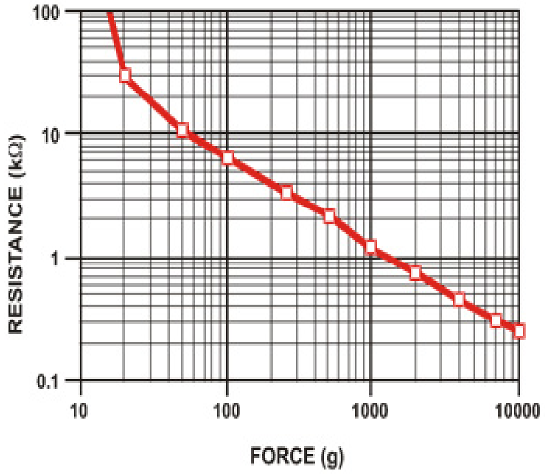
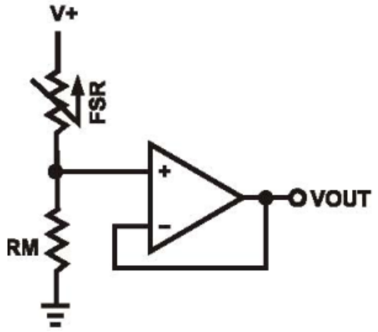


Figure 2 - Typical Schematic



Interlink Electronics - Sensor Technologies

INTERLINK ELECTRONICS
Sensor Technologies

FSR 406
P/N: 30-73258

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

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

Detect tube positioning

Many other force measurement applications

Device Characteristics

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		43.69 x 43.69mm	
Thickness Range		0.2 - 1.25 mm	
Stand-Off Resistance		>10M 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 °C	
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.

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:

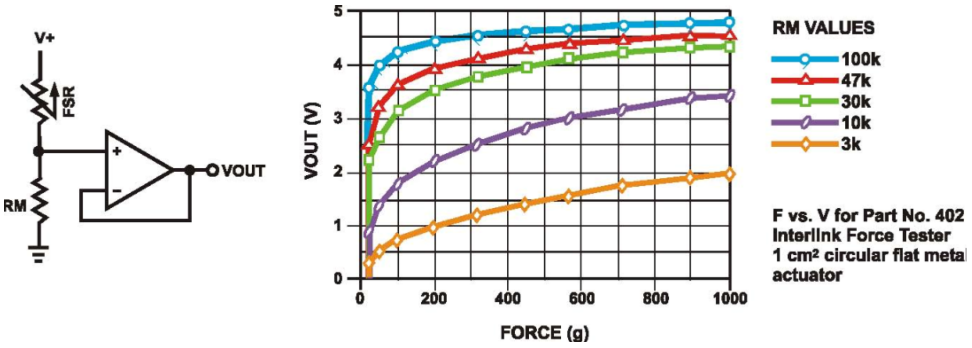
$$V_{OUT} = \frac{R_M V+}{(R_M + R_{FSR})}$$

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



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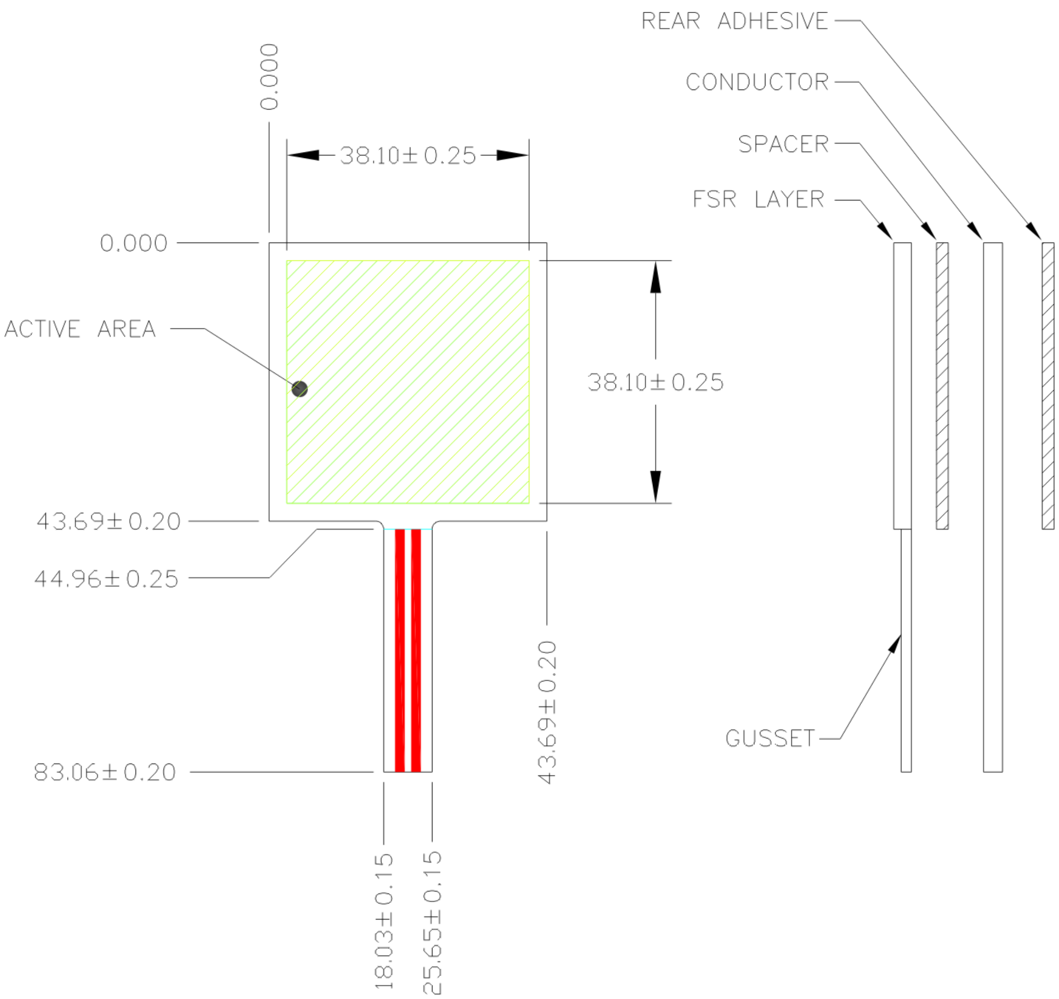
INTERLINK ELECTRONICS
Sensor Technologies

FSR 406
P/N: 30-73258

Part No. 406

- Active Area: 38.1mm x 38.1mm
- Nominal thickness: 0.54 mm

Mechanical Data



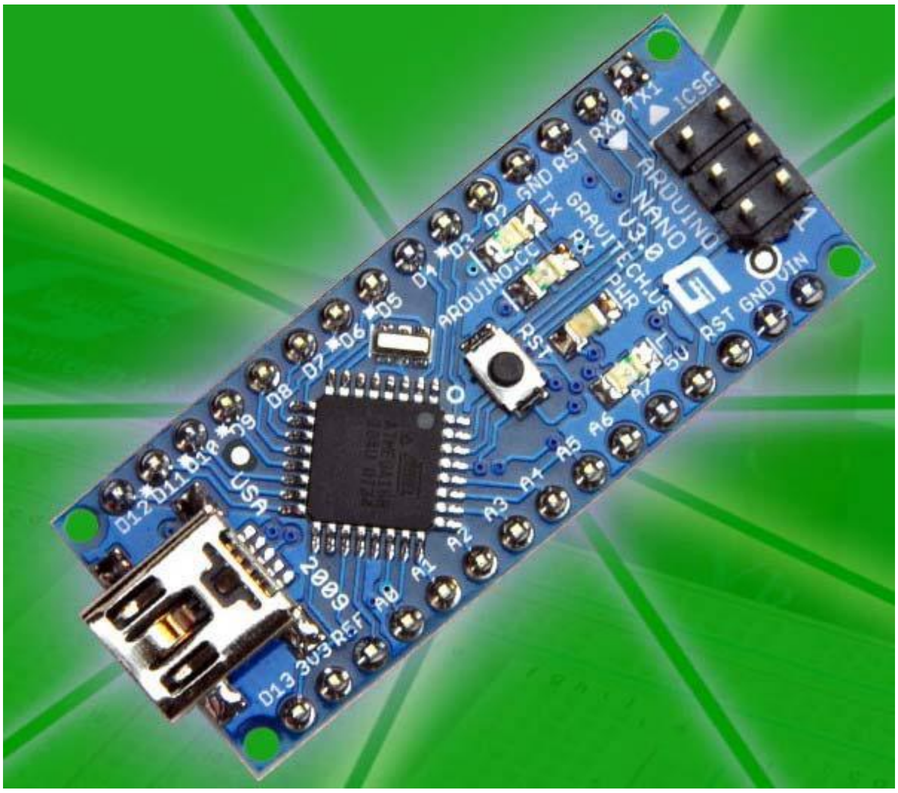
Interlink Electronics - Sensor Technologies

APPENDIX D

Nano Microcontroller

Arduino Nano (V3.0)

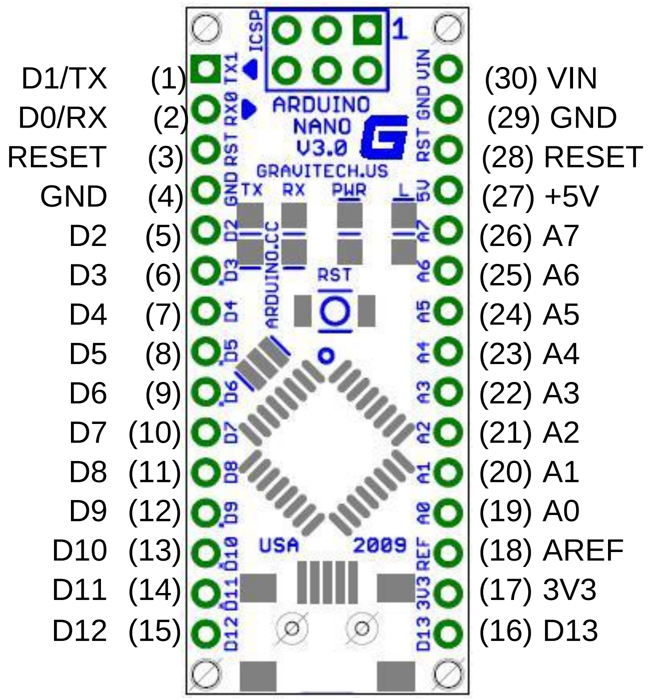
User Manual



More information:

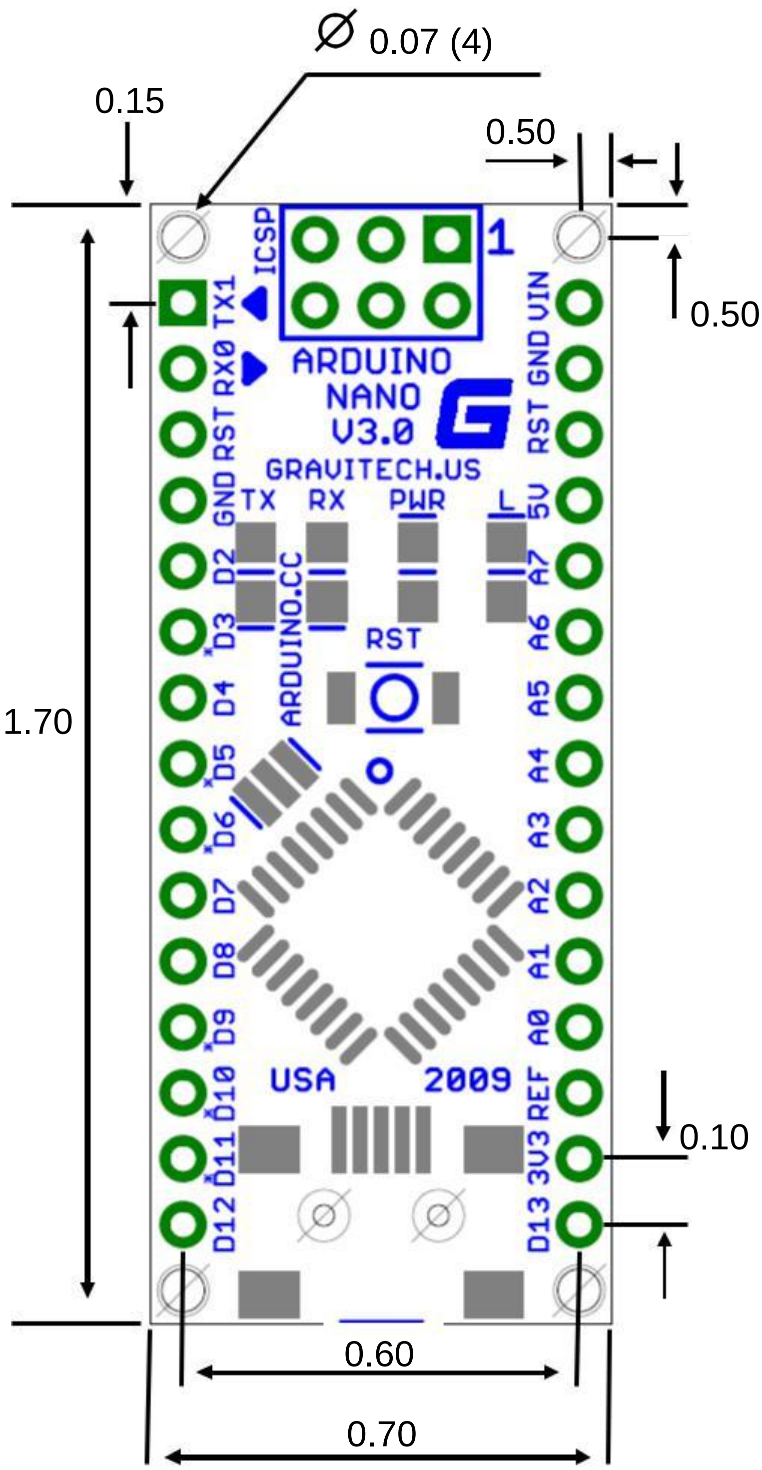
www.arduino.cc Rev 3.0

Arduino Nano Pin Layout



Pin No.	Name	Type	Description
1-2,5-16	D0-D13	I/O	Digital input/output port 0 to 13
3,28	RESET	Input	Reset (active low)
4,29	GND	PWR	Supply ground
17	3V3	Output	+3.3V output (from FTDI)
18	AREF	Input	ADC reference
19-26	A0-A7	Input	Analog input channel 0 to 7
27	+5V	Output or Input	+5V output (from on-board regulator) or +5V (input from external power supply)
30	VIN	PWR	Supply voltage

Arduino Nano Mechanical Drawing



APPENDIX E

9v Lithium-Manganese Dioxide Battery

Li-ion Battery Technology Specification

Part name Li-ion Battery

Model No Li-ion 9V 500mAh

1.Scope

This specification is applied to the reference battery in this Specification

2.Product Specification

No.	Item	Characteristics	Remarks
1	Nominal Capacity	Minimum: 450mAh Typical: 500mAh	Standard discharge（0.2C) after Standard charge
2	Nominal Voltage	7.4V	—
3	Charging Cut-off Voltage	8.4V	—
4	Discharge Cut-off Voltage	5.4V	—
5	Standard Charge	Constant Current 0.5C Constant Voltage 8.4V 0.01 C cut-off	Charge Time : Approx 4.0h
6	Maximum Constant charging Current	500mA	—
7	Standard Discharge	Discharge at 0.2 C to 5.4V	—
8	Maximum Continuous Discharging Current	750mA	—
9	Operating Temperature	Charge 0～45□ Discharge –20～60□	—
10	Storage Temperature	-20～45□ for 1Month -10～35□ for 6Months	—
11	Storage Voltage	7.4-7.7V	—
12	Environmental request	RoHS	If the materials of the product and packaging accord with RoHS standard，there will be a RoHS Id on the box.

3. Appearance

No scratches, dirt, defect, leakage of electrolyte or gassing should be observed as a new product.

4. Standard Testing Environment

Temperature: 25±2□

Relative humidity: 65±20%（unless specially requested）

5. Characteristics

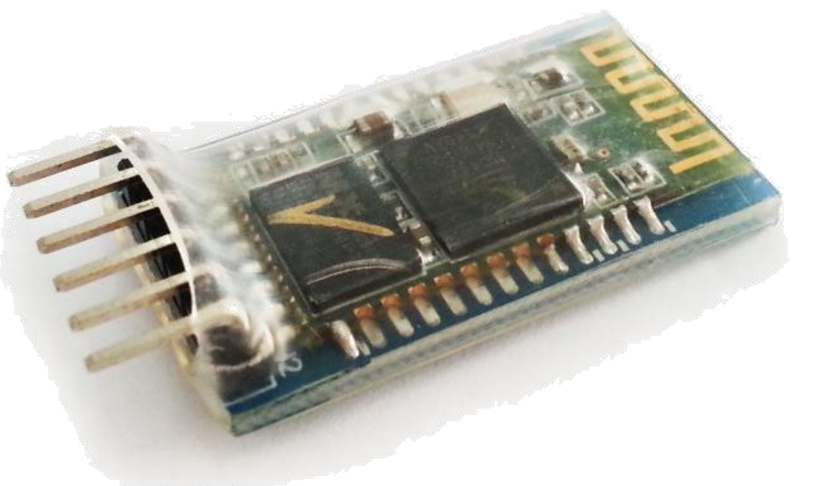
5.1 Electrochemical performance characteristics

No.	Item	Testing Method	Requirements
1	Fully Charged State	CCCV or Constant current charge to 8.4V @0.5C follow by a constant voltage holding at 8.4V until current drops below 5±1mA.	—
2	Rated Capacity	0.5c CCCV 0.01c at 8.4V (per 6.1.1) at room temp. (20±5C), rest for 1-2 hrs then discharge at a constant current of 0.2C to 5.4V, testing will be terminated by either 5 cycles or any one discharge time exceeds 5 hrs	≥450mAh
3	Cycle Life @25□	Discharge to 5.4V @0.2C, then 0.5c CCCV 0.01C charge to 8.4V, rest for 10 min. discharge @ 0.2C to 5.4V and rest for 10 min. Continue the charge/discharge cycles until discharge capacity lower than 70% of rated capacity.	Cycle life ≥500
4	Internal Impedance	Internal impedance is measured on a 50% charged battery at 1KHz AC at ambient temperature（20±2）□	—
5	Capacity Retention	Fully charge cells per 6.1.1, store them at (20±2)□ for 28 days, then discharge the cells to 5.4V at 0.2C.	Discharge Capacity≥400mAh
6	High Temperature Characteristics	Fully charge cells per 6.1.1, store them at (55±2)□ for 2 hours, then discharge the cells to 5.4V at 0.2C.	Discharge Capacity≥400mAh
7	Low Temperature Characteristics	Fully charge cells per 6.1.1, store them at (-10±2)□ for 16~24 hours, then discharge the cells to 5.4V at 0.2C.	Discharge Capacity≥300mAh
8	Cell Voltage during Transportation	Check open circuit voltage (OCV) of cells prior to the delivery to customers	≥7.5V

APPENDIX F

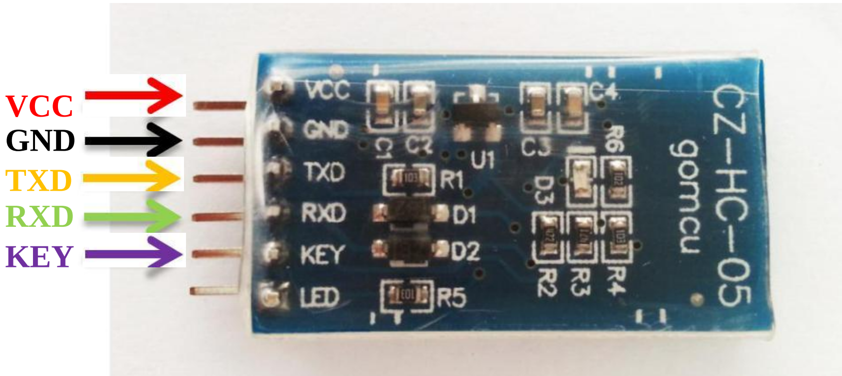
HC-05 Bluetooth Module

HC-05 Bluetooth Module



User's Manual V1.0

Pin Definition



Pin	Description	Function
VCC	+5V	Connect to +5V
GND	Ground	Connect to Ground
TXD	UART_TXD, Bluetooth serial signal sending PIN	Connect with the MCU's (Microcontroller and etc) RXD PIN.
RXD	UART_RXD, Bluetooth serial signal receiving PIN	Connect with the MCU's (Microcontroller and etc) TXD PIN.
KEY	Mode switch input	If it is input low level or connect to the air, the module is at paired or communication mode. If it's input high level, the module will enter to AT mode.

APPENDIX G

Datasheet of HC-06 Bluetooth Module

1. Product's picture

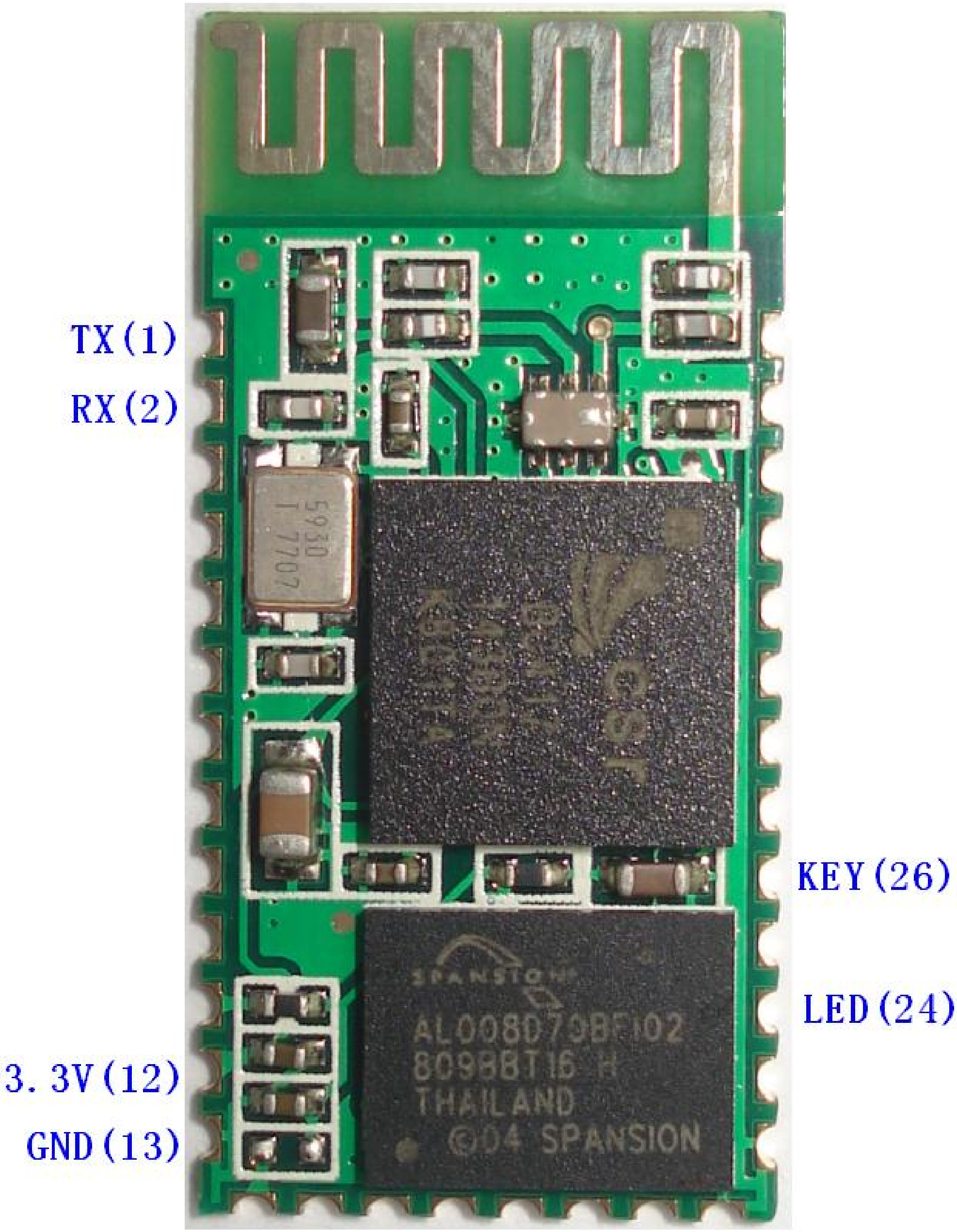


Figure 1 A Bluetooth module

www.wavesen.com Phone: 020-84083341 Fax: 020-84332079 QQ:1043073574
Address: Room 527, No.13, Jiangong Road, Tianhe software park, Tianhe district, Guangzhou Post: 510660
Technology consultant: support@wavesen.com Business consultant:sales@wavesen.com
Complaint and suggestion: sunbirdit@hotmail.com

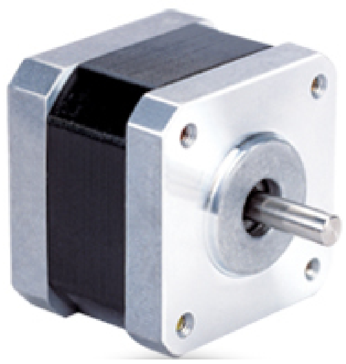
PIO0	23	Bi-Directional RX EN	Programmable input/output line, control output for LNA(if fitted)	
PIO1	24	Bi-Directional TX EN	Programmable input/output line, control output for PA(if fitted)	
PIO2	25	Bi-Directional	Programmable input/output line	
PIO3	26	Bi-Directional	Programmable input/output line	
PIO4	27	Bi-Directional	Programmable input/output line	
PIO5	28	Bi-Directional	Programmable input/output line	
PIO6	29	Bi-Directional	Programmable input/output line	CLK_REQ
PIO7	30	Bi-Directional	Programmable input/output line	CLK_OUT
PIO8	31	Bi-Directional	Programmable input/output line	
PIO9	32	Bi-Directional	Programmable input/output line	
PIO10	33	Bi-Directional	Programmable input/output line	
PIO11	34	Bi-Directional	Programmable input/output line	
RESETB	11	CMOS Input with weak intemal pull-down		
UART_RTS	4	CMOS output, tri-stable with weak internal pull-up	UART request to send, active low	
UART_CTS	3	CMOS input with weak internal pull-down	UART clear to send, active low	
UART_RX	2	CMOS input with weak internal pull-down	UART Data input	
UART_TX	1	CMOS output, Tri-stable with weak internal pull-up	UART Data output	
SPI_MOSI	17	CMOS input with weak internal pull-down	Serial peripheral interface data input	
SPI_CSB	16	CMOS input with weak internal	Chip select for serial peripheral interface, active low	

		pull-up		
SPI_CLK	19	CMOS input with weak internal pull-down	Serial peripheral interface clock	
SPI_MISO	18	CMOS input with weak internal pull-down	Serial peripheral interface data Output	
USB_-	15	Bi-Directional		
USB_+	20	Bi-Directional		
1.8V	14		1.8V external power supply input	Default : 1.8V internal powe r supply.
PCM_CLK	5	Bi-Directional		
PCM_OUT	6	CMOS output		
PCM_IN	7	CMOS Input		
PCM_SYNC	8	Bi-Directional		

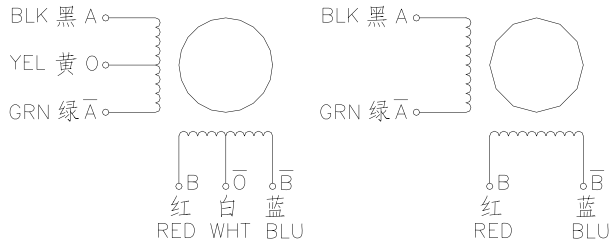
APPENDIX H

Stepper Motor

2 Phase Hybrid Stepper Motor
17HS series-Size 42mm(1.8 degree)



Wiring Diagram:



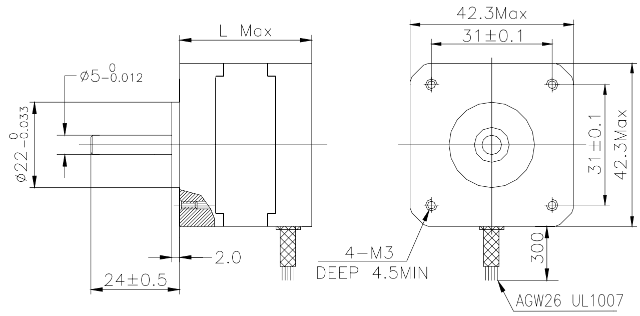
UNI-POLAR(6 LEADS) BI-POLAR(4LEADS)

Electrical Specifications:

Series Model	Step Angle (deg)	Motor Length (mm)	Rated Current (A)	Phase Resistance (ohm)	Phase Inductance (mH)	Holding Torque (N.cm Min)	Detent Torque (N.cm Max)	Rotor Inertia (g.cm²)	Lead Wire (No.)	Motor Weight (g)
17HS2408	1.8	28	0.6	8	10	12	1.6	34	4	150
17HS3401	1.8	34	1.3	2.4	2.8	28	1.6	34	4	220
17HS3410	1.8	34	1.7	1.2	1.8	28	1.6	34	4	220
17HS3430	1.8	34	0.4	30	35	28	1.6	34	4	220
17HS3630	1.8	34	0.4	30	18	21	1.6	34	6	220
17HS3616	1.8	34	0.16	75	40	14	1.6	34	6	220
17HS4401	1.8	40	1.7	1.5	2.8	40	2.2	54	4	280
17HS4402	1.8	40	1.3	2.5	5.0	40	2.2	54	4	280
17HS4602	1.8	40	1.2	3.2	2.8	28	2.2	54	6	280
17HS4630	1.8	40	0.4	30	28	28	2.2	54	6	280
17HS8401	1.8	48	1.7	1.8	3.2	52	2.6	68	4	350
17HS8402	1.8	48	1.3	3.2	5.5	52	2.6	68	4	350
17HS8403	1.8	48	2.3	1.2	1.6	46	2.6	68	4	350
17HS8630	1.8	48	0.4	30	38	34	2.6	68	6	350

***Note:** We can manufacture products according to customer's requirements.

Dimensions: unit=mm



Motor Length:

Model	Length
17HS2XXX	28 mm
17HS3XXX	34 mm
16HS4XXX	40 mm
16HS8XXX	48 mm

APPENDIX I

Bluetooth Electronics Application

Bluetooth Electronics

from KEUWLSOFT

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Bluetooth Electronics

Control your electronic project with an Android device. This app communicates using Bluetooth to an HC-06 or HC-05 Bluetooth module in your project. Since version 1.2 of the app, it will now also communicate to bluetooth low energy modules such as the HC-08 and via USB-serial connection.

This app comes with a library containing 11 Bluetooth examples for Arduino. See the **electronics** page for examples.

It can also be used with Raspberry Pi or any other rapid prototyping system in which you have included a suitable Bluetooth module to your project.

- Ideal for learning electronics in a fun way.
- Ideal for rapid prototyping a new idea.
- Ideal for exhibiting your project.

Some electronics skills required. Requires an Android device with Bluetooth capability enabled.

Large selection of controls available including buttons, switches, sliders, pads, lights, gauges, terminals, accelerometers and graphs, Drag and drop them onto the panel grid. Then edit their properties.

20 customisable panels available.

Import/Export panels to share them.

Discover, Pair and connect to Bluetooth devices. Then click Run to use the panel.

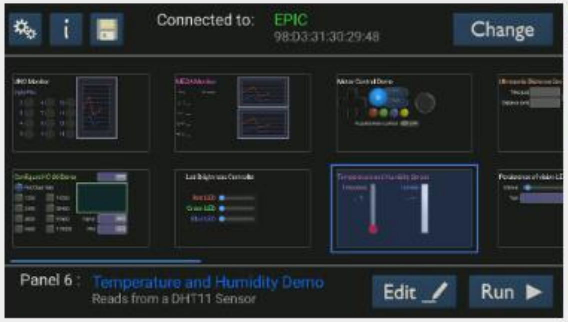
Library of 11 Arduino Examples to get you started:

- **LED Brightness** - PWM with a Slider control
- **RC Car demo** – Basic Button controls
- **Persistence of Vision** – Text control
- **Repeater Demo** – Send and Receive Terminals
- **Ultrasonic Distance Sensor** - Light Indicator
- **MEGA Monitor** – Graphs
- **UNO Monitor** – More graphs
- **Temperature and Humidity** – Temperature Gauge
- **Configure HC-06 Demo** – In-case you want to change Baud rate
- **Motor Control Demo** – Accelerometer and pad controls
- **LED Ring Demo** – Switch & Slider controls

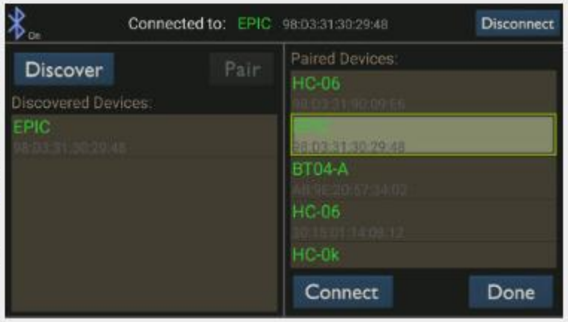
User Guide

The user guide is found in the app by clicking on the 'i' button on the main screen. Alternatively, user guide for version 1.3 of the app is **here**.

Some Screenshots:



Main Screen



Connect to Bluetooth Screen

Edit Screen

Example Run Screen

APPENDIX J

LIPO Battery Voltage Tester and Low Voltage Buzzer Alarm

DYNF0002

• LiPo Voltage Checker
• LiPo-Spannungsprüfer
• Contrôleur de tension Li-Po
• Strumento controllo voltaggio LiPo

Instruction Manual
Bedienungsanleitung
Manuel d'utilisation
Manuale di istruzioni

EN

NOTICE

All instructions, warranties and other collateral documents are subject to change at the sole discretion of Horizon Hobby, LLC. For up-to-date product literature, visit horizonhobby.com and click on the support tab for this product.

Meaning of Special Language

The following terms are used throughout the product literature to indicate various levels of potential harm when operating this product:

NOTICE: Procedures, which if not properly followed, create a possibility of physical property damage AND a little or no possibility of injury.

CAUTION: Procedures, which if not properly followed, create the probability of physical property damage AND a possibility of serious injury.

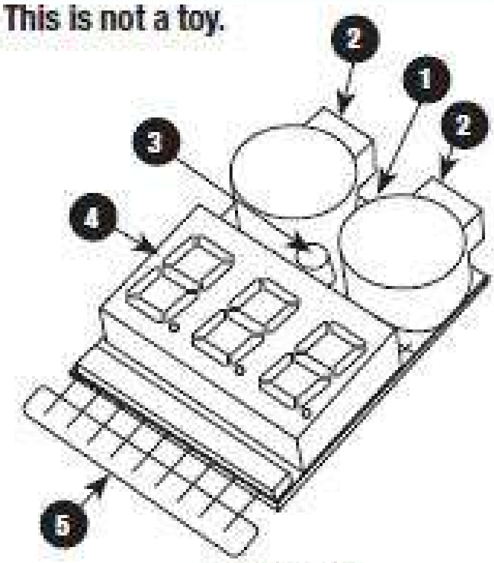
WARNING: Procedures, which if not properly followed, create the probability of property damage, collateral damage, and serious injury OR create a high probability of superficial injury.

WARNING: Read the ENTIRE instruction manual to become familiar with the features of the product before operating. Failure to operate the product correctly can result in damage to the product, personal property and cause serious injury.

This is a sophisticated hobby product. It must be operated with caution and common sense and requires some basic mechanical ability. Failure to operate this Product in a safe and responsible manner could result in injury or damage to the product or other property. This product is not intended for use by children without direct adult supervision. Do not attempt disassembly, use with incompatible components or augment product in any way without the approval of Horizon Hobby, LLC. This manual contains instructions for safety, operation and maintenance. It is essential to read and follow all the instructions and warnings in the manual, prior to assembly, setup or use, in order to operate correctly and avoid damage or serious injury.

Age Recommendation: Not for children under 14 years. This is not a toy.

	SPECIFICATIONS
Input	1S (JST) and 2–8S (JST-XH) LiPo, Li-ION/LiMN/Li-Fe
Voltage Detection Precision	±0.01V
Unit Voltage Display Range	0.5–4.5V
Total Voltage Display Range	0.5–36V
Test Mode Voltage Range	3.7–30V
Alarm Value Range	2.7–3.8V, including off
Dimensions	3.9cm x 2.4cm x 0.9cm



1- Set Button
2- Piezo Speaker
3- LED Indicator
4- LED Readout
5- Battery Connectors

The LiPo Voltage Checker provides a low voltage alarm for 2–8S cell counts. When the voltage is below the set value, an alarm will sound along with illuminating the red LED.

Mount the voltage checker using servo tape or hook and loop tape. The device can be used as a low voltage alarm in products in which the ESC does not have an LVC for LiPo batteries. It can also be used as a hand held voltage checker.

The default detection preset value is set to 3.3V. Change the detection voltage by pressing (then releasing) the set button while a battery is connected. The settings change immediately with each press and cycle in a loop in .1V increments starting at the default 3.3V setting. Settings for 2.8V, 2.9V, 3.0V, 3.1V, 3.2V, 3.3V, 3.4V, 3.5V, 3.6V, 3.7V, 3.8V, and OFF (alarm disabled) are available.

APPENDIX K

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12 volt 4400 mAh Li-ion Rechargeable

Rated voltage: 11.1V-12.6V
Nominal capacity: 4400mAh
Standard discharge current: 0.2C
Maximum discharge current: 1C
Products: ≤ 250m ohm internal resistance
The battery pack built-in battery protection board of PCB!
Applicable scope: all kinds of power model, electric tools, electric toys...
The advantage of using lithium battery:
1 small volume, light weight, large capacity, environmental protection, no memory effect.
The 2 is the power of the portable electronic device of choice, but more delicate use of lithium battery, please pay attention to the following points.
Use common sense:
1 must be charged using a standard lithium battery charger 4.2V.
2 prohibits the large current discharge.
3 prohibits the discharge, the single battery voltage shall not be less than 2.5V.
4 prohibited dismantling, short-circuit the battery, most likely caused by short circuit.

The battery has 2 sizes, please choose the suitable size when buying. Thank you very much!
Please note size according to your demand, such as no note size, random delivery.

1. 110*70*19MM
2. 70*56*37MM

Total weight: 300G
Packing: blue
With protection circuit: have overcharge, over discharge, over current, short circuit protection functions
the battery requirements
1: need li-ion battery chargers for; Constant current constant voltage;
2: the charging voltage: 12.6V
3: charging current: 1A
4: supporting the charger is charging when the red light is full of green light

battery discharge Requirements
1: input: 5.5 * 2.1 plug wire
2: output: 22# thread that is 150 mm long
3: the maximum instantaneous current: 5A
4: maximum working current: 3A
5: output input if there is any other requirement can be contact with the owner, the above parameters for th e default delivery

APPENDIX L

DC –DC Boost Converter Regulator

400KHz 60V 4A Switching Current Boost / Buck-Boost / Inverting DC/DC Converter

Features

- Wide 5V to 32V Input Voltage Range
- Positive or Negative Output Voltage Programming with a Single Feedback Pin
- Current Mode Control Provides Excellent Transient Response
- 1.25V reference adjustable version
- Fixed 400KHz Switching Frequency
- Maximum 4A Switching Current
- SW PIN Built in Over Voltage Protection
- Excellent line and load regulation
- EN PIN TTL shutdown capability
- Internal Optimize Power MOSFET
- High efficiency up to 94%
- Built in Frequency Compensation
- Built in Soft-Start Function
- Built in Thermal Shutdown Function
- Built in Current Limit Function
- Available in TO263-5L package

Applications

- EPC / Notebook Car Adapter
- Automotive and Industrial Boost / Buck-Boost / Inverting Converters
- Portable Electronic Equipment

General Description

The XL6009 regulator is a wide input range, current mode, DC/DC converter which is capable of generating either positive or negative output voltages. It can be configured as either a boost, flyback, SEPIC or inverting converter. The XL6009 built in N-channel power MOSFET and fixed frequency oscillator, current-mode architecture results in stable operation over a wide range of supply and output voltages.

The XL6009 regulator is special design for portable electronic equipment applications.

TO263-5L

Figure1. Package Type of XL6009

400KHz 60V 4A Switching Current Boost / Buck-Boost / Inverting DC/DC Converter

Pin Configurations

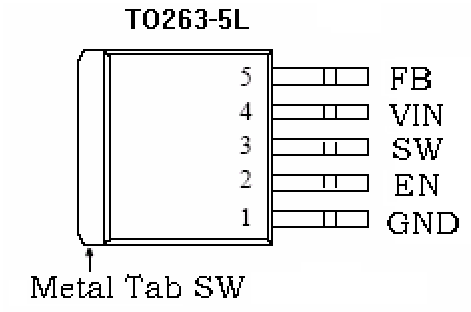

Figure2. Pin Configuration of XL6009 (Top View)

Table 1 Pin Description

Pin Number	Pin Name	Description
1	GND	Ground Pin.
2	EN	Enable Pin. Drive EN pin low to turn off the device, drive it high to turn it on. Floating is default high.
3	SW	Power Switch Output Pin (SW).
4	VIN	Supply Voltage Input Pin. XL6009 operates from a 5V to 32V DC voltage. Bypass Vin to GND with a suitably large capacitor to eliminate noise on the input.
5	FB	Feedback Pin (FB). Through an external resistor divider network, FB senses the output voltage and regulates it. The feedback threshold voltage is 1.25V.

Function Block

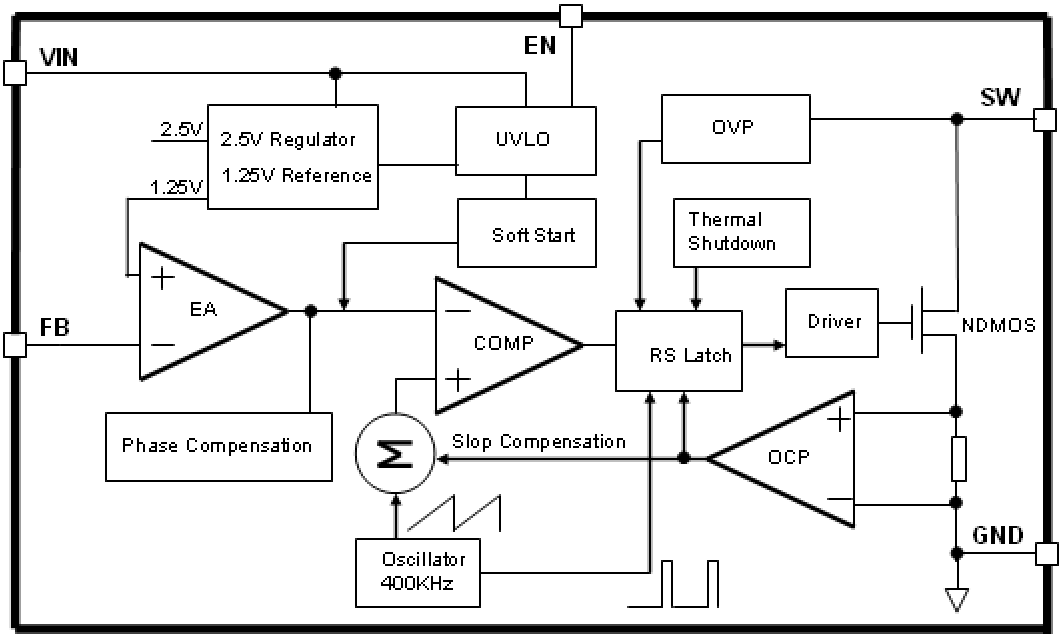

Figure3. Function Block Diagram of XL6009

Typical Application Circuit

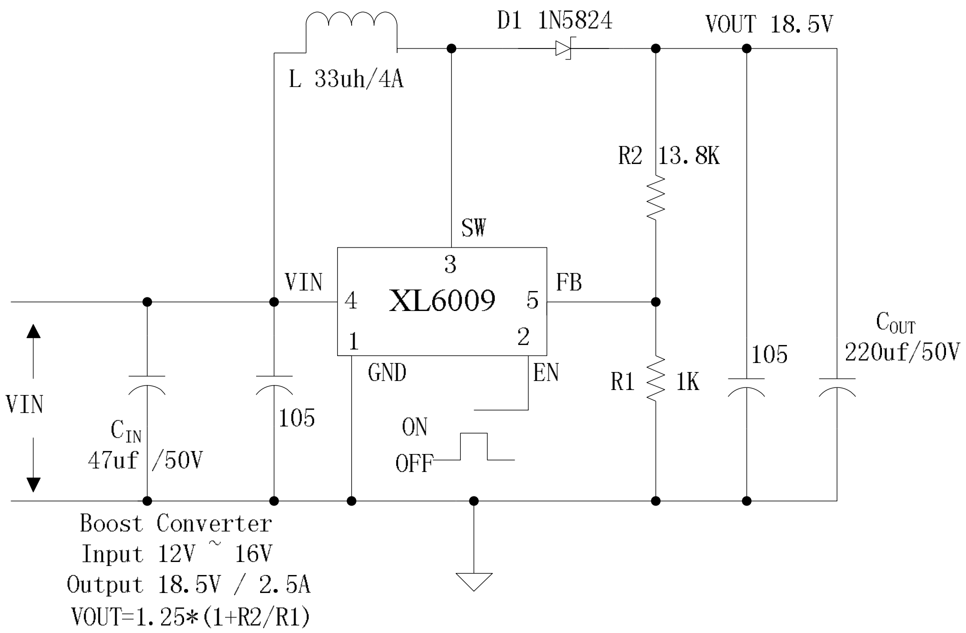

Figure4. XL6009 Typical Application Circuit (Boost Converter)

400KHz 60V 4A Switching Current Boost / Buck-Boost / Inverting DC/DC Converter

Ordering Information

Package	Temperature Range	Part Number	Marking ID	Packing Type
		Lead Free	Lead Free	
		XL6009E1	XL6009E1	Tube
		XL6009TRE1	XL6009E1	Tape & Reel

XLSEMI Pb-free products, as designated with "E1" suffix in the par number, are RoHS compliant.

Absolute Maximum Ratings（Note1）

Parameter	Symbol	Value	Unit
Input Voltage	Vin	-0.3 to 36	V
Feedback Pin Voltage	V_{FB}	-0.3 to Vin	V
EN Pin Voltage	V_{EN}	-0.3 to Vin	V
Output Switch Pin Voltage	V_{Output}	-0.3 to 60	V
Power Dissipation	P_D	Internally limited	mW
Thermal Resistance (TO263-5L) (Junction to Ambient, No Heatsink, Free Air)	R_{JA}	30	ºC/W
Operating Junction Temperature	T_J	-40 to 125	ºC
Storage Temperature	T_{STG}	-65 to 150	ºC
Lead Temperature (Soldering, 10 sec)	T_{LEAD}	260	ºC
ESD (HBM)		>2000	V

Note1: Stresses greater than those listed under Maximum Ratings may cause permanent damage to the device. This is a stress rating only and functional operation of the device at these or any other conditions above those indicated in the operation is not implied. Exposure to absolute maximum rating conditions for extended periods may affect reliability.

XL6009 Electrical Characteristics

T_a = 25℃;unless otherwise specified.

Symbol	Parameter	Test Condition	Min.	Typ.	Max.	Unit
System parameters test circuit figure4						
VFB	Feedback Voltage	Vin = 12V to 16V, Vout=18V Iload=0.1A to 2A	1.213	1.25	1.287	V
Efficiency	ŋ	Vin=12V ,Vout=18.5V Iout=2A	-	92	-	%

Electrical Characteristics (DC Parameters)

Vin = 12V, GND=0V, Vin & GND parallel connect a 220uf/50V capacitor; Iout=0.5A, T_a = 25℃; the others floating unless otherwise specified.

Parameters	Symbol	Test Condition	Min.	Typ.	Max.	Unit
Input operation voltage	Vin		5		32	V
Shutdown Supply Current	I_{STBY}	V_{EN}=0V		70	100	uA
Quiescent Supply Current	I_q	V_{EN} =2V, V_{FB} =Vin		2.5	5	mA
Oscillator Frequency	Fosc		320	400	480	Khz
Switch Current Limit	I_L	V_{FB} =0		4		A
Output Power NMOS	Rdson	Vin=12V, I_{SW}=4A		110	120	mohm
EN Pin Threshold	V_{EN}	High (Regulator ON) Low (Regulator OFF)		1.4 0.8		V
EN Pin Input Leakage Current	I_H	V_{EN} =2V (ON)		3	10	uA
	I_L	V_{EN} =0V (OFF)		3	10	uA
Max. Duty Cycle	D_{MAX}	V_{FB}=0V		90		%