Design and Microcontroller Based Centrifugal System For Tube Balancing Using External Pump.

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Submitted to the College of Engineering
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By the Guidance Of project's supervisor, and by all members in the testing committee, this project delivered to department of electrical engineering in the college of engineering and technology, to be as a partial fulfillment of the requirement of the department for the degree of B.Sc

Project Supervisor Signature

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Committee Signature

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جامعة بوليتكنيك فلسطين

كـــلـــية الهنـــدســـة

دائرة الهندسة الكهربائية

فلسطين-الخليل

أسماء الطلبة

ايه فطافطه	انوار حلايقه	مدلين ابو علي

بناء على نظام كلية الهندسة والتكنولوجيا وإشراف ومتابعة المشرف المباشر على المشروع وموافقة أعضاء اللجنة الممتحنة ، تم تقديم هذا المشروع إلى دائرة الهندسة الكهربائية ،وذلك للوفاء بمتطلبات درجة البكالوريوس في هندسة الأجهزة الطبية.

توقيع المشرف

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توقيع اللجنة الممتحنة

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توقيع رئيس الدائرة

.....

الإهداء

إلى الشمعة التي تحترق لتضيئ دربي.....**نبع العطاء .....أمي**

إلى الماس الذي لا ينكسر ..... **نبع العطاء .....أبي**

إلى ملائكة الأرض .....بشقائق النعمان .....أشقائي

إلى قناديل الدرب.....**الشموع التي لا تنطفئ .....أساتذتي**

إلى رفاق الدرب .....بنات المستقبل .....أصدقائي

إلى من رووا بدمائهم ارض فلسطين .....**صناع الكرامة**.....الشهداء

إلى من رفضوا الذل في زمن الانكسار .....طلاب المجد.....أسرانا

إلى من تجرعوا الم الحرمان.....عشاق الأرض.....المغتربين

إلى كل حر .....محب لفلسطين .....**أوفياء الأمة**

إليكم جميعا **أحبتي** اهدي هذا الجهد المتواضع

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Abstract

The main objective of this project is to design and control a laboratory centrifugal system with high accuracy of tube balancing using an external set that is consist of a pump connected and controlled by Microcontroller.

A predetermined blood volume is injected in to the blood tube, in order to achieve a balance in the system, a solution with similar fluid characteristic (density, volume, mass) in comparison with the blood is used in the balance tube.

A special pump will be used to inject a solution in the balance tube. This pump will be controlled by a microcontroller. When the solution reaches a required level, the balance between the balance tube that is contain a balance sample (solution)and the blood tube that is contain a blood sample is occurred.

ملخص المشروع

يهدف المشروع الى تصميم جهاز فصل عينات الدم المستخدم في المختبرات الطبية والتحكم فيه مع وجود دقه عاليه في المحافظه على توازن الانابيب المستخدمه من خلال وجود جزء خارجي يتكون من مضخه يتم التحكم فيها من خلال متحكم دقيق.

يتم وضع حجم محدد من الدم في داخل الانبوب الخاص بعينه الدم, لتحقيق الاتزان فانه يلزم استخدام محلول في الانبوب الخاص بالمحلول يمتلك نفس خصائص الدم من ناحيه الكثافة, الحجم, و الكتله .

سوف يتم استخدام مضخة خاصة تقوم بضخ المحلول في الانبوب الخاص فيه ويتم التحكم فيها من خلال المتحكم الدقيق , يتحقق الاتزان عندما يتساوى حجم المحلول في الانبوب الخاص فيه مع حجم عينة الدم في الانبوب الخاص فيها.

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MC: Micro Controller

CC: Cubic Centimeter

RPM: Revolution Per Minute

LCD: Liquid Crystal Display

Chapter one

Introduction

1.1 Overview.

1.2 Project Idea.

1.3 Project Motivation.

1.4 Project Objectives.

1.5 Approach.

1.6 Literature Review

1.7 Project Plan

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1.1 Overview

Centrifuges are devices used in a variety of scientific and technical applications which spin carrier vessels (centrifuge tubes) around the central axis at high rotation speeds with the help of electric motor. This device based on centrifugal force generated is proportional to the rotation rate of the rotor (in rpm) and the distance between the rotor center and the centrifuge tube. Cooling centrifuges ,high speed centrifuges and ultracentrifuges are available with the different types of rotors i.e. angle head and swinging bucket types.

The bucket or centrifuge tubes holder must be correctly positioned in the centrifuge, care must be taken to make sure that the contents on each side of centrifuge are balanced, because if centrifugation process started without balance the tubes, the weight imbalance will cause the centrifugal core to break. When spinning at extremely high(RPM), the gravity force attributed to each tube in the centrifuge can change even with a small weight imbalance. It's important to balance the tubes or a very expensive centrifuge might not last very long.

1.2 Project idea

The main objective of this project is to design and control of a laboratory centrifugal system with high accuracy of tube balancing using an external set that is consist of a pump connected and controlled by Microcontroller.

A predetermined blood volume is injected in to the blood tube, in order to achieve a balance in the system, a solution with similar fluid characteristic (density, volume, mass) in comparison with the blood is used in the balance tube.

A special pump will be used to inject a seawater in to the balance tube. This pump will be controlled by a microcontroller. When the solution reaches a required level, the balance between the balance tube that is contain a balance sample (seawater) and the blood tube that is contain a blood sample is occurred.

1.3 Project motivation

Using this technique the balance will be achieved by accurate measurement pumped a predetermined level of balance sample in the balance tube using special pump instead of doing this by observation as usually done by laboratory technicians

1.4 Project Objectives

- Build a centrifuge system using DC motor up to 3000cycle/min.
- Add a new option to the designed centrifuge system to achieve tube balancing.
- Use balance tube sample that has the same density, mass and volume of blood.

1.5 Approach

The project consists of two main parts, it first focus on the problem of unbalance tubes which will be the main part of the project. Designing centrifuge using motor up to 3000rpm controlling speed of motor using suitable microcontroller, there are different type of microcontroller, it will be studied, compared and tried to choose the needed type. Knowing the density of blood and fixed the level of blood in the tubes, this make easy to know solution has same density of blood and so have the same volume and mass of it.

1.6 Literature Review

-Design and implement a centrifuge system, D.r Ramzi Qwasmi, Ashraf Talal Doden, Palestine, 2012

This project is a design and implementation of laboratory centrifuges, for the analysis of blood and separating it into its basic components, using high-speed motor, up to3000 rpm[1]

There is difference between the project and our project. In this project we will design and implement a laboratory centrifuge with additional design, this design will be used for tube balance without observation as usually done by laboratory technicians in the project.

1.7 Project plan

The time planning for the project is shown in the following tables distributed on the weeks during working on the project introduction and the time of the project is scheduled over 16 weeks and how the work was scheduled over the time.

Week / Activity	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Give the idea														
Collection information														
Technique selection														
Circuit design														
Documentation														

Table 1.1: Activities Planning

1.8 Estimated Cost and Budget

Price(NIS)	Quantity	Equipment
70	1	LCD(16x4)
45	1	Keypad
320	1	Inverter
300	1	Arduino
80	1	Brushless DC pump
88	1	External Case components &wires
903		Total

1.9 Report Contents

This project is mainly divided into four chapters, each of them describes specific part of the project as following:

Chapter one: includes the introduction, provides a general overview about the project, its objectives, motivations, literature view, time planning, estimated cost and budget .

Chapter two: Discuss physiology background of blood ,function of blood, and blood component.

Chapter three: discusses the theoretical background. It starts with general information of centrifugation types and principles, and theory of centrifugation, the centrifuge rotor types.

Chapter four: presents the general system design concepts, It includes system objectives, general system block diagram, description of system design ' components and operation'.

Chapter Two

Introduction to the Anatomy of blood

2.1 Blood (Purpose and Components)

2.1.1 Function of the Blood.

2.1.2 The blood cells portion consists

2.1.3 Plasma

2.1.4 Red blood cells (RBC's) or Erythrocytes

2.1.5 White blood cell (WBC's)

2.1.6 Platelets

2.2 Percentages of components in the blood

2.3 The separation of blood components

Chapter2

(Introduction to the Anatomy of blood)

2.1 Blood (Purpose and Components)

Blood is the fluid that circulates through the heart, arteries, veins and capillaries carrying nourishment, hormones, vitamins, antibodies, heat and oxygen to body tissue and taking away waste matter and carbon dioxide. Whole blood composed of cells and plasma as shown in (Figure.2.1)

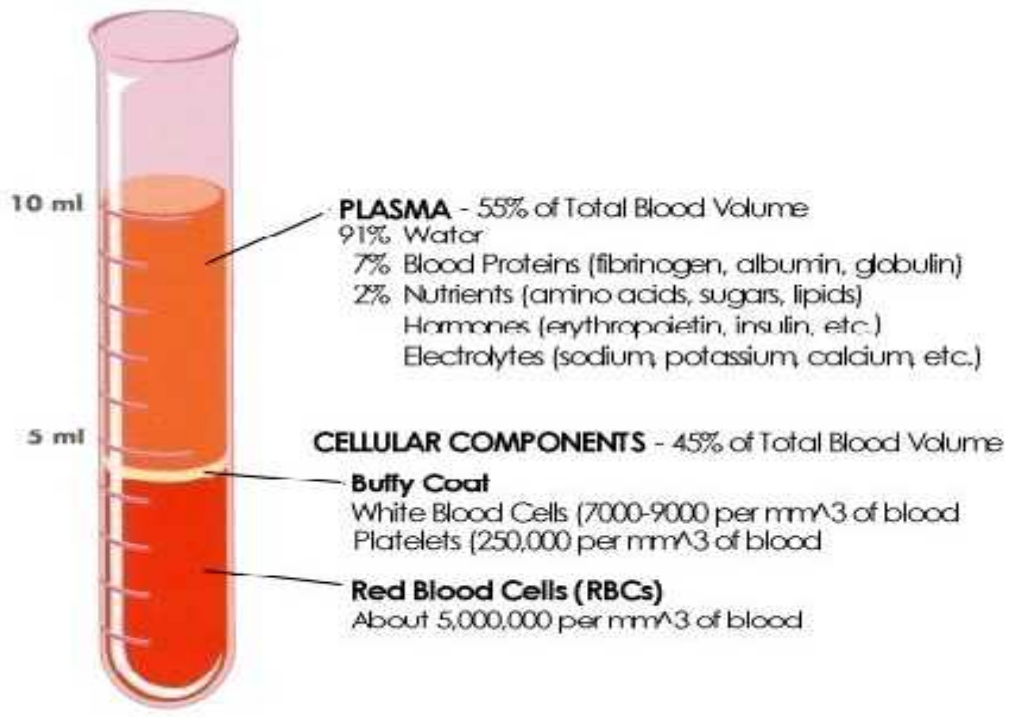


Figure2.1: Whole blood [2].

- Whole blood= RBC+WBC + platelets + Fibrinogen +Plasma.

- Plasma=Whole blood-(RBC+WBC+P).

- Serum=plasma- fibrinogen.

2.1.1 Function of the Blood:

1. Transports oxygen and nutrients to cells.

2. Removes carbon dioxide and wastes from cells.

3. Immunity (protects from disease).

4. Temperature regulation (cold, constricts; hot, dilates).

5. Helps prevent loss of blood by clotting.

6. Transport hormones.

7. Erection of the penis.

2.1.2 The blood cells portion consists :

Blood consists of the following :

A. Plasma

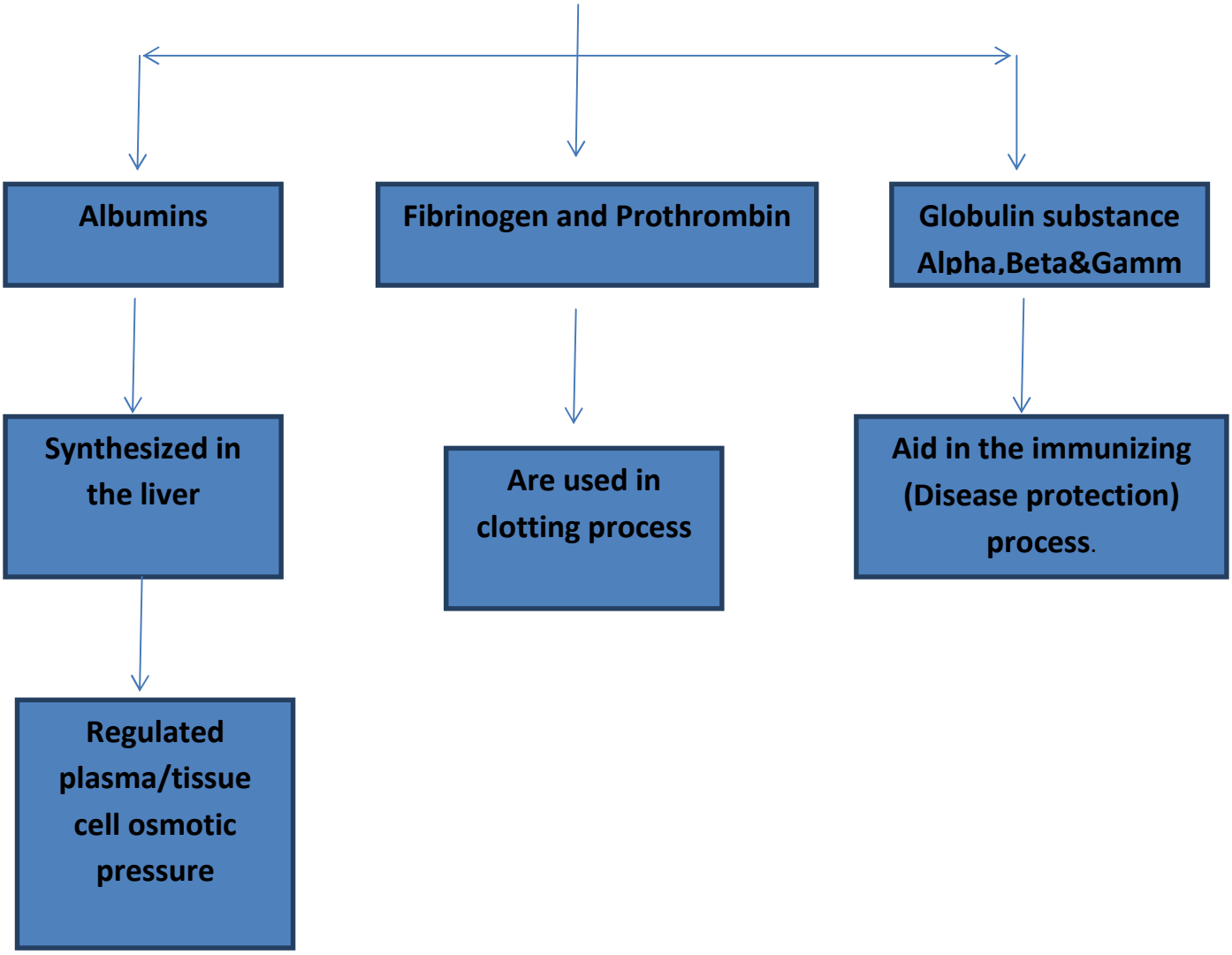
B. Red blood cells

C. White blood cells

D. Plate

2.1.3 Plasma.

-Plasma protein (organic repair substance) contains:



- Plasma nutriments-energy-storing substance:

-Glucose (Blood surgery)

-Lipids (Fats)

-Amino acids (Make up proteins for tissue growth)

- Regulator and protective substance:

-Antibodies (providing immunity against infection)

-Hormones (stimulatory/inhibitory)

-Enzymes (catalysts for digestion and cell metabolism)

- Plasma electrolytes (acid-base and nerve impulse transmission substance):

-Inorganic salts

-Pure chemical substances(Na^+, K^+, CL^-).

Metabolic waste substance:

It contains the following element:

-Urea

-Uric acid waste (from kidney)

-Carbon dioxide waste (From cellular metabolism)

The process of separating plasma protein in the centrifuge have the speed of rotation of the device (3000)rpm , and need 5 minutes for end the separation.

2.1.3 Red blood cells (RBC's) or Erythrocytes

These are concaved disc-shaped cells that contain no nucleus as shown in (Figure. 2.2) and live about 120 days before being replaced by the bone marrow. The number is 4.5 to 5.5*10^{6} $Cells/mm^3$.

Figure 2.2: *Red blood cells[3]*

- Function of the Red blood cells.

Internally, each RBC contains four iron atoms in structure known as the hemoglobin molecule oxygen from the lung alveoli enters hemoglobin to form ox hemoglobin, RBC's transport oxygen to the tissue and pickup carbon dioxide to form carbaminohemoglobin.

The process of separating red blood cells in the centrifuge have the speed of rotation of the device (1500-3000) rpm , and need 3 minutes for end the separation.

2.1.3 White blood cell (WBC's):

These are amoeba like cells that contain a nucleus as shown in (Figure.2.3) and live from 13 to 20 days. Their number is 6 to 10*$\frac{10^3\ cells}{mm^3}$.

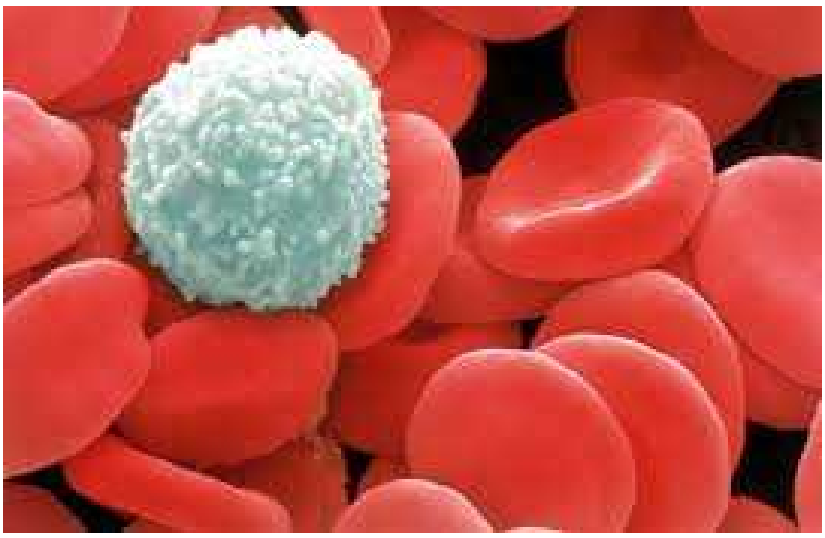


Figure 2.3: White blood cells

They are also present in the lymph fluid and engulf invading bacteria and foreign substance to destroy the invaders'

For example: Bacteria invading the leg are encapsulated by WBC's in the lymph fluid transported to the inferior vena cave, circulated through the right atrium -ventricle, and pumped to the kidneys, where they are extracted in the urine. They are than excreted from the body and the harm less cell fragments

- WBC'S contains:

Non-granular leucocytes

-Lymphocytes (small. Large)

-Monocytes

Granular leucocytes

-Neutrophils

-Eosinophil

-Basophiles

The process of separating White blood cells in the centrifuge have the speed of rotation of the device (1500) rpm , and need 5 minutes for end the separation.

2.1.3 Platelets

These are cell fragment that contain no nucleus as shown in (Figure 2.4), their number is 200 to 800* $10^3 cells/mm^3$, help in blood clot.

Note: serum will not clot, as it contains no fibrinogen.

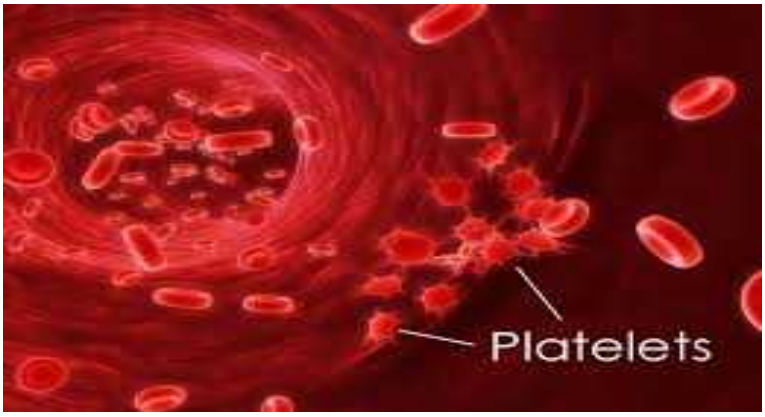
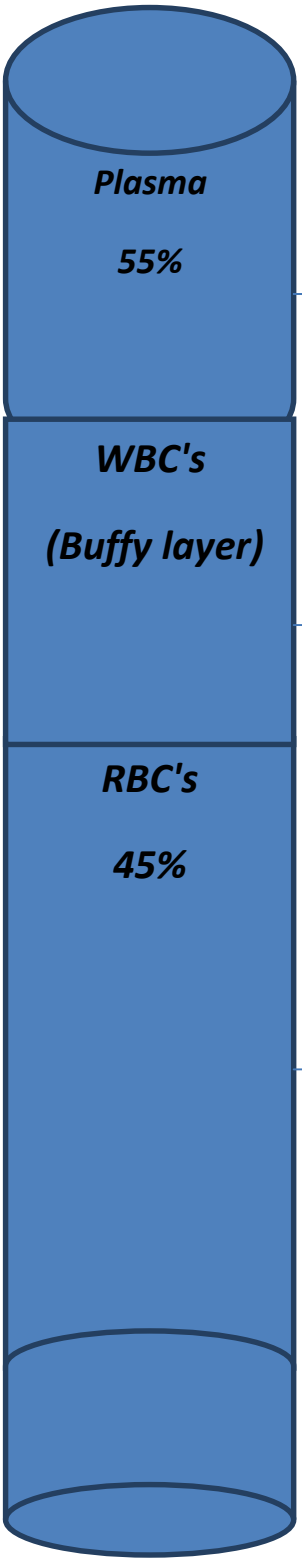


Figure 2.4: platelets

The process of separating platelets cells in the centrifuge have the speed of rotation of the device (1500) rpm , and need 5 minutes for end the separation.[4]

2.2 Percentages of components in the blood .



-90% Water –plasma

Proteins-Albumin, Globulin, Fibrinogen

-Growth /Protective-Hormones, Vitamins

Antibodies, Enzyme

-Inorganic substance, Na^+, K^+, CL^-, Fe **-Organic substance,**

Urea waste protein, Fat ,Glucose nutrient.

-Respiratory gases-O2and CO2.

-White blood cells-leucocytes

***(Defense against bacteria)**

***(Amoeba like shape)**

-Red blood cell-erythrocytes

***(Transport O2andCO2, concaved disc shaped)**

Figure(2.5): Percentages of components in the blood

2.3 Separations of blood components

As shown in (Figure2.6) is used for separation of blood components.

Figure 2.6: Centrifuge equipment

When a blood sample is spin in a centrifuge, the components of the blood separate into layers based on their individual weights. Since the heaviest particles are the red blood cells (erythrocytes), they sink at the bottom of the test tube ,while the least dense constituent , plasma, proceeds to move to the top of the test tube. After the constituents have separated according to their individual weights, a percentage that represent a count of the erythrocytes , leucocytes, or the platelets per unit of blood also known as a hematocrit can be taken.

A blood centrifuge utilizes the abundant, consistent, reproducible, and manageable force of gravity to separate the components of the blood. As the blood spins in centrifuge, the constituents are subject to g-force that allows the blood to separate on their particular densities. With technology advancing, ultracentrifuges have been constructed which utilize density gradients and extremely high g-force to separate compounds with similar properties and densities

Chapter Three

Centrifugation Types And principles

3.1 Introduction

3.2 Types of centrifugal separations

3.2.1 Differential centrifugation

3.2.2 Density gradient centrifugation

3.2.2.1 Rate-zonal (size) separation

3.2.2.2 Isopycnic (density) separation

3.3 Theory of centrifugation

3.3.1 The action of centrifugal force on molecules

3.3.2 Rotor and tube materials

3.4 Balancing of a centrifuge

3.5 Centrifuge rotor types

3.5.1 Fixed-angle rotor

3.5.2 Swinging-bucket rotors

3.5.3 Vertical rotors

Chapter 3

(Centrifugation types and principles)

3.1 Introduction:

Centrifugation is the process by which a centrifuge is used to separate components of a complex mixture. By spinning laboratory samples at very high speeds, the components of a given mixture are subjected to centrifugal force, which causes more dense particles to migrate away from the axis of rotation and lighter ones to move toward it. These particles can sediment at the bottom of the tube into what's known as a pellet, and this isolated specimen, or the remaining solution, can be further processed or analyzed. The theoretical basis of this technique is the effect of gravity on particles (including macromolecules) in suspension. Two particles of different masses will settle in a tube at different rates in response to gravity. Centrifugal force (measured as xg, gravity) is used to increase this settling rate in an instrument called a centrifuge.

3.2 Types of centrifugal separations:

3.2.1 Differential centrifugation:

The simplest form of separation by centrifugation is differential centrifugation, sometimes called differential pelleting (As shown in Figure 3.1). Particles of different densities or sizes in a suspension will sediment at different rates, with the larger and denser particles sedimenting faster. These sedimentation rates can be increased by using centrifugal force. A suspension of cells subjected to a series of increasing centrifugal force cycles will yield a series of pellets containing cells of decreasing sedimentation rate.

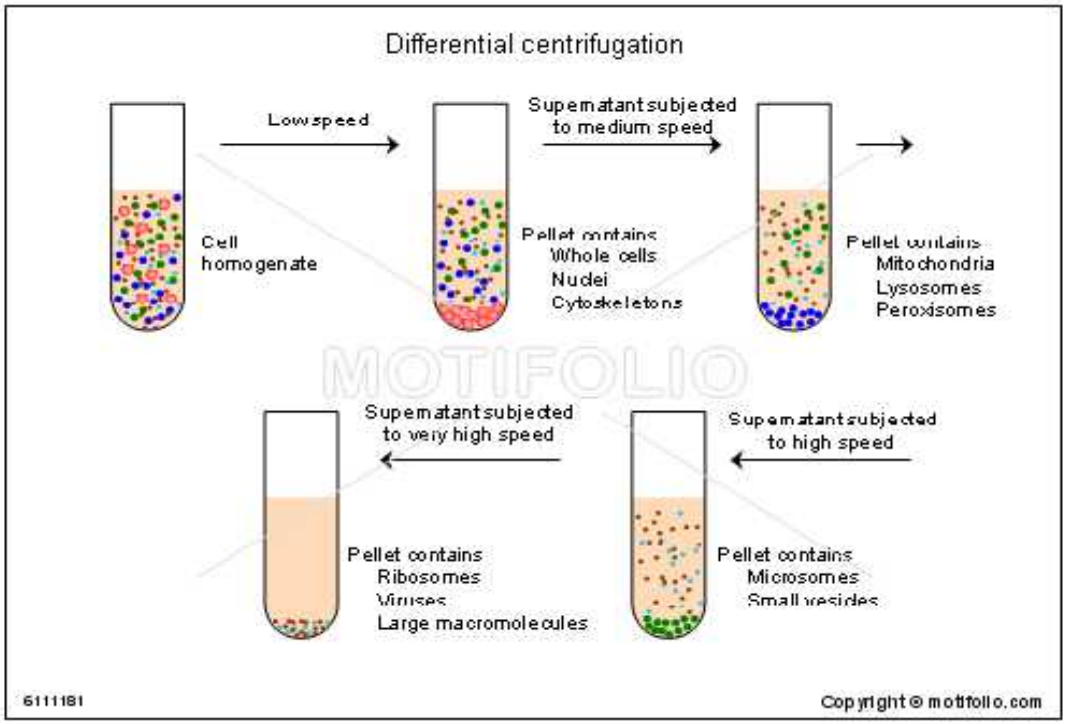


Figure 3.1: Differential Centrifugation[5]

Particles of different densities or size will sediment at different rates with the largest and most dense particles sedimenting the fastest followed by less dense and smaller particles.

Differential pelleting is commonly used for harvesting cells or producing crude sub cellular fractions from tissue homogenate. For example, a rat liver homogenate containing nuclei, mitochondria, lysosomes, and membrane vesicles that is centrifuged at low speed for a short time will pellet mainly the larger and more dense nuclei. Subsequent centrifugation at a higher centrifugal force will pellet particles of the next lower order of size (e.g., mitochondria) and so on. It is unusual to use more than four differential centrifugation cycles for a normal tissue homogenate.

Due to the heterogeneity in biological particles, differential centrifugation suffers from contamination and poor recoveries. Contamination by different particle types can be addressed by resuspension and repeating the centrifugation steps (i.e. washing the pellet).

3.2.2 Density gradient centrifugation

The primary function of density gradient centrifugation is to separate particles, either on the basis of their buoyancy density or their rate of sedimentation. For rate-zonal separations, the function of the gradient is to provide a gradient of viscosity which improves particle resolution while stabilizing the column from convection currents. For isopycnic separations, the important feature is that the maximum density of the gradient media is higher than that of the particles. Density gradient separation can be classified into two categories.

3.2.2.1 Rate-zonal (size) separation.

In rate-zonal centrifugation the problem of cross-contamination of particles of different sedimentation rates may be avoided by layering the sample as a narrow zone on top of a density gradient (see Figure3.2). In this way the faster sedimenting particles are not contaminated by the slower particles as occurs in differential centrifugation. However, the narrow load zone limits the volume of sample (typically 10%) that can be accommodated on the density gradient. The gradient stabilizes the bands and provides a medium of increasing density and viscosity

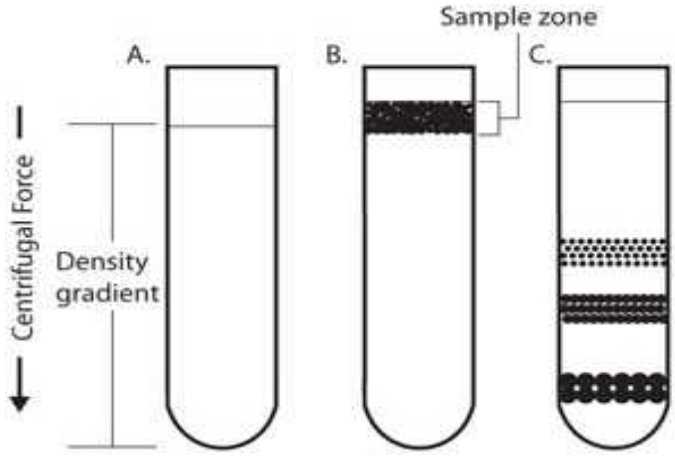


Figure 3.2: Rate-zonal separation[6]

Sample is layered as a narrow zone on the top of a density gradient (**3.2B**). Under centrifugal force, particles move at different rates depending on their mass (**3.2C**).

The speed at which particles sediment depends primarily on their size and mass instead of density. As the particles in the band move down through the density medium, zones containing particles of similar size form as the faster sedimenting particles move ahead of the slower ones. Because the density of the particles is greater than the density of the gradient, all the particles will eventually form a pellet if centrifuged long enough.

Criteria for successful rate-zonal centrifugation:

- Density of the sample solution must be less than that of the lowest density portion of the gradient.

- Density of the sample particle must be greater than that of the highest density portion of the gradient.

- The path length of the gradient must be sufficient for the separation to occur.

- Time is important. If too long runs is performed, particles may all pellet at the bottom of the tube.

3.2.2.2 Isopycnic (density) separation

In isopycnic separation, also called buoyant or equilibrium separation, particles are separated solely on the basis of their density. Particle size only affects the rate at which particles move until their density is the same as the surrounding gradient medium. The density of the gradient medium must be greater than the density of the particles to be separated. By this method, the particles will never sediment to the bottom of the tube, no matter how long the centrifugation time (see Figure3.3)

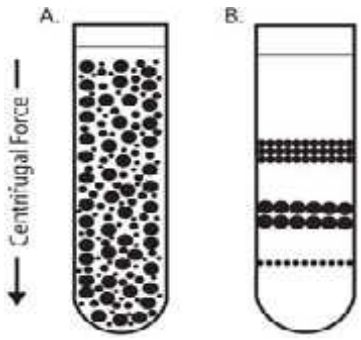


Figure3.3: Isopycnic separation

Starting with a uniform mixture of sample and density gradient (**3.3A**) under centrifugal force, particles move until their density is the same as the surrounding medium (**3.3B**)

Upon centrifugation, particles of a specific density sediment until they reach the point where their density is the same as the gradient media (i.e., the equilibrium position). The gradient is then said to be isopycnic and the particles are separated according to their buoyancy. Since the density of biological particles is sensitive to the osmotic pressure of the gradient, isopycnic separation may vary significantly depending on the gradient medium used. Although a continuous gradient may be more suited for analytical purposes, preparative techniques commonly use a discontinuous gradient in which the particles band at the interface between the density gradient layers. This makes harvesting certain biological particles .

Criteria for successful isopycnic separation:

- Density of the sample particle must fall within the limits of the gradient densities.
- Any gradient length is acceptable.
- The run time must be sufficient for the particles to band at their isopycnic point. Excessive run times have no adverse effect.[7]

3.3 Theory of centrifugation

When a suspension is rotated at a certain speed or revolutions per minute (RPM), centrifugal force causes the particles to move radically away from the axis of rotation. The force on the particles (compared to gravity) is called Relative Centrifugal Force(RCF). For example, an RCF of 500 x g indicates that the centrifugal force applied

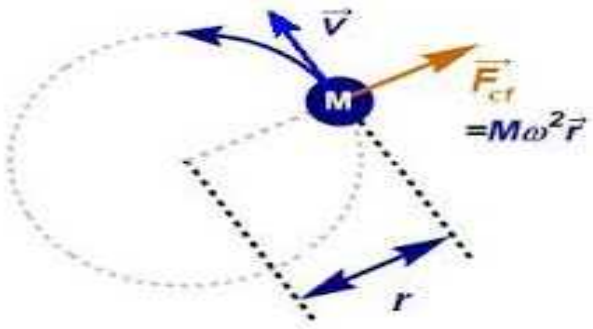


Figure 3.4. Theory of centrifugation[8]

3.3.1 The action of centrifugal force on molecules

As samples spin in a centrifuge the particles in each sample are subjected to centrifugal force. However, this force is proportional to the mass of the particle. To express the centrifugal force applied to a particular molecule its molecular weight (M) in the formula:

-Centrifugal force =M*ω^2*r ……(3.1)

- M: mass of particle
- r: radius of rotation (cm)
- ω: average angular velocity (radian/sec)

ω=2π*(n) /60…….(3.2)

n:#of revolution per minute

-**Relative centrifugal force**:

Because rotors are different from various manufactures, we use RCF to represent the centrifugation force, this force is proportional to the rotation of the rotor(RPM),and distance between the rotor center and the centrifuge tube(the radius)

3.3.2 Rotor and tube materials

Early rotors such as the Svedberg rotors were made of steel and occasionally brass. The high density of these materials and the resulting high rotor weight produces an appreciable load on the centrifuge drive and significantly limits operating speed. In this project rotors will be made of the partly or entirely of aluminum or titanium because they have less density.

Centrifuge tubes or centrifuge tips are tapered tubes of various sizes made of glass or plastic, they may vary in capacity from tens of milliliters, to much smaller capacities used extensively in molecular biology laboratories.

Glass centrifuge tubes can be used with most solvents, but tend to be more expensive. They can be cleaned like other laboratory glassware, and can be sterilized by

autoclaving. Plastic centrifuge tubes, especially micro centrifuge tubes tend to be less expensive. Water is preferred when plastic centrifuge tubes are used. They are more difficult to clean thoroughly, and are inexpensive enough to be considered disposable.[9]

In this project plastic tubes will be used because of reasons discussed above.

3.4 Balancing of a centrifuge

The bucket or centrifuge tubes holder must be correctly positioned in the centrifuge, care must be taken to make sure that the contents on each side of centrifuge are balanced, because if centrifugation process started without balance the tubes, the weight imbalance will cause the centrifugal core to break. When spinning at extremely high(RPM), the gravity force attributed to each tube in the centrifuge can change even with a small weight imbalance. It's important to balance the tubes or a very expensive centrifuge might not last very long.

3.5 Centrifuge rotor types

A centrifuge rotor is the rotating unit of the centrifuge, which has fixed holes drilled at an angle. Test tubes are placed inside these holes and the rotor spins to aid in the separation of the materials. There are three types of centrifuge rotors: swing-bucket, fixed-angle and vertical rotors (see Figure 3.5).Note that each type of rotor has strengths and limitations depending on the type of separation.

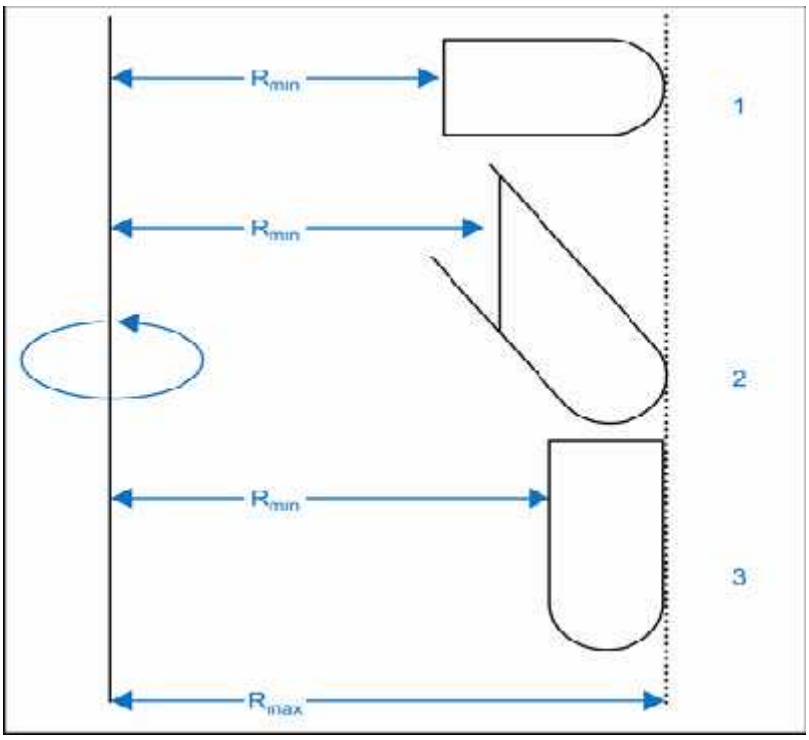


Figure 3.5. Centrifuge rotor type[10]

3.5.1 Fixed-angle rotor

A fixed-angle rotors are generally simpler in design than are singing-bucket rotors. In this type of rotor, the centrifuge tubes are held at a specific and constant angle to the horizontal plane that is the tube does not reorient between the vertical and horizontal positions(see Figure3.6). This type of rotor works very well for simple pelleting centrifugation but has limited and variable success in rate-zonal sedimentation and Isopycnic sedimentation respectively.

Figure 3.6: Fixed angle rotor**[**11**]**

3.5.2 Swinging-bucket rotors

In swinging bucket rotors (see Figure 3.7), the sample tubes are loaded into individual buckets that hang vertically while the rotor is at rest. When the rotor begins to rotate the buckets swing out to a horizontal position this rotor is particularly useful when samples are to be resolved in density gradients. The longer path length permits better separation of individual particle types from a mixture. However, this rotor is relatively inefficient for pelleting. Also, care must be taken to avoid" point loads" caused by spinning or other dense gradient materials that can precipitate. That have advantages are longer distance of travel may allow better Separation, easier to withdraw supernatant without disturbing pellet.

Figure 3.7: Swinging-bucket rotor

3.5.3 Vertical rotors

In vertical rotors, sample tubes are held in vertical position during rotation (see Figure 3.8). This type of rotor is not suitable for pelleting applications but is most efficient for isopycnic (density) separations due to the short path length. Applications include plasma DNA, RNA, and lipoproteins.

Figure 3.8. Vertical rotor

Chapter Four

Hardware and Software Design

4.1 Introduction

4.2 Block Diagram Of Project

4.2.1 Three phase AC Motor

4.2.1.1 Speed Control Of The Motor

4.2.2 Brushless DC Pump

4.2.3 Arduino

4.2.4 LCD Display

4.2.5 Power supply

4.4 Flow Chart System

Chapter 4

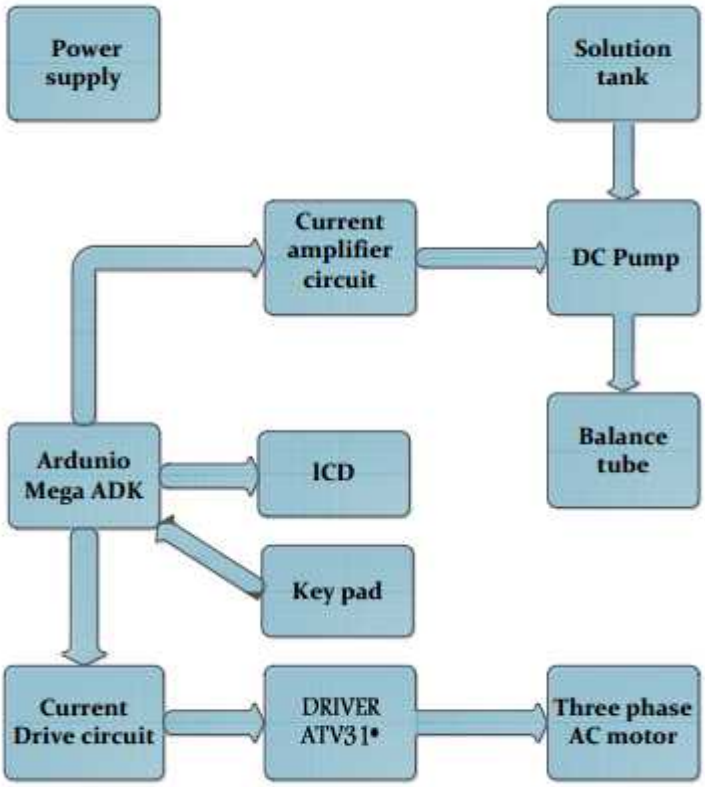
Hardware and Software Design

4.1 Introduction

This chapter demonstrates the design of our project, elements, project design block diagram and theoretical background about project components.

4.2.1 Block diagram of project

This block diagram show the electrical items that are used in our project .



Figure(4.1) Block diagram of project

4.2Three phase AC motor

In this project we use three phase Induction AC motor with speed up to 3000 rpm(As shown in Figure 4.2) to separate the blood sample , and control this motor by Arduino mega. This motor is made of the basic components: a stator, rotor.

Figure (4.2): Three phase AC Motor

-Stator

The stator generates a stationary magnetic field that surrounds the rotor. This field is generated by permanent magnets or electromagnetic windings

- Rotor

The rotor, also called the armature, is made up of one or more windings. When these windings are energized they produce a magnetic field. The magnetic poles of this rotor field will be attracted to the opposite poles generated by the stator, causing the rotor to turn. As the motor turns, the windings are constantly being energized in a different sequence so that the magnetic poles generated by the rotor do not overrun the poles generated in the stator. This switching of the field in the rotor windings is called commutation.

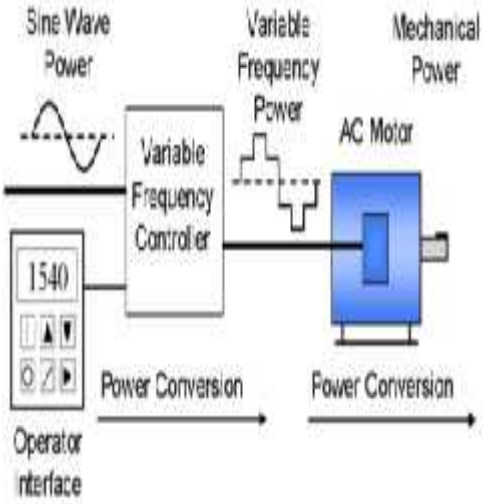
4.2.1.1 Speed control of the motor:

The speed of three phase Ac motors is changed from either stator or rotor sides , In our project it will be controlled from stator side by using frequency control.

-variable-frequency drive (VFD) Or inverter drive

A variable-frequency drive is a device used in a drive system consisting of the following three main sub-systems :as shown in Figure(4.3) AC motor, main drive controller assembly, and drive/operator interface

We need Inverter drive in our project inorder to convert one phase power line to three phase power line and control the speed of the motor of centrifuge system by frequency control.



Figure(4.3): variable-frequency drive (VFD) Or inverter drive

This picture show how three phase AC motor with Arduino

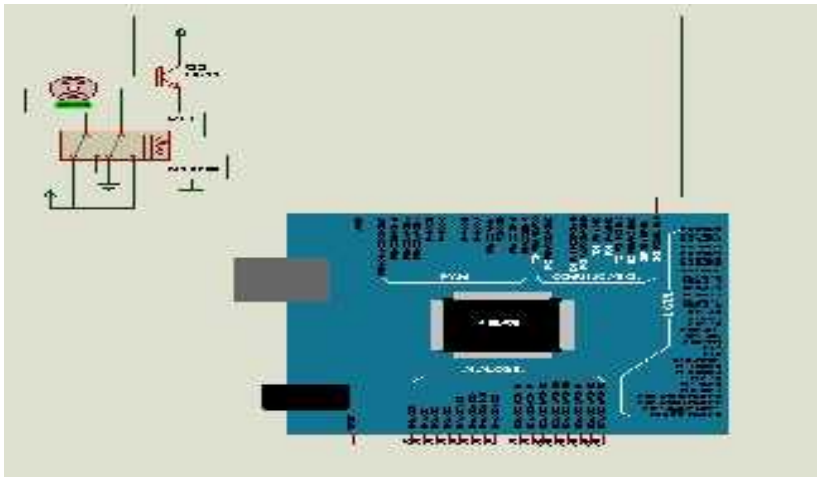


Figure (4.4): three phase AC motor with Arduino

4.2.2 Brushless DC Pump

We need dc brushless pump to transport seawater from small tank to fells a small tube to constant level .

Brushless DC motors have two basic categories – slotted and slotless. Slotted motors are based on an iron core technology, utilizing a wound stator typically with 9 to 12 slots. These motors are typically 4 pole and 3 phase and feature high power density and a small thermal resistance between the coil and the housing. Slotless motors are based on an ironless core technology, utilizing a custom wound coil. The motors are typically 2 pole and 3 phase, featuring zero cogging, reduced iron losses, linear torque versus speed and excellent speed control. Slotted motors typically run at a lower RPM (2,000 to 4,000 RPM) and produce higher torque making them ideal for lower flow applications. Slotless motors run at a higher RPM (8,000 to 16,000 RPM) with lower torque, suited for higher flow applications.[12]

.

The Dc brushless pump will connect to the Arduino as shown in the Figure

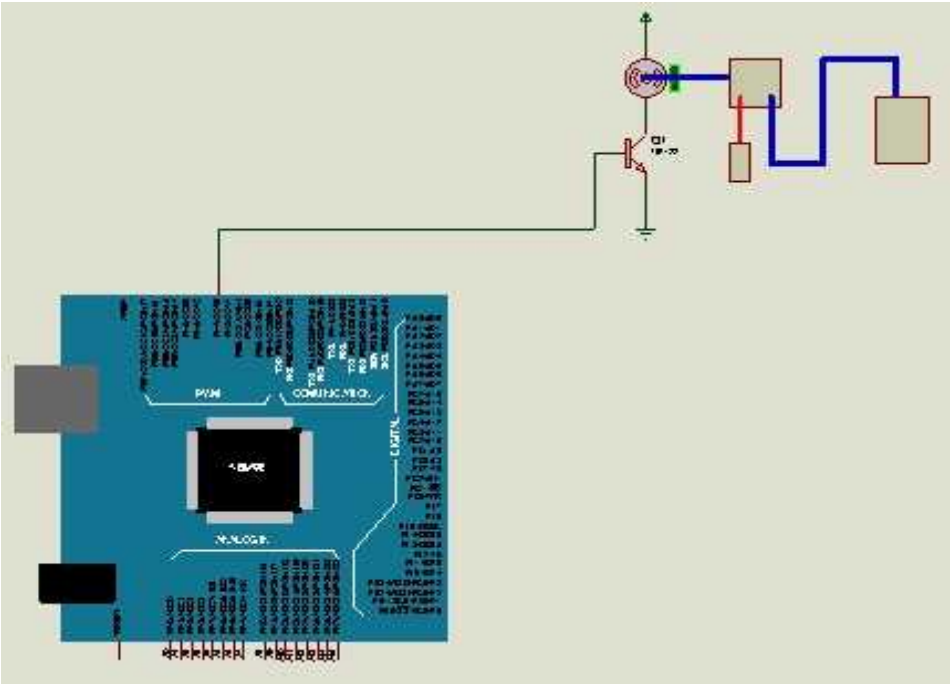


Figure (4.5): Brushless DC pump with Arduino

4.2.3 Arduino

Arduino is an open source board microcontroller, Arduino is designed to make electronic more accessible to artists, designer, hobbyists and anyone interested in creating interactive objects or environments.

Arduino can sense the environment by receiving input from a variety of sensors and can affect its surroundings by controlling lights, motors, and other actuators. The microcontroller on the board is programmed using the Arduino programming language uses a simplified version of C++.

We want to use Arduino in our project because the PIC is a chip, while the Arduino is a complete circuit board with power supply, IO headers, easer to deal with, and easer in programming as shown in Figure (4.6)

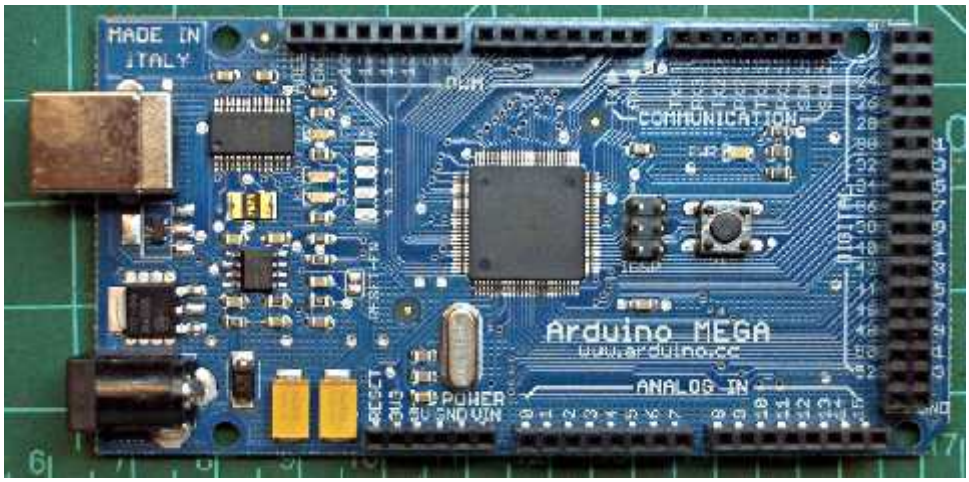


Figure (4.6):Arduino

4.2.4 LCD Display

In our project we need to (4x16) LCD to display the text messages to the laboratory operator and result on the screen, as shown in Figure(4.7)[

Figure (4.7):LCD Display

The LCD will connect to the Arduino as shown in the Figure (4.8) , .

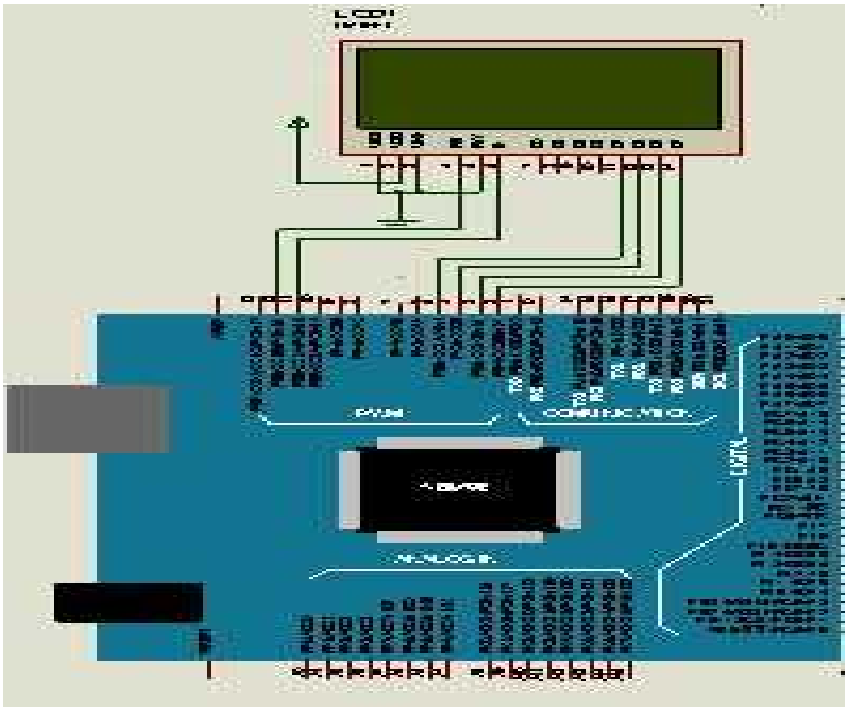
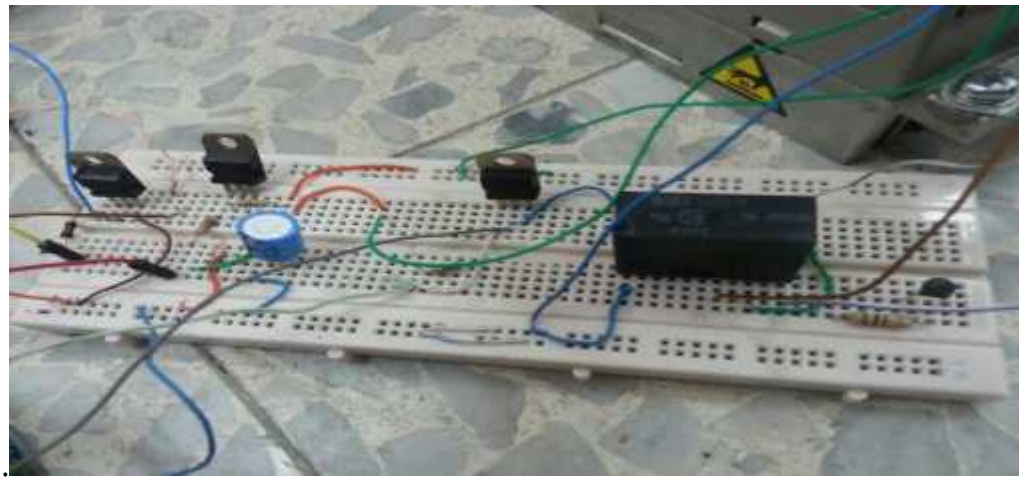


Figure (4.8): LCD display with Arduin

We need to use power transistor(TIP122)to amplify the current that comes from the Arduino to the inverter and so for the current that comes from Arduino th the pump

motor .And use the relay as magnetic switch to provide opposite direction of rotation to the motor to make it stop after reached to the required value ,and the capacitor used for smoothing and rectification for the ripple factor of the lowpass filter because the inverter dealed with step signal as shown in figure (4.9)



Figure(4.9):current amplification circuit

4.2.5 Power supply

In our project we need to power supply (portable) unit to give 5 volt DC for Arduino, 220volt AC for three phase motor, 6 volt for brushless dc pump . The power supply unit mainly consists LM7805 Voltage Regulator and LM7812 Voltage Regulator .the voltage regulator plays an important role in a power supply unit. Output of the power supply unit is always DC which is given to the brushless dc pump and Arduino.and220volt for invertor from the power line

4.3 The final project

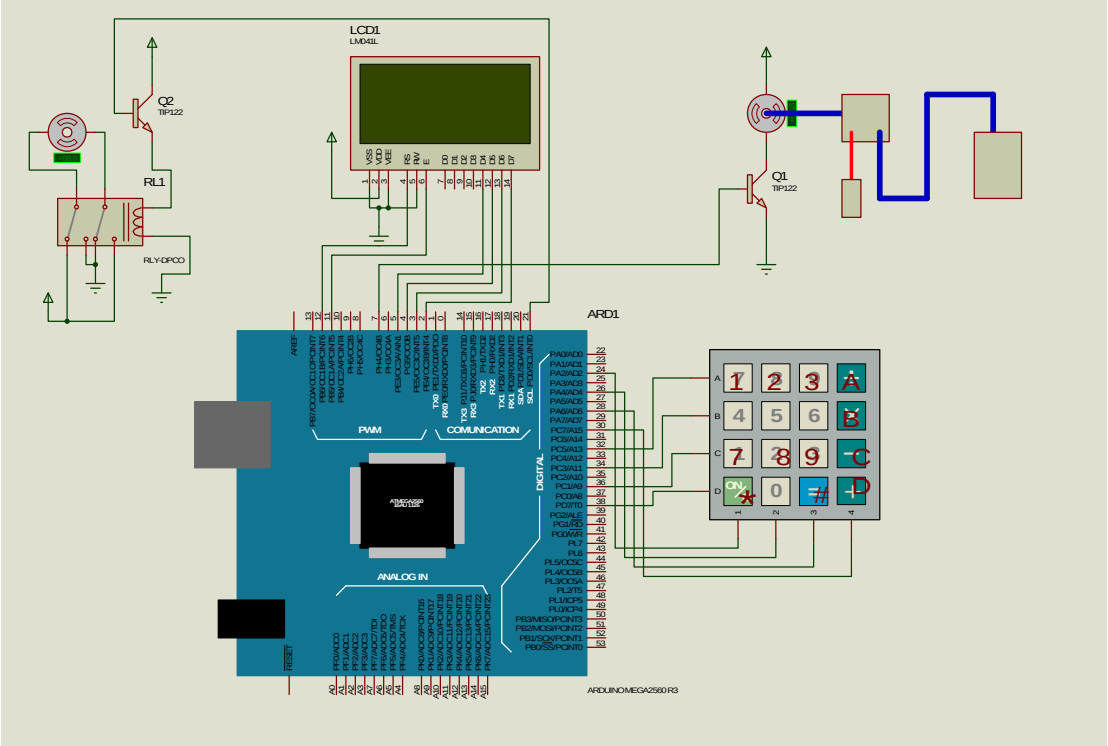
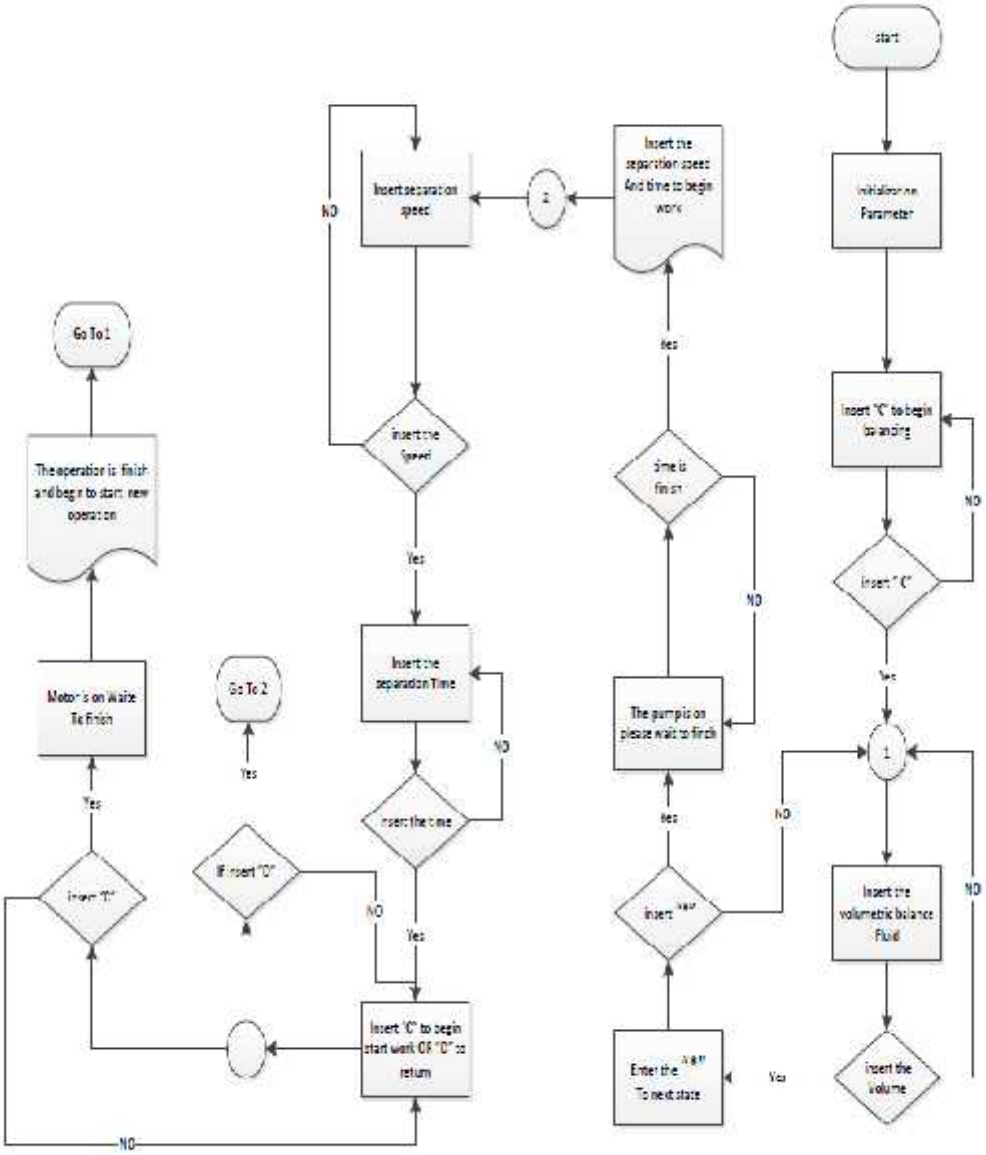


Figure (4.10): The final project circuit

4.4 Flow Chart System



4.5 Tube Balance

In order for tube balance to be occurred we need in this project seawater because it as a density similar (blood density=1.060kg/m^3)at temperature equal 38C ° with blood density with error rate (3%)as shown in table (4.1) , and constant volume (3 cubic centimeter) ,the mass can be calculated by using equation(4.2).

Mass= density/ volume…….(4.2)

Mass: Mass of blood

Density: Density of seawater

Volume: volume of blood

When mass in each tube is equal this means that balance is occurred as shown in table(4.1)

Approximate Physical Properties of Some Common Liquids (SI Units)

Liquid	Temperature (°C)	Density, ρ (kg/m^3)	Specific Weight, γ (kN/m^3)	Dynamic Viscosity, μ (N · s/m^2)	Kinematic Viscosity, ν (m^2/s)	Surface Tension, σ (N/m)	Vapor Pressure, p_v [N/m^2 (abs)]	Bulk Modulus, E_v (N/m^2)
Carbon tetrachloride	20	1,590	15.6	9.58 E − 4	6.03 E − 7	2.69 E − 2	1.3 E + 4	1.31 E + 9
Ethyl alcohol	20	789	7.74	1.19 E − 3	1.51 E − 6	2.28 E − 2	5.9 E + 3	1.06 E + 9
Gasoline[c]	15.6	680	6.67	3.1 E − 4	4.6 E − 7	2.2 E − 2	5.5 E + 4	1.3 E + 9
Glycerin	20	1,260	12.4	1.50 E + 0	1.19 E − 3	6.33 E − 2	1.4 E − 2	4.52 E + 9
Mercury	20	12,600	132	1.57 E − 3	1.15 E − 7	4.66 E − 1	1.6 E − 1	2.85 E + 10
SAE 30 oil[c]	15.6	912	8.95	3.8 E − 1	4.2 E − 4	3.6 E − 2	—	1.5 E + 9
Seawater	15.6	1,020	10.1	1.20 E − 3	1.17 E − 6	7.34 E − 2	1.77 E + 3	2.34 E + 9
Water	15.6	999	9.80	1.12 E − 3	1.12 E − 6	7.34 E − 2	1.77 E + 3	2.15 E + 9

Table (4.1) Physical properties of some common liquid .

Chapter Five

System Implementation and testing

5.1 Introduction

5.2 Testing the External part

5.3 External designed case of the project

5.4Conclusion:

5.5 Challenges

5.6 Recommendation .

System Implementation and testing

5.1 Introduction.

Practical implementation and testing for the project have been done in second semester .When subsystem was implemented and tested individual then connected these subsystem to each other.

5.2 Testing the External part

This picture show the testing of first part of project(pump,Arduino,keypad,LCD) as shown in(Figure5.1)

Figure (5.1):testing of first part of project(pump,Arduino,keypad,LCD)

When the power is on and supplied to the components, text message will displayed on the LCD , this message tell the operator what is the LCD appreviation means to easily use the device , as shown in(Figure5.2)

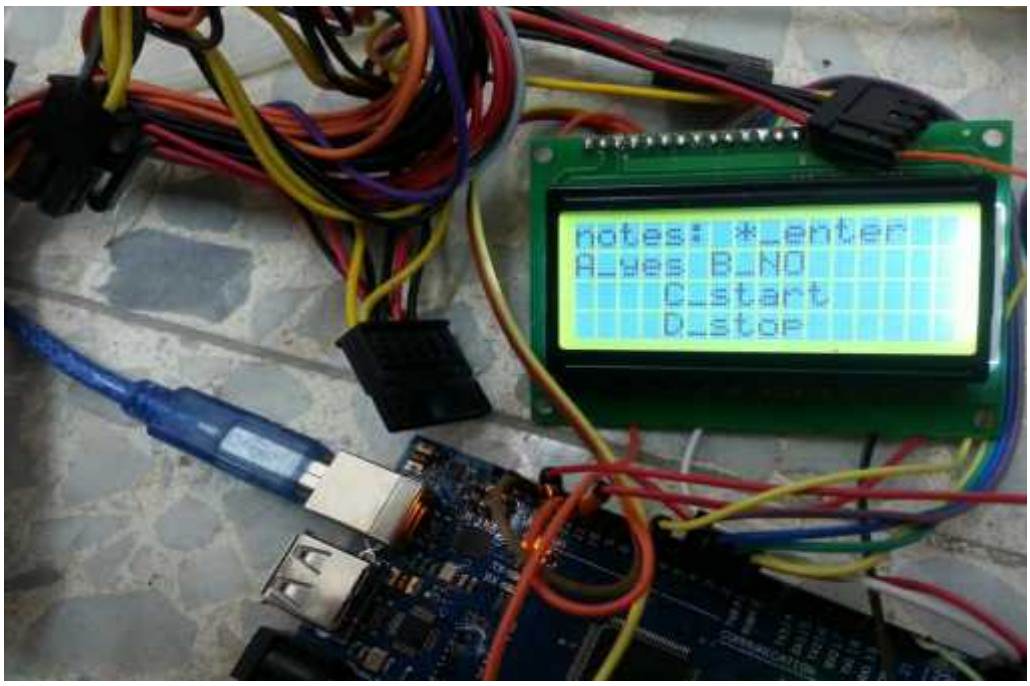


Figure (5.2): First Text message on the LCD

The second message asked the operator to inter how many volume (cc) to be filled by pump in the balance tube, as show in(Figure 5.3).

Figure (5.3):second text message on the LCD

In order to make sure that the pumped volume fill by the pump in the balance tube is the required volume we test this by enter 3cc on the LCD and use a medical syringe to this goal, By the result as shown in Figure(5.4) the volume in tube is the same volume that entered on LCD.

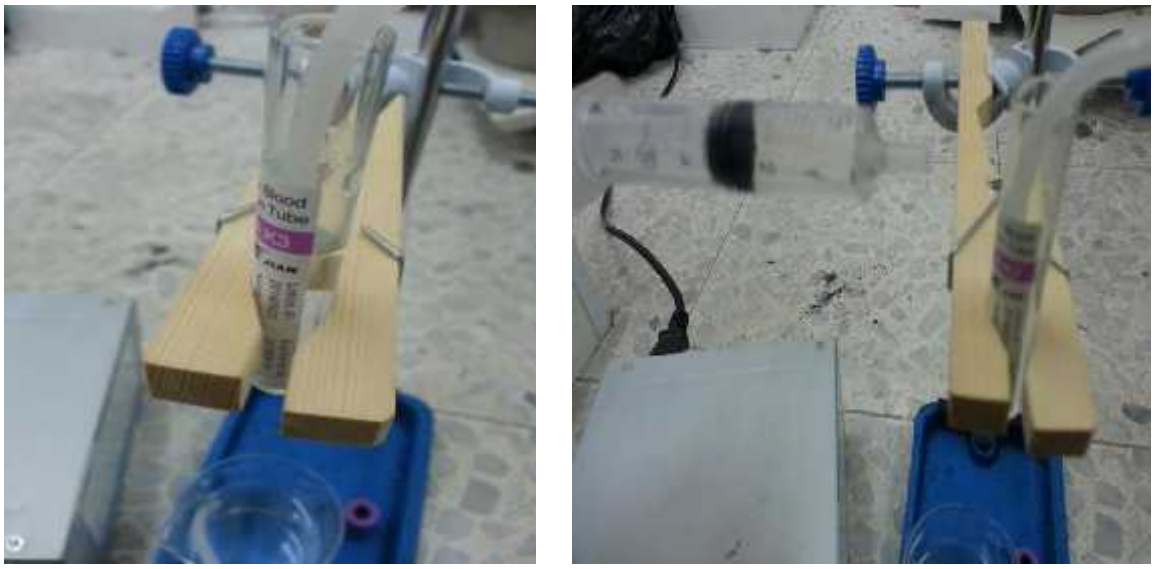


Figure (5.4): Testing the pump

After the pump finishing from filling the balance tube , the next step is to control the motor of centrifuge device by the Arduino , so a message will displayed on the LCD ask the operator to enter the speed that the motor will separate the blood sample and follow it message to enter the time the motor will rotate to get the required results as shown in Figure (5.5).

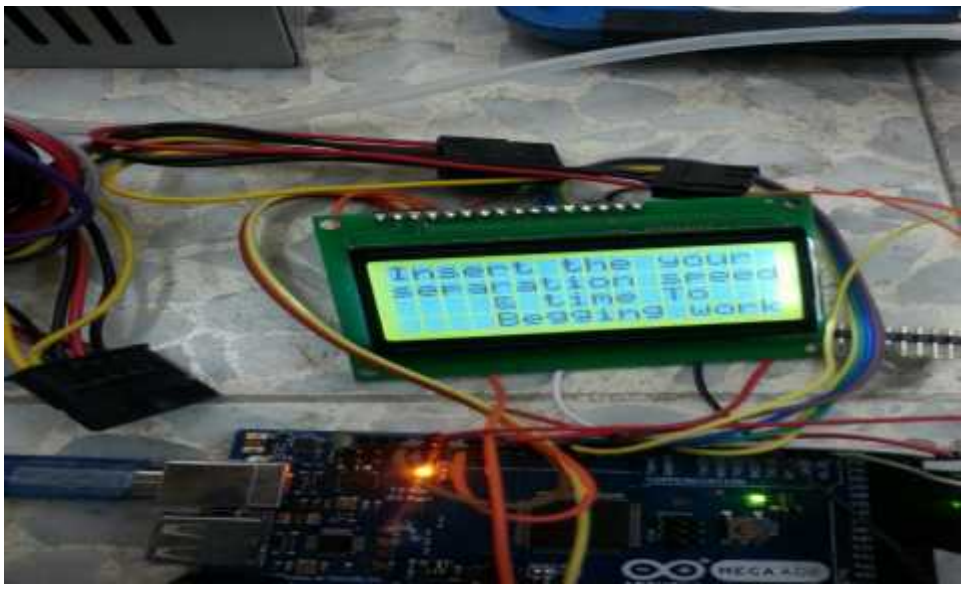


Figure (5.5): Testing the second part of the project

We insure that the speed the motor rotate is the entered speed by busing inverter device as shown in(Figure5.6) .

Figure (5.6): Centrifuge system motor

It most important to mention that after determine every parameter needed for the whole system it will be displayed on the LCD text asked the user if he/she insure from every parameter he/she entered and if not to press special key(described in first picture) to return to repeat the entering process. as shown in(Figure5.7)

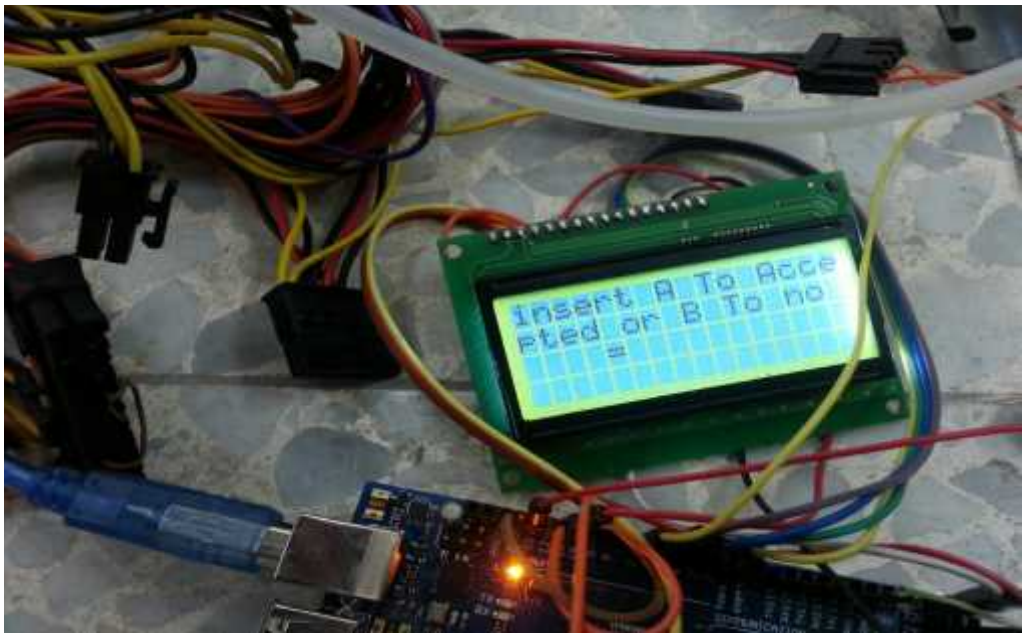
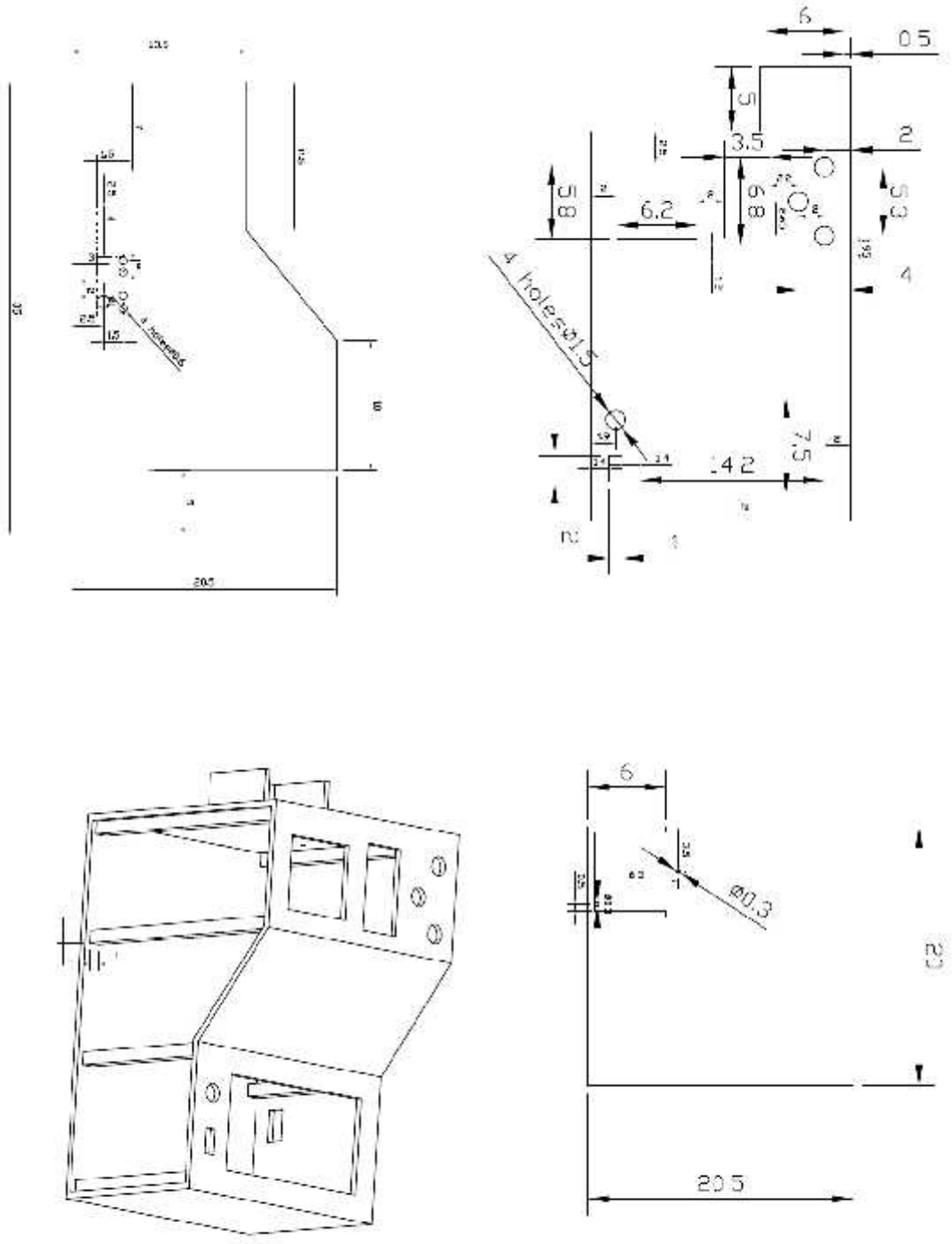
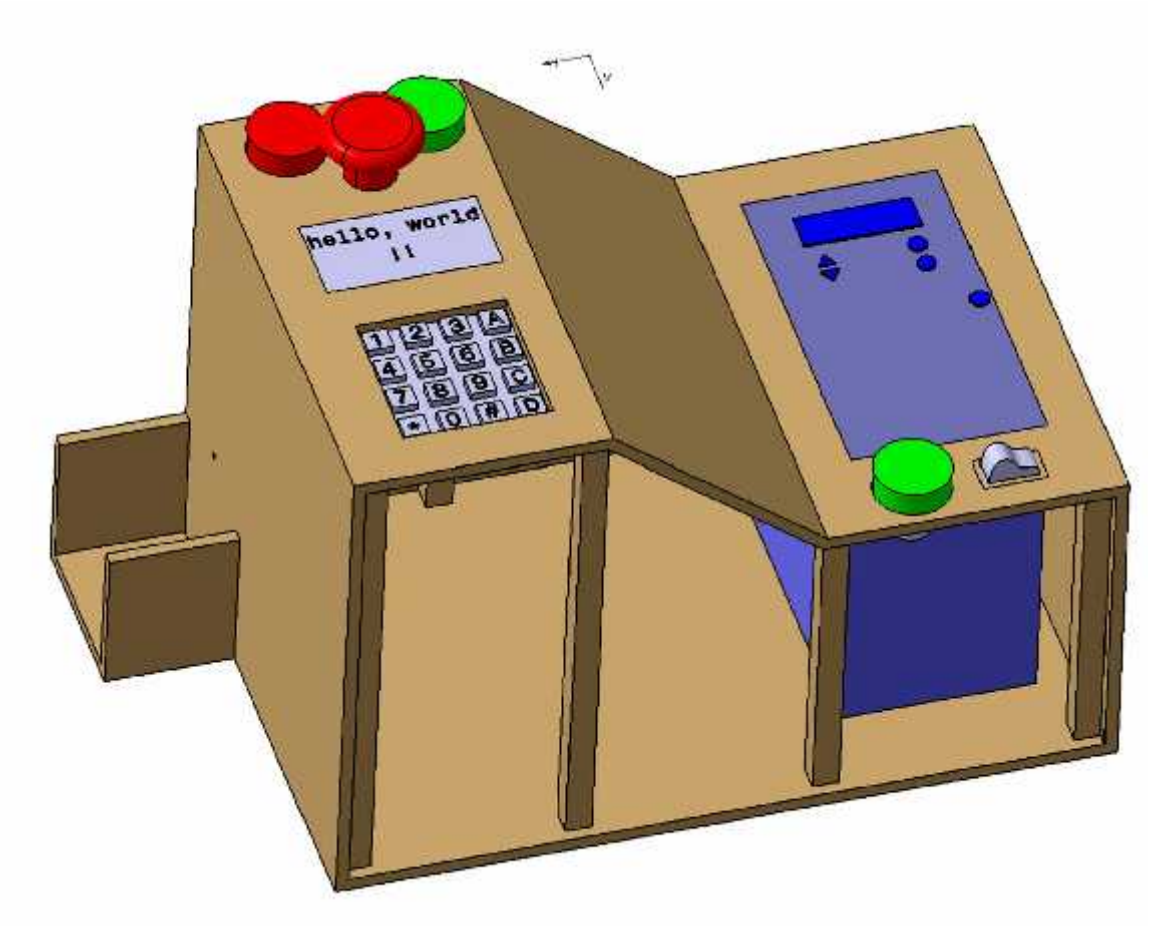


Figure (5.7): User interface message

Finally after determine all the system parameter , the operator will close the door of the centrifuge device and, the motor will rotate with the required speed and time , the speed appear on the LCD until it finishing the separation process and stop rotate , and get ready for another process.

5.3 External designed case of the project





Figure(5.8): External case of the project

5.4Conclusion:

In this semester we complete theoretical design of centrifuge and determined the basic concepts of the system with, adding a new balance tube design and knowing the needed component for this design and all challenges that will face us In the next semester. In next semester we will build the project

5.5 Challenges

1-Control the speed of centrifuge motor .

2-Justify the volumetric (CC) filled by the pump .

3-Convert the single phase power line to three phase and design the structure of the project

5.6 Recommendation.

In this project we did all the work assuming that see water density is constant at all temperatures ,But it must be taken in attention that it is changes at different temperatures.

References:

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[2] http://www.pumpfundamentals.com/images/tutorial/tutorial.pdf

[3] http://www.monzir-pal.net/Bioseparation/Contents/Centrifugation%20Chapter.pdf

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[5] http://trishul.sci.gu.edu.au/courses/7204BPS/Centrifugation_Lecture_2008.pdf

[6] https://physics.ucsd.edu/neurophysics/Manuals/Eppendorf/centrifuge_5417r.pdf

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[9] http://bioshop.pbsci.ucsc.edu/rotor_manuals/TableTop.pdf

[10] http://www.theego.com/HND/UEE%202.pdf

[11]http://www.thermoscientific.com/content/dam/tfs/LPG/LED/LED%20Documents/Application%20&%20Technical%20Notes/Centrifuges/Centrifuge%20Rotors/Ultracentrifuge%20Rotors/D21027~.pdf

[12]http://www.portescap.com/sites/default/files/wp_focus_on_miniature_pumps_selecting_the_right_motor_technology.pdf

Appendix

software implementation

```
// include the library code:
#include <LiquidCrystal.h>
#include <Keypad.h>
// initialize the library with the numbers of the
interface pins
LiquidCrystallcd(12, 11, 5, 4, 3, 2);
const byte ROWS = 4; //four rows
const byte COLS = 4; //four columns
intmotor=13;
intpump=7;////////
intled_alarm=49;
intled_finch=47;
intdoor_sensor=45;
char num=1;
char value[]={0,0,0,0};
char i=0,j=0;
long net=0;
long net1=0;
long net2=0,time2=0;
float speedm=0;
const float time1=1300;//whare 1cc---sec////////
float Delay=0.0;
char customKey;
inten1=21;//////relay
//define the cymbols on the buttons of the keypads
char hexaKeys[ROWS][COLS] = {
{'1','4','7','*'},
{'2','5','8','0'},
{'3','6','9','#'},
{'A','B','C','D'}
};
byte rowPins[ROWS] = {24,26,28,30}; //connect to the row
pinouts of the keypad
byte colPins[COLS] = {32,34,36,38}; //connect to the
column pinouts of the key
//initialize an instance of class NewKeypad
Keypad customKeypad = Keypad( makeKeymap(hexaKeys),
rowPins, colPins, ROWS, C
////////////////
////////////////
void setup() {
pinMode(motor, OUTPUT);
pinMode(pump, OUTPUT);
pinMode(led_alarm, OUTPUT);
pinMode(led_finch, OUTPUT);
pinMode(door_sensor,INPUT);
pinMode(en1,OUTPUT);
```

```
// set up the LCD's number of columns and rows:
lcd.begin(16,4);
// Print a message to the LCD.
lcd.print("notes: *_enter");
lcd.setCursor(0, 1);//// set the cursor to column 0, line
0
// (note: line 0 is the first row, since counting begins
with 0):
lcd.print("A_yes B_NO");
lcd.setCursor(0, 2);
lcd.print("C_start");
lcd.setCursor(0, 3);
lcd.print("D_stop");
analogWrite(motor,255);
digitalWrite(en1,LOW); //
delay(5000);
lcd.clear();
Serial.begin(9600);
}
void loop() {
switch(num)
{
case 1:
if(i==0)
{
lcd.clear();
lcd.setCursor(0, 0);
lcd.print("Insert(C)to begg");
lcd.setCursor(0, 1);
lcd.print("ing start balanc");
lcd.setCursor(0, 2);
lcd.print("= ");
lcd.setCursor(2, 2);
i=1;
}
customKey = customKeypad.getKey();
if (customKey=='C')
{
i=2;
lcd.clear();
}
if(i==2)
{
lcd.print(customKey);
lcd.setCursor(0, 0);
lcd.print(" Insert the volu");
lcd.setCursor(0, 1);
lcd.print("metric balance");
lcd.setCursor(0, 2);
lcd.print(" fluid ");
customKey = customKeypad.getKey();
```

```
if(customKey)
{
if(customKey!='*')
{
value[0]=customKey;
net=value[0]-48;
}
}
lcd.setCursor(0, 4);
lcd.print("= ");
lcd.setCursor(2, 4);
lcd.print((int)net);
if(customKey=='*')
{
num=2;
value[0]=0;
i=0;
}
}
break;
case 2:
Delay=net*(1700/3.0);//////////
Serial.println(net);
if(net==1)
analogWrite(pump,130); // // turn the pump on (HIGH is
the voltage level)
if(net==2)
analogWrite(pump,95);
if(net==3)
analogWrite(pump,90);
lcd.clear();
lcd.setCursor(0, 0);
lcd.print("The pump is on ");
lcd.setCursor(0, 1);
lcd.print("Please wait to");
lcd.setCursor(0, 2);
lcd.print(" finch ");
delay(Delay); // wait for a Time
analogWrite(pump,0); // turn the pump off by making the
voltage LOW
lcd.clear();
lcd.setCursor(0, 0);
lcd.print("The pump isfinch");
delay(2000);
lcd.clear();
num=3;
break;
case 3:
lcd.clear();
lcd.setCursor(0, 0);
lcd.print("Insert the your");
```

```
lcd.setCursor(0, 1);
lcd.print("separation speed");
lcd.setCursor(0, 2);
lcd.print("& time To ");
lcd.setCursor(0, 3);
lcd.print("Begging work");
delay(3000);
lcd.clear();
j=0;
for(i=0;i<4;i++)
value[i]=0;
i=0;
speedm=0;
time2=0;
num=4;
break;
case 4:
customKey = customKeypad.getKey();
if(j==0)
{
lcd.clear();
lcd.setCursor(0, 0);
lcd.print("insert the");
lcd.setCursor(0, 1);
lcd.print("separation speed");
lcd.setCursor(0, 2);
lcd.print("= ");
}
while(j<4)
{
customKey = customKeypad.getKey();
if(customKey)
{
value[j]=customKey;
lcd.setCursor(2, 2);
lcd.print(value);
j++;
}
}
if(j==4)
{
lcd.clear();
lcd.setCursor(0, 0);
lcd.print("insert A To Acce");
lcd.setCursor(0, 1);
lcd.print("pted or B To no");
lcd.setCursor(0, 2);
lcd.print("= ");
j++;
}
delay(100);
```

```
customKey = customKeypad.getKey();


if(customKey=='B')
{
j=0;
for(i=0;i<4;i++)
value[i]=0;
i=0;
}
if(customKey=='A')
{
num=5;
net1=value[0]*1000+value[1]*100+value[2]*10+value[3]+1220
8;
for(i=0;i<4;i++)
value[i]=0;
i=0;
j=0;
}
break;
case 5:
customKey = customKeypad.getKey();
if(j==0)
{
lcd.clear();
lcd.setCursor(0, 0);
lcd.print("insert the");
lcd.setCursor(0, 1);
lcd.print("separation Time");
lcd.setCursor(0, 2);
lcd.print("= ");
}
while(j<3)
{
customKey = customKeypad.getKey();
if(customKey)
{
value[j]=customKey;
lcd.setCursor(2, 2);
lcd.print(value);
j++;
}
}
if(j==3)
{
lcd.clear();
lcd.setCursor(0, 0);
lcd.print("insert A To Acce");
lcd.setCursor(0, 1);
lcd.print("pted or B To no");
```

```
lcd.setCursor(0, 2);
lcd.print("= ");
j++;
}
delay(100);
customKey = customKeypad.getKey();
if(customKey=='B')
{
j=0;
for(i=0;i<4;i++)
value[i]=0;
i=0;
}
if(customKey=='A')
{
num=6;
net2=value[0]*100+value[1]*10+value[2]-5328;
for(i=0;i<4;i++)
value[i]=0;
i=0;
}
break;
case 6:
speedm=(float)(((5000-net1)/4500.0)*255.0);
time2=net2;
if(i==0)
{
lcd.clear();
lcd.setCursor(0, 0);
lcd.print("Insert(C)to begg");
lcd.setCursor(0, 1);
lcd.print("ing start WorkOR");
lcd.setCursor(0, 2);
lcd.print("D To return");
lcd.setCursor(0, 3);
lcd.print("=");
i=1;
}
delay(50);
customKey = customKeypad.getKey();
if(customKey=='D')
{
num=3;
}
if(customKey=='C')
{
lcd.clear();
//Serial.println(time2);
digitalWrite(en1,1); //
delay (200);
analogWrite(motor, speedm);
```

```
lcd.setCursor(0, 0);
lcd.print("motor is on");
lcd.setCursor(0, 1);
lcd.print("waite To finch");
lcd.setCursor(0,2);
lcd.print("Time runing he");
lcd.setCursor(0,3);
lcd.print("=");
for(i=0;i<time2;i++)
{
lcd.setCursor(1,3);
lcd.print(int(i+1));
delay(1000);
}
analogWrite(motor,255);
digitalWrite(en1,0); //
delay(500);
digitalWrite(en1,1);
delay(500);
digitalWrite(en1,0);
num=7;
}
break;
case 7:
lcd.clear();
lcd.setCursor(0, 0);
lcd.print("The operation is");
lcd.setCursor(0, 1);
lcd.print("finch &start to");
lcd.setCursor(0, 2);
lcd.print("new operation");
i=0;
j=0;
time2=0;
speedm=0;
net1=0;
net2=0;
net=0;
num=1;
delay(4000);
break;
}
}
```

The circuit:
* LCD RS pin to digital pin 12
* LCD Enable pin to digital pin 11
* LCD D4 pin to digital pin 5
* LCD D5 pin to digital pin 4
* LCD D6 pin to digital pin 3
* LCD D7 pin to digital pin 2
* LCD R/W pin to ground
* 10K resistor:
* ends to +5V and ground
* wiper to LCD VO pin (pin 3)

Altivar® 31 Quick Reference Guide

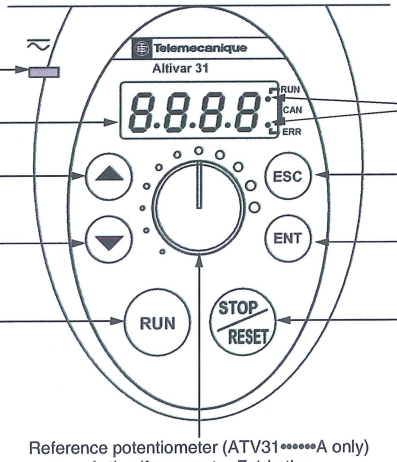
8800HO0403
12/2004

ATV31H••••

Note: Please refer to the ATV31 Installation Guide (VVDED303041US) and the ATV31 Programming Manual (VVDED303042US) for complete installation and programming instructions.

ATV31H••••A

KEYPAD OPERATION



Red LED
DC bus ON

Four 7-segment displays

2 CANopen status LEDs

Returns to the previous menu or parameter, or increases the displayed value

Exits a menu or a parameter, or clears the displayed value to return to the previous stored value

Advances to the next menu or parameter, or decreases the displayed value

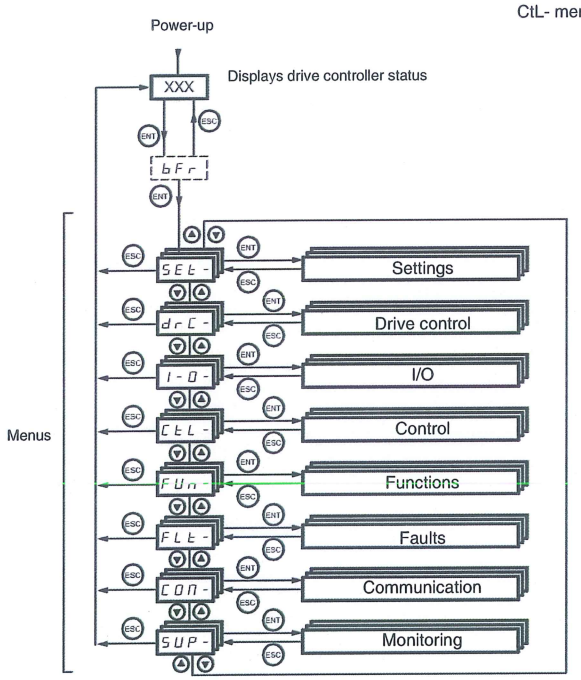
Enters a menu or a parameter, or saves the displayed parameter or value

RUN button (ATV31••••••A only)
Starts the motor in forward direction if parameter tCC in the I-O- menu is configured as LOC

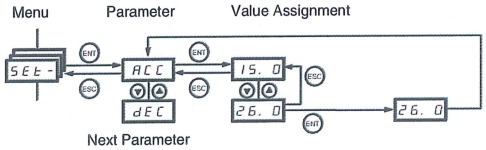
STOP/RESET button (ATV31••••••A only)
Resets faults
Stops the motor:
•If tCC (I-O- menu) is not configured as LOC, pressing the STOP/RESET key commands a freewheel stop.
•If tCC (I-O- menu) is configured as LOC, stopping is on a ramp, but if injection braking is in progress, a freewheel stop takes place.

Reference potentiometer (ATV31••••••A only)
Active if parameter Fr1 in the CtL- menu is configured as AIP

ACCESS TO MENUS

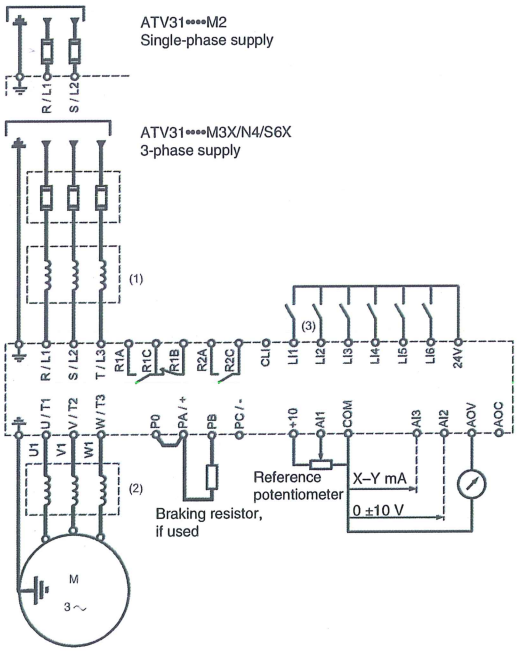


ACCESS TO PARAMETERS



The display flashes when a value is stored. Some functions may require pressing the ENT button for two seconds to store the parameter change.

TYPICAL CONNECTIONS



(1) A line reactor is required for 575 V installations.
(2) A load reactor is recommended for 575 V installations.
(3) When configured for 2-wire control, LI1 is Run Forward (fixed).
When configured for 3-wire control, LI1 is Stop (fixed) and LI2 is Run Forward (fixed).

SEt - SETTINGS Menu

Parameter	Code	Factory Setting
Speed ref. from remote -Hz	LFr	
Internal PI regulator ref. -Hz	rPI	0 Hz
Acceleration ramp time -s	ACC	3 s
Acceleration ramp time 2 -s	AC2	5 s
Deceleration ramp time 2 -s	dE2	5 s
Deceleration ramp time -s	dEC	3 s
Start custom accel. ramp-%	tA1	10%
End custom accel. ramp -%	tA2	10%
Start custom decel. ramp-%	tA3	10%
End custom decel. ramp -%	tA4	10%
Low speed -Hz	LSP	0 Hz
High speed -Hz	HSP	bFr
Thermal current -A	ItH	Varies w/rating
IR compensation -%	UFr	20%
Gain -%	FLG	20%
Stability -%	StA	20%
Slip comp. -%	SLP	100%
DC injection curr -A	IdC	0.7 In
DC injection time -s	tdC	0.5 s
Auto. DC injection time -s	tdC1	0.5 s
Auto. DC injection curr -A	SdC1	0.7 In
Auto. DC injection time 2 -s	tdC2	0 s
Auto. DC injection curr 2 -A	SdC2	0.5 In
Skip freq. -Hz	JPF	0 Hz
Skip freq. 2 -Hz	JF2	0 Hz
Jog operating freq. -Hz	JGF	10 Hz
PI regulator prop. gain	rPG	1
PI regulator int. gain -/s	rIG	1/s
PID coeff	FbS	1
PID inversion	PIC	nO
2nd preset PI reference -%	rP2	30%
3rd preset PI reference -%	rP3	60%
4th preset PI reference -%	rP4	90%
Preset speed 2 -Hz	SP2	10 Hz
Preset speed 3 -Hz	SP3	15 Hz
Preset speed 4 -Hz	SP4	20 Hz
Preset speed 5 -Hz	SP5	25 Hz
Preset speed 6 -Hz	SP6	30 Hz
Preset speed 7 -Hz	SP7	35 Hz
Preset speed 8 -Hz	SP8	40 Hz
Preset speed 9 -Hz	SP9	45 Hz
Preset speed 10 -Hz	SP10	50 Hz
Preset speed 11 -Hz	SP11	55 Hz
Preset speed 12 -Hz	SP12	60 Hz
Preset speed 13 -Hz	SP13	70 Hz
Preset speed 14 -Hz	SP14	80 Hz
Preset speed 15 -Hz	SP15	90 Hz
Preset speed 16 -Hz	SP16	100 Hz
Current limit -A	CL1	1.5 In
Current limit 2 -A	CL2	1.5 In
Low speed oper. time -s	tLS	0 (no time limit)
Restart error threshold	rSL	0
Motor 2 IR compen. -%	UFr2	20%
Motor 2 freq. loop gain -%	FLG2	20%
Motor 2 freq. loop stabil.-%	StA2	20%
Motor 2 slip compen. -%	SLP2	100%
Frequency Lev.Att -Hz	Ftd	bFr
Thermal Level Att. -%	ttd	100%
Current Level Att. -A	Ctd	In
Display para. scale factor	SdS	30
Sw. Freq -kHz	SFr	4 kHz

drC - DRIVE CONTROL Menu

Parameter	Code	Factory Setting
Motor frequency -Hz	bFr	50 Hz
Nom. motor volt -V	UnS	Varies w/rating
Nom. motor frequency -Hz	FrS	50 Hz
Nom. motor current -A	nCr	Varies w/rating
Nom. motor speed -RPM	nSP	Varies w/rating
Motor CosPhi (power fact.)	CoS	Varies w/rating
Cool state stator resistance	rSC	nO
Auto tuning	tUn	nO
Auto tuning status	tUS	tAb
Voltage/frequency ratio	UFt	n
Noise reduction	nrd	YES
Switching frequency -kHz	SFr	4 kHz
Maximum frequency -Hz	tFr	60 Hz
Suppress speed loop filter	SrF	nO
Save the configuration	SCS	nO
Return to factory settings	FCS	nO

I-O - I/O Menu

Parameter	Code	Factory Setting
Terminal strip config	tCC	2C ATV31••••••A: LOC
Type 2 wire	tCt	trn
Reverse operation	rrS	If tCC=2C: L12 if tCC=3C: L13 if tCC=LOC:nO
AI3 low speed -mA	CrL3	4 mA
AI3 high speed -mA	CrH3	20 mA
Analog output config	AOIt	oA
Analog/logic output	dO	nO
Relay R1	r1	FLt
Relay R2	r2	nO

CtL - CONTROL Menu

Parameter	Code	Factory Setting
Function access level	LAC	L1
Ref 1 config	Fr1	AI1 ATV31••••••A: AIP
Ref 2 config	Fr2	nO
Ref switching	rFC	Fr1
Separate ctrl/ref channels	CHCF	SIM
Ctrl channel 1 config	Cd1	tEr ATV31••••••A: LOC
Ctrl channel 2 config	Cd2	Mdb
Ctrl channel switching	CCS	Cd1
Copy channel 1 to channel 2	COP	nO
Ctrl via remote keypad	LCC	nO
Stop priority	PSt	YES
Direction of operation	rOt	dFr

FUn - APPLICATION FUNCTIONS Menu

Parameter	Code	Factory Setting
rPC submenu		
Ramp type	rPt	LIn
Start CUS accel ramp-%	tA1	10%
End CUS accel ramp -%	tA2	10%
Start CUS decel ramp-%	tA3	10%
End CUS decel ramp -%	tA4	10%
Accel ramp time -s	ACC	3 s
Decel ramp time -s	dEC	3 s
Ramp switching	rPS	nO
Ramp switch. thresh -Hz	Frt	0
Accel ramp time 2 -s	AC2	5 s
Decel ramp time 2 -s	dE2	5 s
Decel ramp adaptation	brA	YES
StC submenu		
Normal stop	Stt	Stn
Fast stop	FSt	nO
Decel ramp coef.	dCF	4
DC injection stop	dCI	nO
DC injection current -A	IdC	0.7 In
DC injection time -s	tdC	0.5 s
Freewheel stop	nSt	nO
AdC submenu		
Auto DC injection	AdC	YES
Auto inject. time -s	tdC1	0.5 s
Auto inject. level -A	SdC1	0.7 In
Auto inject. time 2 -s	tdC2	0 s
Auto inject. level 2 -A	SdC2	0.5 In
SAI submenu		
Summing input 2	SA2	AI2
Summing input 3	SA3	nO
PSS submenu		
2 preset speeds	PS2	if tCC=2C/LOC: LI3 if tCC=3C: LI4
4 preset speeds	PS4	if tCC=2C/LOC: LI4 if tCC=3C: nO
8 preset speeds	PS8	nO
16 preset speeds	PS16	nO
JOG submenu		
Jog operation	JOG	if tCC=2C/LOC: nO if tCC=3C: LI4
Jog oper. reference -Hz	JGF	10 Hz
UPd submenu		
Plus speed	USP	nO
Minus speed	dSP	nO
Save references	Str	nO
PI submenu		
PI regulator feedback	PIF	nO
PI regul. proport. gain	rPG	1
PI regul. intergral gain	rIG	1
PI feedback coeff.	FbS	1
Reverse PI regul. direction	PIC	nO
2 preset PI references	Pr2	nO
4 preset PI references	Pr4	nO

FUn - APPL. FUNCTIONS Menu (cont.)

Parameter	Code	Factory Setting
PI submenu (cont.)		
Preset PI ref. 2 -%	rP2	30%
Preset PI ref. 3 -%	rP3	60%
Preset PI ref. 4 -%	rP4	90%
Restart after error thresh.	rSL	0
Internal PI regul. ref.	PI1	nO
Internal PI regul. ref. -%	rPI	0
bLC submenu		
Brake control config.	bLC	nO
Brake release freq. -Hz	brL	Varies w/rating
Release current thresh.-A	Ibr	Varies w/rating
Brake release time -s	brt	0.5 s
Brake engage freq. thresh.	bEn	nO
Brake engage time -s	bEt	0.5 s
Brake release pulse	bIP	nO
LC2 submenu		
Current limit 2 switching	LC2	nO
Current limit 2 -A	CL2	1.5 In
CHP Motor Switching	CHP	nO
LSt Limit switch management		

FLt - FAULTS Menu

Parameter	Code	Factory Setting
Automatic restart	Atr	nO
Max restart duration	tAr	5
Reset fault	rSF	nO
Catch on fly	FLr	nO
External fault	EtF	nO
External fault stop mode	EPL	YES
Motor phase loss fault config.	OPL	YES
Line phase loss fault config.	IPL	YES
Drive overheat fault stop mode	OHL	YES
Mtr overload fault stop mode	OLL	YES
Modbus serial link fault stop	SLL	YES
CANopen serial link fault stop	COL	YES
Auto-tune fault config.	tnL	YES
Signal loss fault stop	LFL	nO
Fallback speed -Hz	LFF	10 Hz
Undervoltage derated oper.	drn	nO
Mains power loss stop	StP	nO
Fault inhibit	InH	nO
Reset oper. time to zero	rPr	nO

COn - COMMUNICATION Menu

Parameter	Code	Factory Setting
Modbus drive address	Add	1
Modbus transmission speed	tbr	19200
Modubus commun. format	tFO	8E1
Modbus timeout -s	ttO	10 s
CANopen drive address	AdCO	0
CANopen transmisson speed	bdCO	125
CANopen error registry	ErCO	
Forced local mode	FLO	nO
Ref & ctrl channel selection in forced local mode	FLOC	AI1 ATV31••••••A: AIP

SUP - DISPLAY Menu

Parameter	Code	Factory Setting
Speed ref. from remote -Hz	LFr	
Internal PI reference -%	rPI	
Freq. ref before ramp -Hz	FrH	
Output freq. at motor -Hz	rFr	
Output value in cust. units	SPd1 SPd2 SPd3	
Motor current -A	LCr	
Motor power -%	OPr	
Line voltage -V	ULn	
Motor thermal state -%	tHr	
Drive thermal state -%	tHd	
Last fault	LFt	
Motor torque -%	Otr	
Operating time -hr	rtH	

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