AN ATTEMPT TO DESIGN LOW COST EFFECTIVE INFUSION DEVICE FOR DELIVERING OF DRUGS DEPENDING ON THE HEART RATE

A THESIS SUBMITTED IN PARTIAL FULFILLMENT

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in

Biomedical Engineering

By

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CERTIFICATE

This is to certify that the thesis entitled, "**An Attempt to Design Low Cost Effective Infusion Devicefor Delivering of Drugs Depending on the Heart Rate**" submitted by **Pratik Das (107BM004),**in partial fulfilment for the requirements for the award of **Bachelor of Technology Degree** in **Biotechnology and BiomedicalEngineering** at National Institute of Technology, Rourkela is an authentic work carried out by them under my supervision and guidance.

To the best of my knowledge, the matter embodied in the thesis has not been submitted to any other University/Institute for the award of any Degree or Diploma.

Date: 13/05/2011

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ABSTRACT

Drug administration and accurate fluid infusion is important for optimum management of critically ill neonate. For thus we need continuous and controlled administration of drugs. This method is preferred mode of therapy for acute care. These drugs are continuously sent to the human body intravenously. The various medications used are inotropic agents, vasodilators, aminophylline, insulin, heparin. In this thesis we are basically controlling the flow rate of drug by measuring the heart rate. To detect heart rate we use plethysmography. In this we are actually detecting the pressure wave that is generated when the heart starts pumping. For this we use reflective type photoplethysmograph. For detecting the pulse waveform we can use our finger, the ear lobe, and the foot. In our thesis we have designed the sensor circuit which has a light source for illuminating the target object and a detector for receiving that light from that object. The signal thus obtained is conditioned by using low pass filters and microcontrollers are used for measurement of pulse rate. Then the stepper motor is integrated with the micro controller with the help of motor driver. The micro controller is programmed in such a way that for a particular value of heart beat, there will be preset value of the speed of motor. Once that range of heart value is obtained, depending on the speed of motor, a mechanical set up is prepared which will allow the flow of fluid from the IV bottle. In this way we are actually preventing overinfusion of drug into the human body. This is specially done for those drugs with short half lives, so as to maintain adequate amount of serum concentration.

Key Words: plethysmography, infusion, heart rate, microcontroller

CONTENTS

Chapter 1

Introduction

Infusion pumps are used for delivering fluid, nutrients, and medication to a patient's vital organs. For example fluids including blood plasma, antibiotics, narcotics for pain relief, chemotherapy drugs and residential administered insulin for diabetics can be delivered by this infusion pump. It is basically used intravenously but sometimes can also be used as subcutaneous, arterial and epidural infusions. Infusion pumps can deliver fluids in a way that would be basically expensive or unreliable if it is performed manually by nursing staff. For example, they can deliver as little as 0.1 mL/hour injections (too small for a drip), injections every minute, injections with repeated boluses requested by the patient, up to maximum number per hour, or fluids whose volumes vary by the time of day.

These infusion pumps produce high but controlled pressures. They inject controlled amounts of fluids subcutaneously basically underneath the skin, or epidurally just within the surface of the central nervous system- a very popular local spinal anesthesia for childbirth. As the entire supply of blood in a human body completely circulates within 60 seconds, so the substances delivered into the circulatory system are distributed rapidly by this pump. There are two basic types of infusion pumps. The first one is syringe displacement in which the plunger is slowly depressed by electromechanical means at a controlled rate. It can be used for Patient Controlled Analgesia (PCA) treatment. The second type is of basically peristaltic type which is used to administer drugs at a particular rate.

Chapter 2

Literature review

2.1 <u>Types of infusions:</u>

- *<u>Continuous infusion</u>* – it consists of small drops of infusion between 500 nanolitres and 10000 microlitres which depends on the pump's design and the rate of these drops depending upon the programmed infusion speed.
- *<u>Intermittent infusion</u>*-it has a high infusion rate, that is alternating with a low programmable infusion rate so as to keep the cannula open. The timings are programmable. This type of infusion is often used to deliver antibiotics and other drugs that irritate a blood vessel.
- *<u>Patient-controlled infusion</u>*- it is done on-demand, usually with an already programmed ceiling to avoid intoxication of drugs. The rate of infusion is controlled by a pressure pad or button that can be activated by the patient himself. It is the method used for patient-controlled analgesia (PCA). This process include repeated small doses of opioid analgesics which are delivered with the device that is programmed to stop delivery before a dose that may cause hazardous respiratory depression.
- *<u>Total parenteral nutrition</u>*-this type of infusion requires an infusion curve similar to normal mealtimes.

2.2 <u>Desirable Specifications:-</u>

A good infusion pump should be

- electrically safe and portable.
- accurate and consistent delivery of drugs.
- easy to set up and use
- robust and reliable
- can be powered with battery and mains both
- proper use of alarms.
- capable of detecting line occlusion.

- should display rate of infusion and volume infused clearly.

2.3 <u>Types of infusion pumps:</u>

- gravity controlled pumps
- position displacement pumps

2.3.1 <u>Gravity controlled pumps:</u>

These pumps include drip rate regulators which rely solely on gravity that regulate the rate of flow. There are systems which are supplied with standard intravenous fluid administration sets which are called dial-a-flow or dosiflow. Rate of infusion is also dependent on pressure difference across the valve, that is height of fluid or venous pressure obstruction. There is also drip rate controller which relies on gravity to provide the infusion pressure. A drop sensor is attached to the drip chamber which usually senses the drip rate and shows it on the display screen. This system uses a feedback mechanism that can adjust the drop rate to the preset value and it doesn't eliminate the error occurred due to changes or variation in drop size.

2.3.2 <u>Position displacements pumps:</u>

As the name suggests it provide a positive displacement of fluid with the help of a motor. The mechanism is such that it prevents infusion of large amount of air or subcutaneous infiltration. These pumps are based on the concept of peristaltic or piston motion.

This pump uses linear or rotary methods. The rotator type peristaltic pump contains rollers on a wheel, as a result it compresses the tubing and hence the fluid can move towards the patient in the tube. The linear mechanism of peristalsis include finger like projections which compresses the tubing against a stationary back plate sequentially and causes a unidirectional flow of fluid.

(i)Drip rate pumps:-

These pump provide pumping mechanism which makes them different from gravity dependent drip rate controllers. They replace gravity as the main force. These pumps uses drip sensors which count the number of drops so as to have a controlled infusion rate. These sensors are attaches to the infusion sets. The speed is dependent on the feedback control from drip sensor which actually counts the number of drops. In these types occlusion pressure is important which is always set at 100mm Hg and sometimes over 200 mm of Hg. The high occlusion pressure can dismantle the system causing the tube to burst. There is a serious drawback of these pumps which happens when there is an extravasation as the pump keeps on pumping fluid into the tissues. For these types of problems volumetric pumps are used.

(ii)Volumetric pumps:-

These types of pumps eliminate the drawback in drip rate pumps. It uses piston type action and peristaltic pumping type action. It uses infusion set which increases the cost of each infusion.
It delivers accurate volume of infusion as it precisely regulates the set of flow rates. These pumps runs on ml per hour.

Volumetric infusion pumps can calculate the amount of fluid going into the body. The volume can be calculated by microprocessor depending on the size of drop and the diameter of tubing. These pumps work on mains and also rechargeable batteries. It has an alarm and warning buzzer which work simultaneously when there is a bubble inside the tube. As a result the pump stops immediately. It has the alarms to show that infusion is completed. it also shows when the battery voltage is low. The occlusion in the flow can be detected. These pumps have the capability of delivering precise quantities of fluids at very slow and fast rates. They are more expensive than the drip rate pumps. They require special IV infusion sets of standard size. So in a way they are actually costly but precise volume can be achieved.

(iii) Syringe pumps:-

These type of syringe pumps are most commonly used for delivery of intravenous drugs. This pump uses a gear reduction mechanism and lead screw for the flow of fluid. This pump doesn’t require any tubing and are extremely accurate. There has been pumps developed by which a nurse can set the weight of the patient, the drug concentration and the infusion rate in the mg per kg per minute. Then the calculator in pump calculates the infusion in ml per minute.

Specifications of syringe pump include:-

1.Microprocessor-controlled stepper motor should be used for accurate delivery.

2.It should have capability of functioning on mains and rechargeable Ni-Cd batteries.

3.It must have few controls as power switch, start switch and reset/stop switch

4.It must have a range of 0.1-99.9 ml/hr with up-to 0.1 ml/hr increments

5.It should display alarm/error messages, infused volume and infusion rate

6.It should have alarms for dis-engagements of syringe clamp, any occlusion, when syringe becomes empty or plunger is out, low battery and mains power failure.

Advantages of syringe pump:-

- Inexpensive
- Reliable and portable
- Accurate amount of volume infused
- Delivery of air bubble is impossible
- Used for small volume infusion

Disadvantages of syringe pump:-

- Can’t be used for large volume

- Comprehensive alarm system not provided.

(iv)Multichannel pumps:-

These are those multi-channel pumps which allow delivery of drugs by 2 or 3 infusions simultaneously. The problem with this system is the probability of incompatible mixings.

(v)Ambulatory pumps:-

These are basically designed for those persons who needs to have it for longer period of time and they have a good alarm and display systems. It uses a linear peristaltic mechanism and have a fluid container that looks like a cassette. They are basically pocket size pumps.

2.4 Requirements for infusion pump and portable medical designs:

An infusion pump has mainly three major components: the fluid container, the catheter system for transfer of fluid into human body and a device that includes electronics with a mechanical mechanism to produce and regulate flow. The regulation is important for the body as it might cause underinfusion or overinfusion if not controlled properly. Both the process can cause serious toxic side effects.

A pump connected with a stepper motor is used to provide the force for the fluid to displace the contents into the volumetric chamber. Depending upon the stepper motor we can influence the flow uniformity. If the volume is not uniform, then we can control through the software.

A processor or microcontroller with advanced GUI (graphical user interface) can be used for monitoring the patients. It also helps in detecting complications and generating an alarm.

2.4.1 Pump mechanism:-

Steppers motors are used to have a controlled flow rate. We can use DC motor with angular position sensors and Hall effect sensors. In this design the motor drive actuators drive the fluid depending upon revolution of the mechanism. The motor drive circuits can be fed onto closed –loop control system to reduce the power consumption and also to adjust the motor drive voltage. Different types of amplifiers, operational amplifiers, comparators and filters are used to make closed-loop control systems.

2.4.2 Power supplies:-

Switch-mode voltage regulators are used to maximize battery life. Low drop-out linear regulators (LDOs) are used in those places where low efficiency can be tolerated or in those parts of circuit where the output voltage of LDO is not lower than the input voltage which results in high efficiency. Digital converters (DACs) are used in power supplies when on-the fly programmability is needed.

2.4.3 Battery management:-

Sometimes we need to transport patients while they still remain on the IV, there the infusion pump should be able to operate from battery for several hours. Rechargeable batteries should be used. The pump should not stop due to failure of battery power. For this an accurate battery fuel gauge is used.
Portability:-

These infusion pumps needs to be portable as these patients are taken care in hospital and home. It should be portable enough to be used in ambulance. It should be light weight, small and battery powered.

2.4.4 User interface:-

These user interface are used to program the flow rate. It also helps in displaying parameters such as amount of fluid being infused, patient information, the life of battery remaining, different types of error messages, alarm conditions. Flow rates are designed for a wide range from 0.01ml/hr to 999ml/hr. There may be errors due to the programming so sophisticated software should be used.

2.4.5 Self test and system monitoring:-

All infusion pumps should undergo power –on self test(POST). This includes tests for all processors, circuitry, indicators, displays and functionality of alarm. Microcontrollers must be held in reset until all power supplies are stable. Analog to digital converters (ADC) are used for sensor readings such as temperature, motor loading, IV line pressure and battery voltage. After POST we must ensure that pump is operating properly during patient use. These pumps shows high efficiency so fans are not needed. These pumps must be splash proof so it is difficult to put them in openings for airflow.

2.4.6 Alarms:-

The infusion pumps require alarm that can be heard and seen properly. Audible alarms are basically simple beepers. Bicolour/tricolour (red/orange/green) LEDs are used as visual indicators.

2.4.7 Time keeping:-

As the patient care is critical so every event has to be done in a perfect time. A small lapse in time may lead to problems to the patient. Every change of configuration like pump door opening or closing, AC power disconnect, battery error etc, every key press, every start and end of infusion and every fault condition reported should be logged and time stamped.

2.4.8Electrostatic discharge:-

While keeping the patient in hospital there is a chance for electrical leakage to the patient. To avoid this the developers needs to meet the requirements of the IEC 60601-1 product safety standard for electrical medical equipment.

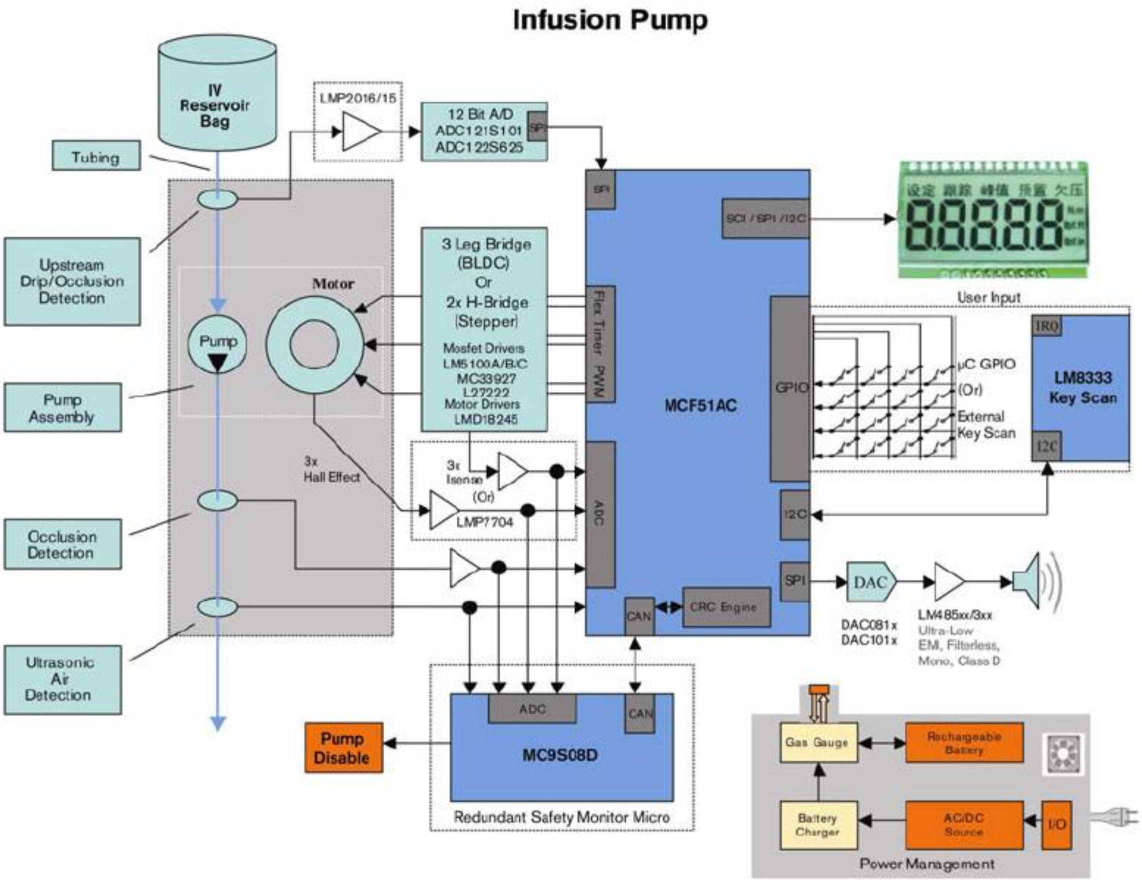

Figure 1: Block diagram of infusion pump (courtesy TERUMO manual)

The first attempt on intravenous medicine was made on 1492. Then slowly this branch of science grew up and the first working infusion device was made in 1658 by English architect Christopher Wren[15]. Then experiments were done on this and better needles were developed. These experiments lead to some deaths and it was closed for some time. Then the bans were lifted and the prototypes of these pumps were made for controlled flow of drugs intravenously. Then in 20th century we got vacuum bottles in place of plastic bags which reduce the air embolism. The major developments happened in 1970s when Dean Kamen[1] invented the first ambulatory pump. This pump gave patients to move while receiving treatment. It helped diabetic people who needed round the clock injections. It also helped in delivering precise doses at regular timed intervals. The infusion pumps which are of this generation have built in drug libraries and has a electronic record for maintaining all the alerts. These pumps give alarms if the line is kinked. The smart pumps are used to prevent medication errors for high alert drugs used for critical care patients.

The external infusion pump is a portable device that provide continous ambulatory drug infusion for an extended time period. It is usually of size of a cassette player that is portable and is worn on the belt around the patient’s waist. This actually runs on battery. The drug reservoir refilling is non invasive. Drug delivery routes in these pumps are intravenous, sub cutaneous, epidural, intraventricular and intrathecal routes. It is used to administer morphine and other parental analgesics which are used for the treatment of severe and chronic cancer pain.

The Medicines and Healthcare products Regulatory Agency (MHRA) had reported an annual increase in patient safety incidences involving infusion devices. After 10 year review of such incidents Smith [19] in 2002 found that in more than 50% of incidents there is no fault in the equipment. 19% of these incidents occur due to user error.

Several studies were done over the years to study the continuous infusion of medications which is required for treatment of radiculopathy. The clinical trial were done for infusion of anaesthetic drug by epidural catheter with respect to single bolus injections for the treatment of cervical radiculopathy. The study showed that epidural catheters were more efficient than single injections.

Pauza et al[4] also studied radiculopathy with the epidural catheter and infusion pump. He found that infusion pump is much more effective than the catheter system. It also didn’t had that much significant complications.

In another trial Kim et al[2] studied patients using continuous epidural block with steroids and anaesthetics that uses a multiday infuser which is connected to epidural catheter. It also didn’t had that much significant complications.

An implantable infusion pump is used to provide continuous or intermittent drug infusion. The drug delivery routes include sub cutaneous, epidural, intravenous, intrathecal. These pumps are placed in the intraclavicular fossa and a catheter is threaded into a desired position. Intrathecal and epidural catheter positions are intraspinal. The driving of drug includes mechanisms such as peristalsis, osmotic pressure, combination of osmotic pressure with an oscillating piston and fluorocarbon propellant. It is used for the treatment of primary liver cancer, head neck cancers, severe chronic intractable pain, and metastatic colorectal cancer.

In a double blind study, Banerjee and associates (2008)[32] assessed the effectiveness of infusion pump for low dose bupivacaine. The results of this study neither supported nor rejected the use of infusion pumps.

2.5 Stepper motor:-

A stepper motor is an electromechanical device that is used to have discrete mechanical movements. It converts electrical pulses in form of voltages to step wise mechanical movements. When the electrical pulses are applied in a proper sequence, the shaft of motor rotates in steps and causes increment in steps. The direction of motor shaft rotation depends proportionally on the sequence of the applied pulses. The length of rotation is directly proportional to number of input pulses given. The frequency of input pulses determines the speed of the motor shaft rotation.

2.5.1 Advantages of stepper motor:-

- The degree of rotation is directly proportional to the input pulse.
- It gives an excellent output to starting or stopping or reversing.
- It is very much reliable as there are no brushes in the motor. So the life of motor is long and depends on life of bearing.
- We can obtain a wide range of speeds as speed depends on frequency of input pulses.
- The response of motor towards digital input pulses provides open loop control which makes the motor simpler and less costly to control.
- Low speed synchronous rotation can be achieved with a load that is couple to the shaft directly.
- In standstill position the motor has full torque.
- There is a precise and repeated movement of motor which increases the accuracy

2.5.2 Disadvantages of stepper motor:-

- These are not easy to operate at extremely high speeds.
- The resonances has to be controlled otherwise it might affect the motor.

2.5.3 Open loop operation:-

It has characteristics of accurately controlling in open loop system. It means no feedback information is needed about the position. It eliminates the use of optical encoders which are basically the feedback devices and the need for expensive sensing. The position can be known by keeping the track of input pulses.

2.6 Types of stepper motor:-

- Permanent magnet type stepper motor
- Variable reluctance type stepper motor
- Hybrid type stepper motor

2.6.1 Permanent magnet type stepper motor:-

It is sometimes referred as a “tin can” or “can stock” motor. It is a low cost and low resolution type motor with typical angles of 7.5° to 15°. These have permanent magnet in the motor structure. It doesn’t have the teeth like the VR motor. As a result the rotor is magnetized. These are magnetized with alternating north and south poles which are placed in a straight line parallel to rotor shaft. These motors have improved torque characteristics as compared with the VR type because these rotor poles provide increased magnetic flux intensity.

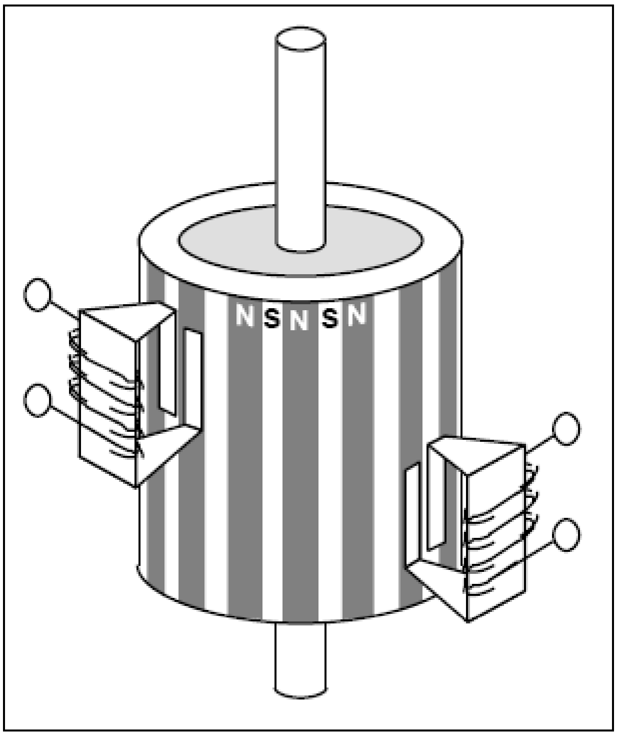

Figure 2: principle of a PM or tin-can stepper motor

2.6.2 Variable reluctance type stepper motor:-

This type of motor has been used for a long period of time. It has a structure which is one of easiest to understand. It contains a soft iron multi toothed rotor and a wound stator. When the stator windings are given the DC current, the poles gets magnetized. When the rotor teeth are attracted to the energized stator poles, the rotation occurs.

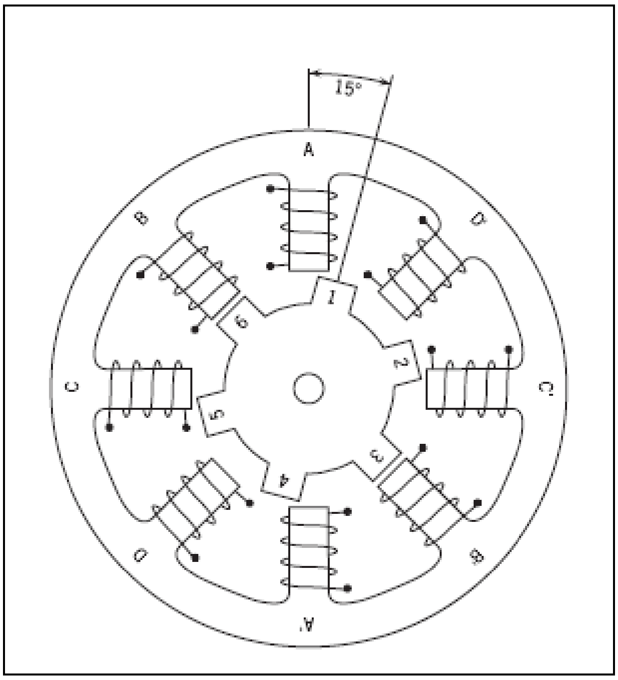

Figure 3: cross section of variable reluctance motor

2.6.3Hybrid type stepper motor:-

This type of motor is more costly than the permanent magnet stepper motor. It provides better performance than permanent magnet stepper motor with respect to step resolution, torque and speed. The degree of rotation range from 3.6° to 0.9°(100–400 steps of revolution).this is basically the hybrid of VR and PM type stepper motor. The rotor is similar to VR motor, basically multi toothed, has an axially magnetized concentric magnet at its shaft. Thus it provides a better path which helps in having magnetic flux at preferred locations in air gap thereby increasing the detent, holding and dynamic characteristics of motor as compared to VR and PM motors. PM and hybrid are most commonly used. For an application first use PM motor otherwise use the hybrid one. It provides low inertia and a optimized magnetic flow path with no coupling between the windings.

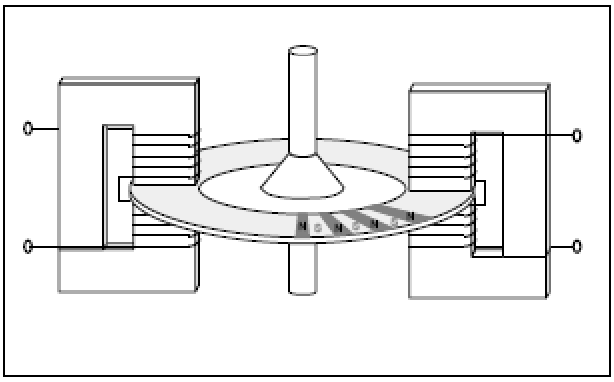

Figure 4: principle of disc magnet motor

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The stepper motor can be classified in terms of size and power. For example size 11 stepper motor has a body diameter of approx 1.1 inches. Similarly a size 23 stepper motor has a body diameter of 2.3inches. The length of the body varies from motor to motor. The available torque output from the motor of précised size will be incremented with an increase in body length. Power required for this type of stepper motor range from 10-20 watts .to calculate this we use PE = V x EI. The motor is always rated at power dissipation level where the motor case rises 65°C. The motor should be used at its maximum power dissipation so that it becomes efficient from size/output power/cost point of view.

2.7 When to use a stepper motor:-

It is used in those places where controlled movement are there. It is used in printers, plotters, high end office equipments, fax machine as it provides control in rotational angle and synchronism.

Torque generation depends the step rate, the driving current in the windings and the drive design or type. The different types of modes used are the wave drive (1 phase on) , full step drive (2 phases on), half step drive (1 and 2 phases on) and micro stepping(continuously varying motor currents).

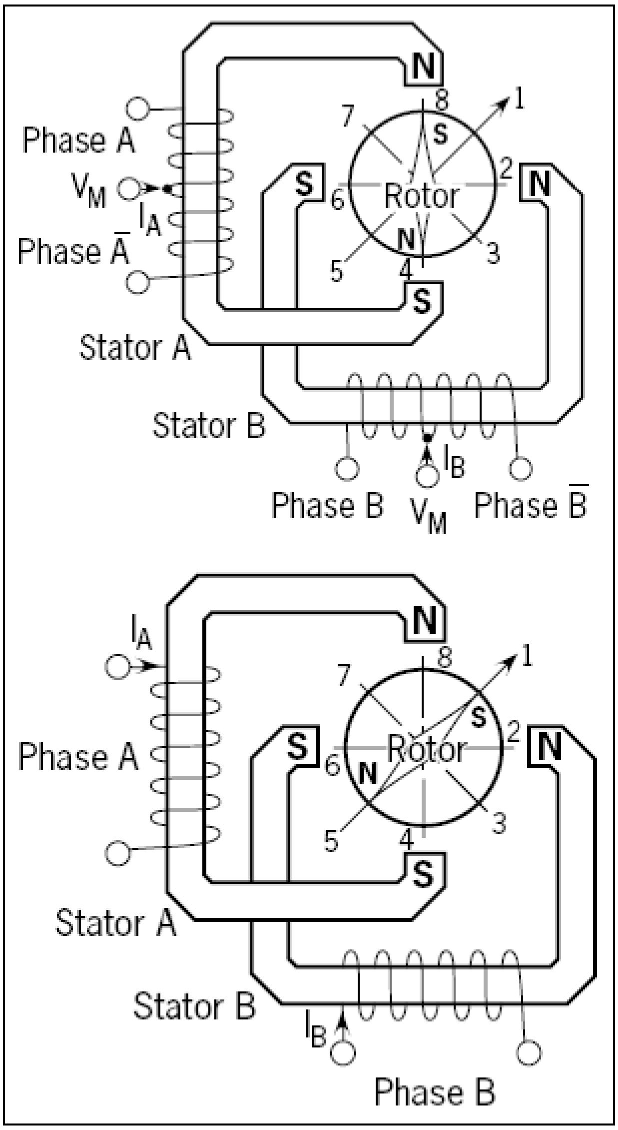


Figure 5: unipolar and bipolar stepper motor

2.8 Microcontroller:-

A microcontroller is a single-chip computer. The microcontroller can store and run a program. It contains a CPU(central processing unit), RAM(random-access memory), ROM(read-only memory), serial and parallel ports, timers and I/O lines(input/output lines). Single chip computer actually means the integrated circuit chip confines the entire computer system in it. There are different types of microcontroller such as 8051, 89C51, Atmega 16, Atmega16L etc. Basically we are using Atmega 16 for this application.

2.9 Features of Atmega16:-

The ability of storing and running a program makes the microcontroller versatile. It has the ability of dealing and performing math and logic functions which makes them a sophisticated logic and electronic circuits. Each pin of the microcontroller has multiple functions. Atmega16 has four 8-bit I/O PORTS which can act as input or output.

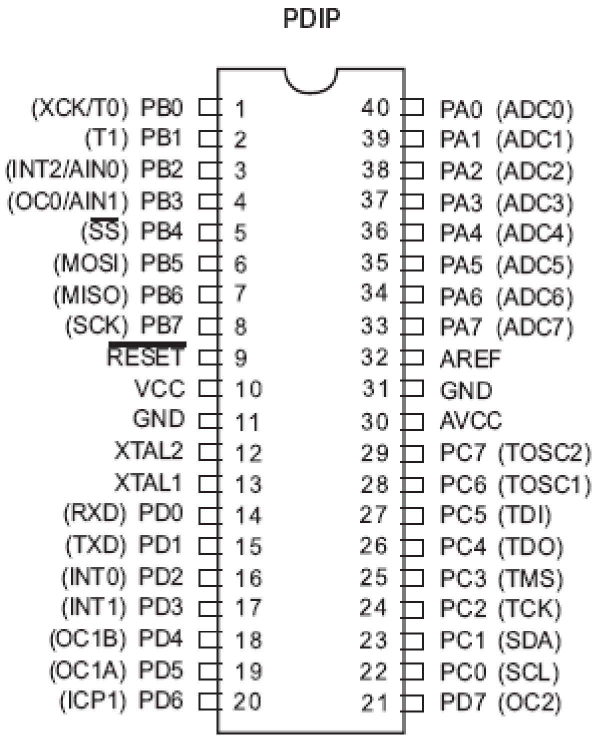


Figure 6:Atmega 16 microcontroller

2.10 Voltage regulators:-

These regulators produce a fixed DC voltage from a variable DC. It can also be used to get low DC voltage from high DC voltage in circuits. For example we convert 12V to 5V using 7805. There are two types of voltage regulators.

(i) Fixed voltage regulators (78xx, 79xx)

(ii) Variable voltage regulators (LM317)

Fixed voltage regulators can also be of 2 types:

(i) Positive voltage regulators

(ii) Negative voltage regulators

2.11.1 Positive voltage regulators:-

These are basically 78xx voltage regulators. The xx shows the voltage they can produce. The most used voltage regulators are 7805 and 7812. An input of 6-14 volts will give 5 volts of output when given to 7805. If we give more than 14 volts, then the IC will heat up and it will burn off and the IC will get damaged. If we give less than 6 volts of input, it won't give 5 volts of output.

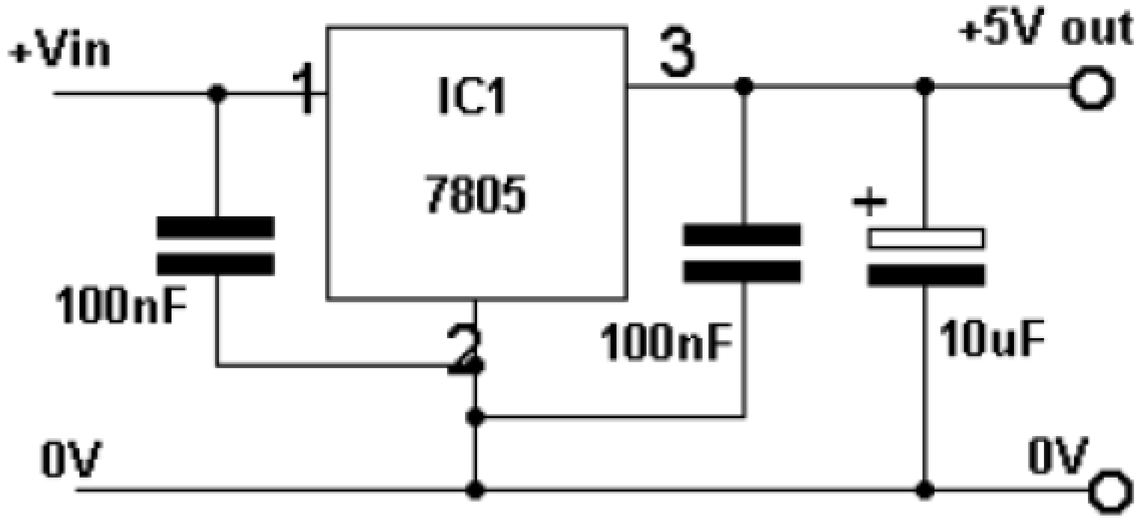


Figure 7: circuit diagram of positive voltage regulator

The diagram above shows how to use 7805 voltage regulator. The coupling capacitors are used for voltage regulation. The mainly available ICs are 7805, 7809,7812, 7815 and 7824.

2.11Motor drivers:-

These are basically switches that are used to drive the stepper motor. They are formed from various switching arrangements which make it very easy to control the direction and the speeds of the motor.

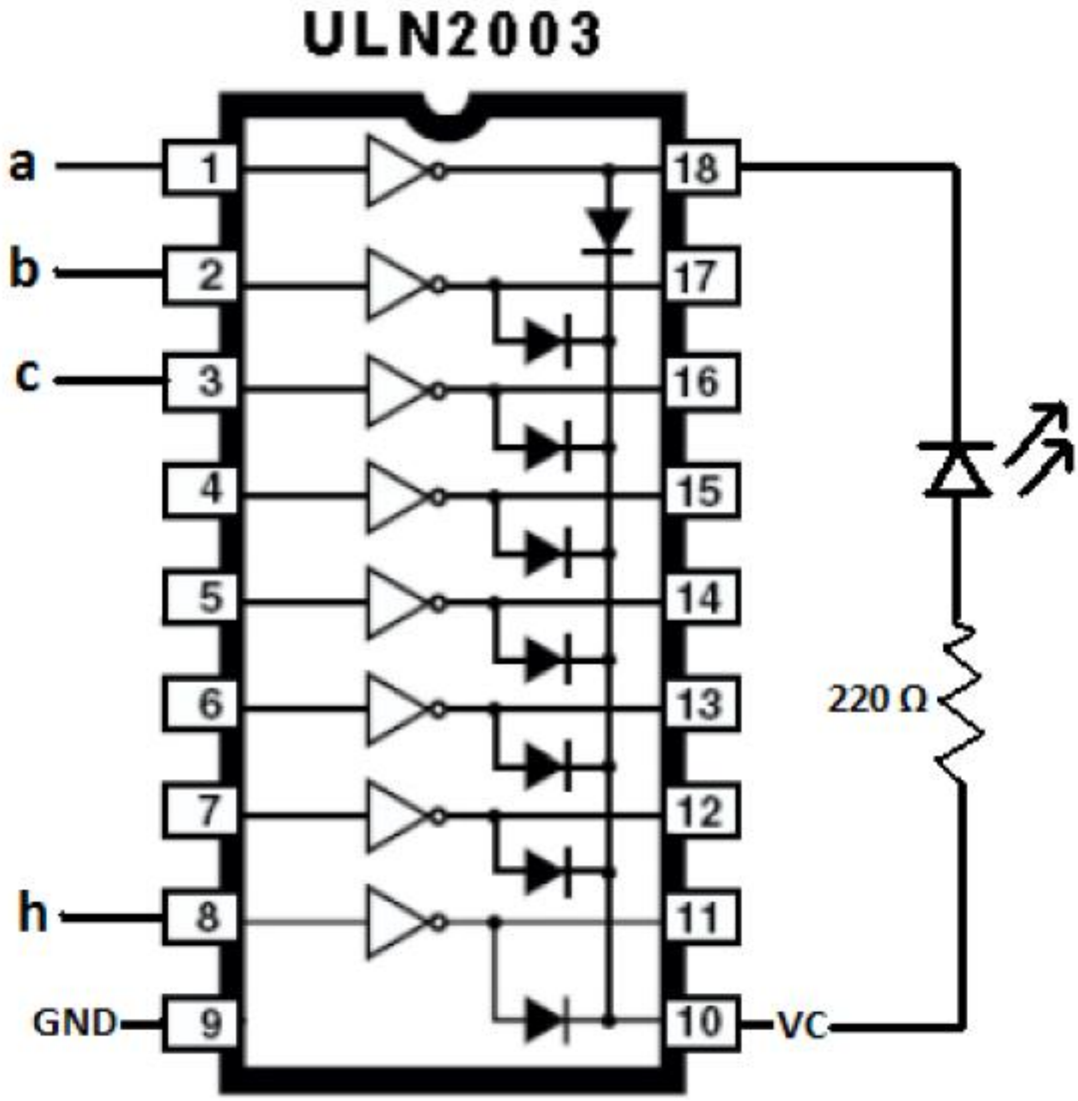


Figure8: block diagram of motor driver

This IC is used to drive an unipolar stepper motor. When we apply **LOGIC 1** at **a** (PIN1) then due to the not gate present a GND appears at PIN 18. Now look at the LED on one side **VC** and on other **GND,** so the **LED** glows.

But if we apply **LOGIC 0**at **a** (PIN1) then VC appears at PIN 18, now on **both** the sides the **LED** has **VC** so the LED won't glow. The same is for **a, b, c…., h** or **1, 2, 3…….., 8.**

If we connect the output of ULN2003 and the VC, then it will either run or stop the motor. But if we want to reverse the direction of motor then we have to use H-bridge drivers.

2.12 Objective:

The basic motivation of designing this model is to allow the delivery of drugs in a controlled way depending on the heart rate. For a patient whose heart rate is normal there is no need of administration of drugs but in case of increase or decrease of heart rate the administration of drugs should be there to make it normal.

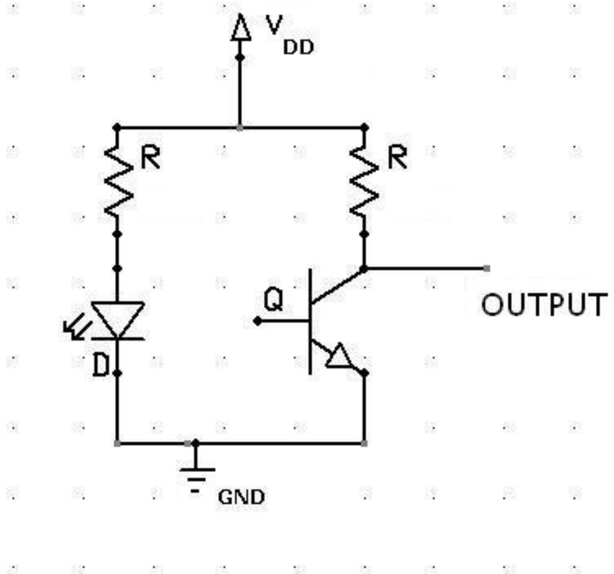
Chapter 3

Materials and Methods

3.1 Sensor circuit:

The sensor circuit contains an IR emitter, IR detector and resistors. Then the photodiode and IR Light emitting diode were placed parallel to each other. When the voltage is applied, there is the emission of light through the IR LED. This light is then reflected to the photodiode which converts it into electrical current.

Figure 9- sensor circuit diagram(left)



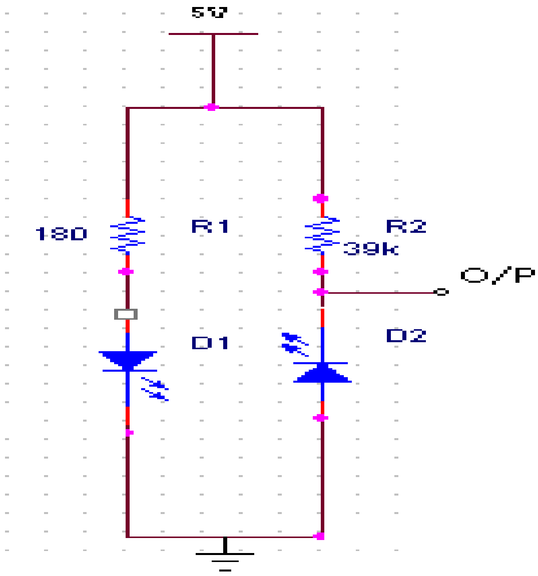


Figure 10 – the circuit diagram of sensor circuit using P-spice(right)

The light source is placed to illuminate the target object. The object is actually area of tissue of the human body. The light source emits light of a particular wavelength. The light is then received by the photo detector. The light that is received may be of one or more light which gets transmitted through the object, which actually depends on the target object, relative positioning of emitter and the photodiode. The light which will be reflected from the surface of target object depends on the photo detector within the target object and positioning of light source. There may be a chance that light is also scattered or reflected by the presence of fluids in the target object. The electrical current produced by the photo detector determines the amount of light incident on its active region as it is proportional to the amount of light.

In this the D1 is the IR emitter and D2 is the IR detector. The resistors are R1 and R2. This is basically implemented using the bread board. The whole circuit diagram made by using bread board is in next page.

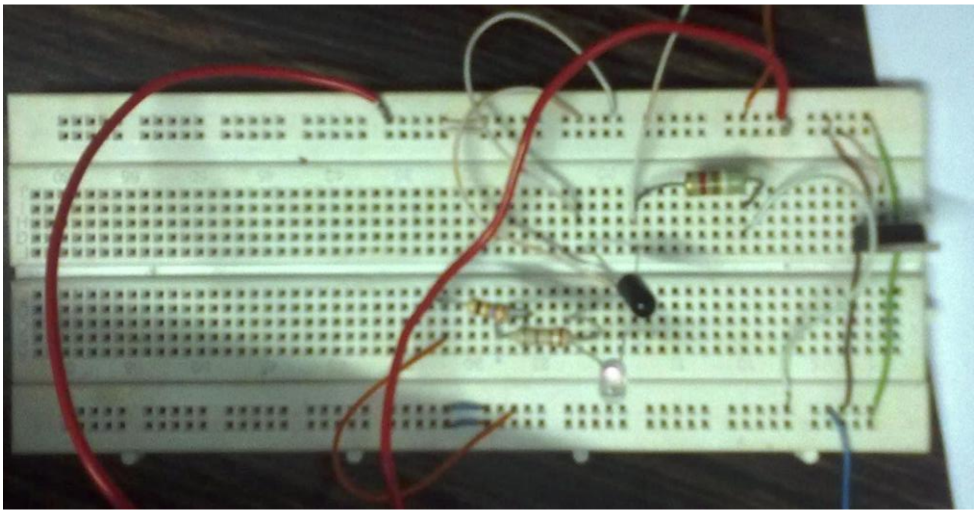


Figure 11 – the sensor circuit using bread board

After the circuit is done then the analysis of sensor circuit is done using a cathode ray oscilloscope (CRO). The CRO will give us the respective photoplethysmogram(PPG). This PPG is basically the heart rate graph which contains both the DC and AC components. Now basically the heart rate is measured from the AC components. So we have to eliminate the DC components. For this we need the signal conditioning or filtering of the circuit.

3.2 **Signal conditioning**:

The signal conditioning circuit basically contains two active low pass filters. The cut off frequency of both is about 2.5Hz. The frequency obtained from plethysomgraphy is generally around 2-5 Hz so for low pass filters the cut off frequency is about 2.5Hz. So maximum 150bpm of heart rate can be measured. The operational amplifier IC which we will be using is LM358. This is basically a dual OpAmp chip which can function at single power as well as dual power supply. It provides large output swing. This filtering process basically blocks the higher frequency noises from the input signal. The capacitor 1uF is used to block the DC components in the signal. These capacitors are present at the input of each stage. The amplifiers provide the required amount of gain to the weak components coming from the sensor circuit to make it a pulse. The gain of both the filters is 117. Every time a heart beat is detected a LED blinks which is connected at the output.

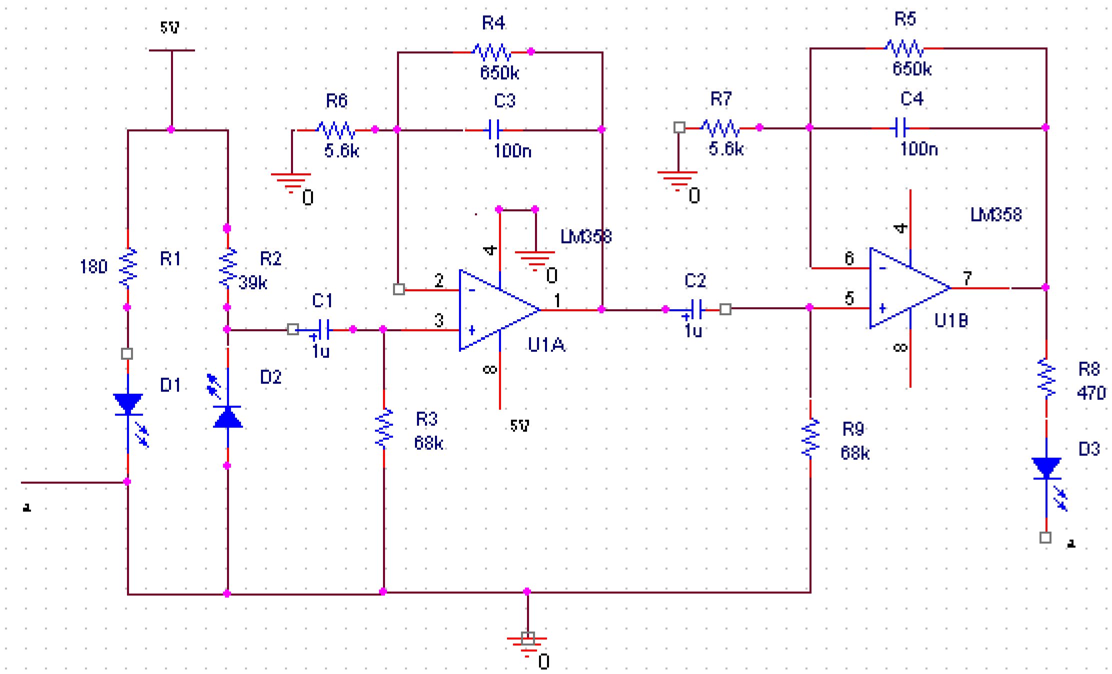


Figure 12: <u>the circuit diagram of filter circuit using P spice</u>

3.3 **How a stepper motor works:-**

These stepper motor contains electromagnets which are in the stationary portion that actually surrounds the motor and also a permanent magnet rotating shaft that is called stator. The figure below shows how the stepper motor rotates. At position A, the rotor is starting at the upper electromagnet which is active now as the voltage is applied on that. Now for clockwise motion the upper electromagnet will be deactivated and the right electromagnet gets activated resulting in the rotor to move 90° clockwise. The rotor will align itself with the active magnet. This process then goes on for the whole cycle and for all electromagnets till we reach the starting position.

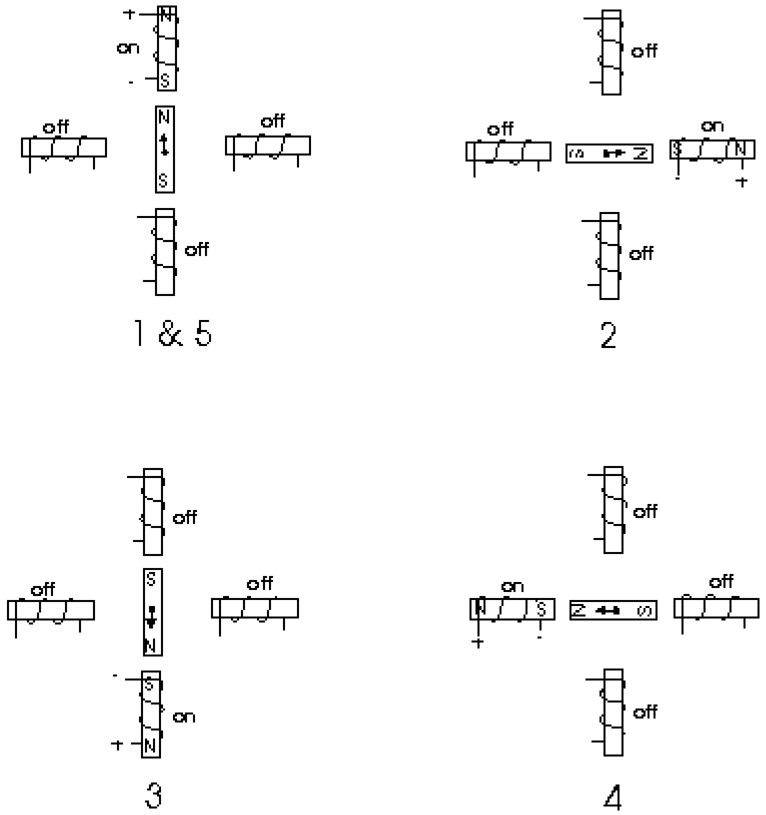


Figure 13: <u>full step sequence working of stepper motor</u>

In this example we are actually using a motor of resolution 90°. The average motor resolution is much higher than this. It is basically amount of degrees rotated per pulse. If we get a motor of resolution 5 degrees will move the rotor 5° per step thus requiring 72 pulses to complete the full revolution.

Now we can increase the resolution by half stepping. We can do this by switching activating both the electromagnets instead of activating one. This will cause equal attraction thus doubles the resolution. In the 2nd position both the top and right electromagnet are active resulting in equal attraction between the two active poles. Thus the rotor remains in an angular position. In the 3rd position the rotor is attracted towards the right as the top electromagnet is deactivated. This process is repeated for the complete rotation.

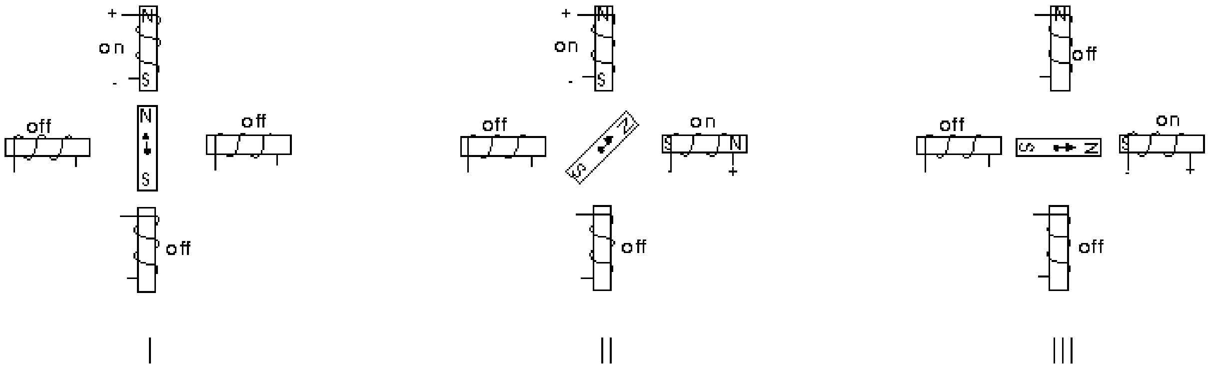


Figure 14:half step sequence working of stepper motor

In this we are actually running the stepper motor in full step sequence. The motor driver ULN 2003 are used to run the stepper motor. The 4 input pins of microcontroller are connected to the motor driver pins and the output pins of motor driver are connected to the stepper motor as shown in the figure.

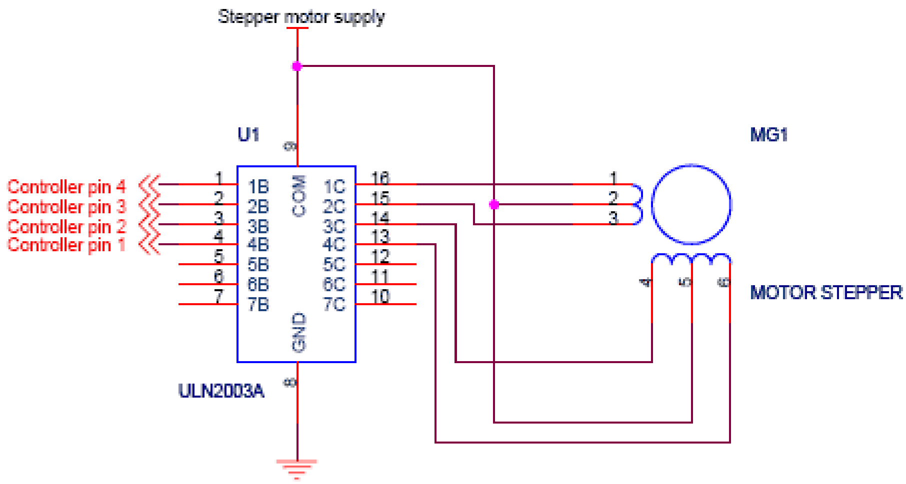


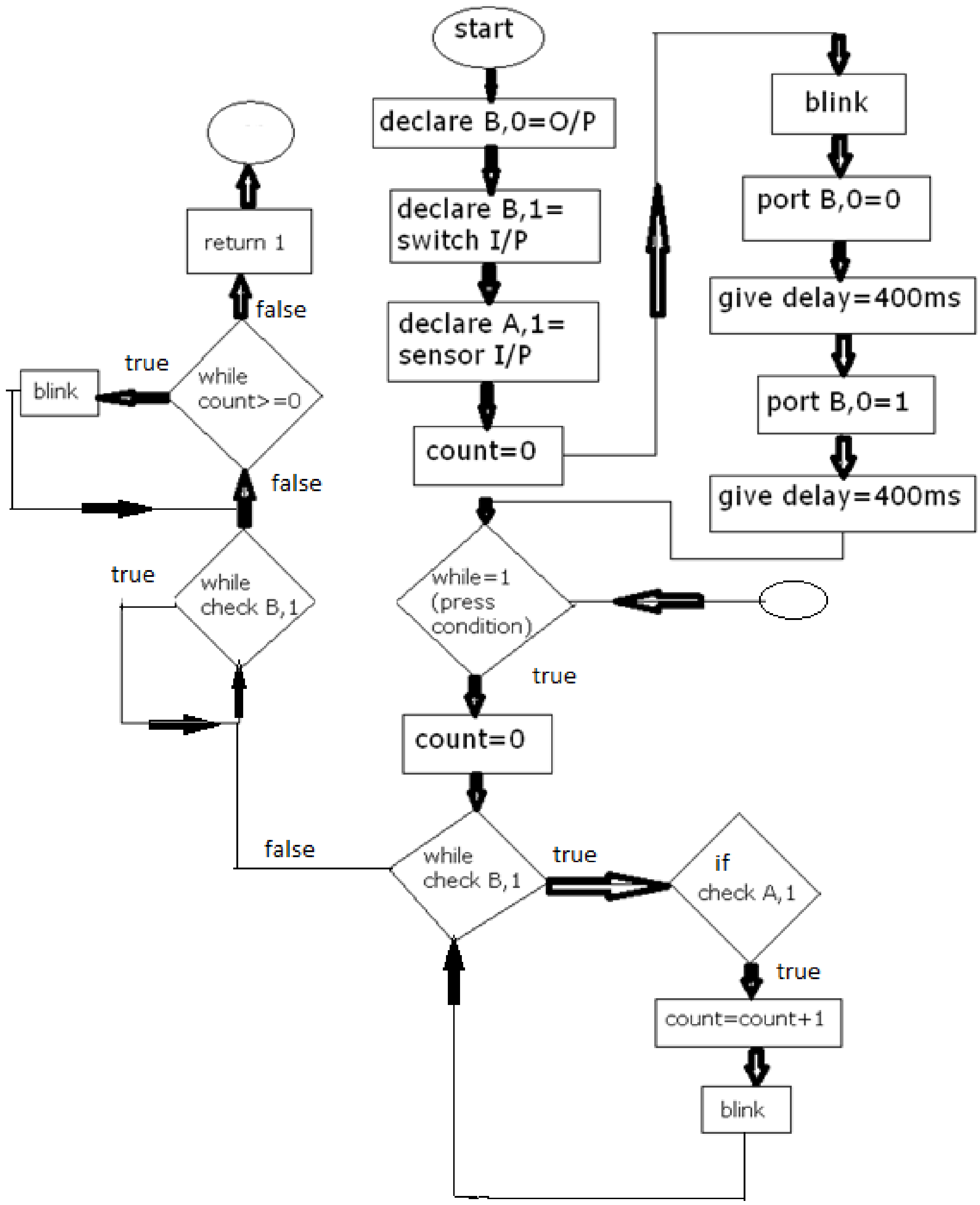
Figure 15: motor driver connection with microcontroller and stepper motor

Figure 16: the full mode sequence of stepper motor

step	A	B	A’	B’
0	1	1	0	0
1	0	1	1	0
2	0	0	1	1
3	1	0	0	1

Here 1 means the stator which is active. The stators are arranged in an order. In the 1st case the controller pin 4 is active which makes A and B are active. Similarly when pin 3 it makes B and A’ active and the process goes on making it complete one revolution.

3.4 Following is the flowchart of the counter logic used:



This flow chart is implemented in C language.

3.5 Algorithm for stepper motor programming

```
Start
  Initialize DDRA = 0xff;
  Initialize DDRB = 0x00;
      While(1)
          If(PINB & 0x01== 1)
          Assign PORTA = 0B00001100 ;
          Delay 500ms;
          Assign PORTB = 0B00000110 ;
          Delay 500ms;
          Assign PORTB = 0B00000011 ;
          Delay 500ms;
          End if
     End while
  Return 1
End
```

Chapter 4

Result

When fingers are placed on the light source which is basically the IR emitter, then the photoplethysmogram(PPG) is obtained on the cathode ray oscilloscope(CRO). The generated output is shown below.

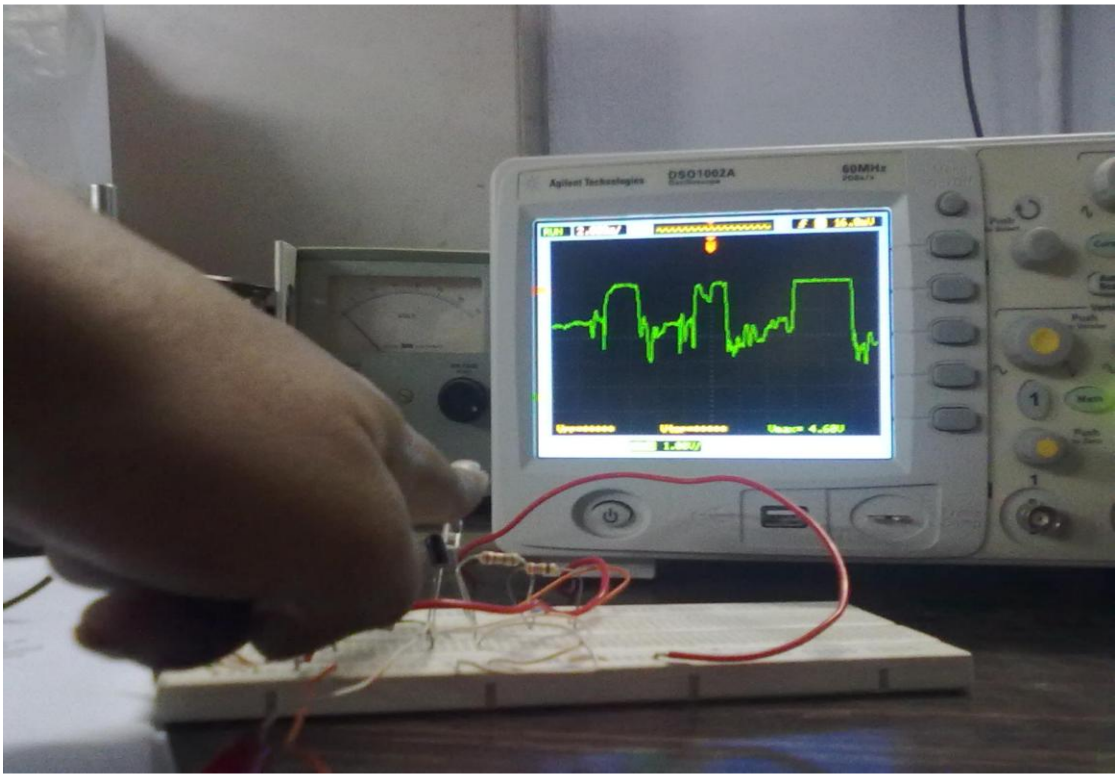


Figure 17: the output from the sensor circuit

We see that there are AC and DC components. This also shows that we are not obtaining a stable photoplethysmogram (PPG) from which we can obtain the cut off frequency. So this photoplethysmogram(PPG) has to be filtered by using low pass filters. So after signal conditioning photoplethysmogram(PPG) obtained is shown below.

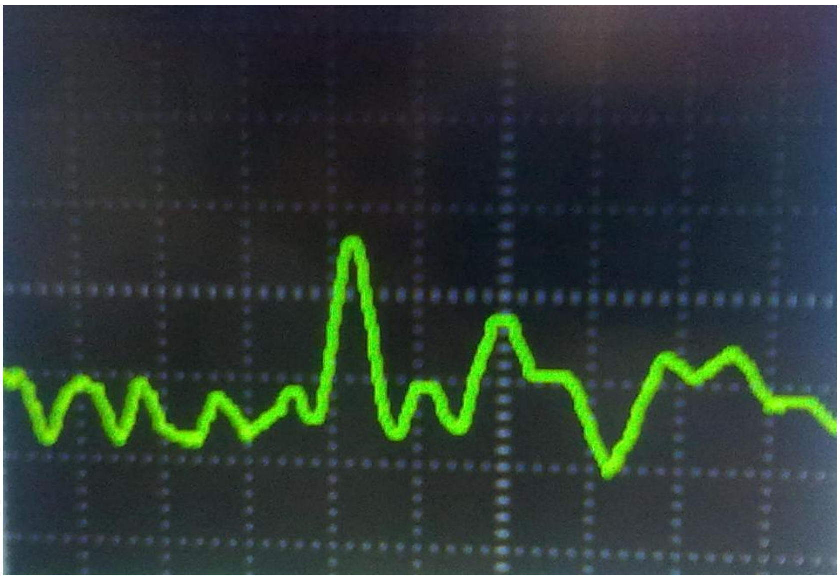


Figure 18: the resultant PPG

This is photoplethysmogram(PPG) which will give us the gain and cut off frequency. The gain at each stage of the filters and the cut off frequency can be calculated by the following equation given R_f = 650k,R_i= 5.6k , C_f = 100nF

Gain =1+ (R_f/R_i) = 119.18

Cut off frequency = $1/(2\pi R_f C_f)$ = 2.434Hz

Beats per minute = 2.434*60 = 146.04bpm

Now the heart rate obtained is 146.04bpm. To measure this heart rate we need to have a microcontroller. Then it is programmed in AVR studio. The figure in the next page will show how the program is compiled using AVR studio software.

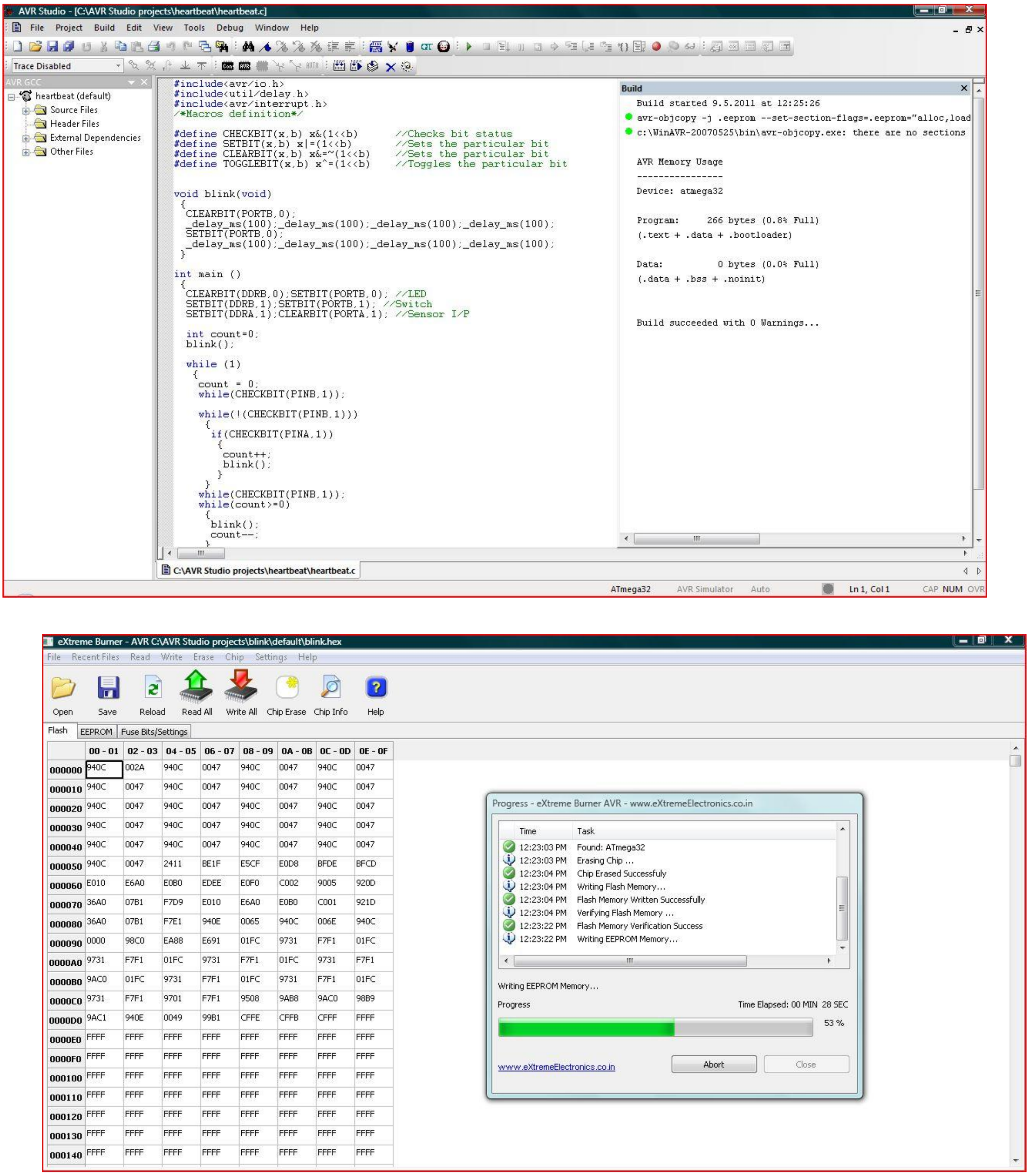


Figure 19 : compilation of program using AVR studio

After compilation of program then the stepper motor is integrated with another microcontroller and then with the help of a mechanical system we can deliver the drugs in an controlled manner.

Chapter 5

Discussions

Photoplethsmography can help in monitoring fluctuations of the plethysmographic wave which may cause heart failure, upper airway obstruction, can be detected. In future we can still modify and construct the sensor circuit for better results. Generally the theoretical frequency of plethysmographic wave is around 2-4 Hz but we are getting around 2.5Hz of frequency. This shows that we are detecting those frequencies with lots of noises. Moreover we can also implement alarming system that can detect overflow of the drug. The alarm system should be designed in such a way that it can detect when the fluid in the IV bottle is over. we should implement alarm system for the sensor being unable to receive the signal in a case where there is improper displacement of finger. We can adopt new type of mechanical system so that it allow controlled flow rate of drug in the body.

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Appendix 1

Program for integrating with microcontroller:

```
#include<avr/io.h>

#include<util/delay.h>

#include<avr/interrupt.h>

/*Macros definition*/


#define CHECKBIT(x,b) x&(1<<b)            //Checks bit status

#define SETBIT(x,b) x|=(1<<b)                  //Sets the particular bit

#define CLEARBIT(x,b) x&=~(1<<b)         //Sets the particular bit

#define TOGGLEBIT(x,b) x^=(1<<b)         //Toggles the particular bit

void blink(void)

 {

CLEARBIT(PORTB,0);

  _delay_ms(100);_delay_ms(100);_delay_ms(100);_delay_ms(100);

SETBIT(PORTB,0);

  _delay_ms(100);_delay_ms(100);_delay_ms(100);_delay_ms(100);

 }

int main ()

 {

CLEARBIT(DDRB,0);SETBIT(PORTB,0); //LED

SETBIT(DDRB,1);SETBIT(PORTB,1); //Switch

SETBIT(DDRA,1);CLEARBIT(PORTA,1); //Sensor I/P
```

```
int count=0;

blink();

while (1)

   {

count = 0;

while(CHECKBIT(PINB,1));



            while(!(CHECKBIT(PINB,1)))

             {

if(CHECKBIT(PINA,1))

               {

count++;

                        blink();

if (count >90 && count <150)

             PORTB = 0x01;

else

              PORTB= 0x00;

       }

             }

while(CHECKBIT(PINB,1));

            while(count>=0)

             {

            blink();
```

```
            count--;
             }
   }
return 1;
  }
```

Appendix 2

Integrating stepper motor with microcontroller:

```
#include<avr/io.h>

#include<util/delay.h>

main()

{

  DDRA=0xff;

  DDRB=0x00;

// for simple running...running in infinite loop

while(1)

{

if((PINB&0x01)==1)

{

        //  INVERSE LOGIC USED AS ULN PRODUCES INVERSE OUTPUT

        //  OUTPUT ON PA0-PA3

        PORTA=0B00001100;

        _delay_ms(500);

          PORTA=0B000000110;

        _delay_ms(500);

        PORTA=0B00000011;

        _delay_ms(500);

        PORTA=0B00001001;

        _delay_ms(500);

}
```

```
}

return 1;

}
```