AUTOMATED INTRAVENOUS INFUSION MONITORING SYSTEM

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CERTIFICATE

This is to certify that project report titled "**Automated Intravenous Infusion Monitoring System**", submitted by **Mohit Sain** (071017), **Utkarsh** (071018) and **Nitin Agarwal** (071021) in partial fulfillment for the award of degree of Bachelor of Technology in Electronics and Communication Engineering to Jaypee University of Information Technology, Waknaghat has been carried out under my supervision.

This work has not been submitted partially or fully to any other University or Institute for the award of this or any other degree or diploma.

Signature of Supervisor ....

Name of Supervisor Ms. Vanita Rana

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Date ....21/05/11....

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Mohit Sain, Utkarsh, Nitin Agarwal

Date ……………………..

SUMMARY

These days, most medical procedures make use of intravenous infusion to administer nutritional fluids and medicines directly into the blood stream of the patient. Though an efficient and convenient approach, it poses great threats to the patient. Dangers like introduction of a bubble in the drip pipe and reverse flow of blood due to vacuum formation in the bottle are always there.

We have considered this problem and have proposed to design and build a solution that can automatically monitor all the intravenous infusions for a patient with minimum involvement of the hospital staff.

We have proposed to build a system that constantly monitors the drip bottle and as soon as the threshold is reached, it stops the flow in the drip pipe to prevent any fatal situation. It also raises an alarm to signal the attendant to replace the exhausted bottle.

Also, we have designed and integrated an automatic syringe system where the doctor can load pre-filled syringes into the system and set a timer for each syringe. Subsequently, when the timer is up, the medicine in the syringe is automatically introduced into the drip pipe (and not the drip bottle; to prevent precipitate formation).

We have taken care make this system user friendly, with the minimum no. of operational buttons and an interactive LCD so that less educated hospital staff can easily use it.

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CHAPTER 1

Introduction

To avoid any fatal situation which may arrive due to carelessness of hospital staff while using intravenous drip infusion method, our project conceptualizes a device which stops the flow of fluid in the drip pipe before it finishes entirely. Thus, stopping the flow of liquid in the pipe may actually prevent any unforeseen situation from taking place. For this, a liquid level detection system has to be developed, which detects the level of the liquid from outside the bottle without coming in contact with the fluid. The device stops the flow of any liquid in the tube as soon as the liquid reaches the pre-decided threshold.

We have also conceptualized the system for installing pre-filled syringe units in the device, which would automatically introduce the medicinal fluid into the tube at the desired time.

This monitoring device would generate alarms for the ward and hospital administration.

1.1 Background of the problem

Nowadays, it is a very common practice in all hospitals around the country to administer fluids directly into the blood stream of the patient (Intra-Venous fluid administration). For patients suffering from mild weakness, stomach disorders and for anyone who has undergone a surgery, fluids like Normal Saline, Glucose solution, Fructose solution and Electrolyte solutions are administered using a drip infusion system. Also, medicines are injected directly into the veins using syringe and needle system. It is the most convenient form of supplying nutrients and medicines into the body when the patient is unconscious or is not in a condition to ingest food and medicines directly.

Though this system is very beneficial in the above situations, there are many hazards associated with it. The main hazards associated with these conventional practices are:

• When the solution in the bottle finishes, there is a chance of air being introduced into the blood stream of the patient. This can prove extremely fatal.

• Nowadays, the bottles being used are disposable plastic bottles which pose a very big threat after the fluid in them is exhausted: they can cause a reverse flow of blood into the bottle – giving rise to a fatal situation.

• The medicines to be injected have to done at a very specific time for the optimum recovery of the patient.

In India, the private hospitals take good care of these hazards but the situation in the government hospitals is pathetic. The ward nurses, who are supposed to take care of these timings, are very careless and often neglect these situations.

Thus, the need of the hour is to design a system that prevents these situations and is also affordable for the general public government hospitals.

CHAPTER 2

Problem and Objective Formulation

The problem that we want to solve is the continuation of flow in the pipe even when the drip bottle is exhausted. Also, the medicines have to be administered at the precise times to ensure proper recovery of the patient.

Therefore, we have to design a system that takes care of all these problems, that is, it stops the flow in the drip pipe and administer the medicines at the right times.

2.1 Concept of Proposed Solution

The objective of our device would be to stop the flow of fluid in the drip pipe (such as liquid glucose or isotonic sodium chloride solution contained in a drip bottle) before it finishes entirely. Thus, stopping the flow of liquid in the pipe may actually prevent any unforeseen situation from taking place. For this, we intend to design a liquid level detection system, which detects the liquid level from outside the bottle without coming in contact with the fluid. The device stops the flow of any liquid in the tube as soon as the liquid reaches the pre-decided level.

We have also conceptualized a system for installing pre-filled syringe units in the device, which would automatically introduce the medicinal fluid into the tube at the desired time.

This monitoring device would be connected to two levels of alarms. One alarm would for the ward and one for the central hospital administration. Initially, the ward alarm would be raised and if the device is not reset within 5 min. then the central alarm would be raised.

1.2 Setting of Objectives

We have set the following objectives for designing our system: -

- Detecting the arrival of the threshold.
- The level sensor mechanism should be non-intrusive.
- The flow in the drip pipe should be stopped without damaging the pipe.
- The medicine in the syringe should be administered at the right time.
- The operation of the system should be easy and intuitive.

CHAPTER 3

Concept and Technical Approach

We intend to design a compact device that can be hung on the drip bottle stand itself. Thus, we have to design a compact sensor, flow stopper, microcontroller circuit and syringe mechanism. We have conceptualized the device and named it as Automated Intravenous Infusion Monitor (AIIM).

3.1 Description of Major Blocks

'AIIM' stands for Automated Intravenous Infusion Monitors, which would be installed by each patient and would constantly monitor and control all IV infusion activities. It consists of the controller circuit, level sensors, flow stopper and syringe Following is a block diagram in accordance with our perception of an Automated Intravenous Infusion Monitor. As apparent from the diagram, the level sensor would signal the microcontroller about the threshold, and the microcontroller would, in turn, activate the flow stopper. Also, the user can program the timers with the help of the buttons and LCD display and at the precise moment, the microcontroller would activate the syringe module.

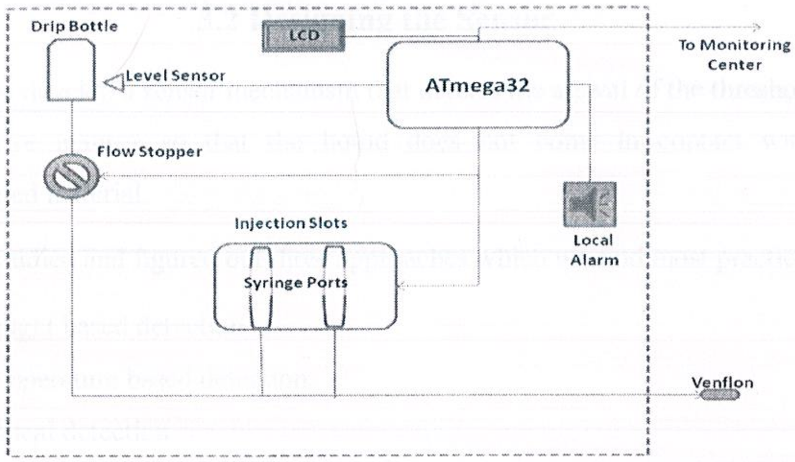


Fig.3.1: Description of Major Blocks

For using the aforementioned approach, we identified the following sub-blocks that needed to be designed and developed: -

- Designing the sensor for detecting the threshold level in the drip bottle.
- Designing the actuator system for stopping the flow of the IV fluid.
- Designing the syringe module to control the actuator with the precise speed so that the syringe plungers are not depressed too fast.
- Designing the alarm system to alert the hospital staff about an exhausted bottle.
- Designing the interactive control panel using the LCD and keypad.
- Designing the algorithm for the 8051 microcontroller which reads the data from the sensor and controls all the actuators and alarm in real time.

3.2 Designing the Sensor

We have to develop a sensor mechanism that detects the arrival of the threshold in a non-intrusive manner so that the liquid does not come in contact with any contaminated material.

We have studied and figured out three approaches which we find most practical:

- Weight based detection
- Temperature based detection
- Optical detection

In the following chapters, we would take up the aforementioned techniques and analyze the results.

3.3 Designing the Actuator System

Actuators are required in the flow stopper mechanism as well as in the syringe module to drive the plungers. We would use DC geared motors as the main actuator. There are many intricacies involved with the designing like:

- Choice and design of proper driving and isolation circuit to run the motors as they need very high current and can also generate considerable amounts of back – EMF
- Choice of proper thread to attach between motor and end effecter of actuator.

We would address the following problems and go on to design an effective actuator system in the subsequent chapters.

3.4 Designing the Algorithm

The main algorithm has to be designed so that no important functionality suffers and also the system should be extremely user friendly and intuitive. Care has to be taken that the code should be optimum in size as a larger code would mean slower execution and also, we have a memory limitation with our microcontroller.

CHAPTER 4

Hardware and Software Design

4.1 Designing the Sensor

The situation that we had to detect was the precise moment when the IV fluid is about to be exhausted so that a fatal situation can be avoided. The biggest complication for this detection was that the IV fluid is available only in sealed plastic bottles and it is extremely necessary that the fluid does not come in contact with any other material as it has to be injected intravenously to the patient.

After much brainstorming, we singled out the following methods to detect the threshold: -

- Weight
- Temperature
- Level

4.1.1 Detection of threshold by weight

We explored the possibility of detecting the arrival of the threshold in the IV drip bottle by monitoring the weight of the whole bottle. We conducted some experiments using a spring based weighing scale and monitored the change in the reading but the following factors posed problems regarding consistency of the readings: -

- The tension from the drip pipe could lead to false readings
- The quality of the IV fluid
- The material of the drip bottle

We could not arrive on a solution for overcoming these problems so we proceeded to the next approach of temperature monitoring.

4.1.2 Detection of threshold by temperature

We also explored the possibility of detecting the threshold by monitoring the temperature at the threshold level of the bottle. Obviously, the temperature should increase as soon as the level drops below the monitoring point. But we had to drop the idea in the early stage as temperature sensors have the possibility of many false readings depending on the environment and also, thermal isolation of the drip bottle would be a very complex thing to achieve.

4.1.3 Detection of threshold by optical level detection (IR Based)

The final approach we took was to detect the threshold was detecting drop the level of the liquid using optical sensors. Optical sensors seemed a good choice for non-intrusive level detection. We first explored the possibility of Infra Red detection as there are not much problems of stray IR beams that can result in false readings and alarms. We used two different approaches for IR sensor design: -

4.1.3.1 Standard IR LED and Phototransistor Setup

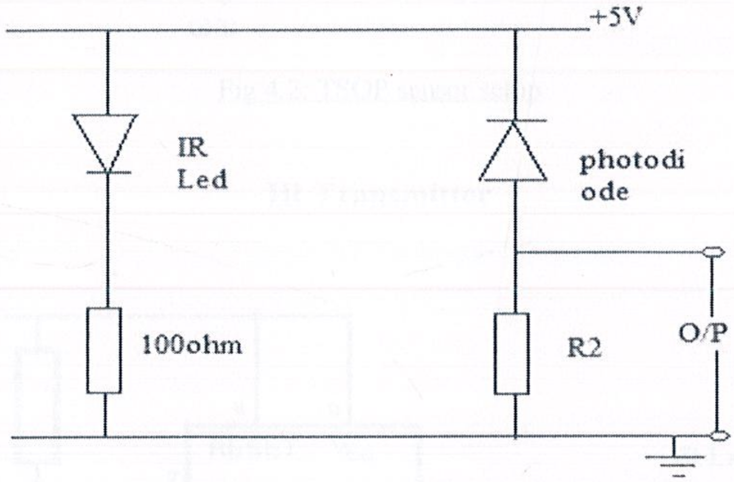


Fig 4.1: Standard IR LED and Phototransistor Setup

4.1.3.2 IR LED and TSOP sensor setup

IR Receiver

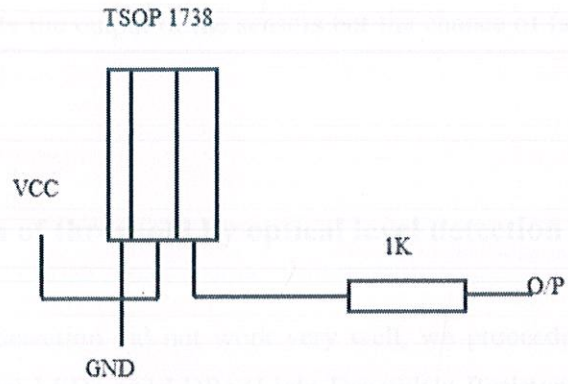


Fig 4.2: TSOP sensor setup

IR Transmitter

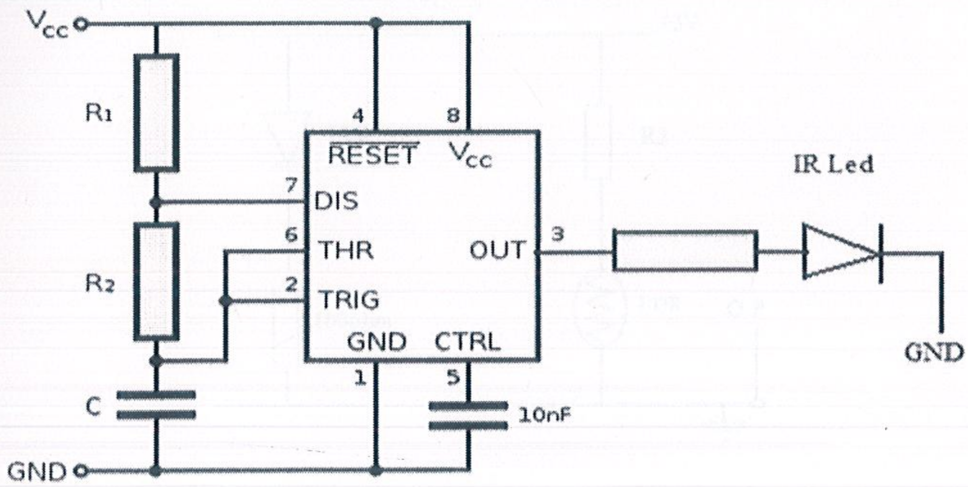


Fig 4.3: IR Transmitter for TSOP Receiver

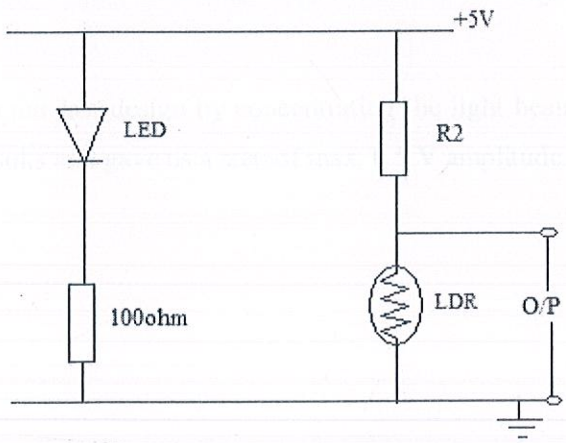
We did not get very impressive results using IR LEDs. The voltage drops were very little (of the magnitude of 0.3 V max.) and we could not rely on such little drop as the chance of a false alarm would be very high. We also considering designing an amplifier to amplify the output of the sensors but the chance of false alarms would still not be reduced.

4.1.4 Detection of threshold by optical level detection (LDR Based)

As the IR based detection did not work very well, we proceeded to designing a sensor using normal LEDs and LDRs (Light Dependant Resistors). We developed the final design of our sensor in five stages: -

4.1.4.1 Single LED and LDR pair

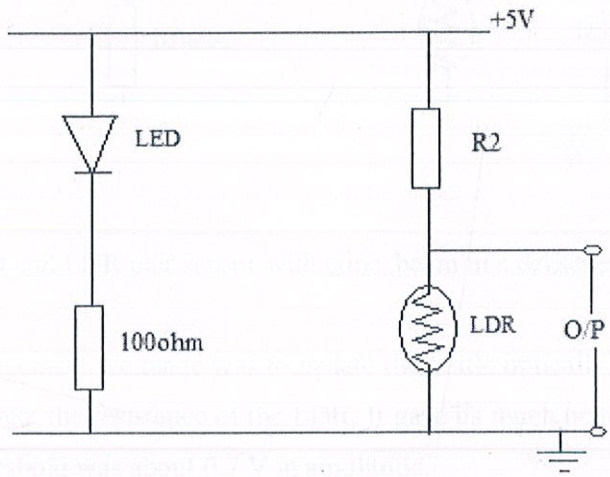
Fig 4.4: Single LED and LDR pair sensor



We designed a standard sensor using a LED and LDR. The setup was fairly simple but did not give any sharp voltage changes which we required.

4.1.4.2 LED and LDR pair using a concentrated light beam

Fig 4.5: LED and LDR pair sensor using a concentrated light beam



We improved on our last design by concentrating the light beam from the LED. It gave us better results and gave us a step of max. 0.5 V amplitude.

4.1.4.3 LED and LDR pair with conc. beam in a darkened environment

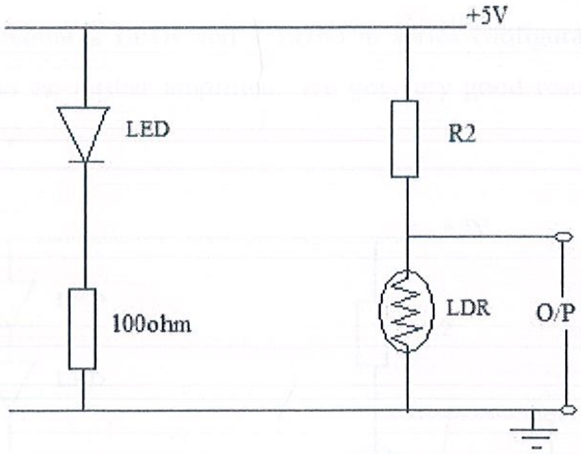


Fig 4.6: LED and LDR pair sensor with conc. beam in a darkened environment

The next improvement we made was to isolate the bottle optically so that any stray light did not affect the resistance of the LDR. It gave us much better results and the spike at the threshold was about 0.7 V in amplitude.

4.1.4.4 Multiple LEDs and LDRs with conc. beams in darkened environment

We proceeded to mount 2 LEDs and 2 LDRs in series configuration so that the voltage spike could be further amplified. We got very good results with a max. spike of about 1.3 V.

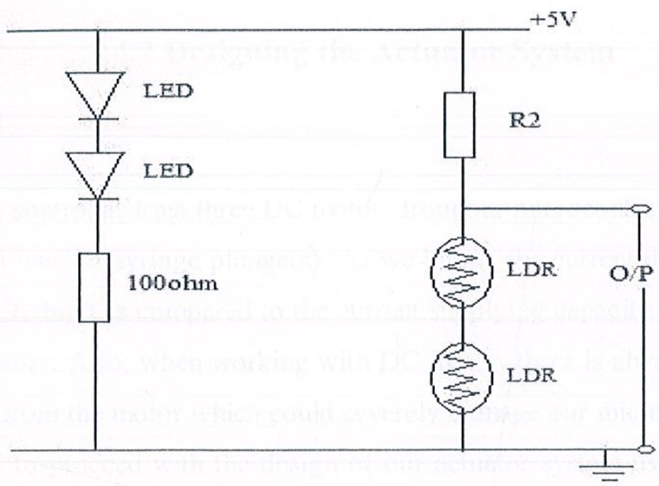


Fig 4.7: Multiple LEDs and LDRs with conc. beams in darkened environment

We also made use of the fact that just at the transition there is a considerable dark area as a result of Total Internal Reflection in liquids. This phenomenon helped us in getting a very crisp spike at the transitional threshold which could be easily detected by our microcontroller and processed accordingly.

4.1.4.5 Multiple LEDs and LDRs with conc. beams in darkened environment with an extra error detection/calibration LDR

We had achieved a very crisp reading for the detection of the threshold but there still remained a minor glitch: in the event of a failure in the optical isolation of the drip bottle, the LDR can render unexpected results. To overcome this problem, we have placed a separate LDR near the bottle surface but away from any direct beam from the LEDs. Thus, by monitoring this parameter, we can detect the presence of stray light in the vicinity of the drip bottle and take the necessary action.

4.2 Designing the Actuator System

We have to control at-least three DC motors from our microcontroller (one for flow stopper and two for syringe plungers). As we know, the current drawn by any DC motor is quite high as compared to the current supplying capacity of any pin of the microcontroller. Also, when working with DC motor, there is always a danger of a back-EMF from the motor which could severely damage our microcontroller. Thus, we decided to proceed with the design of our actuator system using a L293D IC, which is a monolithic high voltage, high current integrated circuit four channel driver in a 20 pin DIP.

It is designed to accept standard TTL or DTL input logic levels and drive inductive loads (such as relays, solenoids, DC and stepping motors). The device may easily be used as a dual H-bridge driver: separate chip enable and high voltage power supply pins are provided for each H-bridge. In addition, a separate power supply is provided for the logic section of the device. L293D has output current of 600mA and peak output current of 1.2A per channel and the output supply (VCC2) has a wide range from 4.5V to 36V.

4.2.1 Using the dual H-Bridge

L293D is a dual H-Bridge motor driver, So with one IC we can drive two DC motors which can be controlled in both clockwise and counter clockwise direction and if you have motor with fix direction of motion the you can make use of all the four I/Os to connect up to four DC motors.

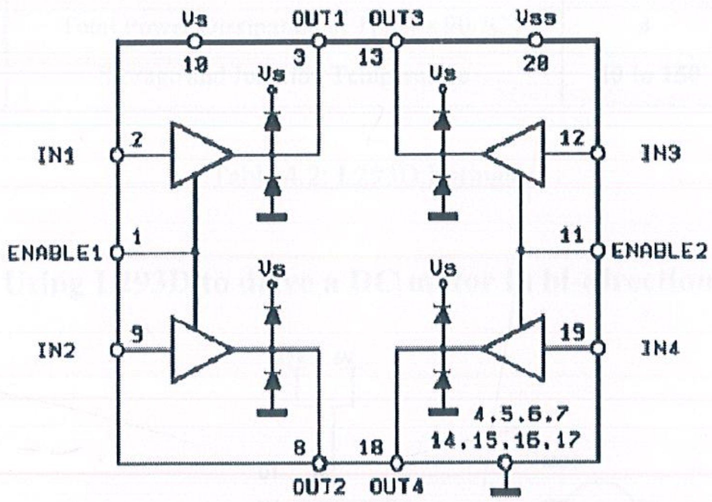


Fig 4.8: L293D usage

Truth Table

IN1	IN2	Description
Low	Low	Motor Stops or Breaks
Low	High	Motor Runs Anti-Clockwise
High	Low	Motor Runs Clockwise
High	High	Motor Stops or Breaks

Table 4.1: L293D Truth Table

4.2.1.1 Absolute Maximum Rating

Symbol	Parameter	Value	Unit
VS	Supply Voltage	**36**	**V**
VSS	Logic Supply Voltage	**36**	**V**
Vi	Input Voltage	**7**	**V**
Ven	Enable Voltage	**7**	**V**
Io	Peak Output Current (100 ms non repetitive)	**1.2**	**A**
Ptot	Total Power Dissipation at Tpins = 90 °C	**4**	**W**
Tstg, Tj	Storage and Junction Temperature	**-40 to 150**	°C

Table 4.2: L293D Ratings

4.2.1.2 Using L293D to drive a DC motor in bi-directional mode

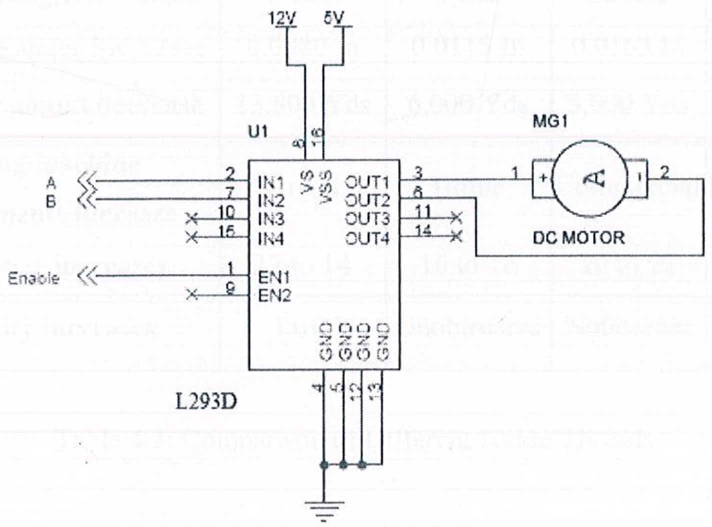


Fig 4.9: Using L293D to drive a DC Motor in bi-directional mode

4.2.2 Using Nylon Threads in Actuator Design

The thread used in actuator system of our device is nylon thread. The nylon thread have high strength-to-size ratio and shows excellent resistance to mildew, aging and abrasion, that increases the reliability of the nylon thread as well as of our device. Middle weight (Size 69) nylon has a tensile strength of about 8 pounds.

Size refers to a thread's thickness--not the amount of thread on the spool. As thread size increases it affects the thread's strength, diameter, sewing machine used, yards per pound, visibility. Here are specifications for four sizes :

	Size 33	Size 69	Size 138	Size 346
Tensile strength increases	5 Lbs	8 Lbs	22 Lbs	53 Lbs
Thread diameter increases	0.0080 In	0.0115 In	0.0163 In	0.0258
Yards per pound decrease	13,800 Yds	6,000 Yds	3,000 Yds	1,200 Yds
Sewing machine requirements increase	Home	Home	Commercial	Heavy Duty
Needle size increases	12 to 14	16 to 18	20 to 22	26 to 28
Visibility increases	Low	Unobtrusive	Noticeable	Stands Out

Table 4.3: Comparison of Different Nylon Threads

4.2.3 Designing the Flow Stopper Mechanism (Closed loop)

We had to design a system that could efficiently stop the flow in the drip pipe whenever signaled by the microcontroller. For designing this system, we used a

12V- 45rpm DC geared motor that would provide us with the required torque to stop the flow. Also, we designed a flap mechanism that was driven by this motor and was tethered by a high strength nylon thread to support the high torque from the motor.

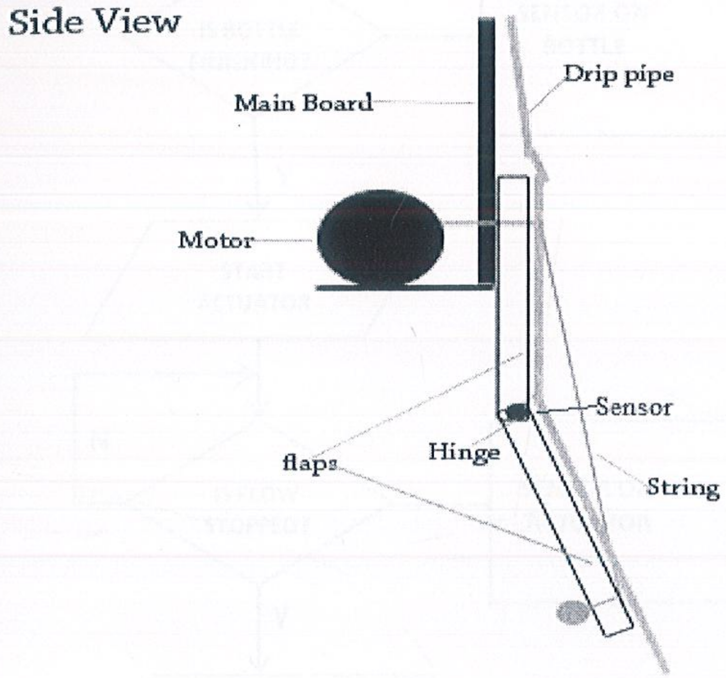


Fig 4.10: Flow Stopper Assembly (Side View)

We also designed a sensor for detecting the precise moment when the flow would be stopped (when the flap assembly could no longer be contracted) so that the drip pipe would not be damaged.

4.2.3.1 Logic Design for the Flow Stopper (Closed loop)

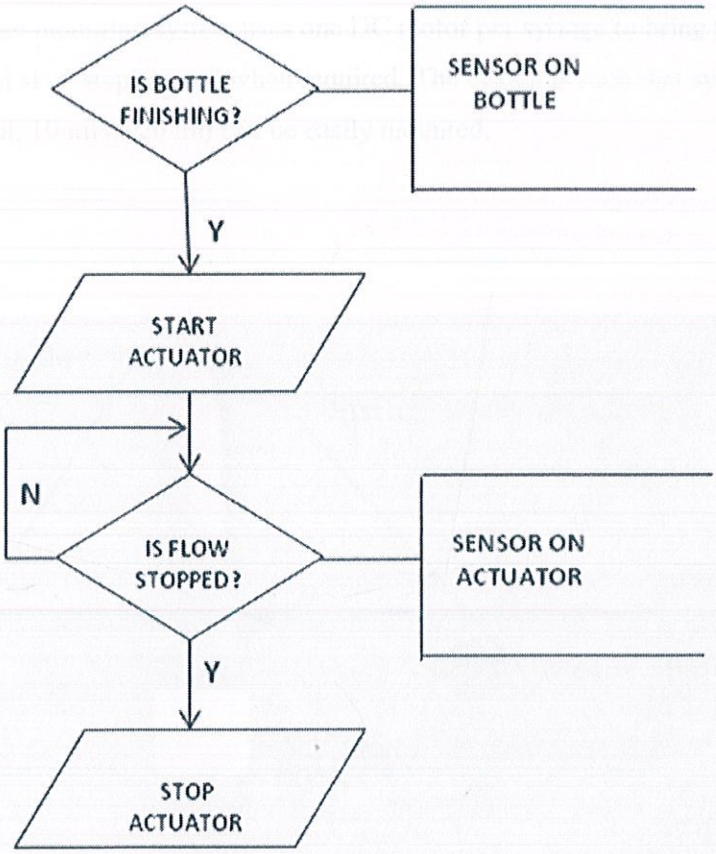


Fig 4.11: Flow Chart of Flow Stopper Logic

4.2.4 Syringe Driving Actuator System

Syringe actuator system is used for installing pre-filled syringe units in the device, which would automatically introduce the medicinal fluid into the tube at the desired time. The syringe mounting system uses one DC motor per syringe to bring the plunger down in slow steps as and when required. The design is such that syringes of all sizes (5 ml, 10 ml or 20 ml) can be easily mounted.

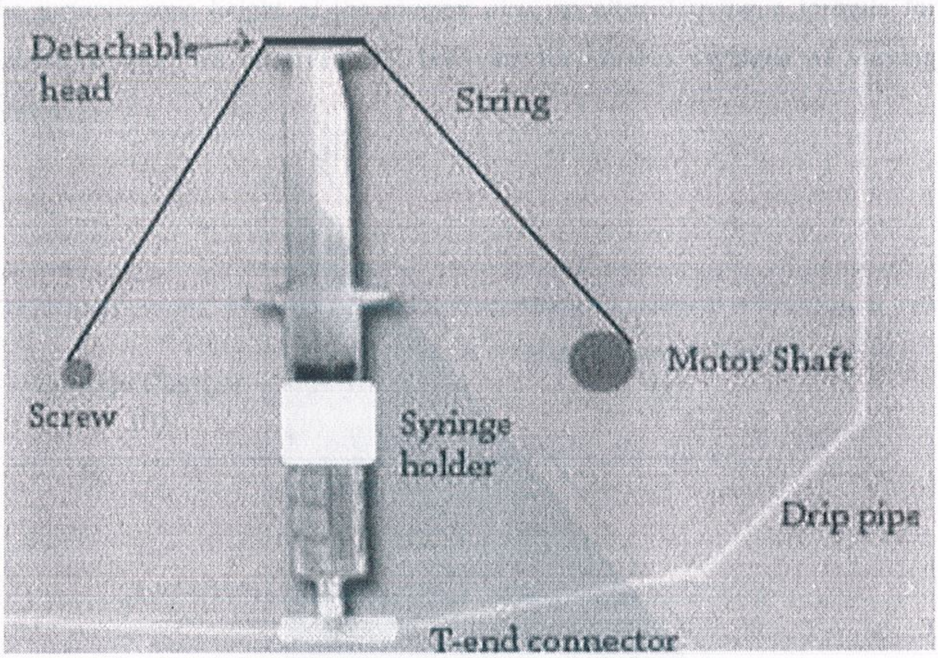


Fig 4.12: Syringe Driving Actuator System (Front View)

4.2.4.1 Mathematical Analysis of the Flow

To analyze the rate of flow from the syringe, we did detailed mathematical analysis on the assembly. Following is a figure representing the right angled triangle formed by the thread (hypotenuse), plunger (height) and the perpendicular distance between the syringe and the motor shaft as the base.

Now the motor pulls the thread but as we are interested in the rate of flow of the medicine from the syringe, we have to deduce the rate with which the plunger moves. As it would be seen in the following derivation, the rate would be dependent on the instantaneous height of the plunger also, so after deriving a formula for instantaneous rate, we observed it's behavior for various syringes of varying capacities.

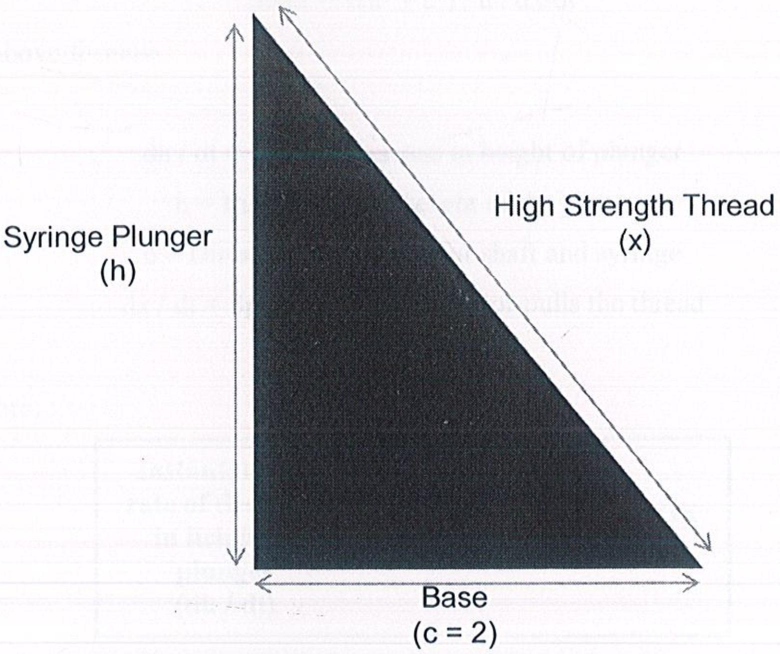


Fig 4.13: Actuator Design (Mathematical Perspective)

Mathematical Analysis: -

By Pythagoras Theorem,

$$x^2 = h^2 + c^2$$

Therefore,

$$h^2 = x^2 - c^2$$

$$h = \sqrt{(x^2 - c^2)}$$

Now differentiating,

$$dh / dt = \tfrac{1}{2} \cdot 1 / \sqrt{(x^2 - c^2)} \cdot 2x. \; dx / dt$$

Simplifying,

$$dh / dt = x / \sqrt{(x^2 - c^2)} \cdot dx / dt$$

Substituting x by $\sqrt{(h^2 + c^2)}$,

$$dh/dt = \sqrt{(h^2 + c^2)} / h \cdot dx/dt$$

In the above formula,

dh / dt = Rate of decrease in height of plunger

h = **Instantaneous** height of the plunger

c = Distance between motor shaft and syringe

dx / dt = Speed with which motor pulls the thread

Therefore:

Instantaneous rate of decrease in height of plunger (dh / dt)	=	$\mathbf{\dfrac{\sqrt{(h^2 + c^2)}}{h} \times \dfrac{dx}{dt}}$

4.3 Designing the Algorithm

We have prepared a rough draft for the major functions that the 8051 microcontroller has to take care of in the form of a flow chart.

As we know, the foremost responsibility of the control circuit is to check if the bottle is finishing. If yes, it has to stop the flow of the fluid in the drip pipe. Once it has done so, it starts beeping and alarm to alert about the exhausted bottle. It resumes flow once the bottle is replaced.

Also, it helps the user to program timers for the syringe and once the timer is up, it firstly stops the flow from the drip bottle (to make sure that the medicine from the syringe does not flow back into the bottle) and then drives the syringe plunger in short gentle steps to introduce the programmed volume of medicine in the drip pipe. Subsequently, it starts the flow from the drip bottle.

The following flow chart is a simplified version of the algorithm depicting only the major functionalities and omitting the timer programming and UI modules. Also, the program burnt into the microcontroller is repetitive, i.e., it repeats the following algorithm again and again.

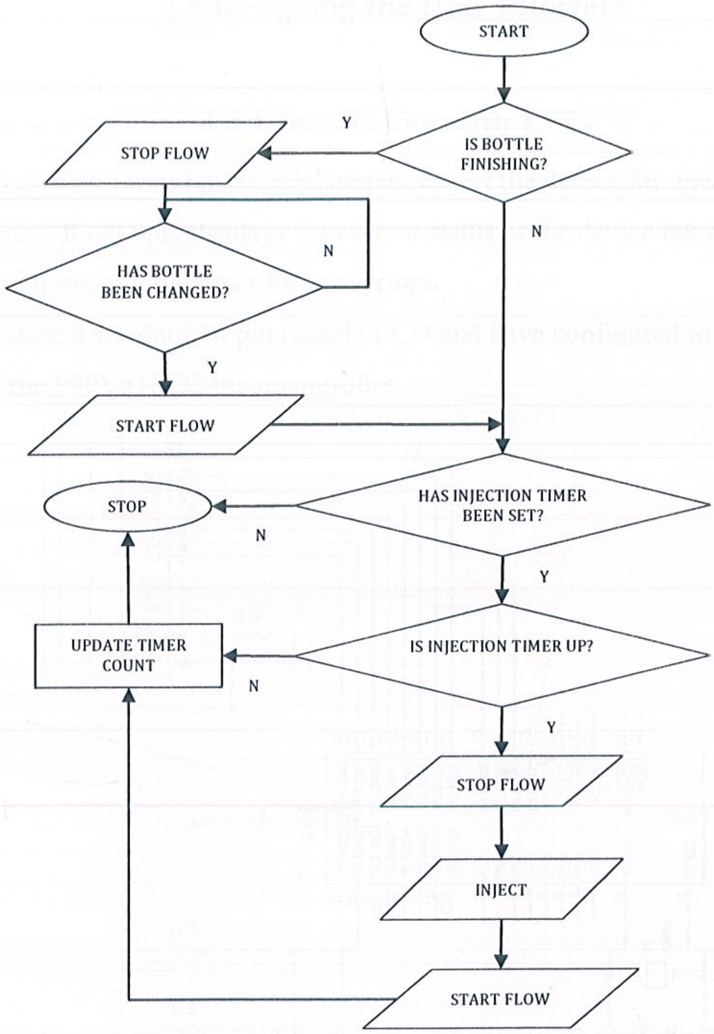


Fig 4.14: Flow Chart (Simplified) for the main Algorithm

4.4 Designing the User Interface

4.4.1 Interfacing with LCD

The LCD display forms an essential component of the device for operational convenience. It not only displays the current status of the device but also helps the user in programming the timer for the syringe.

We have used a standard 14 pin Hitachi LCD and have configured to use it with Port 2 of the P89V51RD2 microcontroller.

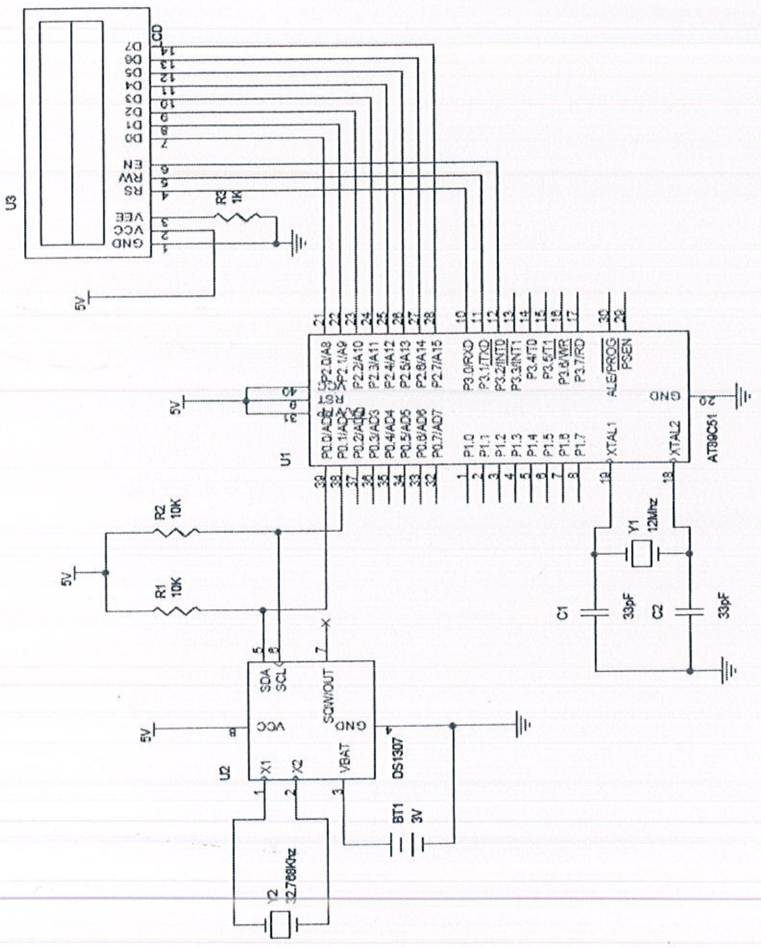


Fig 4.15: Interfacing with LCD

4.4.2 Designing the Interacting Button Panel

We have developed a 4 button system for the control of the device. The buttons are standard push buttons and are connected to Port 0 of our microcontroller. We have developed an interacting method so that all features like programming the two syringes, replacing the bottle and manual override – all can be done using the 4 switches.

CHAPTER 5

RESULTS

We had designed different circuits before making the choice for the best and final circuit of the level detection sensor. After getting poor results fine results from Infra-Red sensors, we switched to the LDR as receiver and LED as Transmitter. The initial setups did not give good results but some design modifications in the same led us to achieving crisp results.

For the Syringe Driving Actuator System we have derived the formula for controlling the rate of flow of liquid in syringes. We have also performed the experiments using syringes of different volumes.

The results of all the experiments are discussed below:-

5.1 Level Detection Sensor

5.1.1 Standard IR LED and Phototransistor Setup

Table 5.1: Observations for Standard IR LED and Phototransistor Setup

D (c.m.)	V_1 (V)	V_2 (V)	R_2 (ohm)
2	1.8	1.5	10k
3	1.6	1.3	10k
4	1.3	1.1	10k
5	1.1	0.9	10k

2	2.9	2.7	1M
3	2.5	2.4	1M
4	2.2	2.1	1M
5	1.9	1.8	1M
2	4.1	3.8	10M
3	3.6	3.4	10M
4	3.1	2.9	10M
5	2.6	2.5	10M

D – Distance between Transmitter and Receiver

V_1 – Output Voltage with Empty Drip Bottle

V_2 – Output Voltage with Filled Drip Bottle

5.1.2 IR LED and TSOP sensor setup

Table 5.2: Observations for IR LED and TSOP sensor setup

D (c.m.)	V_1 (V)	V_2 (V)
2	3.9	4.1
3	4.0	4.1
4	4.4	4.5
5	4.8	4.8

D – Distance between Transmitter and Receiver

V_1 – Voltage with Empty Drip Bottle

V_2 – Voltage with Filled Drip Bottle

As it is clear from the observations of the above two IR based experiments, they are not giving good results so we moved on the LDR based design.

5.1.3 Detection of threshold by optical level detection (LDR Based)

5.1.3.1 Single LED and LDR pair

Table 5.3: Observations for Single LED and LDR pair sensor

D (c.m.)	R_{LDR1} (ohm)	R_{LDR2} (ohm)	R_2 (ohm)	V_1 (V)	V_2 (V)
2	7k	8.5k	2k	3.8	4.0
3	8.2k	10k	2k	4.0	4.1
4	9k	11k	2k	4.1	4.1

Results were not satisfactory; maximum voltage difference achieved was 0.2 V

5.1.3.2 LED and LDR pair using a concentrated light beam

D (c.m.)	R_{LDR1} (ohm)	R_{LDR2} (ohm)	R_2 (ohm)	V_1 (V)	V_2 (V)
2	6k	7k	2k	3.7	3.9
3	6.8k	8k	2k	3.9	4.0
4	8k	10k	2k	4.1	4.2

Table 5.4: Observations for LED and LDR pair sensor using a concentrated light beam

This gave us little better results but still they were not satisfactory.

5.1.3.3 LED and LDR pair with conc. beam in a darkened environment

D (c.m.)	R_{LDR1} (ohm)	R_{LDR2} (ohm)	R_2 (ohm)	V_1 (V)	V_2 (V)
2	10k	21k	5k	3.3	4.0
3	14k	29k	5k	3.7	4.3
4	16k	30k	5k	3.8	4.2

Table 5.5: Observations for LED and LDR pair sensor with conc. beam in a darkened environment

These results were much more promising as we had achieved a maximum voltage spike of about 0.7 V.

5.1.3.4 Multiple LEDs and LDRs with conc. beams in darkened environment

D (c.m.)	R_{LDR1} (ohm)	R_{LDR2} (ohm)	R_2 (ohm)	V_1 (V)	V_2 (V)
2	21k	63k	20k	2.5	3.8
3	25k	67k	20k	2.7	3.9
4	27k	68k	20k	2.9	3.9

Table 5.6: Observations for Multiple LEDs and LDRs with conc. beams in darkened environment

This setup gave us the best results with a maximum voltage spike of around 1.3 V. This value was good as this could be amplified also and still there would be minimum chances of noise getting amplified to this level.

We have used this as the final setup in our system.

5.2 Syringe Driving Actuator System

5.2.1 Observations with Different Syringes

12 ml Syringe:

dx/dt (mm/sec)	h (mm)	dh/dt (mm/sec)	R0 (ml/sec)
0.8	60	0.8004	0.137211429
0.8	70	0.8003	0.137194286
0.8	80	0.8002	0.137177143
0.8	110	0.8001	0.13716
0.8	120	0.8001	0.13716
0.8	130	0.8	0.137142857
0.9	60	0.9004	0.154354286
0.9	70	0.9003	0.154337143
0.9	80	0.9002	0.15432
0.9	110	0.9001	0.154302857
0.9	120	0.9001	0.154302857
0.9	130	0.9	0.154285714
1	60	1.0005	0.171514286
1	70	1.0004	0.171497143
1	80	1.0003	0.17148

1	110	1.0002	0.171462857
1	120	1.0001	0.171445714
1	130	1.0001	0.171445714

Table 5.7: Flow Analysis for 12 ml Syringe

6 ml Syringe:

dx/dt (mm/sec)	h (mm)	dh/dt (mm/sec)	R0 (ml/sec)
0.8	45	0.80079	0.106772
0.8	60	0.800444	0.106726
0.8	75	0.800284	0.106705
0.8	90	0.800198	0.106693
0.9	45	0.900888	0.120118
0.9	60	0.9005	0.120067
0.9	75	0.90032	0.120043
0.9	90	0.900222	0.12003
1	45	1.000987	0.133465
1	60	1.000555	0.133407
1	75	1.000355	0.133381
1	90	1.000247	0.133366

Table 5.8: Flow Analysis for 6 ml Syringe

Where:

dx/dt = drawing rate of thread by the motor

h = height of plunger at a given instant

dh/dt = rate with which the syringe plunger in pushed

R0 = Rate of flow of liquid from the syringe

CHAPTER 6

CONCLUSION

The project has been successfully completed within the stipulated time frame. We have designed our own sensor for this purpose and it has given very accurate results.

Also, to performance of the system as a whole was very satisfying and in more than 50 test runs, we did not find and flaw in the design, circuit or the algorithm.

We are in the process of documenting this entire concept in a research paper entitled "Automated Intravenous Infusion Monitoring System".

The need for such systems is increasing day by day, especially in the government hospitals where there is extreme shortage of hospital staff. Thus, the future prospects of our project seem very bright and we hope that the user friendly operability and low cost would help us in making this a huge success.

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