Design of Portable Low Cost Biomedical Suction Device for Fast Healing of Diabetic Wounds Using Embedded Systems

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Abstract— Nowadays, Biomedical Instruments are gaining more importance. They play a vital role in diagnosis and assist doctors to take immediate decisions on the mode of treatment appropriate for patients. In India, there are numerous diabetic patients suffering from unhealed wounds, because of continuous pus secretion. Currently, in hospitals the pus secreted from the wound of the diabetes patients are continuously collected, to leave the wound dry to heal. In this mode, the dressing of the wound is done periodically and it have to replace once it becomes wet. Due to continuous contact of dressing material the wound is always wet and it takes more time to heal. To overcome the above scenario, this device, "A Low cost Bio medical suctioner using Embedded Systems" is developed. This device creates vacuum over the surface of the wound and the suction pump will collect the pus from the wound in a disposable container. Due to this, the wound remains always dry and the process of healing is faster.

Keywords— Bio medical suction device, Embedded Systems, Diabetes, Healing

1. Introduction

EVERY human deserves a healthy life. The role of biomedical devices in health care is inevitable. Gone are the days where there are no such bio medical instruments in hospitals. Today, every hospital has bio medical engineers to look after the bio medical instruments. These bio medical instruments help doctors to identify the disease and diagnose.

The role of the biomedical instruments ends in the hospital itself. This project is an extension to make the bio medical device accessible for patients. This project is for Patients with chronic or non-healing wounds who feel that there is no hope for recovery. This project offers hope for the patients with chronic wounds that fail to show healing within two or four weeks.

Therapy creates an environment where wound healing is promoted by delivering negative pressure at the wound through a proprietary foam dressing, the wound edges are drawn together, infectious materials are removed, edema is reduced, and granulation tissue formation is promoted [2].

The Bio Suctioner is a device to remove septic fluid from the body. It is mainly used for the removal of pus from the wound of the diabetic patients. When the pus is removed the air circulation and blood circulation increases, wound contraction occurs and the wound heals soon. The Bio Suctioner setup consists of a vacuum pump, motor, a speed control circuit, and a Microcontroller. A negative pressure (vacuum) is applied on the wound. The pressure to be applied on the wound is created by the vacuum pump. The pressure can be controlled by controlling the speed of the vacuum pump. A microcontroller controls the speed of the motor and thus directly controlling the vacuum produced. The microcontroller also displays the pressure level on the LCD and gets user input using four buttons. The inputs of the button correspond to pressure control and timing control. The pressure can be controlled in terms of 25mm Hg [13]. The timing settings can also be given predefined on and off. The last setting is retained in the system. The pus fluid is collected in the tank. The Bio medical suctioner is designed in such a way that it is user friendly and can be operated by patients if demonstrated once

2. Literature Review

The skin acts a barrier and protects from the external environment [1–3]. In recent years one-third of the adult population has diabetes and 6.5 million cases has chronic skin ulcers yearly. This creates need for investigation in the process of healing wounds [1].

Chronic wounds are epidemic and has influence on the financial structure of our healthcare economy. Because of increasing diabetic and obesity persons, the financial burden had increased for treating the chronic wounds. Every year, huge amount of over $25 billion is spent for the treatment of the chronic wounds. The costs are even higher when one factor is in loss of productivity for affected individuals [4]. This paper gives solution for the financial burden on treating wounds by making it low cost and easy to operate. The lifetime probability of diabetics developing a chronic foot ulcer are between 10% and 25% [5,6]. Diabetes is the main cause for non-traumatic leg amputations in the United States [6]. The number of cases of pressure ulcers within inpatient settings has been reported to be 22%, with as many as 50–80% acquired within the hospital [7]. Pressure ulcers and Diabetic foot ulcers (DFUs) are the major sources of morbidity. Sen and colleagues argue that investigation on tissue regeneration in chronic wound repair is more important as there is increasing incidence of diabetes and increased need for wound care of our veterans [4].

Blood sugar is the amount of sugar present in the blood. Glucose acts as a fuel for brain function. So, blood sugar level must be maintained at correct level for the normal function of brain. After consuming carbohydrate or protein rich food, blood sugar level of a person varies between 120 and 130 milligrams per deciliter (mg/dL) and not above 140 mg/dL. Blood sugar levels can even vary in people without diabetes time to time.

Hypoglycemia is also known as low blood sugar. The person with hypoglycemia has too low blood sugar and causes impairment of function. Hyperglycemia is also known as high blood sugar. The person with hyperglycemia has too high blood sugar levels and diagnosed as diabetes. Hyperglycemia causes damage to the blood vessels and organs the blood goes. Diabetes can be confirmed by a testing the blood samples. When the person has symptoms like thirsty, large amount of urination, the blood sugar usually will be higher than 200 mg/dL and may be 300s or 400s or even higher.

Understanding insulin gives a better understanding in diabetes. Insulin is a hormone secreted in the pancreas located behind the stomach. Insulin allows the cells to absorb glucose in the blood and this glucose can be used for energy. When carbohydrates rich food is consumed, the blood glucose level increases. Due to this increase in blood sugar level, the release of insulin from beta cells in pancreas occurs. The insulin unlocks the cells to glucose and the blood sugar level comes back to normal as glucose enters the cells. Sometimes, an injection has the role in reducing weight and change in lifestyle has dramatic effects on diabetes.

As a result of fluctuating blood glucose levels, people with diabetes face unique wound care needs. Diabetic patients often notice that their skin gets dry and is easily injured. Dry skin easily cracks which leads to compromised skin. Bacteria and germs can get into the cracked dry skin and feed on the elevated glucose in the body and cause infection. The body is slower to heal wounds due to poor blood circulation. A person with diabetes may not even notice an injury until infection has already set in. When an infection is not quickly healed the skin would become gangrened. This can lead to amputation. As blood circulation is poorest at the extremities, the hands and feet of people with diabetes are particularly susceptible to infection. It is very important for people with diabetes to check their hands and feet for cracks, or any other injuries so that wounds can be cared for immediately to prevent infections.

2.1. Overview of Diabetic foot ulcer

A diabetic foot ulcer is a wound that present on the foot of a diabetic person. It is usually not painful because of loss of pain sensation [12]. A diabetic person often has peripheral vascular disease. Due to poor blood circulation, the wound in feet takes time to heal. The person might have diabetic. Neuropathy is a condition in which damage in nerves due to diabetes causes decreased sensation in the legs and feet. The person can have an open area due to pressure or a cut and the person cannot feel the wound. When it is not treated, a diabetic foot ulcer can be developed in the damaged area.

2.2. Blood Flow

Several studies observed the increasing blood flow in wounds when treated with NPWT therapy. Moryk was et al [5] placed a laser Doppler probe inside the wounds of twenty five pigs and the blood flow level was studied. NPWT was applied from 25 mmHg up to 400 mmHg in increasing range for interval of fifteen minutes, and they identified that the optimal pressure was 125 mmHg. To maintain the above result, they found that pressure should be applied at pause of two minutes between each five minutes of application [5]. The above data were used for the establishment of the baseline settings for treatment of different typologies of wounds. Wackenfors et al [6, 7] measured the blood flow to an inguinal and sternal wound model using 50 to 200 mmHg using the laser Doppler technique. The increase in micro vascular flow was observed few centimeters from wound edges. From this study, it was found that soft and dense tissue has different distribution of negative pressure. The risk of schematic effects can be reduced by low negative pressure [6, 7]. Chen et al [8] treated the wounds in white rabbit's ears where the wounds are created experimentally, with vacuum-assisted closure therapy using microcirculation microscope and image pattern analyses and examined the blood flow. It was observed that there was increased blood flow due to the increased blood flow velocity and volume and vascular diameter [8]. By considering these things, tissue treated and idea pressure levels have an impact on the setting of optimal pressure. This setup shows an increase in blood flow which makes the wound to heal.

2.3. Diagnosis and Tests

The affected individual usually recognizes the diabetic foot ulcers. The provider can diagnose the foot ulcer by seeing the wound. To check infection, a culture of the fluid can be sent to the laboratory, if the ulcer is found to be draining fluid. There are many methods to check for infection. One such method is wound drainage method. A wound drainage culture is a test that finds germs such as bacteria , fungi , or viruses in a wound. A bacterial culture is a test that is used for determining bacterial or fungal infection on a wound.

2.4. Treatment and Monitoring

There are 10 major areas of treatment. They are described as follows.

- Peripheral vascular disease is monitored
- Monitoring of diabetic neuropathy, or nerve damage from diabetes are monitored.
- Correcting of risk factors. That is a person who smokes should quit smoking
- A person with diabetes doing regular exercises to improve circulation to the feet
- Treating any sign of skin damage aggressively.
- Treating any fungal infections of the foot by wearing well-cushioned walking shoes, athletic shoes, or special prescriptions
- A person with diabetes can follow a team approach. This team can include the person with diabetes, the primary care physician, the assistant of the physician, the diabetes educator, the nutritionist and the surgical specialist
- A person with diabetes can perform daily foot care. In addition to this, examination of the person's feet should be done by the healthcare provider at each visit

A person with diabetes should learn about diabetes. The individual must be responsible for their health and should learn the methods to prevent ulcers [16].

3. Some Common Mistakes

3.1. Power supply

The power supply circuit of the biomedical suctioner consists of diodes, voltage regulators and filters. The input power supply is stepped down to a voltage of 12-0-12 V ac. this stepped down alternating voltage is then fed into the bridge rectifier built using four diodes. Pulsating dc (DC with ripples) is the output of bridge rectifier. The dc can't be applied to the circuits with ripples in it. Therefore, the pulsating is applied to a filter (capacitive filter) and thus it removes the ripples from the input. A voltage regulator of 12 V and 5V are connected at the output of filter. Thus the voltage regulators help in providing constant voltage of 12V and 5V irrespective of higher voltages at the input of the transformer.

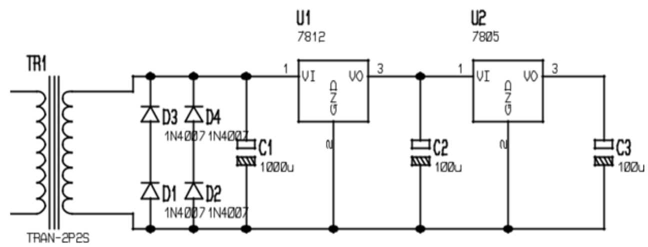

Fig. 1Power Supply circuit for the Biomedical Suctioner

Figure 1 represents the block diagram that contains the power supply circuit. A transformer is connected with the ac voltage of typical value 230 V rms. This transformer steps the ac voltage down to the level for the required dc output. The full-wave rectified voltage is provided by diode rectifier. A simple capacitor filter filters this full-wave rectified voltage to produce voltage which is dc. Some AC voltage variation or ripple or is present in this resulting DC voltage. This dc input is used by a regulator circuit to provide the DC voltage. This DC voltage has very less ripple voltage and remains the same even though the input DC voltage varies, or the load is connected to output DC voltage changes. By using one of the voltage regulators such as 7805, 7812, the voltage regulation is obtained.

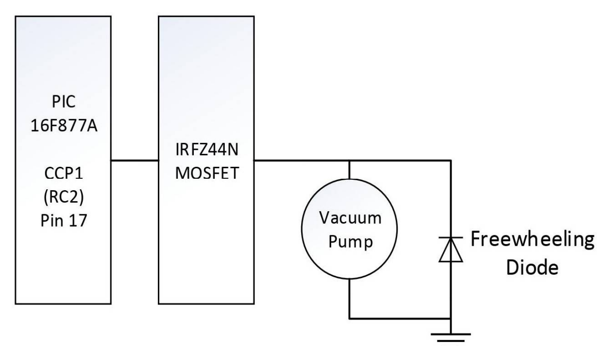

Fig. 2Block Circuit connection of Biomedical Suctioner

The above circuit diagram is of dual purpose serving both as a +5V and a +12V power supply. The output voltage of +5V and 0V is obtained using the voltage regulator IC7805 and +12V and 0V using IC7812.

3.2. Motor Specifications

Type: M42x20/I
M: Motor
42mm: Motor Diameter
20mm: Anchor Diameter
I: Ball bearings

3.3. DC Chopper

The PWM signal from microcontroller is fed to gate of IRFZ44N (nMOSFET).It acts as a DC chopper. It converts fixed DC to variable DC. And the output from the chopper is given to the input of the pump with a freewheeling diode.

The circuit connection of the Biomedical Suctioner is shown in the figure 2.

4. PCB Design

4.1. Introduction

The core of electronic domestic and industrial equipment is formed by Printed circuit boards or PCBs. PCBs are intensively used in process control, computers, instrumentation and telecommunications

4.2. Manufacturing

There are two methods of manufacturing process. They are print and plate, print and etch etc. Using the print and etch method, the single sided PCBs are usually manufactured. Using the print plate and etch method, double-sided plate through-hole boards are manufactured. The multilayer boards are made using both methods. And the inner layer is printed and etched. After pressing the inner layer, outer layer is produced by print, plate, etch.

4.3. Software

By using Orcad software, the schematic layout is obtained.

4.4. Penalization

The schematic is transformed into the working positive and negative films. The repeating of circuit is done to accommodate economically many circuits in a panel. The circuits in panel could be operated in every sequence of subsequent steps in the PCB process. The above process is known as penalization. Drilling is the next operation for PTH boards.

4.5. Drilling

A state of the art operation is PCB drilling. High speed CNC drilling machines drills a very small hole which gives a wall finish with no smear or epoxy.

4.6. Plating

Plating is the most important process in the PCB manufacturing process. Before the deposition of copper, the holes in the bored are treated using the process of electro less copper plating.

4.7. Etching

Multilayer board is drilled. Then the deposition of electro less copper is observed. The image is transferred on to outside by photo printing using the process of dry film printing. The boards are electrolytically plated on the circuit pattern with copper and tin. The tin-plated deposit serves as an etch resist when copper in the unwanted area it is removed by the conveyor spray etching machines with chemical etching agents. The etching machines are attached to automatic dosing equipment. Automatic dosing equipment analyses and controls the etching agent’s concentration.

4.8. Solder Mask

To avoid bridging of conductors, a solder mask has to be applied on the both sides of the circuitry since PCB design may need close spacing between conductors. By using screening, the ink is dried, exposed to UV, and cured by using UV and thermal energy.

4.9. Hot Air Leveling

Soldering of circuit pads is done after applying the solder mask. The process of hot air leveling is used to do this. The bare bodies are fluxed and dipped into a molten solder bath. After removal of board from the solder bath, hot air is blown on both sides of the board through air knives in the common finishes given to the boards. Thus, manufacturing of the double side plated whole printed circuit board is done. And it is ready for the components which are to be soldered.

5. Operation of the Bio Suctioner

The Pulse Width Modulation is used for the controlling input voltage of the pump which in turn controls the pressure. By using the data, the duty of pulse to output can be changed into CCP1 by Pulse Width Modulation. When the time which made the H level of the pulse of CCP1 long, the time of ON becomes long FET. That is, the drive electric current of the motor gets increased. Oppositely, when the H level time of the pulse of CCP1 is short, the ON time of FET becomes short. And the drive current gets decreased. To drive the motor, N-channel.

MOSFET is used. The P-channel MOSFET can also be used. In the above case, duty control of CCP1 pulse is opposite. The FET acts as a DC chopper. The PWM signal is fed to the gate. As duty cycle varies the input voltage varies hence the suction pressure varies. The suction pressure is varied in steps of 50mmHg form 0 to 200 mmHg. It is set by the user as prescribed by the doctor. The operation of bio suctioner is shown as a flowchart in figure 3.

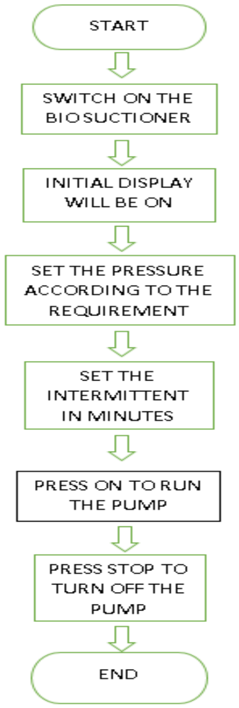

Fig. 3 Flow chart

The operating procedure of the biomedical suctioner is as follows

1. Turn on the biomedical suctioner.
2. Choose the settings for pressure and timing.
3. Run in the desired mode.

5.1. Calibration of the Pump

Table 1 Calibration of Pump

S.No	Timer preset(P)	Duty cycle (P/256*100) %	mmHG
1	0	0.0	0
2	62	24.2	50
3	88	34.4	100
4	103	40.2	150
5	111	43.4	200

5.2. Microcontroller

The PIC microcontrollers can be programmed either in assembly or high level language. The MPLAB provides the assembler for assembling the assembly code. The MPLAB also provides Integrated Development Environment where the tool chains from Microchip or from Other Third Party Vendors can be installed. The compiler tool chain reduces the time required to develop the code by providing library functions. For example, in the configuration of ADC, the inbuilt libraries help to reduce the time so much, since standard library functions are available to control and get the result from the ADC unit. The microcontroller used in this biomedical suctioner is PIC 16F877A. It is a low cost microcontroller and is having CCP modules, which can be used to control the speed of the vacuum pump.

6. Results

The project was tested in GVN hospital at trichy on a diabetic patient who was 60 years old lady. She has the chronic wound at right thy (shown in figure).

Fig. 4 Before application of Biomedical Suctioner

Fig. 5 After application of Biomedical Suctioner

The pus was continuously secreted from the wound of the patient, therefore the dressing had to be change frequently. This makes the patient to suffer a lot. By introducing our bio medical device the wound was always kept dry so frequent dressing is avoided. Below figure 4 is the wound of the patient before treated by the device.

Fig. 6 Complete Equipment setup and Application

The wound was dressed with airtight dressing material by placing the suction tube over the wound where the suction tube is connected to the collection tank. The other end of the tank is connected to the suction device. The device was set to operate in the continuous mode at the pressure level of 150mm Hg. The system was monitored for 48 hours and the collection tank was cleaned after it gets full. Then the treatment was continued for four more days and the figure 5 shows that the wound of the patient after the treatment.

The figure 5 clearly indicates that the wound has recovered very soon due to introduction of our suction device. On the other hand, the patient had no inconvenience or pain during the collection of pus.

The figure 6 shows the cost effective bio suctioner and the application of the device on the patient with diabetic wound.

7. Conclusion

As observed from the result, the objective of the system is to be a cost effective solution for healing the diabetic wounds. Now the equipment can be used effectively in place of existing systems/methods in hospitals.On advice of doctor pressure can be varied for patients from 50-125 mmHg in steps of 10. Two modes of operation namely continuous and intermittent mode with varying time slots Wound state can be maintained dry resulting in early healing. Further enhancement includes making this project into product. This involves designing of casing collection tank, commercial, developing a protocol and for hiring of the equipment through internet and database maintenance of the patients.

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