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Designing a Device that Uses Sensor to Measure Blood Sugar Levels

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Annotation: Diabetes is the most commonly occurring diseases around the world; approximately 415 million people among the 8 billion population of the world suffer from diabetes. Diabetes is caused due to increase in the blood sugar concentration which may affect the heart, blood vessels, kidney and nerves, etc. The monitoring of blood sugar level is very important in case of diabetic patients, since it is necessary to keep the blood sugar level in limit. Hence, it is necessary to regularly monitor the blood glucose level of the diabetic patients. Currently, the measurement of the blood sugar level is done only by pricking the finger which is a painful process and may cause infections, the patients get suffer from physical pains and it has a higher risk of infection. The non-invasive procedure does not involve any pricking of the finger; hence there is no pain or chance of infections. Therefore, we propose a non-invasive method using infrared sensor for transmission and receiving of rays to and from fingertip for real-time monitoring of the sugar level. Because to determine blood sugar levels is only done by put finger index on the sensor, the results will display after 30 seconds, and does not hurt the fingers. So that this tool can be used by all groups, both medical and non-medical personnel to measure blood sugar non-invasively. This study uses the MAX30100 sensor as a non-invasive measure of blood sugar levels.

The Value of blood sugar levels in this instrumentation is displayed on LCD. Tests were carried out on 20 Normal patients and people with diabetes mellitus. Based on the testing and analysis that has been done, this tool still needs to be developed with more data collection, so that the accuracy of checking is getting better.

CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

The blood glucose level is the amount of glucose present in the human's blood. Glucose is a simple sugar contains approximately 4 grams of glucose which are present in the blood of 70-kilogram (150lb) humans at all time. Glucose is stored in the form of glycogen in skeletal muscle and liver cells; in fasted individuals, blood glucose is maintained at a constant level at the expense of glycogen stores in the liver and skeletal muscle. This contributes to cell dysfunction and the pathology grouped together as complications of diabetes. A continuous rising in the blood glucose leads to glucose toxicity, this disease is becoming one of the main causes of death in the world [1], and The World Health Organization (WHO) estimates that diabetes is the 7th deadliest disease. Diabetes is a very dangerous disease that affects most people and requires a lot of attention to stay healthy. According to Ministry of Health of the Republic of Iraq, Diabetes is caused by a lack of the hormone insulin produced by the pancreas to reduce blood sugar levels. Diabetes mellitus is characterized by persistent hyperglycemia from any of several causes, and prominent diseases related to failure of blood sugar regulation. Diabetes mellitus can be classified into Type 1 diabetes, Type 2 diabetes and Gestational diabetes. Nowadays even a newborn babies also affected by diabetes mellitus which leads to growth abnormalities. Normal sugar levels in the human body are divided into two conditions, normal blood sugar levels checked when not fasting are <200 mg/dl, and normal blood sugar levels when fasting are <126 mg/dl [2]. Current measurement methods require a blood sample for analysis with a glucose meter using blood from a vein or fingertip. This procedure is painful and inconvenient for patients, especially those who need to check multiple times a day. This condition motivates us to design device for glucose measurement in non-invasive method.

CHAPTER 2

LITERATURE SURVEY

2.1 LITERATURE REVIEW

In NIR based blood glucose detection method transmitted signal strength decreases with increase in the glucose level, because of the absorption of light by blood glucose. This is an inverse proportion of the transmitted signal strength to the blood glucose level. A study on this shows the strong correlation between actual concentration of glucose and noninvasively measured concentration [3].

A study on Non-Invasive blood glucose monitoring based on Transmittance and Refraction of Laser Light results of the experiments showed that wavelength 650 nm red visible light is suitable for non-invasive blood glucose monitoring. Visible laser light with a wavelength of 650 nm has a transmittance by both the human finger and water 30 times higher than that of Near Infrared Light [4]. Results of an experiment showed that as the glucose concentration in the solution increases the refractive angle of laser light decreases, the laser light intensity decreases on the photo detector, which in turn increases the output voltage [4].

In near infrared LED diffusion reflectance method, the main principle is Beer lambert's law. When the light interacts with human tissues attenuation will occurs due to absorption and scattering of the light. When the concentration of glucose is increases then absorption is also increasing but scattering is decreases. For this reason, the diffuse reflectance is decreases. In this method for error checking they used Clarke Grid Error analysis (CGE) [5]. The obtained prototype can be converted into a simple wearable device. The errors can be minimized by making the light reaching the photo detector and effect of sunlight should be more stable.

2.2 LITERATURE REVIEW

In Near-Infrared Spectroscopy with Remote Data Logging method [6] the absorbance of samples is greater at a wavelength of about 845 nm, so we prefer (SFH4550) NIR. When the light intensity on the photodiode increases, as the sample absorption of light also increases, there results a change in current passing through the diode then we use a current to voltage converter that results in a voltage which is proportional to the current. The photoplethysmography signal is obtained by filtering the unwanted signals from voltage by effectively designing the bandpass filter circuits. And the patient's data is transmitted to the remote server.

In NIR spectroscopy method the required measuring components are photodiode, LED light and arterial pulse. If the LED is passed through the finger the transmission will occur, attenuated light wave transmitted by the finger is measured by using a photodiode. To indicate pulse rate is measured by using an arterial pulse. DC supply of 5V is used for powering the LED [7]. The obtained current from the photodiode is converted into voltage. To obtain the actual visible output, the resulting output signals are given to the amplifiers. Using the 2nd order Butterworth low pass filter, the obtained signals are filtered with a cut-off frequency of 180 Hz. Butterworth filter removes all high-frequency noise from the signals. The finger is placed in the sensor we will get photo plethysmograph waveform as final results. Due to the variation in signal attenuation, the output voltage is obtained from the NIR sensor. To perform A to D conversion the signal can further give to the Arduino microcontroller. These hardware results can be monitored on the LCD display

2.3 LITERATURE REVIEW

Absorbance of glucose is maximum at 940nm wavelength. The concentration of glucose and the voltage have the good linear relation. LCD displays or digital displays are interfaced with the obtained results can get by using Arduino

CHAPTER 3

METHODOLOGY

3.1 METHODOLOGY

In the proposed design system model, we are using Arduino mega2560 as microcontroller for monitoring the Max30100 sensor .In our design we are applying Beer Lamberts law principle. It states that the light absorption is directly proportional to the concentration of the medium. Beer lamberts Law Equation is given in Equation. (1).

$A \alpha C$ ……. (1)

Where A is act absorption and C is acting concentration (mol /L).

When we would place the finger on Max30100sensor, then due to the molecules present in the tissues light rays would interact with the molecules and results in attenuation the light. From the output signal of the Max30100 we obtain analog data this will be converted into digital value by using inbuilt ADC in Arduino microcontroller. The obtained patients' blood glucose values from the output of regression equation are displayed on16x2 LCD.

3.2 BLOCK DIAGRAM OF PROPOSED SYSTEM

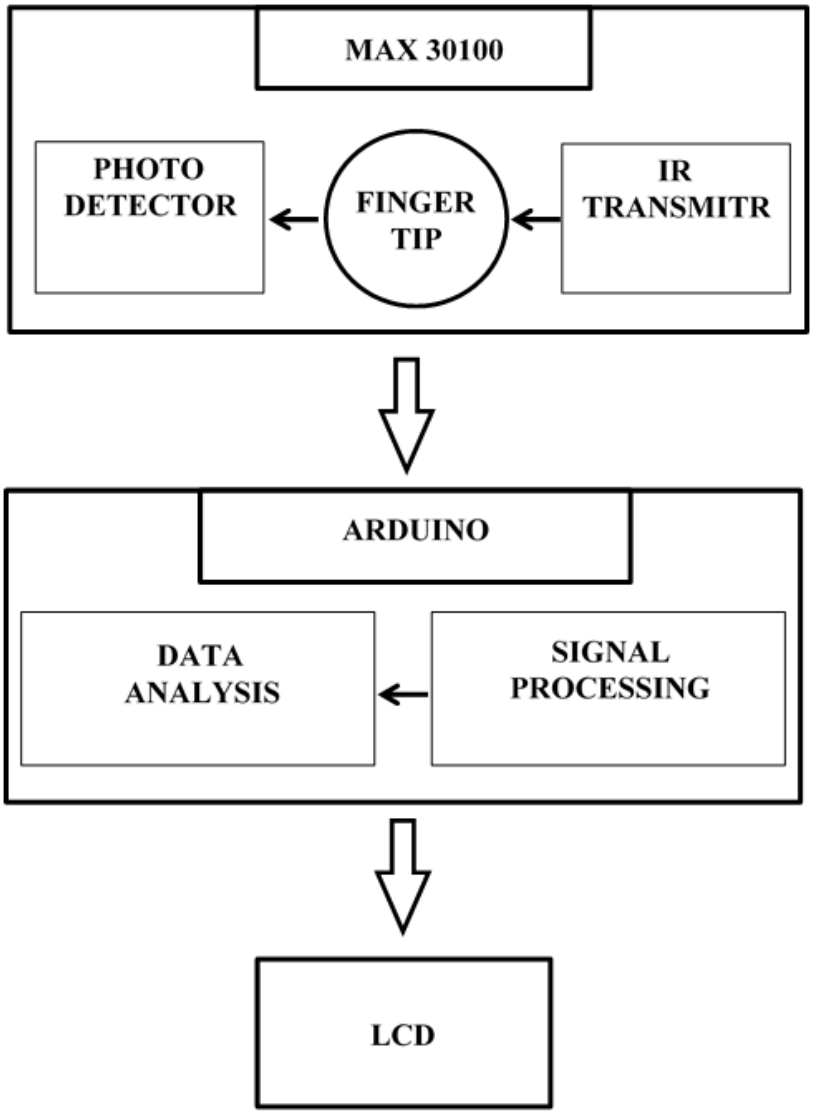

Fig (3-1): Block diagram of Proposed system

3.3 FLOWCHART OF THE PROPOSED SYSTEM

3.4 PROJECT PARTS

3.4.1 Resistors

A resistor is a passive two-terminal electrical component that implements electrical resistance as a circuit element. In electronic circuits, resistors are used to reduce current flow, adjust signal levels, to divide voltages, bias active elements, and terminate transmission lines, among other uses. High-power resistors that can dissipate many watts of electrical power as heat may be used as part of motor controls, in power distribution systems, or as test loads for generators. Fixed resistors have resistances that only change slightly with temperature, time or operating voltage. Variable resistors can be used to adjust circuit elements (such as a volume control or a lamp dimmer), or as sensing devices for heat, light, humidity, force, or chemical activity.

Fig (3-3): Resistors

3.4.2 Push-button

A push-button (also spelled pushbutton) or simply button is a simple switch mechanism to control some aspect of a machine or a process. Buttons are typically made out of hard material, usually plastic or metal. [6] The surface is usually flat or shaped to accommodate the human finger or hand, so as to be easily depressed or pushed. Buttons are most often biased switches, although many un-biased buttons (due to their physical nature) still require a spring to return to their un-pushed state.

Fig (3-4): Push-button

3.4.3 LCD

Liquid crystal displays (LCDs) combines the property of both liquid and crystals. They have a temperature range in which the molecules are almost unstable as they would be in liquid stage but are grouped together in order to form similar crystal. It consists of two glass panels made up of liquid crystal material sand witched in between them. The inner surface is coated with transparent electrodes. It consumes less power and compatible with low power electronic circuits which can be powered for long duration.

Fig (3-5): LCD

3.4.4 LED

A light-emitting diode (LED) is a semiconductor device that emits light when current flows through it. Electrons in the semiconductor recombine with electron holes, releasing energy in the form of photons. The color of the light (corresponding to the energy of the photons) is determined by the energy required for electrons to cross the band gap of the semiconductor. White light is obtained by using multiple semiconductors or a layer of light-emitting phosphor on the semiconductor device.

Fig (3-6): LED

3.4.5 Microcontroller

The Arduino Mega 2560 is a microcontroller board based on the ATmega2560. It has 54 digital input/output pins (of which 15 can be used as PWM outputs), 16 analog inputs, 4 UARTs (hardware serial ports), a 16 MHz crystal oscillator, a USB connection, a power jack, an ICSP header, and a reset button.

Microcontroller	ATmega2560
Operating Voltage	5V
Input Voltage (recommended)	7-12V
Input Voltage (limit)	6-20V
Digital I/O Pins	54 (of which 15 provide PWM output)
Analog Input Pins	16
DC Current per I/O Pin	20 mA
DC Current for 3.3V Pin	50 mA
Flash Memory	256 KB of which 8 KB used by bootloader
SRAM	8 KB
EEPROM	4 KB
Clock Speed	16 MHz
LED_BUILTIN	13
Length	101.52 mm
Width	53.3 mm
Weight	37 g

Fig (3-7): Arduino Mega 2560

3.4.6 MAX30100

The Max30100 is a sensor used to detect the patient's oxygen saturation level and acts as a heart rate monitor. It includes two LED's, a photo detector, optimized optics, and low-noise analog signal processing to detect oxygen saturation level and heart-rate signal. It operates between 1.8V to 3.3V power supplies. It has high sample rate capability and fast data output capability. The device has two LEDs, one of which emits red light and the other of which emits infrared light. The wavelength of red light is 660nm, whereas the wavelength of infrared light is 940nm.

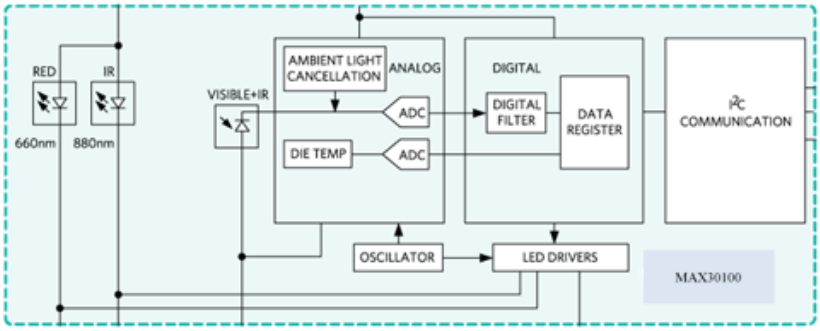

Fig (3-8): Internal components of MAX 30100

Fig (3-9): MAX30100

3.4.7 Battery 9V

A 9V battery is a small, rectangular-shaped battery commonly used in portable electronic devices such as remote controls, smoke detectors, and small audio devices. It is called a 9V battery because it provides a nominal voltage of 9 volts when fully charged.

9V batteries are typically made up of six cylindrical or rectangular cells connected in series inside a single housing. The cells are usually made of carbon-zinc or alkaline chemistry and are designed to provide a stable voltage over a relatively long period of time.

The terminals of a 9V battery are usually located at one end of the housing, with a positive and negative terminal for connection to an electronic device. The battery is typically designed to be easily replaceable, with a Snap-On or slide-in connector that allows it to be quickly and easily removed and replaced as needed.

Fig (3-10): Battery 9V

3.5 Circuit Diagram using Fritzing simulation

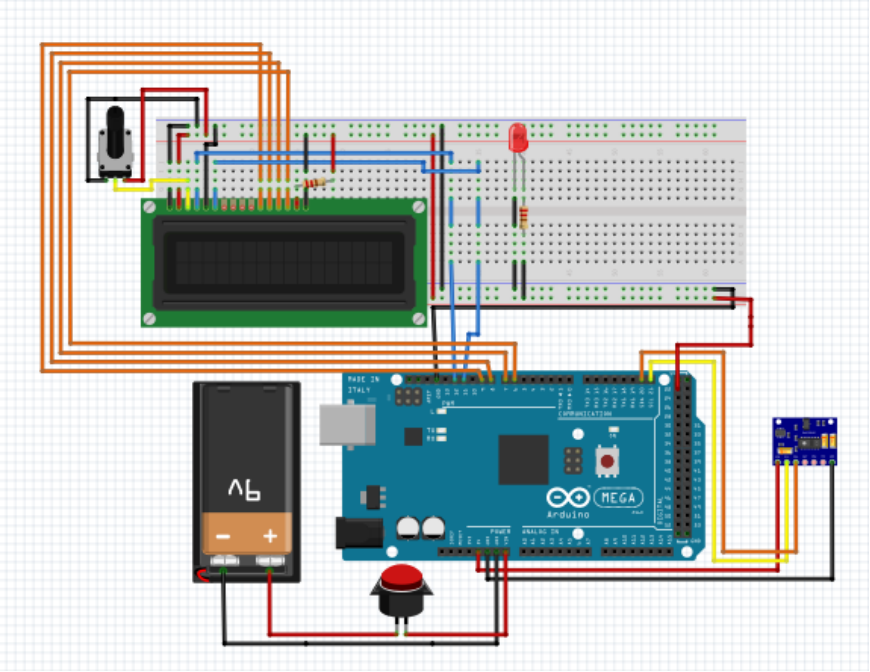

Fig: (3-11) Circuit Diagram

3.6 Procedures required for use this project:

1. Select a timing option by means of the rotary switch SW1.
2. Choose 15, 30- or 60-minutes operation.
3. Select “Stop” or “Alternate” mode operation by means of SW2.
4. With SW2 closed (Stop mode operation) the electromagnetic radiation stops after the preset time is elapsed.
5. With SW2 opened (Alternate mode operation) the device operates for the pre-set time, then pauses for the same amount of time: this cycle repeats indefinitely.
6. Place the unit under the pillow and sleep like a log.
7. To reset a cycle press P1 pushbutton.

Notes:

L1 is obtained by winding randomly 600 turns of 0.2 mm, enameled wire on a 6 mm, diameter, 40 mm, long, steel bolt and secure the winding with insulating tape.

Mean current drawing is about 7mA, decreasing to less than 4mA during pauses when in Alternate mode operation.

Battery life can be dramatically increased omitting LED D2 and its associated resistor R5. Use a plastic box to enclose the circuit: metal cases can severely limit electromagnetic radiation.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 RESULTS

To test the MAX30105 Sensor, there is a standard **calculation used, namely:**

- **Error**

To get the Error, we need the Error Percentage Formula,[7]

The Error Percentage Formula is:

$$EP = \frac{(Xt-Ft)}{Xt} \times 100\%$$

Where Xt is act Data in period t and Ft is acting the predicted value in period t,

From the formula above, we can make the formula into:

$$\boldsymbol{Error}(\%) = \frac{|\boldsymbol{Noninvasive\ test - invasive\ test}|}{\boldsymbol{invasive\ test}} \times \mathbf{100}$$

- Accuracy Check

$$\boldsymbol{Accuracy\ Check} = \mathbf{100}\% - \boldsymbol{Error}(\%)$$

4.2 Test results for blood sugar

Patient	Sex	Age	Invasive method (mg/dL)	Non-invasive (mg/dL)	Error(%)	Accuracy(%)
Patient1	M	22	91	82	10	90
Patient2	M	24	85	74	13	87
Patient3	F	28	82	71	13	87
Patient4	F	31	85	79	7	93
Patient5	M	29	97	82	15	85
Patient6	F	38	87	75	13	87
Patient7	M	31	81	72	11	89
Patient8	F	21	79	68	14	86
Patient9	M	33	75	63	16	84
Patient10	F	45	88	72	18	82
Patient11	F	41	105	86	18	82
Patient12	F	25	78	75	4	96
Patient13	M	32	93	85	9	91
Patient14	F	39	110	101	8	92
Patient15	M	44	97	86	11	89
Patient16	M	23	76	72	5	95
Patient17	F	41	79	73	8	92
Patient18	M	22	133	121	9	91
Patient19	F	34	83	79	5	95
Patient20	F	36	127	107	15	85

Test results for blood sugar

4.3 Discussion

This project includes creating a device to check blood sugar levels in a non-invasive way by placing the finger on the near infrared sensor. It has many benefits.

Benefits:

1- Conduct a medical examination without piercing the body

2- Reduces the risk of virus transmission.

3- A quick procedure compared to the invasive method.

4- It does not require a test strip.

5- Safe.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

Instrumentation for detecting blood sugar levels non-invasively (not injuring the body) is made using the MAX30100 sensor and the Programming Algorithm on the Arduino IDE. The measurement of noninvasive blood sugar levels in this study was done by attaching the index

finger to the sensor, and did not have to hurt the fingers until blood appeared. The value of blood sugar levels in this instrumentation is displayed on LCD test results Non-invasive blood sugar detection instrumentation with industry standard blood sugar measuring instrument (Invasive) resulted in an accuracy of 90.3% blood sugar reading with a deviation value of 1.2 - 39.6 mg / dL. Tests were carried out on 20 Normal patients and people with diabetes mellitus.

5.2 Recommendations

1. Consult with experts in the field: Before attempting to create a biomedical device, it's essential to consult with experts in various fields, such as engineering, biology, and safety and regulatory compliance. They can help ensure the safety, efficacy, and compliance for project.
2. Conduct thorough research: It's important to conduct thorough research on the scientific literature, regulatory requirements, and potential risks and benefits associated with the use NIR based blood glucose detection method
3. Prioritize safety: Safety should be the top priority in any biomedical project. Make sure to follow all safety guidelines and regulations and consult with experts to ensure that device is safe for use.
4. Test and evaluate device: Once you have created device, it's important to test and evaluate its effectiveness and safety in a controlled environment. This can help to identify any potential issues and refine the design.
5. Consider alternative approaches: If you are unable to create a safe and effective biomedical device, he most promising technologies are 1) near-infrared light spectroscopy, 2) far-infrared radiation spectroscopy, 3) radio wave impedance, 4) optical rotation of polarized light, 5) fluid extraction from skin, and 6) interstitial fluid harvesting., as well as technical problems to overcome

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