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Experimental

DEVELOPMENT OF MICROCONTROLLER BASED BODY MASS INDEX MACHINE

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Abstracts
An essential diagnostic tool for monitoring body mass distribution with the associated health implications in humans is a Body Mass Index (BMI) machine. This widely used metric for body mass is derived from measuring human height and mass which its manual/orthodox determination is very tedious and prone to errors. This study developed a microcontroller based BMI machine for automatic, accurate, interactive monitoring means of human health. The system design was achieved through Proteus 8.9 electronic simulation application software and, the development was actualised through construction using soldering, fitting, and coupling of electronic components. Body mass load cell in a Wheatstone format with HX711 and ultrasonic based (HC_SR04 sensor) were utilised for capturing mass and height. The machine is controlled by Arduino microcontroller programmed in C language to calculate the BMI and provides confidential result (interpretation) through a dedicated SIM card of GSM Module SIM900L to a medical practitioner. The system automatically output user's BMI parameters and value on a Liquid Crystal Display (LCD) and include BMI interpretation as text for medical diagnosis to a dedicated doctor's line. The system was accurate, reliable and can be adopted as a screening tool for obesity and other related diseases.

Keywords: Body mass index, liquid crystal display (LCD), microcontroller, GSM module SIM900L, ultrasonic sensor, wheatstone.

1.0 INTRODUCTION

Body mass index (BMI) is a widely-used method to assess a person's weight status by comparing their weight in relation to their height. BMI is calculated by dividing a person's weight in kilograms by the square of their height in meters. A BMI machine is a device that measures a person's weight and height and calculates their BMI automatically. In this study explore the development of BMI machines and their impact on healthcare (National Heart, Lung, and Blood Institute, 1998; World Health Organization, 2000).

The development of BMI machines can be traced back to the early 2000s when electronic scales with built-in height measurement devices began to be used in clinics and hospitals. These machines provided an automated method for the calculation of BMI, eliminating the need for manual calculations. However, these early machines were often bulky and expensive, limiting their accessibility to healthcare providers (Abana, Llamelo, Daña, Cafugauan, & Angelo, 2020).

As technology advanced, BMI machines became more affordable and portable. In recent years, BMI machines have become widely available for use in gyms, health clinics and homes with the aid of mini computers known as microcontroller (Dipika, Varsha, Mhatre., Prashant, & Ayane, 2015). Many of these machines are equipped with additional features such as body fat percentage measurements and muscle mass analysis, providing users with a more comprehensive understanding of their weight status.

The use of BMI machines has several advantages in healthcare. They provide a quick and easy method for healthcare providers to assess a patient's weight status, allowing for the early detection of obesity and other weight-related health issues (Alao, Olajide, Musiliyu, & Owolabi, 2020). BMI machines also provide patients with a non-invasive method for monitoring their weight, which can be an important motivator for weight loss and healthy living (Akpan, Joshua, Agbogun, & Omotehinwa, 2019).

Obesity is a major health concern in most parts of the world. It is associated with several health problems such as diabetes, hypertension, heart diseases, and stroke (Flegal, Graubard, & Williamson, 2005; Chumlea, 2006; Etchison, Minton, Thompson, Collins, Hunter, & Dai, 2011). Body Mass Index (BMI) is a widely used metric for determining the health of an individual. BMI is a measure of body fat based on an individual's weight and height (Mokdad, Ford & Bowman, 2003; Baladad, Magsombol, Roxas, De Castro, & Dolot, 2016). It is calculated as the weight in kilograms divided by the square of the height in meters (kg/m^2). A

BMI of 25 or above is considered overweight, and a BMI of 30 or above is considered obese.

The accurate measurement of BMI is essential for the diagnosis and management of obesity-related diseases. The manual calculation of BMI can be time-consuming and prone to errors (Ewetumo, Adedayo, Lawal, Edun, & Orokhe, 2019; Owolabi, Akpan, & Oludola, 2021). Therefore, the development of a microcontroller-based BMI machine can help in the accurate and efficient measurement of BMI.

2.0 MATERIALS AND METHODS

This section of the study highlights the materials used in realizing the system, this can be categorised into three parts namely: electronics/electrical components, structural/mechanical framework and the computer with application software.

Table 1: Materials and their functional descriptions of the system

S/N	Description	Functions
		Electronics/Electrical Components
1	Power supply Unit	Transformer, diode, filter and voltage regulator
2	Ultrasonic Sensor	This is used for calculating the distance between obstacle (user head) and itself using the principle reflection of signal in Physics
3	GSM Module SIM900L	This is a communication module for transmitting and receiving result signal (text) between the system and medical practioner.
4	Connecting Wires	Serve as links between subsystems of input, microcontroller and the output components
5	Liquid Crystal Display (16x2)	This outputs the processed information of the microcontroller in form digital display.
6	HX711 Circuit Amplifier	This serves as signal converter that drives the load cell data in appropriate format to the microcontroller.
7	Push Button	These are switches for changing the signal state of the device.
8	Adapter and Data Transfer cable	For serial communication of signal between components of subsystems
9.	Load Cell (50kg)	Four pieces each of 50kg mass capacity connected in Wheatstone bridge format to measure user's mass.
		Structural/Mechanical Framework
10	Glass Weighing Base (TS-2003A)	This serves as structural basement that houses the load cell on which user's mass is captured.
11	Iron pole and base construction	For structural framework, support and protection of internal components
		Computer with application software
12	Proteus 8.9 electronics simulation software	This is an application platform for designing and simulating system circuitry
13	ARDUINO IDE	Arduino Integrated Development connects the Arduino hardware for programs uploading and subsystem communication.
14	SIM Card	Serves network communication carrier
15	Computer System	Dell latitude laptop, core i7, 512 SSD, 16 GIG RAM, 2.80 GHz processor speed,
16.	Arduino UNO	This is the microcontroller board that receives inputs processes it and send the output to GSM module and LCD.

Design and Analysis

The main hardware components in this system include load cell, HC-SR04 ultrasonic sensor, Arduino UNO (ATMEGA) microcontroller, 16 x 4 liquid crystal display (LCD), 4 x 4 Matrix Keypad, load cell amplifier, Connecting Wire, GSM Module. Figure 1, shows the subsystem assemblage in block diagram format of microcontroller based body mass index machine.

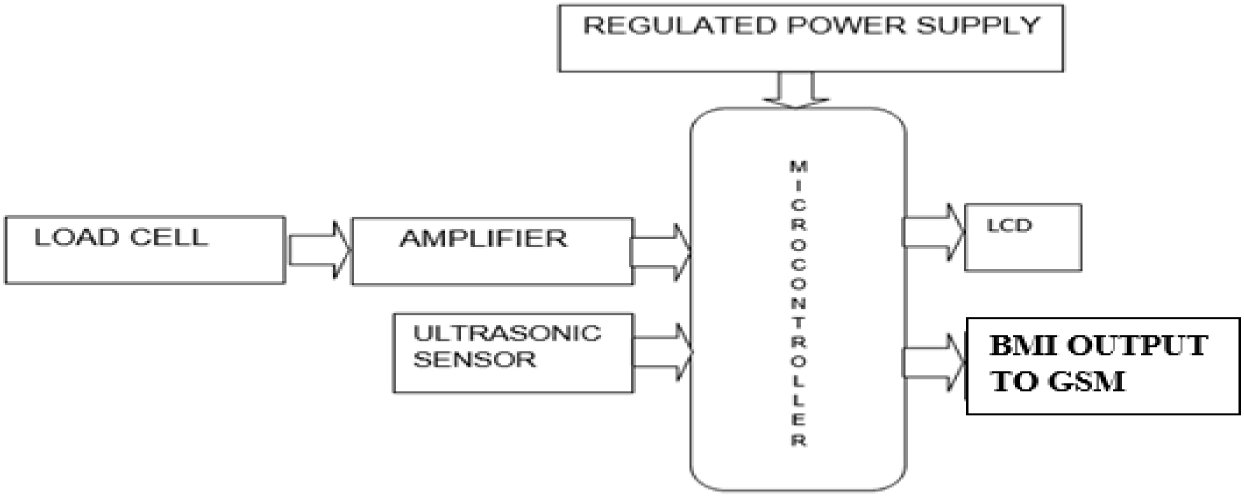


Figure 1: Block diagram of the system

The machine consists of a load cell, a height sensor, a microcontroller, an LCD display, GSM module and a power supply as shown in the system circuit diagram in Figure 2. The load cell is used for measuring the weight of the individual, and the height sensor is used for measuring the height of the individual. The microcontroller is used for processing the weight and height measurements and calculating the BMI in real-time. The LCD display is used for displaying the weight, height, and BMI of the individual.

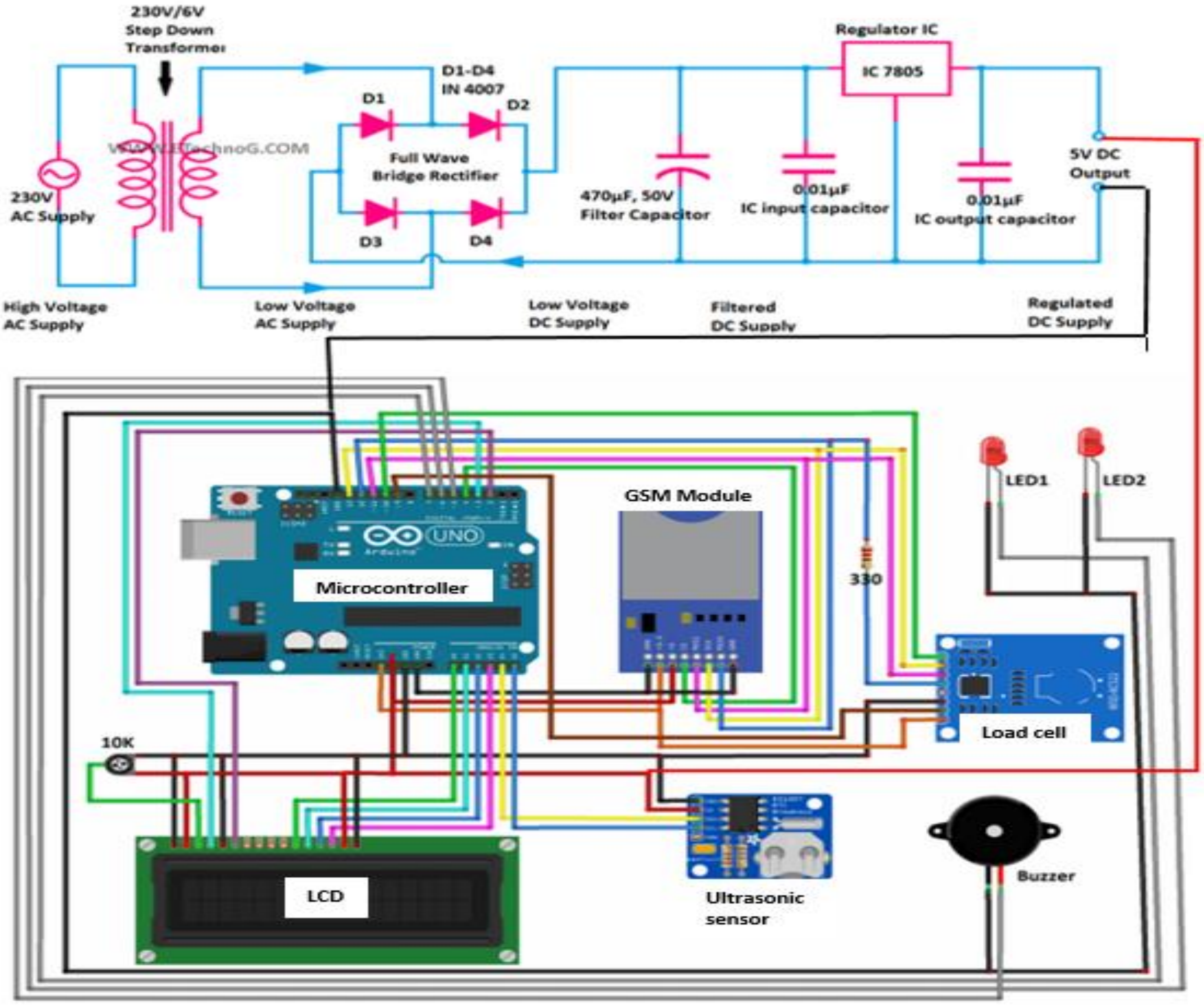


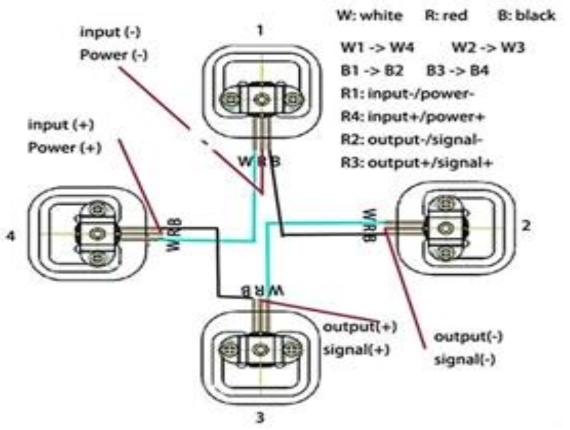
Figure 2: Complete Circuit Diagram of BMI Machine

System Power Supply

The system is driven by regulated 5V power supply unit. The power supply unit comprises of a stepdown transformer that have 220V (AC) mains as input steps it down to 9V, this is passed through a full wave bridge rectifier for conversion to direct current signal, a Pi-RC filter was designed to remove ripple and unwanted signal (noise), and finally passed through a voltage regulator (LM7805) for steady output signal.

Load Cell Circuitry for User's Mass Measurement

Four human body load cells of 50kg mass capacity each therefore effective total mass capacity of 200kg are connected in full bridge Wheatstone format, the signal from load cell is driven into the microcontroller through a HX-711 amplifier. Figure 3. shows the circuit connection of the load cells and HX-711 amplifier all placed and soldered in the glass basement.



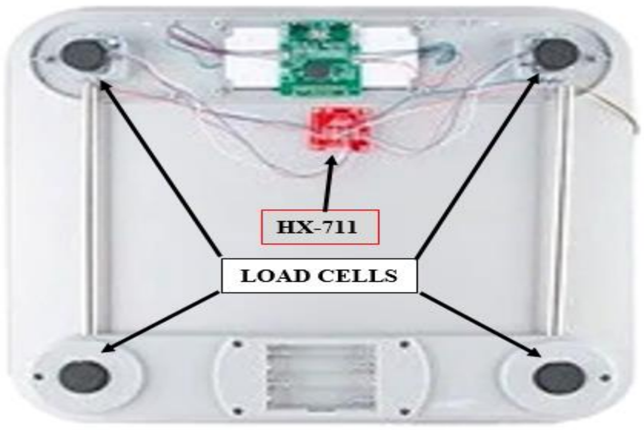


Figure 3: Load cells and HX-711 Amplifier Circuitry

Interfacing HC-SR04 Ultrasonic Sensor for Height Measurement

The sensor works based on reflection phenomenon, one of the two transducers acts as a transmitter which will emit a shot of audio burst at the barrier or surface and the same is received by the second transducer which acts as a receiver. Based on the time of transmission to when it is received by the receiver, the distance can be calculated based on the speed of sound. The sensor is attached to the system framework above the user's head for measurement of height.

Arduino Microcontroller Inputs and Output Interfacing

The microcontroller, which uses the Arduino Uno microcontroller board based on Atmega328 with fourteen (14) digital input and output pins and powered by a 5V power supply is used as the system brain box. The algorithm for the microcontroller written in C++ language was designed to receive inputs from the ultrasonic sensor, the load cell and processes it to calculate the BMI of the user based on Equation (1) as outputs to the LCD and the GSM communication module.

$$BMI = \frac{Mass(kg)}{(Height)^2(m^2)} \tag{1}$$

3.0 RESULTS AND DISCUSION

Complete System Framework

The system was designed with proteus8.9 electronics simulation software according circuit diagram, it was constructed through soldering, fitting and assemblage of components and subsystems. System is powered with 220V AC mains and a switch button is pressed to initialize the booting process of the computer. Figures 4. show the microcontroller based body mass index machine and when occupied with user.

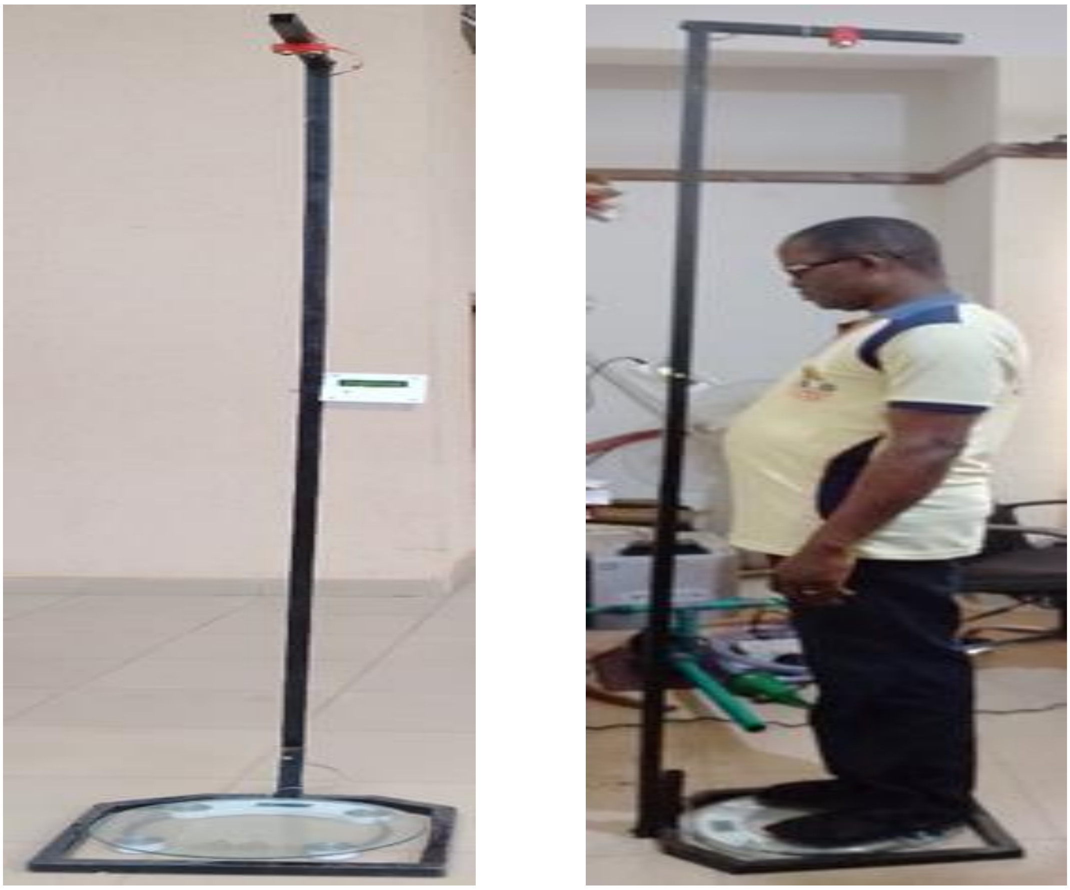


Figure 4: Microcontroller Based Body Mass Index Machine with User

Performance Test for LCD and Microcontroller

One thousand ohms of the resistor is used to limit the current going to the crystal display, and a variable resistor is used to vary the crystal display on the board. The LCD shows the BMI value as calculated by the microcontroller. Figure 5a. shows cascaded phases of the LCD when in the OFF and ON (booting and working) states.

The microcontroller does not only communicate the results on the LCD but programmed to send a backend confidential result about the interpretation of the BMI to a designated GSM contact of a medical practioner for report. Figure 5b. shows a screenshot of the result communication between the microcontroller and the GSM module.

Figure 5: (a) LCD Interface at Different States (b) Backend Confidential Communication between GSM module and Microcontroller

4.0 CONCLUSION

After the whole construction and the design analysis, the BMI Machine was able to display the weight and height, BMI (kg/m^2), BMI interpretation such as: Underweight, Overweight, Normal Weight, Obesity and often considered as a machine checker of body fatness. The result of the BMI is displayed on the LCD and also sent to the registered GSM which can be used to aid the Doctor's report.

In conclusion, the development of BMI machines has provided healthcare providers and patients with a convenient and accessible method for assessing weight status. While BMI machines have limitations, they have the potential to improve healthcare outcomes by promoting early detection and monitoring of weight-related health issues. As technology continues to advance, it is likely that BMI machines will become even more accurate and widely available, further improving their impact on healthcare.

This study can be adopted in medical centres/laboratory, institutes and homes that needs BMI measurements for an easy calculation of their patient's BMI. It can be used to measure the height or weight as an optional value of the machine.

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