Automatic Body Mass Index Measurement Device

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ABSTRACT— Body fat composition is a function of the BMI. The BMI is used for screening the health of the general population due to the strong correlation between being overweight or obese and having health problems, chronic disease and premature death. People who are overweight or obese have an increased risk of hypertension, coronary heart disease, and stroke, type 2 diabetes, osteoarthritis, respiratory problems and so on. An increase in BMI happens so subtle that one may not take notice of it quickly. And since one is not ready to go through the stress of measuring his/her height and weight every day, we have decided to develop a device that will automatically calculate the BMI of a person in lessthan seconds. To achieve this, we used the ultrasonic sensor and the weight cell. This projectis achieved by using Ultrasonic sensor, 200kg weight cell, ATMega328p Microcontroller and 2004 LCD display. At the completion of the project, the test was carried out. The test result demonstrates suitability for an Automatic Basic Mass Index Measurement Booth.

INTRODUCTION

The higher risk of death resulting from excess adiposity may be attenuated by physical activity (PA). However, the theoretical number of deaths reduced by eliminating physical inactivity compared with overall and abdominal obesity remains unclear. **(Ekelund et al., 2018).**
The Body Mass Index (BMI) is a simple tool that estimates body fatness using a mathematical formula. The only instruments necessary to measure your BMI are a scale, a tape measure to determine your height and a calculator.

Why the BMI Measurement is Important

Once you know your BMI number, you'll want to know what it means. BMI is divided into weight status categories. Your health risk depends on the category you fall into.

A BMI of 18.5 or less is considered underweight, while a value between 18.5 and 24.9 is considered a normal weight. A BMI between 25 and 29.9 is overweight and 30 or greater is considered obese. For good health, you want to fall into the normal weight category. A higher BMI increases your risk of developing a chronic illness such as heart disease, diabetes or cancer. And having a BMI that's too low may pose a different set of health risks **(Manios, 2012).**

Determining a person's health based on weight and height squared was first developed in the early 19th century, according to a 2006 article about BMI published in the Archives of Disease in Children. But it wasn't until the 1980s that it was used more regularly by healthcare professionals as a means to assess health, and this was only because researchers were finding a correlation between the number calculated and health risk, according to a 2014 article published in Today's Dietitian.

Your BMI is determined by plugging your weight and height into a mathematical formula:

For example,
1.1 A 5-foot, 10-inch person weighing 210 pounds has a BMI of 30.1. This is because

A good scale, an accurate height measurement and a calculator are all that's necessary to estimate your BMI, making it easy to measure.

BMI Compared to Other Fat-Measuring Techniques

A number of other techniques are used to measure body fat, including underwater weighing, dual-energy X-ray absorptiometry, skinfold measurements and bioelectric impedance. But most of these require a special machine and/or a trained professional for accurate testing. While BMI is not a perfect tool, it's been compared to these other forms of measuring body fat and stands up fairly well on its own **(Sara Police, 2017).**

Dual-energy X-ray absorptiometry, or DXA, is considered one of the most accurate ways to measure body fatness and health risk. But because of the expense and complexity, the test is used primarily by those in research facilities.

BMI is a simple, easy-to-calculate tool that can be used anywhere and may be just as good as the more complicated body fat measurements. In fact, BMI measurements compare favorably to DXA measurements, according to a 2005 cohort study published in the International Journal of Obesity. This study compared the use of DXA against BMI, skinfold measurements of body fatness and risk of heart disease in a group of adolescents. The researchers found that both BMI and skinfold measurement correlated well with DXA for assessing health **(International Atomic Energy Agency., 2010).**

METHODOLOGY

The methodology implemented in the accomplishment of this research work includes the following;

1. Identification of components and tools to be used for the research work.
2. Documentation andobtaining of the required components.
3. Implementation of the components on a bread board for testing.
4. Programming of the microcontroller.
5. Powering of the setup circuit to see if it meets desire results.
6. Transferring of the circuit to a Vero board.
7. Implementation of the design.

REVIEW OF FUNDAMENTAL CONCEPTS

Load Cell

Load cells are transducers used to convert weight (Mass x Acceleration) into an electrical signal.
This signal can come in a number of different formats, such as a voltage change, current change or frequency change, while the majority of devices are based on the fundamental principle of change

of resistance in response to an applied load. Typically, a load cell consists of four strain gauges in a Wheatstone bridge configuration, while one strain gauge (Quarter Bridge) or two strain gauges (half bridge) are also available. A number of different options are available, including hydraulic load cells, pneumatic load cells and strain gauge load cells.

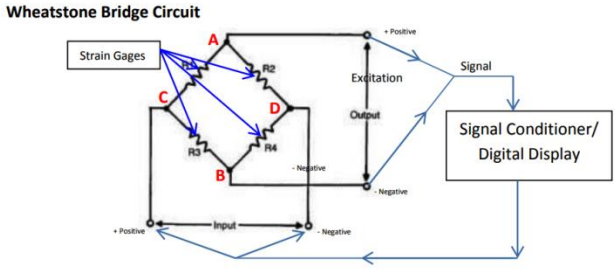


Figure 1: Diagram of a Wheatstone bridge circuit (**Dunnicliff, 1988)**

Strain gauge-based load cells

Strain-gauge load cells have become increasingly popular within the industry; in part because of the highly-precise and linear measurements they are capable of giving. Moreover, temperature changes do not have a big impact on their operations, while they are smaller in size when compared with other load cell options. Because of the lack of operating parts in the device, it has a relatively long operating life and it is very easy to produce **(Dunnicliff, 1988**).

For example**:** The KR high power load cell is specified for industrial applications such as tanks, silos and weighing bridge. It is operational for force and traction loads up to 30tonnes and comes with the protection class IP65. Boasting accuracy of 0.2%, it has an operating temperature of between -15ºC and 75ºC. Featuring a DMS strain-bridge (shear-beam device) for industrial applications, the SB8 Martens load cell with ATEX option is available as standard or with alterations made. Its maximum overload is 200% and a breaking load of 300%.

Ultrasonic Sensor

Ultrasonic sensors are used around the world, indoors and outdoors in the harshest conditions, for a variety of applications. Our ultrasonic sensors, made with piezoelectric crystals, use high-frequency sound waves to resonate the desired frequency and convert electric energy into acoustic energy, and vice versa. Sound waves are transmitted to and reflected from the target back to the transducer. Targets can have any reflective form, even round. Certain variables, such as the target surface angle, changes in temperature and humidity, and reflective surface roughness, can affect the operation of the sensors **(Migatron Corp., n.d.)**.

There are two types of ultrasonic sensors

a. **Proximity Detection:** An object passing within the preset range will be detected and generate an output signal. The detect point is independent of target size, material or reflectivity.

b. **Ranging Measurement:** Precise distance(s) of an object moving to and from the sensor are measured via time intervals between transmitted and reflected bursts of ultrasonic sound. Distance change is continuously calculated and outputted.

Microcontroller

A microcontroller is a computer present in a single integrated circuit which is dedicated to perform one task and execute one specific application.

It contains memory, programmable input/output peripherals as well a processor. Microcontrollers are mostly designed for embedded applications and are heavily used in automatically controlled electronic devices such as cell phones, cameras, microwave ovens, washing machines, etc.**(Lipovski, 2004).**

MATERIALS AND METHODS

HX711 Based on Avia Semiconductor's patented technology, HX711 is a precision 24-bit analog-to-digital converter (ADC) designed for weigh scales and industrial control applications to interface directly with a bridge sensor. The input multiplexer selects either Channel A or B differential input to the low-noise programmable gain amplifier (PGA). Channel A can be programmed with a gain of 128 or 64, corresponding to a full-scale differential input voltage of ±20mV or ±40mV respectively, when a 5V supply is connected to AV_{DD} analog power supply pin. Channel B has a fixed gain of 32. On chip power supply regulator eliminates the need for an external supply regulator to provide analog power for the ADC and the sensor. Clock input is flexible. It can be from an external clock source, a crystal, or the on-chip oscillator that does not require any external component. On-chip power on -reset circuitry simplifies digital interface initialization. There is no programming needed for the internal registers. All controls to the HX711 are through the pins.

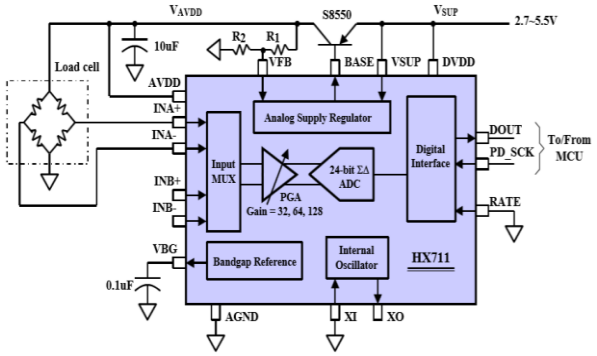


Figure 2: Application of the Hx711**(Avia Semiconductor, 2016)**

50kg load cell

This single disc load cell (sometimes called a strain gauge) can translate up to 50kg of pressure (force) into an electrical signal. Each load cell is able to measure the electrical resistance that changes in response to, and proportional of, the strain (e.g. pressure or force) applied to the disc. With this gauge you will be able to tell just how heavy an object is, if an object's weight changes over time, or if you simply need to sense the presence of an object by measuring strain or load applied to a surface.

Figure 3: 50 kg load cell **(SparkFun, 2018).**

Disc load cells are a bit easier to mount than bar-style load cells, making them more straightforward to implement into a design.

Each load cell is made from a steel-alloy and is capable of reading a capacity of 50kg. These load cells have four strain gauges that are hooked up in a Wheatstone bridge formation. The color code on the wiring is as follows: red = E+, green = O+, black = E-, and white = O-. Additionally, these load cells offer an IP66 protection rating.

***Ultrasonic sensor* HC-SR04 Ultrasonic sensor** is a 4 pin module, whose pin names are Vcc, Trigger, Echo and Ground respectively. This sensor is a very popular sensor used in many applications where measuring distance or sensing objects are required. The module has two eyes like embeded in the front which forms the Ultrasonic transmitter and Receiver. The sensor works with the simple high school formula that

The Ultrasonic transmitter transmits an ultrasonic wave, this wave travels in air and when it gets objected by any material it gets reflected back toward the sensor this reflected wave is observed by the Ultrasonic receiver module as shown in the Fig. 3.3 below

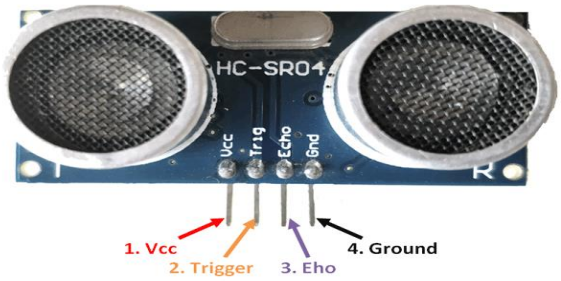


Figure 4: HC-SR04 Ultrasonic sensor (Borschbach, 2017)

Now, to calculate the distance using the above formulae, we should know the Speed and time. Since we are using the Ultrasonic wave we know the universal speed of US wave at room conditions which is 330m/s. The circuitry inbuilt on the module will calculate the time taken for the US wave to come back and turns on the echo pin high for that same particular amount of time, this way we can also know the time taken. Now simply calculate the distance using a microcontroller or microprocessor

ATMEGA328P

The high-performance Microchip 8-bit AVR RISC-based microcontroller combines 32KB ISP flash memory with read-while-write capabilities, 1KB EEPROM, 2KB SRAM, 23 general purpose I/O lines, 32 general purpose working registers, three flexible timer/counters with compare modes, internal and external interrupts,serial programmable USART, a byte-oriented 2-wire serial interface, SPI serial port, 6-channel 10-bit A/D converter (8-channels in TQFP and QFN/MLF packages), programmable watchdog timer with internal oscillator, and five software selectable power saving modes. The device operates between 1.8-5.5 volts.

For this design work, the Atmega328 was chosen because of its simplicity and the available pins needed for the connection of the design components as show below:

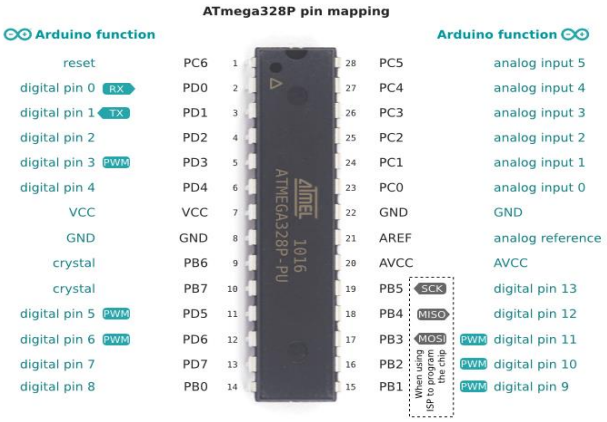


Figure 5: ATmega328P pin mapping **(Jordan, 2016)**

Hardware

The schematic diagram was drawn and the circuit was setup on breadboard and tested. As the testing gave a positive result, the circuit was transferred finally to a veroboard.

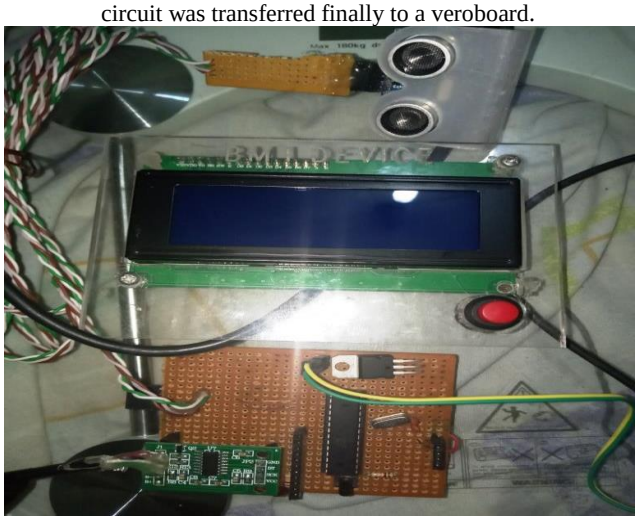
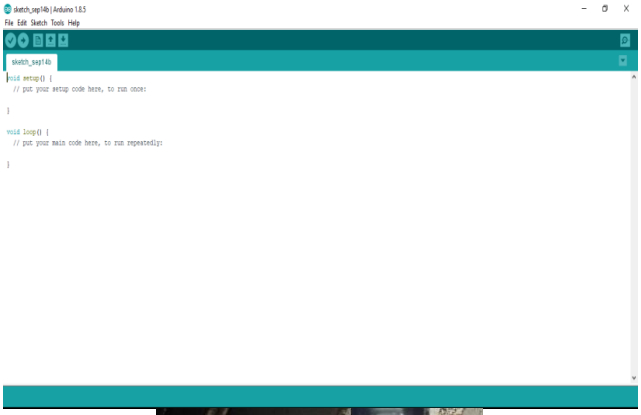


Figure 6: The Picture of the BMI Device

Software

The coding of the Atmega328 microcontroller was done using arduino IDE which is C++. Then the code was then transfer to the MCU controller with the help off Arduino Uno board show in plate I below



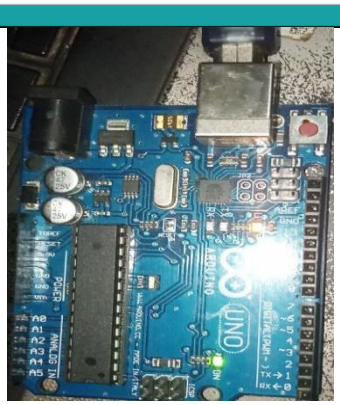


Figure 7: Arduino IDE and Uno Programmer in use.

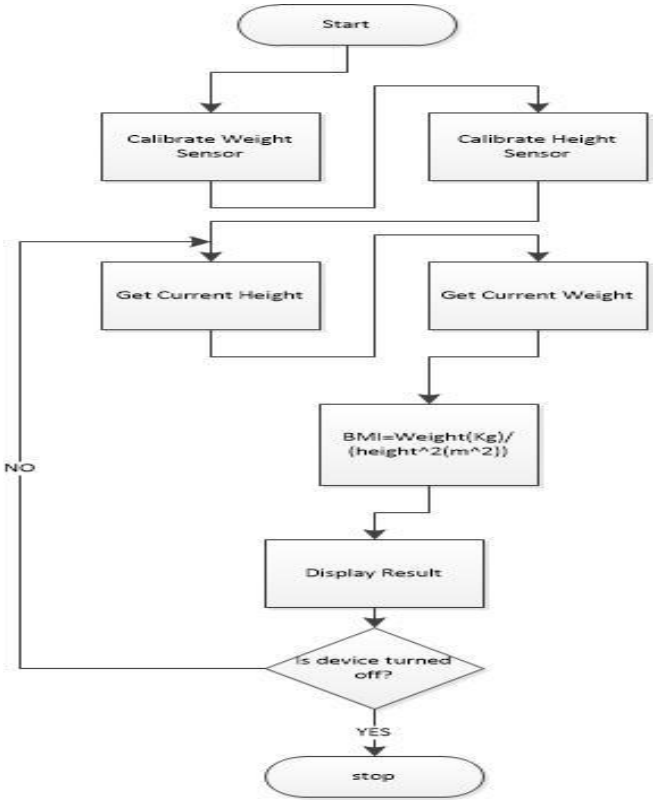


Figure 8: Flow Chart of Automatic Body Mass Index Measurement Device

I. RESULTS ANALYSIS AND DISCUSSION

During Setup, the height between the surface of the weight scale and ultrasonic sensor, SH is measured and stored as show in Plate III. When a subject climbs on it, the distance between the subjects head and the sensor is taken as SHH. The height of the subject; MH, is measured by subtracting SHH from SH i.e.

…… (4.1)

The weight (Kg) of the subject is simultaneously taken as the height is taken. Then the BMI is calculatedas shown in plate V and VI using equation (ii) below

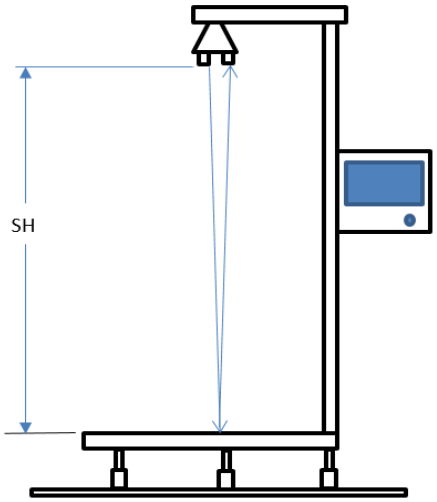


Figure 9: Setup or idle State

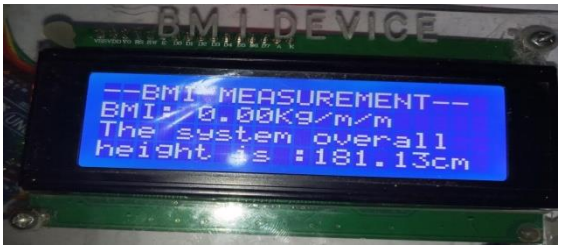


Figure 10: The Figure Show The Device In Idle Mode

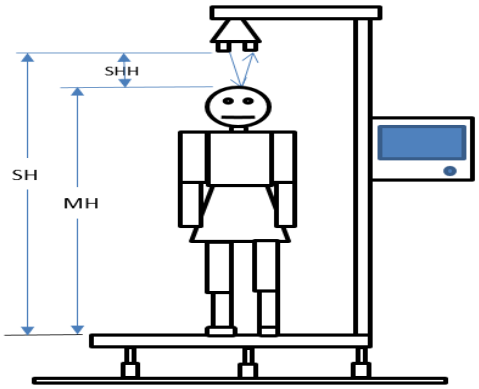


Figure 11: Demonstrates the device in Service

Figure 12: Device display the BMI, Height and Weight of the subject been measured.

COST OF MATERIAL

The table below shows the cost of material used for this design.

Table 1: Shows the list and cost of material used for the embedded system

Item	Cost	Quantity	total
Atmega328	1200	1	1200
LCD 2004 Display	2000	1	2000
50kg load cell	500	4	2000
Crystal Oscillator	50	1	50
0.22 uF capacitor	10	2	20
Button	20	2	40
10k resistor	10	2	20
LED	10	1	10
Casing	1500	1	1500
Total cost			**6,840**

CONCLUSION

This project has developed a system which automatically measures the body mass index of a person at a price relative cheaper than taking a Magnetic Resonance Imaging (MRI) scan. The objective function is achieved by using the microcontroller technology. The system is constructed using a load cell sensor to measure weight, ultrasonic to measure height, a microcontroller to process data received and LCD display to display the result in Kg/m^2.
The result achieved is faster and cheaper when compared to an MRI scan. The efficiency of the proposed system will improve the efficiency of the BMI system by reducing the time it takes to get a result at a very low cost.

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