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Development of an Ultrasonic-based Digital Height Measurement System

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ABSTRACT
This paper presents the design, sensor selection, circuitry, firmware development, and testing of an ultrasonic-based digital height meter. An Atmega328 microcontroller is used in the design to handle sensor measurements as it investigates the utilization of HC-SR04 ultrasonic sensor technology. Firmware was developed in the Arduino IDE environment, and the sketch was uploaded to the microcontroller. The designed circuit was constructed on a Veroboard, and the casing was designed for convenience of use. Ultrasonic digital height meters are more accurate, dependable, and quick when compared to hospital meter rules. The apparatus was mounted at a height of 2 meters to ease the measurement of humans. Results from the measurement of nine people were compared with those of the hospital scale, and a percentage error of 0.55% was obtained. A digital height meter can be a very useful instrument for many different applications, including medical, educational, engineering, and surveying, with careful planning and implementation.
Keywords: Arduino; Height; Microcontroller; Sensor; Ultrasonic.

1.0 INTRODUCTION

An important indication of human health is height. Height measurement is a crucial parameter for healthy growth and is typically done as part of regular practice. It is a crucial component of getting checked out by a doctor. When tracking growth and health, measuring height is crucial. Up to a certain point, most people are probably aware of their height, but being half an inch to an inch shorter could be a critical sign of one's health. To ensure that youngsters and the elderly are growing at a healthy rate, it is crucial to keep an eye on both of their heights. Growth assessment requires accurate and precise measurement (Rueger, 1996; Zakari & Aliyu, 2014).

The Body Mass Index (BMI), a measurement of body fat, is calculated using height measurement together with weight measurement information when known. It is the ratio of a person's weight in kilograms to their height in meters squared. The BMI only considers the analysis of height and weight calculations. These measurements must be as precise as possible and performed quickly, especially when they are directly related to health. The BMI is also used to analyze pulmonary function and diseases like marasmus and kwashiorkor in youngsters (Haryanto et al., 2023; Qibthiyah, 2022). When it comes to teenagers, height evaluation is a significant factor in the selection standards for several sports. The height will be more advantageous for occupations like those in the military, lifeguarding, and firefighting, among others. In sports where the height measurement has sway, a cutoff height is used as the starting point for selection. A precise height evaluation becomes extremely important in these circumstances (Chen & Wu, 2011; Pedhazur & Schmelkin, 1991).

There are various ways to measure the distance. Typical measuring tools like measuring tapes, rulers, and stadiometers, among others, are used. A stadiometer is often used to measure height in clinical settings and academic contexts. It comprises a vertically mounted ruler on a wall with a movable horizontal portion that rests on the subject's head. Based on where it is on the ruler, this component displays the height (Shoewu et al., 2015). These approaches are becoming antiquated. They take too long to read, especially when numerous people's heights need to be assessed. Typically, no precise and accurate measurements are taken because rounding or approximations are frequently done. They are difficult to use, often provide erroneous results, need calibration services, and parallax problems are common. Hence the requirement for a modern height measurement tool that is more precise, trustworthy, and time-saving and then records its measurement digitally (Ishihara et al., 2009; Mehta & Tiwari, 2018; Shamsul & Tajrian, 2013).

Height can also be measured optically, electromagnetically, and ultrasonically in addition to using the earlier-mentioned techniques (Mutinda & Kuria, 2020; Ratan et al., 2015; Rueger, 1996). An ultrasonic device can be used to measure the distance between two points more precisely than other tools like a measuring tape or stadiometer. This makes it helpful for determining the distance between two items (Abdullah, 2015; Carullo & Parvis, 2001; Üstun & Mohammed, 2020). With the advancement of technology in every aspect of our lives, sensors and embedded systems have gained significance. A portable, user-friendly solution for height measurement is offered by the ultrasonic ranging module HC-SR04 (Mutinda & Kuria, 2020). The ultrasonic transducer in the digital height system generates an ultrasonic tone that is reflected off the measurement target. It also does away with the requirement for direct physical touch between the source and the target (Janwardi, 2019; Ratan et al., 2015). Shamsul and Tajrian (2013) explore the use of ultrasonic waves at a frequency of 40 kHz for distance measurement. It was the idea of measuring distance without making physical contact with the target item. When a sound pulse strikes a specific surface and bounces back as an echo, ultrasonic receivers record the time it takes for it to happen (Shamsul & Tajrian, 2013).

The purpose of this endeavor is to design and build an ultrasonic digital height meter. The design's particular goals are to: create an ultrasonic electronic circuit that can measure height precisely and automatically utilizing a reflected signal; display measured height on an LCD; and analyze the produced device's performance.

2.0 MATERIALS AND METHODS

The system design consists of hardware and software components, as presented in the block diagram in Figure 1. The schematic consists of the power supply, sensors, microcontroller, liquid crystal display, and buzzer.

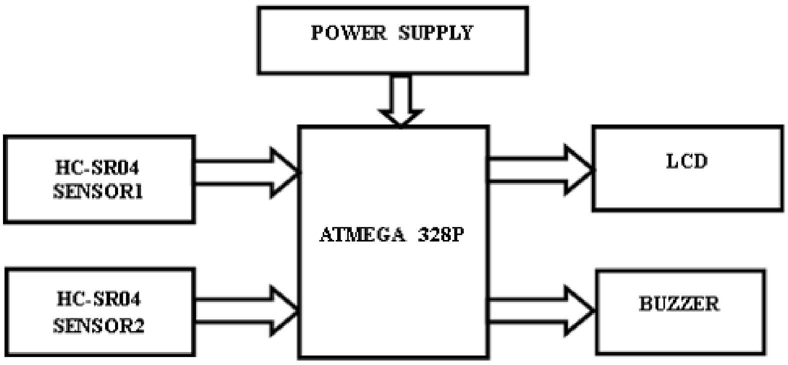

Figure 1: Block Diagram of an Ultrasonic-Based Digital Height Measurement System

2.1 Power Supply Section

The power supply consists of a step-down transformer, a rectifier, a filtering section, and a regulator. To lower the hazardously high mains alternating current (AC) voltage of 220V to a safer low voltage of 12V, a 220V/6V 0V/6V step-down transformer was used. The transformer connects directly to four numbers of IN4007 diodes in a bridge rectifier arrangement. The rectifier changes the AC signal to a direct current (DC) of 12 volts. The IN4007 was employed since it can run on 1000VA power. To reduce the ripple in the converted DC voltage, a 2200-F electrolytic capacitor was connected across the rectifier output. The necessary value for the filtering capacitor is provided by the equation below.

Filtering capacitors for ripple,

$$C = \frac{I}{2*f*V_{pp}} \qquad (1)$$

where represents the expected maximum current of, represents the frequency of, and represents peak-to-peak voltage after rectification.

$$C = \frac{I}{2*f*V_{pp}} = \frac{1.5}{2*50*10.6} = 0.001415094F \approx 2200\mu \qquad (2)$$

A 2200F capacitor is used, though, to provide enough filtering with the material at hand. The ultrasonic sensors and microcontroller both work at 5 volts; thus, the LM7805 voltage regulator is attached to control the voltage from 10.6 V to 5 V DC. The output value was obtained through PIN 3, while the regulator's GND pin was connected to the ground. The resulting power supply circuit is presented in Figure 2.

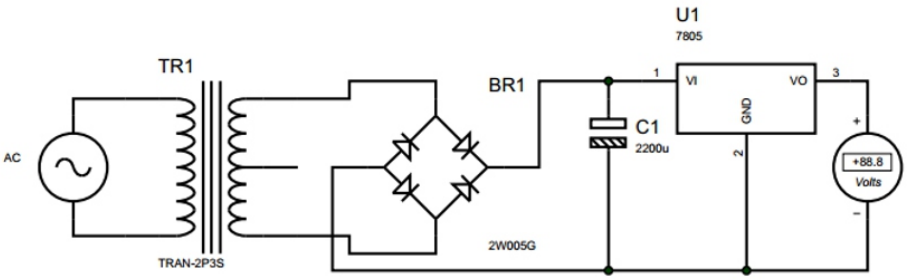

Figure 2: Power supply circuit.

2.2 Microcontroller

The microcontroller chosen for this work is the Atmega328P. It is a high-performance Microchip picoPower® 8-bit AVR®Reduced Instruction Set Computer (RISC) based microcontroller. It features 32KB of read-or-write In-System Programming (ISP) Flash memory, 1024B of Electrically Erasable Programmable Read-Only Memory (EEPROM), 2KB of Static Random Access Memory (SRAM), 23 general-purpose input/output (I/O) lines, 32 general-purpose working registers, three flexible timer/counters with compare modes, internal and external interrupts, serial programmableuniversal synchronous/asynchronous receiver/transmitter (USART), a byte-oriented Two-Wire serial interface, Serial Peripheral Interface (SPI) serial port From 1.8 to 5.5 volts are needed to run the device. The device achieves throughputs close to one Million Instructions Per Second (MIPS) per MHz, balancing power consumption and processing speed, by executing potent instructions in a single clock cycle. The device's other components slumber while the crystal/resonator oscillator is active. Due to this, a startup can happen very quickly while using very little power. Atmel's high-density non-volatile memory technology is used in the creation of the product. By using a typical non-volatile memory programmer or an on-chip boot program running on the AVR core, the Flash program memory can be reprogrammed natively through the SPI serial interface. To download the application program into the application flash memory, the boot program can use any interface. To provide true read-while-write operations, software in the boot flash area runs concurrently with updating the application flash section. All these can be performed with the aid of the Arduino Integrated Development Environment (IDE).

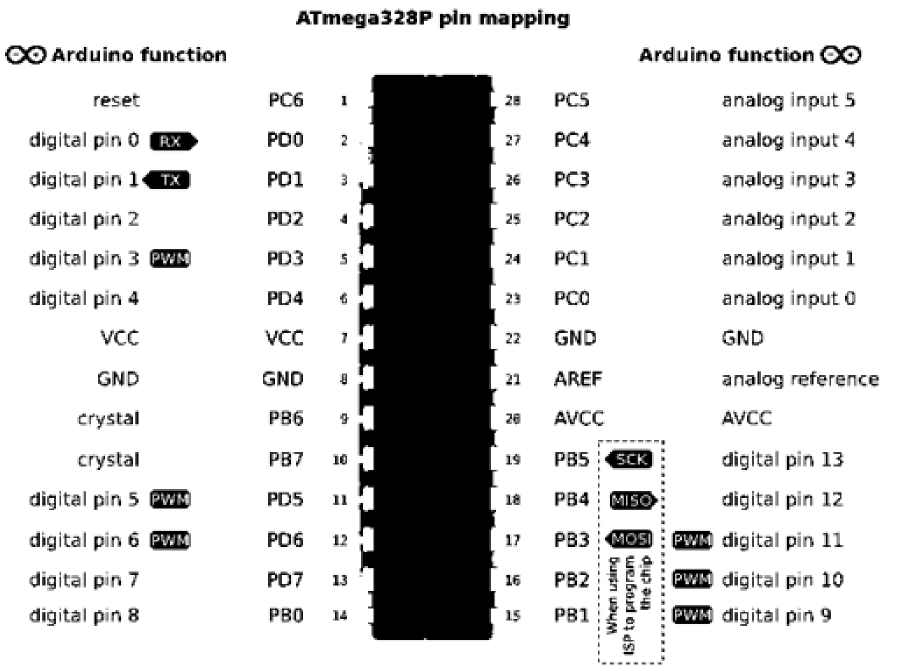

Figure 3: Pin configuration of Atmega329P and its Arduino Mapping Pin.
(https://in.pinterest.com/pin/414401603184128742/)

2.3 Liquid Crystal Display (LCD)

Two lines of sixteen characters each comprise the LCD 16x2 screen. Using a 5x7 dot matrix, each letter is created. The supply voltage and whether the message is displayed on one line or two lines both affect how accurately the display contrasts. A variable voltage of 0-VDD is therefore applied to the pin designated as VEE. This usually involves the use of a trimmer potentiometer. Blue or green diodes are included in some models' backlights. A current-limiting resistor should be used if the device is to be used in service.

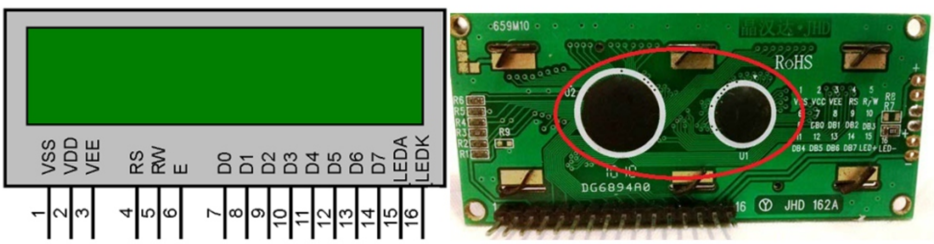

Figure 4: LCD connection with microcontroller

2.4 Ultrasonic Sensor (HC-SR04)

The HC-SR04 was chosen as the ultrasonic sensor. Its four pins are named Vcc, Trigger, Echo, and Ground, respectively. This sensor is widely used in applications where it is necessary to measure objects and distances. An ultrasonic transmitter and receiver are formed by two protrusions that resemble eyes on the front of the module(Telan et al., 2019).

HC-SR04 shown in Figure 5 features an operating voltage of +5V and a theoretical measuring distance between 2cm to 450cm. In the actual sense, the practical measuring distance: 2cm to 80cm. It has a measuring angle covered <15°, an operating current of less than 15mA, and an operating frequency: 40KHz. An easy formula governs how the sensor operates.

$$\text{Distance} = \text{speed} \times \text{time} \tag{3}$$

Ultrasonic waves are emitted by an ultrasonic transmitter, travel through the air, and are reflected by a sensor when they are interrupted by an obstruction. The ultrasonic receiver module monitors this reflected wave as depicted in Figure 6. The formula above is used to determine distance; timing and speed are required. By using ultrasonography, we may determine that 330 m/s is the ultrasonic waves average room-temperature wave velocity. The module's internal circuit measures the time it takes for the ultrasonic waves to return and simultaneously switches on the echo pin. We may also determine the time involved in this way. Simply use a microcontroller to compute the distance from here. Picture of the HC-SR04 Ultrasonic Sensor Module is as presented in Figure 5.

Figure 5: HC-SR04 Ultrasonic Sensor Module

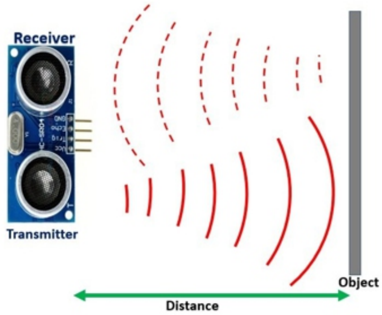

Figure 6: HC-SR04 and Object Picture

The complete circuit of Figure 7 shows the interconnections between the components. The microcontroller is configured to trigger the ultrasonic sensors to send bursts of ultrasound that bounce off the ground and return to the receiver. The sensors send an echo signal to the microcontroller when they notice the return wave. The travel time of the ultrasonic wave from the sensors to the floor and back is measured between the trigger and the echo signal. This time interval is measured by the microcontroller, which then calculates the round-trip distance using the ultrasound's speed. The difference between the two distances will be the height, which can be expressed in feet, inches, and tenths. The measured height is displayed on the LCD screen and a buzzer indicates that the measurement has been taken.

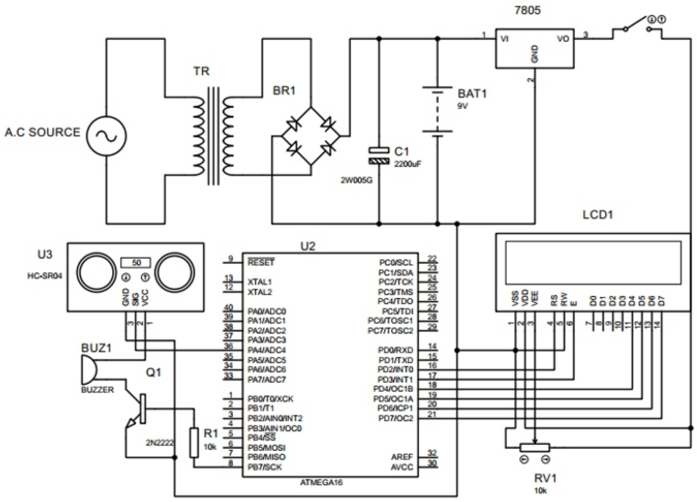

Figure 7: Complete circuit diagram of digital height system.

The flowchart depicting the relationship among the processes involved in the system is as shown in Figure 8.

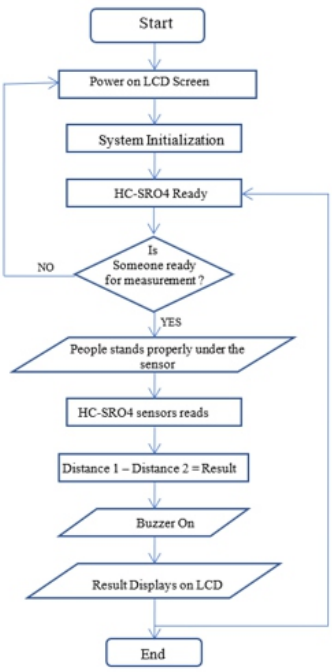

Figure 8: Flowchart of the digital height system.

3. RESULTS AND DISCUSSION

The circuit of Figure 6 was constructed and testing for performance. The construction stages are shown in Figures9 to 11. Before taking the measurements of the subjects' heights for the created work outcomes analysis, the apparatus was appropriately mounted at a height of 2m. This was done to make sure the gadget produces accurate results when measuring people's heights because a poor mounting of the device will change or impair the accuracy of the estimated height result. Additionally, after measuring a specific height and showing it on the LCD, the device was set to be "delayed" for 5 seconds. In order for the individual whose height was measured to view the results before the device reset to prepare for another test, this had to be done. The gadget is relatively error-free, has good precision, and can be used to measure height precisely, according to the result of the percentage error being obtained to be 0.55%.

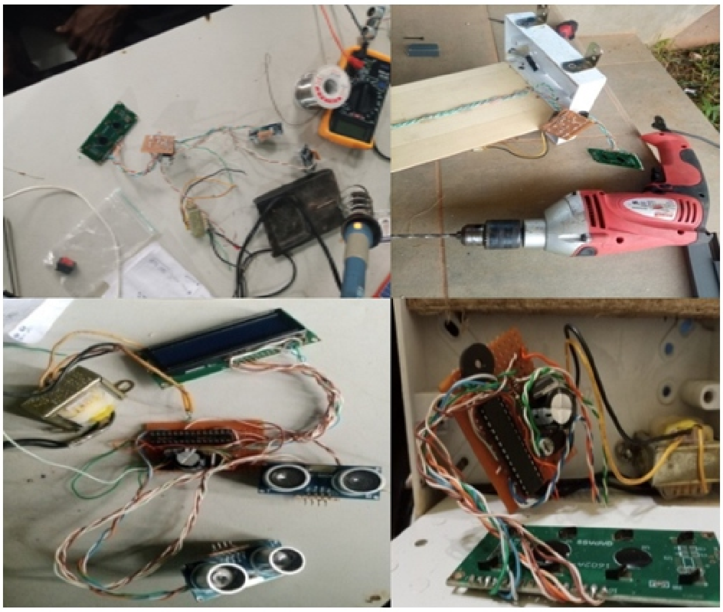

Figure 9: Pictures of Construction Stages

Figure 10:Constructed Device in Horizontal View

Figure 11: Comparison of Measured Value with Linear Scale

Measurement obtained using a manual height measuring tape was compared with the ones obtained using the digital height system to make sure that they were accurate. The computation of the results was performed using a sample of nine different individuals. The results acquired and the results compared are shown in the table below.

Table 1: Comparison of manual height measuring tape and the Digital height system results

S/N	Measuring Tape readings (m) ??	Digital Height System (m) ??	Difference ?? - ??	Percentage (%) Error
1	1.70	1.70	0	0
2	1.82	1.81	0.01	0.55
3	1.79	1.79	0	0
4	1.78	1.77	0.01	0.55
5	1.65	1.64	0.01	0.55
6	1.69	1.68	0.01	0.55
7	1.64	1.63	0.01	0.55
8	1.55	1.54	0.01	0.55
9	1.49	1.48	0.01	0.55

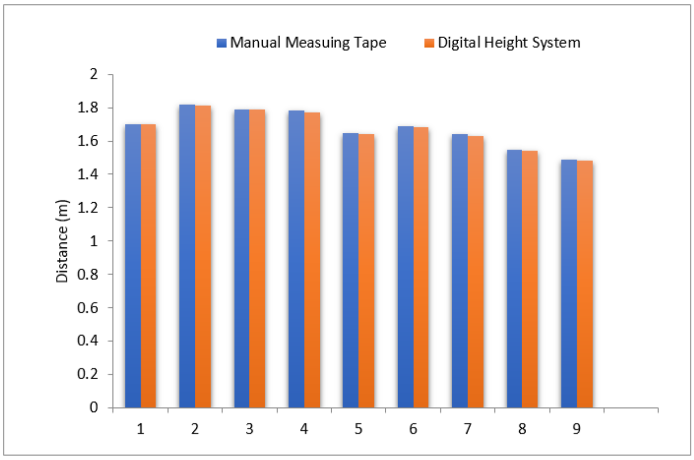

Figure 12: Comparison of the results from the Manual Measuring Tape and Digital Height System

4.0 CONCLUSION

This work has successfully proven a portable digital height measurement system that measures height and then displays the output result on the LCD. The system is functional and accurate. In contrast to the widely used methods of height measurement through measuring tape, steel rule, or the extremely expensive commercially available stadiometers, it offers an easy alternative means of capturing human height automatically, digitally, and accurately using reflected signals of ultrasound waves. With the use of technology, short individuals can easily match the height of tall people. Future work on this similar device may include a portable printer to automatically print the results after the measurement, weight measurement to provide results for BMI, and also by the expansion of memory to store the measured height for routine assessment for the monitoring of growth or height.

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