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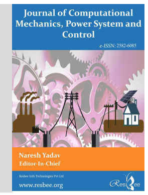

Design and Construction of Microcontroller Base Simple Pendulum with SD card Module

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Abstract: Pendulum experiments have long been a fundamental part of physics education, offering insights into the principles of oscillatory motion. However, traditional methods often suffer from inaccuracies and inefficiencies due to manual measurements and human error. This study presents the design and construction of a microcontroller-based simple pendulum system to enhance the accuracy and efficiency of pendulum experiments. Leveraging an Arduino microcontroller, the system automates the measurement of oscillation periods, thereby addressing limitations in traditional methods and reducing human error. Key components include a sensing unit, SD card, display unit, control unit, and a user selection feature for customizing oscillation counts. The system provides results via an LCD and stores data for further analysis. Experimental findings validate the theoretical principles of pendulum motion, demonstrating reliable and precise measurements of oscillation periods. The system not only simplifies experimental procedures but also enhances the learning experience by providing faster and more accurate outcomes. Future enhancements could include additional monitoring capabilities and data transmission features to expand functionality. This microcontroller-based system represents a valuable contribution to experimental physics education, offering a modernized approach to traditional pendulum experiments.

Keywords: Microcontroller, Simple Pendulum, Aurdino, Sensor, Led.

Nomenclature

Abbreviation	Expansion
LED	Light Emitting Diode
LDR	Light Dependent Resistor
SHM	Simple Harmonic Motion
IR	Infrared

1. Introduction

From Galileo Galilei's first scientific investigations of the pendulum around 1602, the regular motion of pendulums has been central to timekeeping. Pendulums were the most accurate timekeeping technology until the 1930s [7]. Christiaan Huygens' invention of the pendulum clock in 1658 set a new standard in timekeeping, widely used in homes and offices for 270 years. These clocks achieved remarkable accuracy, losing only about one second per year until quartz clocks replaced them as the time standard. Pendulums have also found applications in scientific instruments like accelerometers and seismometers and were historically used as gravimeters for measuring gravitational acceleration and as a standard of length. The term "pendulum" originates from the Latin word *pendulus*, meaning "hanging" [8].

Pendulums are simple devices that have been studied extensively since the 17th century. Galileo conducted the first experiments in the early 1600s, and Christian Huygens developed the first pendulum clock in 1656. A pendulum consists of a weight suspended from a pivot, allowing it to swing freely. When displaced from its equilibrium position, gravity exerts a restoring force that accelerates the pendulum back toward equilibrium. This results in oscillatory motion, where one complete cycle (a swing to the left and right) is called the period. The period depends primarily on the pendulum’s length and, to a lesser extent, on its amplitude and swing width [9].

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The simple gravity pendulum is an idealized model—a weight (or bob) on a massless cord, swinging without friction. Under ideal conditions, it swings at constant amplitude when given an initial push. In reality, factors like friction and air resistance reduce the amplitude over time. The period of such a pendulum depends on its length, the local gravitational strength, and slightly on the maximum swing angle (amplitude), while remaining independent of the bob's mass. Interestingly, all swings, regardless of amplitude changes, take equal time.

Pendulums were historically crucial in measuring periodic motion, exemplified in clocks like cuckoo and grandfather clocks. The to-and-fro motion is a type of simple harmonic motion. Galileo first observed that a pendulum's period is independent of its mass and the size of its swing arc, relying instead on its length and the gravitational acceleration (9.8 m/s^2 on Earth). Longer pendulums have longer periods than shorter ones, demonstrating the mathematical relationship between the period and pendulum length. This relationship is often explored in experiments investigating pendulum motion.

In modern applications, systems like Arduino serve as controllers for pendulum experiments, enabling data display on LCDs and storage on SD cards. Physical experiments combine theoretical and experimental approaches to validate findings and guide investigations, as noted by researchers such as Y. Dasriyani, Hufri, and Yohandri (2016). A simple pendulum, modeled as a small, dense sphere suspended by a light string, exemplifies periodic motion. The time for one oscillation (period T) and the frequency of oscillation ($f = 1/T$) characterize this motion. Despite the simplicity of the pendulum, its study reveals intricate dynamics of oscillatory systems.

1.2 Statement of the Problems

Some problems associated with the pendulum experiment conducted manually include people sometimes not measuring from the center of the mass and errors in counting and timing which facilitate wrong data acquisition and bad experimental results. Hence the project of the microcontroller base Simple Digital pendulum eliminates these errors as it includes a selecting unit for selecting the number of oscillations required, once the number count is reached a buzzer will make a buzz, the result is then automatically Saved on an SD Card, the Number of counting and timing will be displayed on LCD. The deployment of Arduino Uno Microcontroller as the control unit and other mentioned components make it more efficient in eliminating errors associated with the experiment that is conducted manually because in each experiment an effective result is the result obtained with very low errors. Hence conducting a pendulum experiment using a microcontroller will facilitate reasonable data, very high-speed data acquisition, and will optimize the time for the experiment.

1.3 Research Methodology

The methodology in this project 'microcontroller base simple pendulum' consists of the power supply unit, bob sensor unit (forward and backward sensor), microcontroller unit used as a clock, and counting a bob under swinging and displaying the result on the LCD. The power supply unit provides power to the Arduino Microcontroller ATmega328p which in turn also supplies 3.3V to the LCD. Then Sensor Unit is made up of an Active infrared Sensor, the Active infrared works as an object detector sensor, and the sensor both emits and detects infrared radiation. An active IR sensor has two parts: an LED and a receiver. When the swinging bob comes close to the sensor, the infrared light from the LED reflects off of the swinging bob and is detected by the receiver. Based on the intensity of the reception by the IR receiver, the output of the sensor is defined the output from the sensing unit is connected to the Arduino which measures the period of an oscillation and thus calculates the local value of acceleration due to gravity. An LCD has the whole parameters of time, bob swinging, and counting. The buzzer acting as the alarming unit also connected to the Arduino will give an alarm once the event is completed, and the SD card stores both the time and count into a memory.

1.4 Aim and Objectives

Though in many institutions and secondary schools, the simple pendulum experiment is perpetually conducted manually, this project aims to design, construct, and simulate a microcontroller-based simple pendulum with a data logger using Arduino. The set of objectives is as follows:

1. To design and construct a power supply unit.
2. To design and construct a bob swing sensing unit.
3. To design and construct a stopwatch selecting unit
4. To design and develop a program Arduino control unit.
5. To configure SD card as a memory storage unit.
6. To configure LCD as a display.

1.5 Significance of the Study

The main reason for designing this system is to save a lot of time needed in experimenting. It is also designed to give the reading of timing and counting in less than half the time required doing this manually, this is achieved by having a microcontroller that does the computations and displays the result on LCD, this result are saved in a data logger. So we use a buzzer to notify when the desired parameters are achieved, also while experimenting with the conventional way there's a need to monitor the stopwatch and the bob swinging continually, with the microcontroller this makes it easy by just selecting the number of count and it will automatically be generated and display the result on the LCD and once the set point is reached the system stopped and the buzzer make a sound, it therefore make it effortless to achieved the result efficiently. Other significance includes:

1. Facilitate reasonable data
2. Very high-speed data acquisition
3. Optimize the time for the experiment.

1.6 Scope and Limitation

The scope of this project is to come up with the design of a microcontroller-based simple pendulum, this system uses a bob swing and sensing unit, the SD card unit, the Display Unit, the power supply, and the control unit (microcontroller) working together to achieve the desired objectives of the design, this system has a mode selection unit, the selection unit is used to set the number of counts i.e. the number of revolution per second of the bob swinging, once the start button is press then the action begins once the set point is attained it will display the timing and counting and the corresponding result is saved into the Memory, a buzzer usually make a sound to show that the action has completed. The limitation of this project is that the Microcontroller base simple pendulum can only save the result in the SD card and the user has to put the number of counts required.

1.7 Project Organization

This work consists of five major chapters and each chapter is summarized in brief: In chapter one (1), the background of the study, aims and objectives, Motivation, and Methodology were adequately stated. In Chapter Two (2), all relevant theories surrounding the origin of the project and the literature of other similar works of others were reviewed. Chapter three (3) contains materials, circuit description & principles of operation, and also the processes, and methods that led to the finalization of the project construction. Chapter four (4) comprises the results and discussions obtained from the prototype. Chapter five (5) being the final chapter contains the conclusion and recommendations obtained from the work.

2. Literature Review

P. Arun and Naveen Gaur, (2002) [14], focused on microprocessors, primarily composed of digital devices, communicating in binary (1s and 0s) through specific voltage levels. To measure the time interval of an oscillating pendulum, a laser source and a Light Dependent Resistor (LDR) were arranged such that the pendulum's bob interrupted the light path during oscillation. This disruption altered the current in the LDR, which had to be converted into TTL-compatible digital voltage for the microprocessor to process. This method emphasized the use of analog-to-digital conversion to enable precise time-interval measurement during oscillations.

Wan J.J (2012) [1] inverted pendulum system, position of inverted pendulum (or bar) is controlled to keep it upright by applying various control strategies. Many researchers proposed different control strategies for various configurations of inverted pendulum system including sliding mode control.

Kim et al., (2015) [5] explored the dynamics of a pendulum mounted on two wheels, which introduced different mechanical complexities. When driven by a single motor, the system resembled traditional four-wheeled devices, whereas independently driven wheels allowed for both linear and rotational motion. The mechanical system became non-holonomic, differing from other holonomic systems. This study highlighted the adaptability and complexity of pendulum-based dynamics when additional degrees of freedom were introduced.

Yulkifli, zurian Affandi et al, (2018) [18] developed a system to measure gravitational acceleration using a simple harmonic motion pendulum and digital technology. The system incorporated photogate sensors, Arduino Pro Mini, and a seven-segment display. The Arduino processed timing data from the photogate sensor, displaying the oscillation time. Results showed high accuracy (98.76%) and precision (99.81%), confirming the system's effectiveness for physics experiments, particularly in determining gravitational acceleration.

Jingwen li et al, (2011) [10] employed the Bag-of-Features (BOF) model to count pedestrians using the CASIA dataset and an SVM classifier. Real-time monitoring was implemented through expensive camera modules. The system automatically differentiated pedestrians and non-pedestrians, updating the classifier for specific scenes. While effective, the reliance on costly hardware posed a challenge for broader application.

Carlonerigatus (2013) [17] developed an automatic bidirectional visitor counter using an 8051 microcontroller. The system counted individuals entering or leaving a space and displayed the count on a seven-segment display. It was divided into three components: sensor, controller, and counter display. The system effectively tracked up to 9,999 entries and exits and was suitable for use in public areas and parking lots.

Franklin et al., (2009) [15], implemented modifying controllers for tracking trajectories alongside stabilization. Using an 8085 microprocessor interface, the system measured the pendulum's time period, studying variations with increasing oscillations. Results emphasized the importance of adhering to experimental precautions for accurate measurements of simple harmonic and large-angle oscillations.

Yamakita et al., (1999) [16], explored pendulum actuation via rotating disks or arms, presenting an alternative to traditional linear tracks. Depending on orientation, the configurations included rotary or Furuta pendulums. These designs provided robust solutions with low inertia, suitable for control experiments requiring compact setups.

Spong, (1995) [12], analyzed pendulums mounted on rotating disks or arms, highlighting differences in dynamics compared to linear systems. The configurations supported various actuator placements, allowing for a range of motion control applications, including vertical plane rotations and Acrobat setups.

Denis Vavouglos, et al., (2017) [2], demonstrated the use of real and virtual labs with sensors and data loggers to enhance conceptual understanding. Results showed that combining real and virtual labs maintained student interest and improved critical thinking and learning outcomes, particularly when the learning sequence alternated between the two environments.

Kocijancic, S., O' and Sullivan, C., (2004) [6], evaluated the educational impact of real and virtual labs, finding both effective and optimal when combined. Their research underscored the value of designing experiments that encourage interaction and cooperation, with sensors and data loggers enhancing cognitive outcomes.

Psillos, D., and Niedderer, H., (2002) [13], highlighted the role of experiments in linking theory with practice. Their study confirmed that experimental teaching strategies, whether real, virtual, or sensor-based, significantly enhanced understanding of physical phenomena and scientific thinking.

George S. Loannidis, (2017) [2], investigated the optimal teaching sequence for pendulum experiments, comparing real-first and virtual-first methods. Results favored sensor-integrated approaches for improving understanding of pendulum dynamics, including dependencies on length, gravity, and amplitude.

2.3 Major Components

Some major components that are used to accomplish the aims and objectives of this project were briefly explained under this heading.

2.3.1 Arduino Uno

The Uno is a microcontroller board built around the ATmega328p. It features 14 digital input/output pins (6 of which can function as PWM outputs), 6 analog inputs, a 16 MHz quartz crystal, a USB connection, a power jack, an ICSP header, and a reset button. It includes all the components necessary to operate the microcontroller. To begin using it, you simply connect it to a computer with a USB cable or supply power through an AC-to-DC adapter or battery. The Uno is designed to be user-friendly, allowing experimentation without significant concern for errors; even in the worst-case scenario, the chip can be replaced inexpensively, enabling you to restart with ease. The name "Uno," which means "one" in Italian, was selected to commemorate the release of Arduino Software (IDE) 1.0. Both the Uno board and Arduino Software (IDE) version 1.0 served as foundational references for the Arduino platform, which has since progressed to newer versions. The Uno is the first USB-based Arduino board and the reference model for the Arduino platform. For a comprehensive list of current, historical, or obsolete boards, refer to the Arduino index of boards.

Fig. 1. *Arduino Uno*

2.3.2 Micro SD Card Module for Arduino

The module, shown as the Micro-SD Card Adapter in Fig. 2, functions as a Micro-SD card reader. It utilizes the SPI interface, along with a file system driver and a microcontroller system, to enable the reading and writing of files on a Micro-SD card. Arduino users can conveniently perform card initialization and read-write operations using the SD card library that comes integrated with the Arduino IDE.

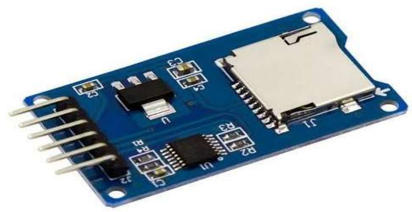

Fig. 2. *SD Card module for Arduino*

2.3.3 LCD

An LCD is an alphanumeric display capable of showing alphabets, numbers, and special symbols, making it a user-friendly device for displaying various messages. Unlike segment displays, which are limited to numbers and some alphabets, LCDs offer greater versatility. However, a seven-segment display has the advantage of being more robust and visible from longer distances compared to an LCD. In this case, a 16 x 2 alphanumeric display has been used, allowing for the display of two lines with up to 16 characters per line. The LCD is depicted in Fig. 3.

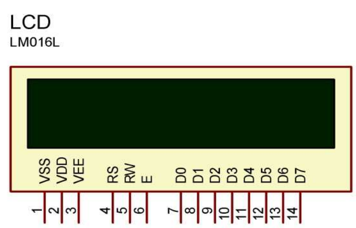

Fig. 3. *16 x 2 LCD*

3. Circuit Design and Component Description

The block diagram of the overall project is shown in Fig. 4 below, this consists of the Control Unit (Arduino) the Arduino board is a self-contained USB development board centered on an ATMega328P. All the activities of the pendulum are processed in the control unit; the control unit senses the swinging of the bob through an active infrared sensor and thus measures the time and period of an oscillation which in turn calculates the local value of acceleration due to gravity. We have counted select buttons and push buttons serve to activate the mode by the user. The buzzer acts as the alarm and makes a buzz sound once the action is completed the LCD is connected to pins of the Arduino board, and the LCDs the whole parameters including time and the bob swinging count. The entire parameters are saved on an SD card which can be used at a later time. The depicted figure below is the block diagram of the entire project.

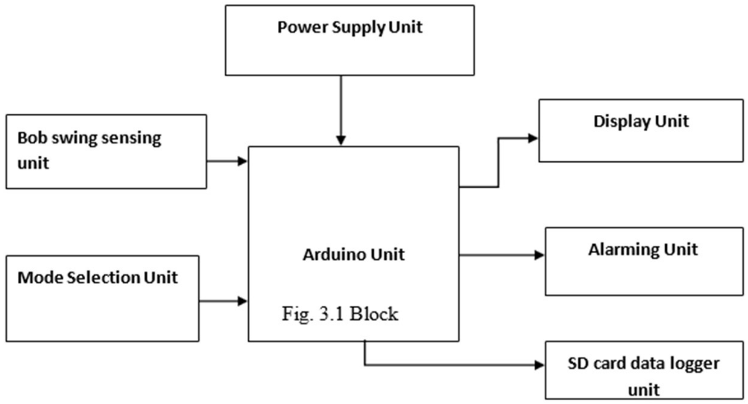

Fig: 4. *Block diagram of a microprocessor-based simple pendulum*

3.1 Microcontroller Unit (Arduino Uno)

The Arduino UNO is an open-source microcontroller board developed by Arduino and based on the Microchip ATmega328P microcontroller. It features digital and analog input/output (I/O) pins that can interface with various expansion boards (shields) and circuits. The board includes 14 digital pins and 6 analog pins and is programmable using the Arduino IDE (Integrated Development Environment) through a Type B USB cable. It can be powered either via a USB connection or an external 9-volt battery, with an input voltage range of 7 to 20 volts.

The ATmega328 microcontroller on the Arduino Uno is preprogrammed with a bootloader, enabling code uploads without the need for an external hardware programmer. It uses the original STK500 protocol for communication. The Arduino IDE compiler is employed to compile the uploaded code, allowing the board to execute its functions. In this project, the Arduino board is utilized to measure the time period of an oscillation and calculate the local acceleration due to gravity.

The Arduino Uno is a standalone USB development board built around the ATmega328P. It operates at a voltage of 5V, regulated by an onboard voltage regulator. Power can be supplied either through the USB connection or a 9V DC power source connected to the V IN terminal. For this project, a 9V DC connection was used to power the board. A detailed schematic of the Arduino UNO board is illustrated in Fig. 5.

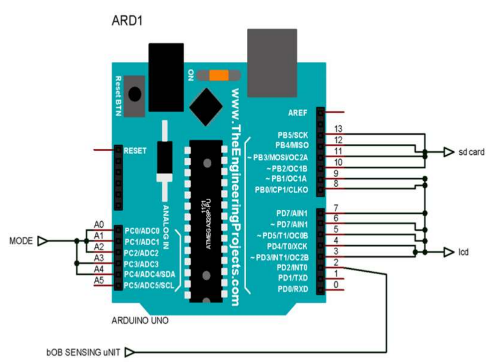

Fig. 5. *Arduino Uno board*

3.4 Modes Selection Unit

This unit is employed to select a mode for counting the bob swinging.

3.4.1 Push Button

A push button (Fig. 6) functions by electrically connecting wires beneath it when pressed, enabling the flow of current. When the button is not pressed, the wires remain disconnected, preventing current flow. A push button is a straightforward switch mechanism used to control various aspects of a machine or process.

Typically made from hard materials such as plastic or metal, push buttons often have a flat surface or are ergonomically shaped to fit human fingers or hands, making them easy to press. While most push buttons are biased switches that return to their original state with the help of a spring, some unbiased buttons also rely on springs to reset after being released. The act of pressing a button is commonly referred to using terms such as pressing, depressing, mashing, slapping, hitting, or punching. In this project, three push buttons are utilized.

***Fig. 6**. Pushbutton*

3.4.2 Pull Up Resistor

Pull-up resistors are essential components in logic circuits, ensuring a well-defined logical level at a pin under all conditions. Digital logic circuits operate with three states: high, low, and floating (or high impedance). The high-impedance state occurs when a pin is not pulled to a high or low logic level, leaving it "floating." An example of this scenario is an unconnected microcontroller input pin, which is neither in a high nor low logic state. In such cases, the microcontroller might unpredictably interpret the input as either a logical high or low.

Pull-up resistors address this issue by pulling the pin's value to a logical high state, as illustrated in Fig. 7. Without a pull-up resistor, the microcontroller's input would float when a switch is open and only be pulled down when the switch is closed. These resistors are not specialized components but rather standard fixed-value resistors connected between the voltage supply (commonly +5V) and the appropriate pin. This connection ensures a defined input or output voltage in the absence of a driving signal.

Pull-up resistors also play a critical role in microcontrollers, preventing floating inputs when external devices are disconnected or have high impedance. They allow normal operation while enabling programming voltage to be applied without causing damage to the target system's 5V supply. Rp is a pull-up resistor values of the resistors were found as

$$R_P = \frac{\left(V - V_o\right) R_i}{V_o} \tag{1}$$

where

Ri is the internal resistance of the IC (4.2KΩ).

Vo is the voltage into the PIC (2.5v).

Therefore

$$R_P = \frac{(V - 2.5V)4.2K\Omega}{2.5V} \tag{2}$$

The value of the pull-up resistor is = 4.7kΩ

When the switch is open, no current flows through the resistor, so there is no volt drop, and the output voltage remains the same as the supply (+5V). When the switch is closed the output is connected directly to 0 V and the pull-up resistor prevents the supply from being shorted to ground.

$$V_o = \frac{5R_i}{R_p + R_i} \tag{3}$$

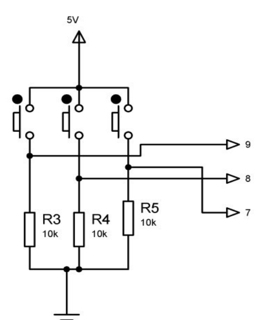

***Fig 7.** Pull-up resistor*

3.5 Bob Swinging Unit

A simple pendulum consists of a relatively heavy object suspended by a string from a fixed support. In its equilibrium position, it typically hangs vertically. The object is commonly referred to as the pendulum bob. When the bob is displaced from its equilibrium position and released, it begins to oscillate back and forth around the fixed equilibrium point. This motion is regular and repetitive, making it an example of periodic motion [4].

The simple gravity pendulum is a theoretical model, where a weight (or bob) is attached to the end of a massless cord suspended from a pivot point, assuming no friction. When given an initial push, it swings back and forth with a constant amplitude. In reality, however, pendulums experience friction and air resistance, causing the amplitude of their swings to gradually decrease. The bob is shown in Fig. 8.

Fig. 8. *A bob swinging*

3.6 Infrared Sensor

An IR sensor is an electronic device designed to detect and measure infrared radiation in its surrounding environment. Infrared radiation was first discovered by astronomer William Herschel in 1800 when he observed that the temperature just beyond the red light, measured through a prism, was the highest. Infrared radiation is invisible to the human eye because its wavelength is longer than visible light, though it is still part of the same electromagnetic spectrum. Any object emitting heat (with a temperature above approximately five degrees Kelvin) emits infrared radiation.

Infrared sensors can be classified into two types: active and passive. Active infrared sensors both emit and detect infrared radiation. These sensors consist of two components: an LED and a receiver. When an object comes near the sensor, the infrared light emitted by the LED reflects off the object and is detected by the receiver.

3.6.1 Infrared Remote Transmitter

In this unit, the 555timer, 7809, battery 9V, laser diode, and discrete components are used. The 555 timer, resistors, and capacitors are connected in a stable mode to generate a frequency at a range from 10kHz-36kHz maximum, and this frequency is transmitted through infrared with the help of a laser diode, the battery supplies the energy to the circuit and regulator 7809 keep the voltage constant as shown The frequency is given by

$$F = \frac{1}{T} = \frac{1.44}{\left(R_1 + 2R_2\right)C} \tag{4}$$

For the higher frequency $F = 36KHz$ and choosing $R2 = 10K\Omega$, $C1 = 10nF$. From equation 4 yields,

$$36X10^3 = \frac{1.44}{\left(R_1 + 2X10X10^3\right)10X10^{-9}} \tag{5}$$

$R1 = 20K\ \Omega$

$R1 = P1 + R$

The standard values P1=10KΩVariable resistor

R= 15KΩ

Laser diode drop= 2.9V

$$\frac{5-2.9}{20X10^{-3}} \leq R_3 (I = 20mAfromDatasheet) \tag{6}$$

Hence, R3=100Ω (standard)

Active IR sensors act as proximity sensors, and they are commonly used in obstacle detection systems (such as in robots). In this project, an active IR sensor is used. An infrared (IR) sensor is an electronic device that measures and detects infrared radiation in its surrounding environment. Active infrared sensors both emit and detect infrared radiation. Active IR sensors have two parts: an LED and a receiver.

3.6.2 Infrared Receiver Design

This unit deals with a GPUI25X photodiode that serves as a receiver that enables to trigger of a 555timer connected in monostable mode and the transistor BC547 acts as a switch for negative clocking the next unit.

The GPUI25X has the following specifications.

- Maximum supply voltage- 6.3V

- Recommended operating voltage- 5.0V
- Current dissipation- 5.0mA
- Bandpass center frequency- 36KHz
- Wavelength- 3.5meter

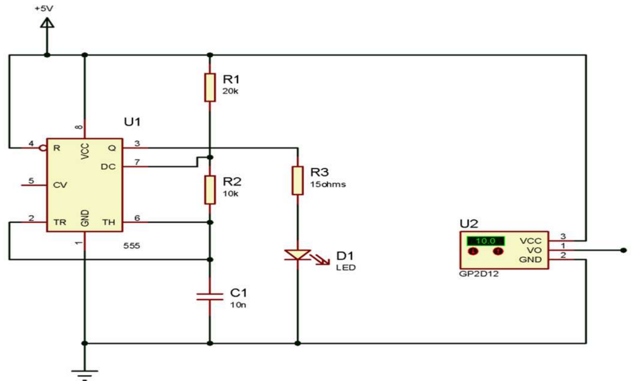

Fig. 9. *IR Sensor*

3.7 Power Supply Unit

The following components are required for the power supply design as shown in Fig. 9.

1. Transformer 12V/500mA
2. A full wave bridge rectifier
3. The capacitor is a filter.
4. A 9V, IC regulator.

Table 1. *Current Estimate of the system*

Components	Quantity	Max current (mA)	Total max current (mA)
NE555	1	200	200
ARDUINO	1	50	50
SD CARD	1	10	10
LCD	1	10	10

Total= 285mA

The total load current from Table 3.2 was 285mA, and the voltage was 5V.

$$Powerinput = Poweroutput$$

$$Fuse\ current\ (IF) \times\ 220\ =\ 5\ \times\ 285\ \times\ 10^{-3} IF = 6.48 \times\ 10^{-3} A$$

This value is not available in the market and therefore Fuse current (IF) =20mA, 220V

The Transformer Utilization Factor is

$$T.U.F = \frac{PowerDeliveredToTheLoad}{ACratingOfTransformer} \tag{7}$$

For full-wave,

$$0.693 = \frac{5X285X10^{-3}}{ACrating}$$

$$ACrating = \frac{5X0.285}{0.693}$$

$$ACrating = 2.06VA$$

$$TransformerCurrent = \frac{2.06}{12}$$

Where the 12V transformer is selected =0.171A =171mA.

Practical = 300mA, 500mA 12V, 500mA transformer selected.

3.7.2 Rectifier Selection

For full-wave

$PIV = 2Vmax$

$$V_{\max} = V_{rms} X\sqrt{2}$$

$$V_{\max} = 12X\sqrt{2}$$
$$V_{\max} = 16.97V$$
$$PIV = 33.9V$$

The rectifier diode present is IN 4001, from the datasheet has a PIV =50V, 1A. Hence, IN4001 is selected for the full wave rectifier.

3.7.3 Filter Selection

$$\gamma = \frac{1}{4X\sqrt{3XFXCXRl}} \tag{8}$$
$$F = 50Hz$$
$$Rl = \frac{Vl}{Il}$$
$$Rl = \frac{12}{285X10^{-3}} = 42.1\Omega$$
$$\gamma = 0.07$$
$$C = \frac{1}{0.07X4X\sqrt{3X50X42.1}} = 9.8X10^{-4}F$$

The selected capacitor is 1000µF.

$$V_c = \frac{V_{ip}}{1 + \frac{i_{dc}}{4XFXCXV_{ip}}}$$
$$V_{ip} = V_{\max} - 2(DiodeDrop)$$
$$V_{ip} = 16.97 - (2X0.7) = 15.57$$
$$V_c = \frac{15.57}{1 + \frac{0.285}{4X50X1000X10^{-6}X15.57}} = 14.3V$$

The voltage that the capacitor will stand should be twice of the Vc The capacitor for the filter should be 1000µF, 25V.

3.7.4 Regulator Selection

That is 5V, 300mA

$$V_r = V_{ip} - (2XV_{ripple}) \tag{9}$$
$$V_{ripple} = \frac{Idc}{4FC} = \frac{0.285}{4X50X1000X10^{-6}} = 1.425\text{V}$$

$Vip = 15.57V$
$Vr = 15.57 - (2 \times 1.425)$
=12.72V (it is enough to bias a diode).

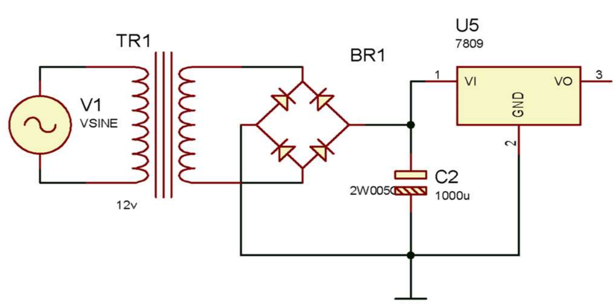

Fig. 10. *circuit of power supply*

3.8 LCD (Display Unit)

A Liquid Crystal Display (LCD) is an alphanumeric display capable of showing not only numbers but also letters and special symbols, making it a user-friendly device for displaying a variety of messages. Unlike a segment display, which is limited to displaying only numbers and a few letters, an LCD offers more flexibility. However, the primary disadvantage of an LCD compared to a seven-segment display is that seven-segment displays are more durable and can be viewed from a greater distance. In this case, a 16x2 alphanumeric display is used, meaning it can display two lines, with a maximum of 16 characters per line, as shown in Fig. 11.

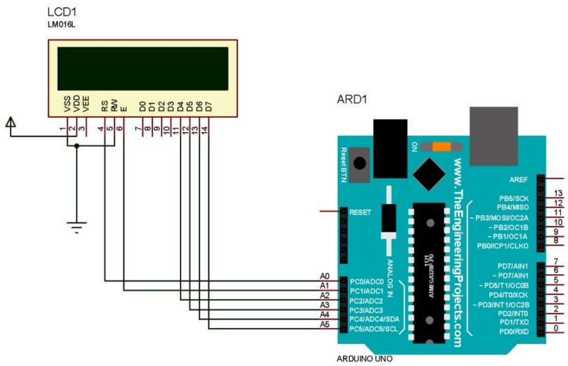

Fig. 11. *LCD interface to the Arduino*

3.9 Buzzer (Alarm Unit)

The buzzer serves (Fig 12) as an alarm that produces sound after the experiment is completed. The magnetic buzzer used in this project has the following features;

1. Low Frequency
2. Low Voltage
3. Small and Slim Size

The buzzer also has the following standard specifications at normal operating conditions which are mentioned in Table 2.

Table 2. *Buzzer specification table*

S/n	Buzzer specification	Normal operating condition
1	5VDC/10cm	85dB(A)
2	Rated Voltage	5VDC
3	Max. Consumption	30mA/5VDC
4	Operating Voltage	4~6.5VDC
5	Resonant Frequency	2300±300Hz
6	Max. Response Time	50ms
7	Operating Temperature	-40~+85°C
8	Storage Temperature	-40~+85°C
9	Weight	2g

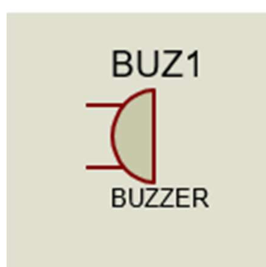

Fig. 12. *Buzzer*

3.10 SD Card Module

The module (Micro-SD Card Adapter) is a Micro SD card reader module, and the SPI interface is via the file system driver, and microcontroller system to complete the Micro-SD card read and write files. Arduino users can directly use the Arduino IDE comes with an SD card to complete the library card initialization and read-write. Features: Supports micro SD card (<=2G), micro SDHC card (<=32G) (high-speed card) Level conversion circuit board that can interface level is 5V or 3.3V □ Power supply is 4.5V ~ 5.5V, 3.3V voltage regulator circuit board Communication interface is a standard SPI interface 4 M2 screw positioning holes for easy installation Size: 4.1 x 2.4cm. Control Interface: A total of six pins (GND, VCC, MISO, MOSI, SCK, CS), GND to ground, VCC is the power supply, MISO, MOSI, SCK is the SPI bus, CS is the chip select signal pin.

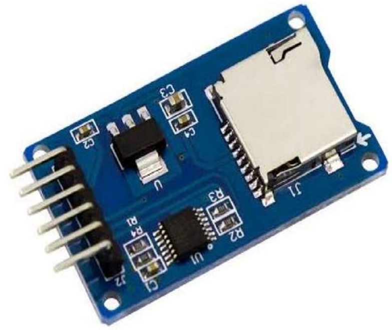

Fig. 13. *SD Card Module*

3.11 Software Design

The software refers to the program code that is loaded onto the microcontroller (Arduino) program memory. It is the execution of the instructions contained therein, that aids the microcontroller in carrying out its primary functions of the peripheral device attached to it. The program is usually written in high-level language and then translated to generate a hexadecimal code file (machine code). The Arduino compiler was used for developing c language and debugging into machine codes, the steps are as follows:

1. Create a project file and add source files. In the menu bar, click Project→ Project Wizard. The project wizard dialogue box appears. Click 'Next.' In the 'Next' window, select the device as ARDUINO from the drop-down menu. Click 'Next' and select 'COM' suite from the drop-down menu. Click 'Next,' name your project file as 'energy meter' and specify its location.

The file is automatically saved with 'energy meter.ino.' Click the Next→ Finish button. Now your project is created and the source files are added.

2. Compile the project. To compile the software, click the 'Build' option in the 'Project' menu. The software is compiled and the 'Build Successful' message appears in the output window. After successful compilation of the program, the file energy meter.hex is generated. The complete source code of the design is given in the appendix.

3.12 Components Assembling and Construction

Before assembling the component onto a circuit board, a test board was initially used to test whether all the components arranged could perform the expected function. The construction procedures are as follows:

1. All the required components were tested using a digital multimeter to confirm their functionality before being taken to the circuit for soldering
2. The components were plugged in vertically in the position specified in the circuit connection and Vero board conductors arrangement, also flexible wires were used where necessary.
3. The components were soldered on the board using soldering iron and lead wire.
4. The soldered connections were tested using a multimeter and other equipment to ensure efficient soldering.
5. In case of any partial contact or line short circuit, the joint should be re-soldered if partial contact or line short circuit, the joint should be re-soldered if partial contacts are sucked out to clear the short circuit.
6. A wire to move the motors mounted on the board to wipe the board is connected to the DC supply battery.
7. Finally, after testing and ensuring that there was continuity around the circuit and confirming that the circuit works, the components and joints were appropriately soldered.

3.13 Precautions Taken During the Soldering Process

To avoid any burn or damage to the board or the components, the following precautions were taken:

1. It was ensured that the soldering iron was tested by placing a little solder on it before it was used to avoid unexpected damage.
2. It was ensured that the solder was placed first on the joint before the iron to avoid premature melting which may disfigure the board or worse the connections.
3. It was also ensured the soldering iron was left on its stand when not in use to avoid contacts with contact with undesirable materials.
4. It was also ensured that too much solder was not placed on joints to avoid unnecessary connections.

3.14 Equipment Used For the Construction

The following are equipment or tools used during construction:

1. Soldering iron
2. Lead
3. Connecting wires
4. Side cutters and Screwdrivers
5. Project board
6. Vero board

3.15 Overall Circuit Diagram of the Project

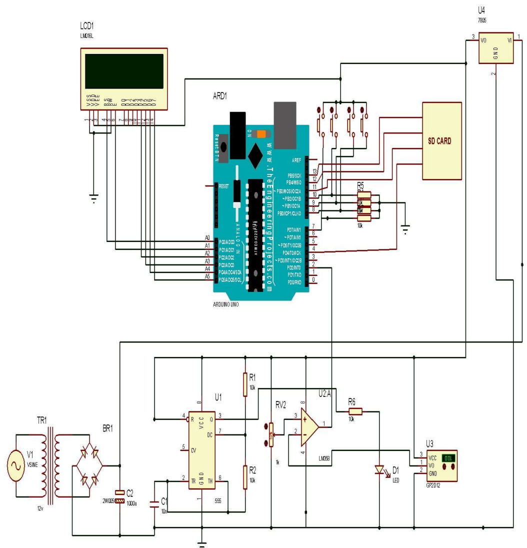

Fig. 14. *Overall Circuit Diagram*

4. Testing, Result and Discussion

4.1 Simulation

The program was written in Arduino and debugged from C- language into machine code (hex- -file) and then simulated in the PROTEUS ISS professional and tested. The program was found to be working successfully with only minor errors and mistakes which were corrected before the completion of the project. The program was written in Arduino and debugged from C- language into machine code (hex- -file) and then simulated in the PROTEUS ISS professional and tested. The program was found to be working successfully with only minor errors and mistakes which were corrected before the completion of the project.

4.2 Loading and Burning the Program.

The written debugged program (HEX-file) was burnt into the Arduino using an Arduino board programmer adaptor which interfaces Arduino IDE software installed in the PC. After burning the program, it was tested on a testing board and found to be working successfully.

4.3 preliminary Testing of the Construction

The whole project was constructed preliminary on the breadboard and found to be working successfully. Then the whole components were transferred to copper stripped board and then enclosed in a case after testing. The construction on the copper-stripped board was done using a soldering iron, solder lead to connect wires and the respective components. Jumper wires were used to avoid burning the ICs and solder sucker was used during the construction for easy removal of the ICs.

4.4 Packaging of the Project for Overall Test

The system was made of plastic polymer to provide protection. The dimensions of the system were chosen to suit the application and provide enough space for the project.

4.5 Testing

Upon the completion of the construction, the following test was carried out with a multimeter which was used to check the continuity and connectivity of the overall circuit. The polarity of the component was tested and checked. Also, measurements of the voltage, resistance, and current were taken and compared with the design value. The microcontroller interface with the sensor was tested, and the sensor communicated with the microcontroller effectively.

Table 3. *Table of values for a simple pendulum*

Height of the bob (cm)	Time for 20 oscillation	Period T=t/20	T2 (S2)
7.00	70.00	3.5	12.25
37.00	65.00	3.25	10.56
67.00	64.00	3.2	10.24
97.00	59.00	2.95	8.70

4.6 Result Discussion

This project focuses on keeping accurate time and counting hence the two most important parameters that are of utmost importance are timing and counting of the bob swinging, therefore Table 3 shows the simple pendulum values at different lengths of the bob from the pivoted joint, starting from 97cm and the length is reduced by 30cm thrice and the time for 20 oscillation was recorded for the different length. The period (T) which is expressed as T=t/20 was calculated and the values corresponding to each period were recorded and they are in turn squared. The values were used to plot a graph and hence the acceleration due to gravity (g) is calculated from the slope of the graph.

5. Conclusion and Recommendation

5.1 Conclusion

At the end of this project with the title "Microcontroller base simple pendulum". Although there were a lot of difficulties and errors preliminarily at the end of this work, the aims and objectives stated herein were all attained and verified, which conform with the theoretical aspect of a simple pendulum. A simple pendulum is a weight suspended from a pivot so that it can swing freely. When a pendulum is displaced sideways from its resting, equilibrium position, it is subjected to a restoring force due to gravity that will accelerate it back toward the equilibrium position. In the design of an embedded system to perform this with little effort and minimal error, the idea of a microcontroller based simple pendulum comes into being. The microcontroller-based simple pendulum consists primarily of six major units, which are; the power supply unit, the bob swinging/sensing unit, the control unit, the display unit, the alarm unit, the SD card module, and the count select unit. These units combined are used to perform the experiment which facilitates a very reliable result, the results are usually displayed on the LCD which are in turn saved into the SD card. Upon the completion of the construction, the following test was carried out with a multimeter which was used to check the continuity and connectivity of the overall circuit. The polarity of the component was tested and checked. Also, measurements of the voltage, resistance, and current were taken and compared with the design value. The microcontroller interface with the sensor was tested, and the sensor communicated with the microcontroller effectively.

In the end, the local acceleration due to gravity was calculated and is in line with the theoretical aspect of the simple pendulum.

5.2 Recommendation

This project has been constructed and it has covered its aims and objectives. While further improvement can be made to this system, if a monitor is added to this system, a graph of a simple pendulum can be plotted by using specific software which will make it easier to understand the characteristics of a simple pendulum through the graph. Additionally, this system can be interfaced with the Ethernet module in such that it can send the experimental values through the data database of the instructor, it can be interfaced with the Ethernet module to send the result of the experiment to the examination board.

Compliance with Ethical Standards

Conflicts of Interest: Authors declared that they have no conflict of interest.

Human participants: The conducted research follows the ethical standards and the authors ensured that they have not conducted any studies with human participants or animals.

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APPENDIX

Arduino IDE software is used in building a program suitable for microprocessor base simple pendulum. The source code is written below.

```
#include <LiquidCrystal.h>
#include <SPI.h> //for the SD card
module #include <SD.h> // for the SD
card float pulseCount=0;
byte sensorInterrupt = 0;  // 0 = digital
pin 2 byte sensorPin       = 2; int i=0;;
int set=0;
int pen=0;

int
cntt=
0; int
stop1
=0;
int
timer
=0;
int
sec=0
;
// initialize the library with the numbers of the interface pins
LiquidCrystal lcd(A0, A1, A2,A3,A4,A5);
const int chipSelect = 4;

// Create a file to store the data
File
myFile;
void
setup() {
  // put your setup code here, to run once:
lcd.begin(16, 2); // initialize the
lcd  lcd.setCursor( 0, 0 );
lcd.print("Simple Pendulum");
  lcd.setCursor( 2, 1 );
lcd.print("   system");
delay(2000);
Serial.begin(9600);
lcd.clear();
  attachInterrupt(digitalPinToInterrupt(2), buttonPressed, FALLING);

 pinMode(6, OUTPUT);
pinMode(7, INPUT);
pinMode(8, INPUT);
pinMode(9, INPUT);
pinMode(5, INPUT);
  // setup for the SD card
  Serial.print("Initializing                  SD                  card...");
if(!SD.begin(chipSelect)) {
    Serial.println("initialization
failed!");      lcd.setCursor( 0, 0 );
lcd.print("SD Card failed");
delay(1000);   lcd.clear();
return;
  }
  Serial.println("initialization done.");
  //open file
  myFile=SD.open("DATA.txt", FILE_WRITE);
```

```
  // if the file opened ok, write to it:
  if (myFile) {
lcd.setCursor( 0, 0 );
lcd.print("SD Card
OK");
Serial.println("File
opened ok");     //
print the headings
for our data
myFile.println("Coun
t,Pen,sec");
delay(1000);
lcd.clear();
  }
myFile.cl
ose(); }
void
loop() {
  // put your main code here, to run
repeatedly: lcd.setCursor( 0, 0 );
lcd.print("Pen:");   lcd.print( pen);
lcd.setCursor( 0, 1 );    lcd.print("set:");
lcd.print(cntt);   lcd.setCursor( 10, 0 );
lcd.print("T:");   lcd.print(sec);
  if(pen>=cntt)    {
stop1=0;
lcd.setCursor(
10,          1          );
lcd.print("Stop
");
  }
if(stop1==1) {
timer++;
if(timer>100  &&
pen>0)
{
  sec++; delay(10); timer=0;
}
if(mil
l==2)
  {
pe
n+
+;
mi
ll=
0;
  } }
if(i>
=2)
{
mill
++;
dela
y(10)
;
i=0;
  }
  if (digitalRead(8) == HIGH)
  {
   cntt++;  delay(100);
  }
```

```
  if (digitalRead(9) == HIGH)
 {
  cntt--;  delay(100);
 }
  if (digitalRead(7) == HIGH)
 {    stop1=1;
lcd.setCursor( 10,
1 );
lcd.print("Start
");
 }
  if (digitalRead(5) == HIGH)
 {
 }
}             void
buttonPresse
d()
{
output=
LOW;
  i++;
}
```