

ECE 445

SENIOR DESIGN LABORATORY

REVISED PROPOSAL

Clickers for ZJUI Undergraduate

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1 Introduction

1.1 Problem

Improving student engagement in class remains a challenge for instructors, not only for online classes but also for in-person classes. Engaging students through active learning pedagogies that rely on attendance is important for improving the quality of teaching. In fact, a 2010 meta-analysis found that attendance positively affects both course grades and GPA, and is the single strongest predictor of college grades. [1]. It is important to engage with them through active learning pedagogues that rely on student attendance. Thus, the i-clicker system can help stat the attendance rate effectively, and improve the students' concentration by encouraging them solve the in-class problems.

The I-clicker system used in UIUC for undergraduates was designed for solving these problems. It requires students to participate in class and answer questions to earn credit. Nowadays there are mainly two kinds of i-clickers: One is based on an embedded system and the other is based on a web application. Compared with the web applications running on laptops and cell phones, those wireless i-clickers have the following advantages: they are easy to carry, they can accurately match and identify user tags, they are difficult to cheat, and would not distract students. Unfortunately, most of the i-clickers used on campus have the following problems: inconsistency, high response delay, poor signal, and manual matching.

1.2 Solution

The signal transmission chip in some clicker in UIUC is time out. So we can deal with the problem mentioned above by using a newer signal transmission chip.

To deal with the problem of high delay and poor signal, we decide to replace the origin chip with nrf24l01, which has higher transmission efficiency and wider channel. It can match up to 256 receiving ports by modifying the communication protocol. More details with this chip will be covered on tolerance part. As it can support up to 256 receivers, it can meet the size of user group. But the cost of each clicker will increase by 0.3\$.

1.3 Visual Aid

Here is a comparison between nRF24l01 chip and CC1101 chip.

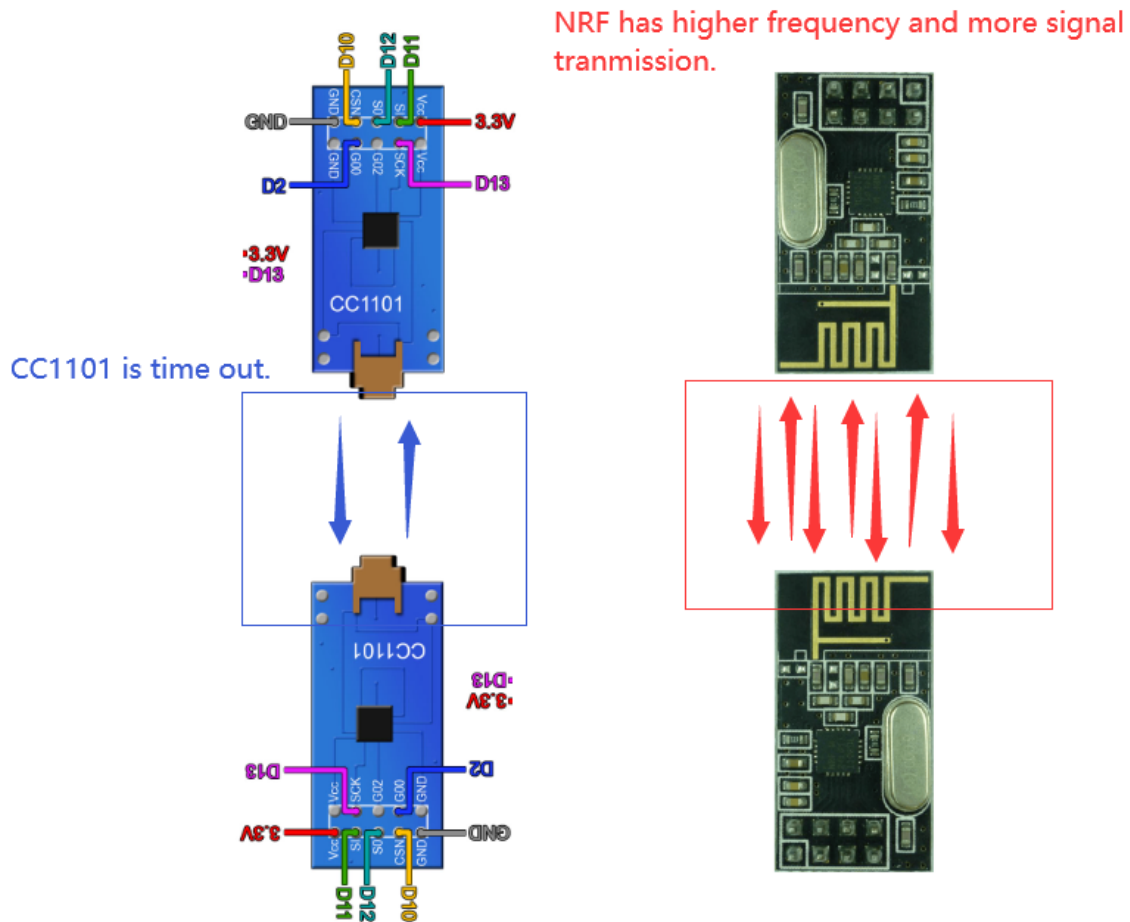


Figure 1: Visual Aid

1.4 High-level Requirement Lists

1. The total power of the portable i-clicker system should be between 2W to 5W to effectively prolong the battery life for long-time operation.
2. The transceiver's effective working radius should be at least 120 meters and support up to 125 multichannel connections to cover most classroom structures. The base station should also have a Low Noise Amplifier module to improve the quality of signal reception and eliminate noise signals.
3. The data transmission between i-clicker and transceiver should be completed within 500 milliseconds to ensure timeliness of the polling results.

2 Design

2.1 Block Diagram

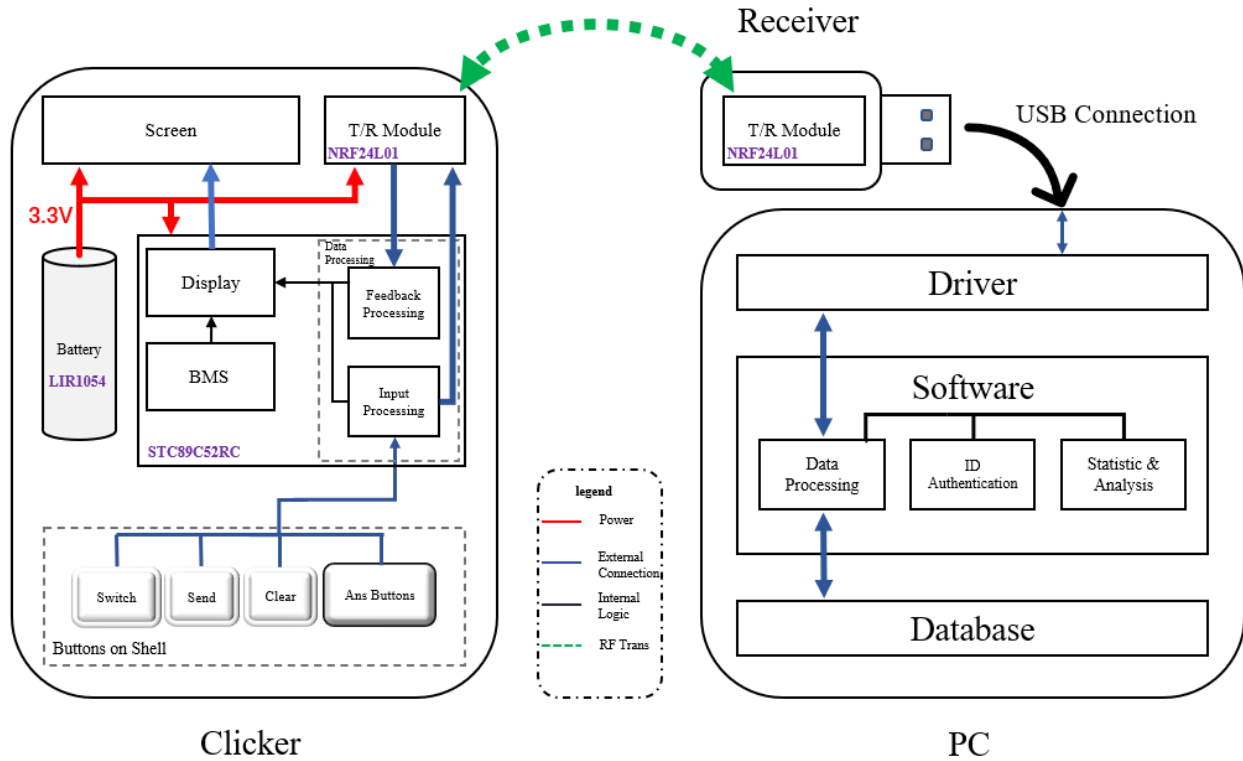


Figure 2: Visual Aid

2.2 Subsystem Overview and Requirement

2.2.1 DC Power Subsystem

We need a direct power supply to power our SCM and LCD display. Considering product size and LCD brightness, voltage should be 3.3V-5V and current should be less than 5 mA. Too high voltage can easily cause eye damage to the screen and too high a current is likely to cause security risks. And it must also be packaged into the clicker product. So we will going to use button battery LIR1054(fluctuation voltage from 3.6v to 4.2v) for power.

2.2.2 Display Module

Clicker needs a screen to provide feedback to users. We choose LCD1602A to display to users. LCD1602A will receive data stream from SCM and 3.3V - 5V voltage from DC power. Users can receive feedback on their display screen via driver, nRF24l01 Hardware side and STC89C52RC.

2.2.3 SCM Hardware Logic Subsystem

We use a SCM to compile the display module, send and receive message from wireless transceiver module and receive hardware signal from keystroke. It also needs a voltage supply. STC89C52RC is a common and popular SCM at present, and its supply voltage is between 3.4V to 5.5V. This is exactly what we need. This module should run all the time after power is on and send data stream to the wireless transceiver module upon receipt of a keystroke command. During power-on, SCM should always keep the screen refreshed, that is, update the contents of the screen every unit of time.

2.2.4 Wireless 2.4GHZ Signal Transceiver Module

This module is divided into two parts, one is connected to the software side of the computer, the other is connected to the hardware side of the SCM. A DC power is also needed. We choose nRF24l01 chips as our signal transmission part. One chip on the hardware side should be connected to STC89C52RC and DC power, the other chip on the software side should be connected to AS06 bottom plate and then connected to USB port on the computer. Once one side receives the data stream from the procedure, it sends it to the other one over 2.4GHZ wireless signal.

2.2.5 Hardware circuit connecting module

We will use eight buttons to form a three-bit keystroke input signal. The only function is to connect to the SCM, by giving different signals as different commands, and then transfer the SCM into different states.

2.2.6 Clicker Overview

After all the subsystems are connected, we need a plastic shell to encapsulate it. STC89C52RC, 8-buttons keystroke, DC power LIR1054, LCD1602 screen and one nRF24l01 wireless transceiver chip should be wrapped in it.

2.2.7 Signal Conversion Subsystem

A driver is required on the USB interface. After receiving data stream from hardware, computer need a driver to Convert hardware signals into software signals. Similarly, when the software wants to send a feedback signal to the hardware, it should also use this driver to convert the software signal into the hardware signal.

Functions of driver:

1. Reception
 - (a) Read response messages from USB port.
 - (b) Filter out messages with incorrect format.

- (c) Extract ID and answer information from messages.
- 2. Sending
 - (a) Add wrapper to feedback messages from Data Processing Unit.
 - (b) Write Feedback message to USB port.

We choose module pySerial which encapsulates the access for the serial port to implement the driver. It provides back ends for Python running on Windows, OSX, Linux, BSD (possibly any POSIX compliant system) and IronPython. The module named "serial" automatically selects the appropriate back end.

The driver we design should be able to detect the port the Receiver is plugged into. To receive data from USB port, serial port should be initialized with Baud Rate = 9600, which refers to the rate of the effective data signal modulation carrier, that is, the number of times the carrier modulation state changes per unit time.

Communication Protocol

The communication protocol is embedded into the driver. In the primary communication protocol, we set the format of response to be "ID{4}+ANS{1}", totally 5 digits. Similarly, the format of feedback to be "ID{4}+Correctness{1}". For "Correctness" field, 1 is for correct, and 0 is for wrong. The driver should filter out messages with incorrect format by a helper function.

2.2.8 Data Processing Subsystem

Software ought to be able to process the data from driver accurately, analyse the data and generate feedback to each Clicker.

Functions of Data Processing Unit:

1. Attendance
2. Score
 - (a) Mark each answer.
 - (b) Record the answer or score in database.
3. Enquiry
 - (a) Query the class attendance history.
 - (b) Query students' answer or score history.
4. Generate Feedback

Teacher could keep track of the students' answers and display it visually through statistical charts. After each "Answer Section", data processing unit will count the number of

each option and draw a histogram correspondingly, where the bar of correct answer is green and the one of wrong answer is red, . Data processing unit could correct students' answers according to the correct answer input by teacher previously. The data processing unit will score each student's final answer and record the score and option of each student in database. Meanwhile, the unit will generate feedback according to the correctness to students at the end of each "Answer Section". It will deliver feedback message with format "*ID{4}+Correctness{1}*" to the deliver.

At the beginning of each course, teacher starts a "Course Section". Once a student answer a question within the "Course Section", the unit will record his/her attendance. After class, teacher could check the detailed attendance on student list or overall attendance with a sector diagram.

Interacting with database, Data Processing Unit is able to provide historical data to teacher. Hence, teacher could have a better grasp of students' learning and make adjustment to optimize teaching content.

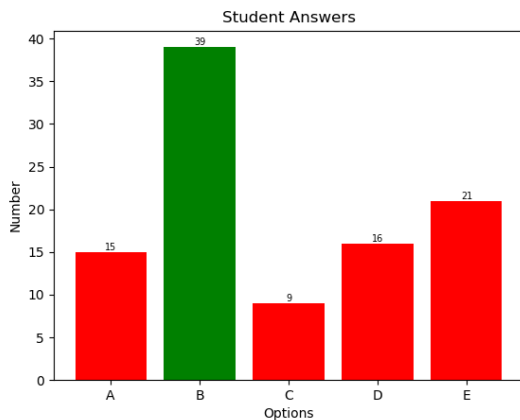


Figure 3: Student Answers

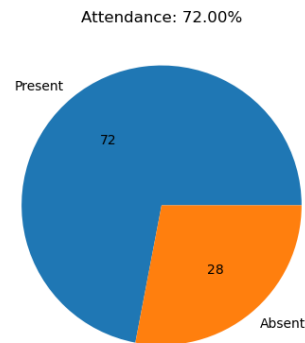


Figure 4: Attendance

2.2.9 ID Authentication

Clickers is identified by the unique identifier on SCM chip. Correspondingly, users could also bind their identities to Clicker identifier at the beginning of a semester or the time they get the Clicker. The method of registration is yet to be decided. Current scheme is as follows.

Identity Binding Methods:

- **Manual Binding.** I-Clicker system in the UIUC use this method, which requires teaching professor to collect students' ID together with I-Clickers' identifier on a notebook, and then, bind them together manually. But, obviously, it is inefficient.
- **Signal Binding.** A type of clicker apply this method, which requires teaching professor to open up an ID collecting section for student to input and send their id to terminal equipment (Teacher's computer). This method is quite efficient, but could be unfriendly for students who missed the section and number keys should be implemented on the design.
- **Internet Binding.** An other potential scheme is to build up a website for registration where students can bind/unbind the machine on their own no matter when. But, there will be extra effort to build such a website.

2.2.10 Database Subsystem

We need a local MySQL database to store the historical record on the computer. Before the data processing subsystem returns feedback, it will firstly store the results and scores of the data processing into the database. The database stores information in Key-Value Pairs and has interfaces for processing subsystem calls scores or raw data and for ID Authentication to record, modify, query or delete the ID binding information.

A valid entry in database should contains student's ID as primary key, Clicker's ID, total score & attendance, and detailed score & attendance for each Course Section.

2.3 Tolerance Analysis

Based on our hardware design, the RF24 wireless system are basically work with half-duplex network system, thus we should consider the Media Access Control to avoid the signal collision. Due to the performance limitation, we can not synchronize among all the i-Clickers, then we would apply unslotted CSMA/CA algorithm to control the communication between base and clickers. In order to reduce delay and ensure the reliability and stability, the performance of our network need to be deeply studied.

Now we assume that there are n clickers are associated to the central base server in a class, and each device only have one packet to transmit per communication window. It is possible that students may want to resubmit their answers, thus we assume that each device would generate packets according to Poisson process with the rate λ . Furthermore, we assume that the payload packet transmission time would be T_{Tx} , and the ACK packet transmission time would be T_{ack} , and the expected server response time would be $E[S]$,

and the average turnaround time would be T_{turn} . According to the algorithm, the clickers must wait for a whole Clear Channel Assessment(CCA) time before counting down their back-offs or start transmitting, thus we assume that the CCA time would be T_{cca} . We also define that the max trial times is M. After M trial, the packet would be discarded.

By referring to the article posted by Tae Ok Kim etc. [2], we could evaluate the whole model in M/G/1 queuing model. According to the model, we could know that during one busy cycle, the average successful transmission number would be $(1 - P_{Loss}) * E[\Gamma]$, where the P_{Loss} would be the packet loss rate, and the $E[\Gamma] = \frac{1}{1-\rho}$ is the number of packets served in that busy period, with the traffic intensity ρ :

$$\rho = \lambda * (E[D_{hol}] + T_{Tx} + 2 * T_{turn} + T_{ack}) \quad (1)$$

With the $E[D_{hol}]$ denotes that delay between the packet generated and the period that just before the packet being transmitted or discarded in our scenario. The $E[D_{hol}]$ can be calculated as below:

$$\begin{aligned} E[D_{hol}] &= \sum_{v=0}^m \alpha^v (1 - \alpha) \sum_i^v = 0 \frac{W_i - 1}{2} * \delta + (v + 1) * T_{cca} \\ &+ \alpha^{M+1} \sum_{i=0}^M \frac{W_i - 1}{2} * \delta + (M + 1) * T_{cca} \end{aligned}$$

With the α denotes the possibility that the channel is busy when the node's back-off is zero, and the article also gives the equations to resolve the value:

$$\alpha = \frac{(n - 1)(1 - P_{Loss})E[\Gamma](T_{cca} + T_{Tx} + 2 * T_{turn} + T_{ack})}{\frac{1}{\lambda} + E[\Gamma] * E[D_{hol}]} \quad (2)$$

$$= \frac{(n - 1)(1 - P_{Loss})(T_{cca} + T_{Tx} + 2 * T_{turn} + T_{ack})}{\frac{1}{\lambda} - (T_{Tx} + 2 * T_{turn} + T_{ack})} \quad (3)$$

With the equations above we can calculate the expected total delay $E[D]$ of the system according to the queuing model given by [3]:

$$E[D] = \frac{\lambda * E[s * 2]}{2(1 - \rho)} + E[D_{hol}] \quad (4)$$

In our model, according to our design, the nRF24 would use a payload packet with 64bytes and a Ack packet with 48 bytes. Hense, we would apply transmission rate at 256Kbps, and the average serving time would be 100ms for each packet. Based on the classroom structures, we would set our typical transmission time T_{turn} at 0.4ms, and the T_{cca} at 0.8 ms accordingly. By inserting in corresponding parameters obtained from data-sheet, and consider the general conditions above, we could acquire the expect delay over the numbers of students with different i-clicker answering rate λ :

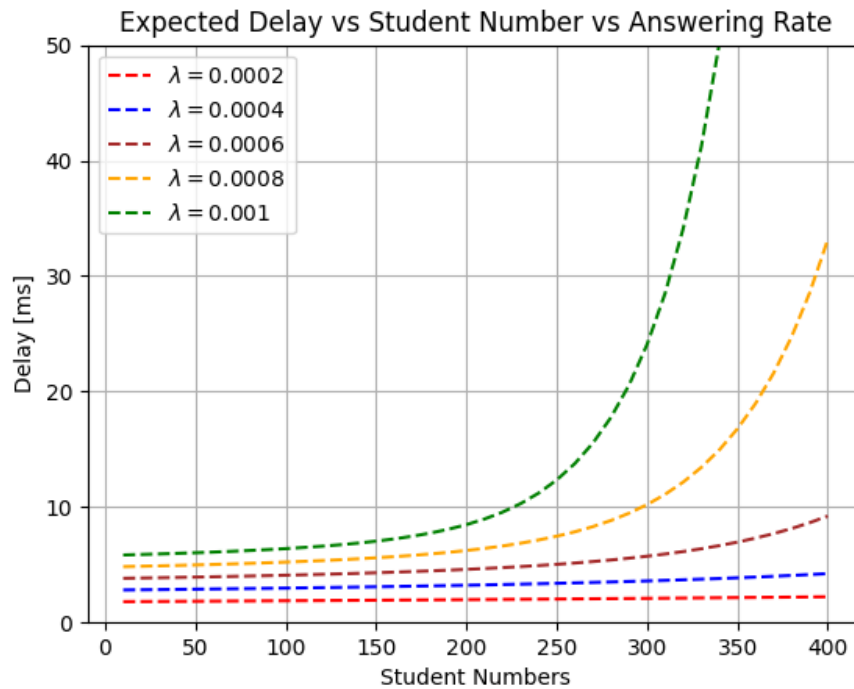


Figure 5: Expected Delay vs Student Number vs Answering Rate

We can find that the latency increased sharply when λ larger than 0.001, which means if all the students start to transmit answers at average rate of 1 times/sec, there is a high probability that the system will be clogged. The system capacity figures below would also shows this:

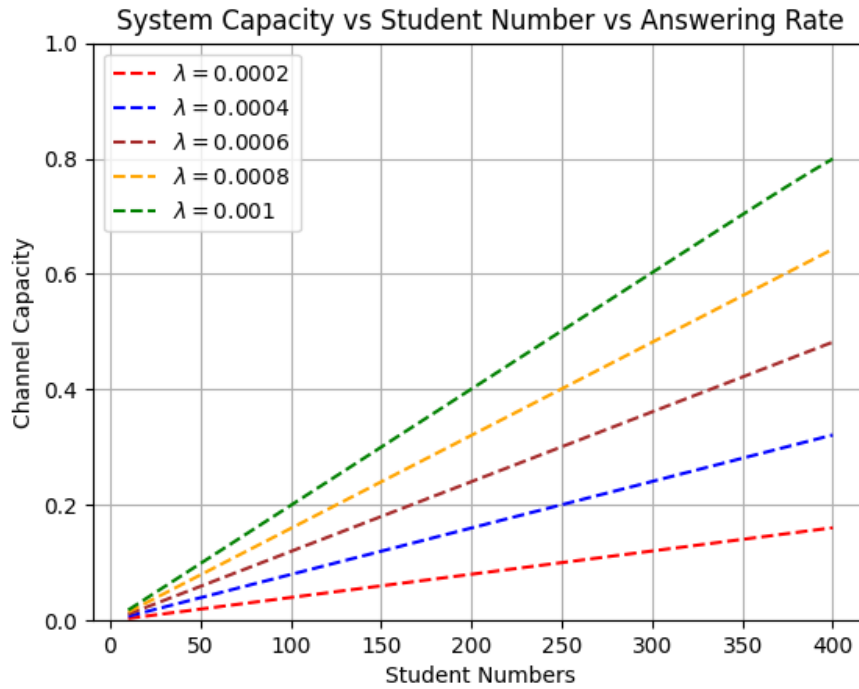


Figure 6: Expected Capacity vs Student Number vs Answering Rate

Hence, we should set the built-in send intervals in our transmitting logic, in order to avoid the potential crash possibilities. The built-in send intervals would set around 2 seconds, to keep the overall flow of communication.

3 Ethics & Safety

3.1 Ethics

During the development and use of our project, we must commit ourselves to the highest ethical standards and avoid any breaches. One important consideration is that our devices use 2.4GHz Wi-Fi as a data transmission medium, which may interfere with the normal operation of some vital devices, particularly medical devices. This violates the first principle of the IEEE Code of Ethics, which is to hold paramount the safety, health, and welfare of the public [4]. To address this, we must propose limits on the wireless frequency range of equipment used and specify the scenarios in which they can be used, as well as use warnings to relevant groups.

We should also take responsibility for any problems that arise from the use of our products. According to the sixth principle of the IEEE Code of Ethics, we must maintain and improve our technical competence and only undertake technological tasks for others if we are qualified by training or experience or after full disclosure of pertinent limitations [4]. Therefore, during the development process, we should ensure that our designs and codes are easy to maintain and upgrade for additional functions, user-friendly, and reliable since they will be used by various students for a long time.

3.2 Safety

In terms of safety concerns, our final product will contain widgets that may fall off and be swallowed by a child. Therefore, we should include safety-related labels on the device to keep it away from children. Additionally, our devices contain rechargeable Li-ion batteries, which means they can only be used within a specified room temperature range of 0 to 45 degrees Celsius and should be recycled through a formal process. All electronic devices used in the experiment are below the safe voltage for human bodies, but it is still important to follow safety rules to avoid electrocution.

References

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