Palestine Polytechnic University

Collage of information Technology and

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Model of Vaccine Monitoring and Warning System of Cold Storage Units

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Abstract:

Vaccine monitoring is an important task that is currently done in the ministry of health of Palestine. It is done using data loggers that measure and store cold storage temperatures and then it’s logged manually three times a day (during work time) by health workers in public health clinics. This way is not efficient in handling cases when the temperature is not within the acceptable range (2-8) C after the end of the workday of health workers. It is also costly in matters of time and effort, and is prone to human errors.

We aim through this project to solve those problems to ensure the efficiency of the vaccine management system by building a low cost model that monitors and logs vaccine cold storage unit temperatures then issues warnings in cases that may affect the quality of vaccines to ensure a timely response from authorized personnel who are responsible of handling those issues

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Our intended method of reaching those aims is by building a system that monitors temperatures of cold storage units using two devices: a transmitting device, and a receiving device.

The transmitting device contains a temperature sensor. It also has an LDR sensor to ensure that cold storage unit doors are closed tightly after being opened by health workers. Data from both sensors are sent to the receiving device via Bluetooth.

The receiving device has an Arduino Mega microprocessor which checks if temperature is between 2C and 8C, if otherwise it issues a warning. It also issues a warning when the battery percentage is less than 20% and when the temperature sensor stops working efficiently, . Warnings are issued using GSM SIM900 module. in addition the device has a website designed for logging the temperatures of storage units.

After implementing the system, our system is able to work 24/7, measure temperature, and light the LED strip while the unit door is open, upload temperatures to dedicated website, show temperature value, battery levels and system component issues on the TFT screen. Finally, it issues a warning when the previously mentioned unsuitable conditions occur.

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Chapter 1: Introduction:

1.1 Overview:

Public Health is considered as one of the most important and among the highest priorities of every government with the aim of having healthy society with no or minimum epidemic and transmitted diseases with a high focus on targeting new born and young people. Efficient and high-quality Vaccine Management System (VMS) is extremely important to ensure the quality of the stored vaccines. Any damage in vaccines will be very costly and will be associated by lots of difficulties in importing new vaccines in a timely manner. Israeli Occupation is considered as a threat multiplier and a very challenging environment when it comes to vaccine import as a result of complicated regulations and instructions.

1.2 Motivation:

Our children are our most valuable assets, and since their health is our highest priority; the first thing to do is to provide them with vaccines that protect them from illness and diseases and improve their quality of life especially during their first years.

1- Vaccines should be managed in a very efficient and high quality manner in order to be effective and useful so it must be stored following the manufacture instructions and guidelines.
2- Health care providers in addition to their duties, must check the temperature of cold storage units three times a day all over the year (according to ministry of health protocols) to ensure the quality of the stored vaccines, which in case of loss or damage can be costly in Time and effort consumption.
3- Vaccines might be prone to human errors during the management and recording by the health care provider who are usually working under pressure.
4- In cases where vaccine is damaged and not possible to be used, the government has to replace it with new ones, which can be a liability since vaccines, are extremely costly and hard to import.
5- To ensure timely response in case of an emergency in order to preserve the quality of vaccines.

1.3 Importance:

What makes our project vital to the ministry of health are the following:

1- It is extremely important to ensure that the vaccine is in active and in a good quality in order to be assured that its efficiency is well reserved and the planned results are well maintained.

2- To prevent all possible human errors that can result from manual monitoring and management to reduce the amount of annual expenses to substitute for the lost vaccines.

3- To ensure that Palestine health care system which deals with vaccines is well equipped and well managed at all levels vertically and horizontally (vertically means at the central level while horizontally means all geographical areas which includes primary and secondary health care centers that provide vaccination services to target groups).

1.4 Objectives:

Our aim through this project is to ensure:

1. Keeping and preserving the effectiveness of the vaccines by keeping the cold storage system under continuous control and to avoid vaccines damage and loss as a result of change in temperature out of the recommended range.
2. Avoiding losses in vaccines which is considered very costly and not easy to be imported from its resources in the international market through Israeli Occupation controlled borders which impose lots of barriers and challenges in that regard.
3. A timely response in case of electricity cut or there was any change in the cold storage system out of the recommended ranges (2-8) C [1] which the health care provider must be aware of instantly.
4. To relive healthcare providers from the burden of daily manual monitoring by providing a website that logs temperatures.

1.5 Scope of the project:

This model system will be our first step to build an efficient system that will cover every cold storage unit in all public health centers that lie in the state of Palestine.

1.6 Short description:

Our system consists of two devices:

Transmitting device: It measures temperature, light intensity and battery voltage and sends them to the receiving device via Bluetooth (placed inside the cold storage unit).

Receiving device: It receives the data and then it sends the temperature values to the server then website by Ethernet shield, the device checks that the temperature is within the appropriate range, if not; a warning is issued in a form of an SMS detailing the problem followed with a call. The same warning is issued when the battery percentage of the transmitting device reaches 20%. The light intensity values are also received and when they indicate that the light intensity is high (the unit door is opened) an LED strip that surrounds the device lights a warning light till the door is closed. The data received from the transmitting device is displayed on the screen in the following order: Date & time, temperature value, battery percentage, Bluetooth connection status, the word "problem" followed by the name of modules that are not working successfully.

1.7 Problem Analysis:

Primary and secondary health care centers are lacking an early warning system that informs the health care provider of any deviation in the appropriate conditions for keeping the effectiveness of the vaccines (temperature) of the cold storage unit. The current system can only record the temperature in an attached data logger without being connected to an alarm system. The lack of an automated system may result in vaccine damage in case if there was a cut in the electricity or failures in the storage unit that result in an increase or decrease in the temperature out of the recommended range. This will result in vaccine damage and it might lead to large economic losses.

1.8 List of requirement**:**

1- The system must work 24x7 to ensure the quality of vaccines.

2- The warning light must work in the case of cold storage doors were not closed tightly.

3- The system must send a warning SMS and call if it is experiencing unsuitable conditions (temperature outside of recommended range or 20% battery charge left in transmitting device).

4- The system must send an automated SMS every month to ensure that the SIM card is still active.

5- In cases where a component stops working properly the failing component's name is displayed on the screen as a warning since it is a critical system.

6- The system must be affordable so it would be easy job produce it and to adopt it in all of the primary health clinics.

1.9 Expected results**:**

We expect to build an affordable system with the following specifications:

→ It should display The temperature, time, date, warnings and battery percentage on the screen.

→ In case of an emergency (temperature not within recommended range or 20% battery charge left in transmitting device), the system must send alerts (SMS and calls) to the health care providers correctly.

→ Medical staff should be alerted whether the door of the vaccination refrigerator is closed tightly or not.

→ The daily refrigerator temperature data should be displayed correctly on the website.

→ In case one of the devices malfunctions, a warning should be successfully displayed on the screen.

1.10 Project Time Line:

Task No.	Task Name	Duration (Weeks)
1.	Project planning	4
2.	Determination project requirements	4
3.	Project design and analyzing	8
4.	Project development	10
5.	Project testing and maintenance	4
6.	Documentation	28

1.11 Project Gantt Chart:

Task	Duration (Weeks)													
	First Semester							Second Semester						
	2	4	6	8	10	12	14	2	4	6	8	10	12	14
Planning	■	■												
Project Requirements			■	■										
Analyzing and design				■	■	■	■							
Project development								■	■	■	■	■		
Project testing and maintenance										■	■	■	■	■
Documentation	■	■	■	■	■	■	■	■	■	■	■	■	■	■

Because of the current situation the world is facing because of the pandemic we weren't able to stick to the timetable.

2.12 Constrains:

1. **1.** Getting a strong enough cellphone network coverage in case the system needs to send an alarm.
2. **2.** The system only covers clinics that have only one cold storage units (currently that's the case for all clinics).
3. **3.** This system is only designed for vaccine cold storage units that operate on the temperature range of (2-8) C and is not suitable for vaccine freezers.

Chapter 2: Background:

2.1 Overview:

This chapter introduces a theoretical background of the project, some description of hardware and software components used in the system and discussion of the specification and design constrains.

2.2 Theoretical background:

Vaccines are substances used to stimulate the production of antibodies and provide immunity against one or several diseases, prepared from the causative agent of a disease, its products, or a synthetic substitute, treated to act as an antigen without inducing the disease [2].

In order to preserve the quality of vaccines it should be stored in cold storage units where its temperature is kept within the recommended ranges or else it would be no longer affective which is costly to replace and will deprive children from one of their basic needs till it becomes available again.

There are currently two types of cold storage units that are used in public health departments of Palestine:

The first one is used for cooling vaccines and keeping their temperatures within (2-8) C and this type of cold storage units is the one we have built a prototype to monitor.

The second type is used for freezing vaccines that need to be kept in temperatures below 0 C, one of these is the Polio vaccine.

To ensure that the temperatures of vaccines are kept within the acceptable ranges health providers check cold storage units three times every day.

Figures (2.2.1) show one of the cold storage units in Palestinian clinics and as we see, it has vaccines and some devices are used to monitor the temperature of the unit as shown in figures (2.2.2). The blue boards that are shown contain cold water to keep the unit temperature within the suitable range. Figure (2.2.3) shows the logging document where health care providers manually record temperatures.

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Figure 2.2.1 A) cold storage unit.

Figure 2.2.2 A) temperature monitoring devices

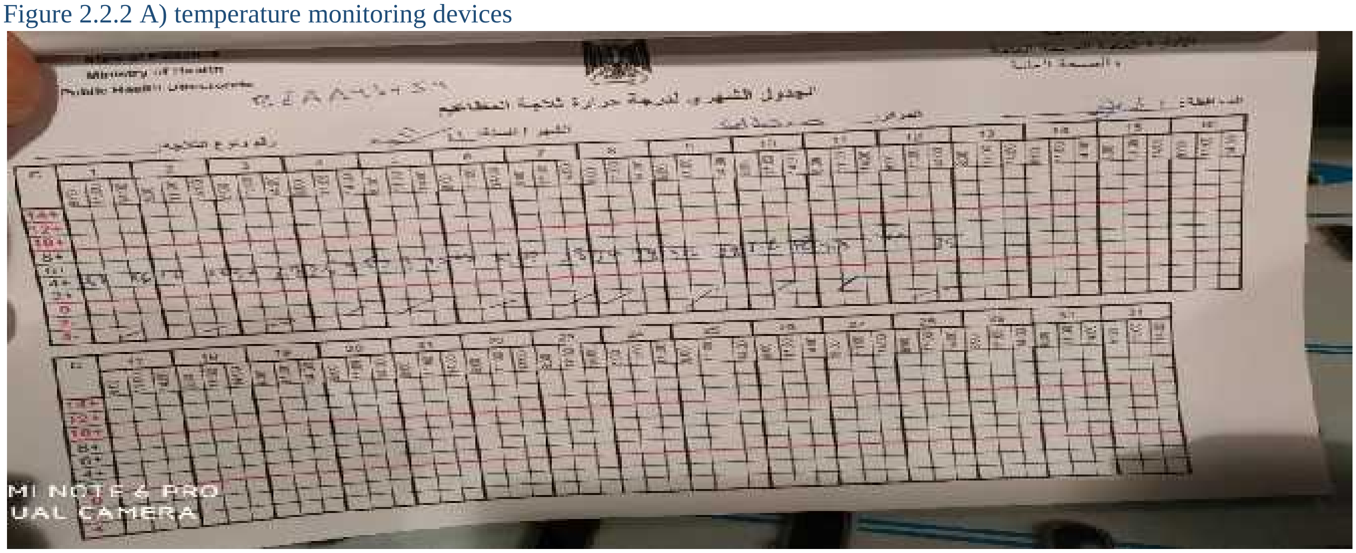


Figure 2.2.3 temperature logging document.

2.3 Literature review:

The ministry of health already uses a device that is close in functionality to our proposed system; this device only exists in central health departments because it is too expensive to be installed in every cold storage unit in Palestine. This device is called SmartSense Xbee Wireless Temperature Sensing Device [3]. It is powered by batteries and it monitors temperatures of cold storage units and shows them on an LCD screen it also sends their temperature through Wi-Fi to a database that projects them on a website called SmartAlert [4]. The device also issues a call to the authorized personnel according to the hierarchical task priority control for vaccine issue handling of ministry of health when the temperature is not within acceptable ranges. The device can be used to monitor pharmacies vaccine storage units, supermarkets, restaurants and supply chains that means that it is not vaccine monitoring specific.

Figure 2.3.1 SmartSense devices[1]

Although our system will do the same functions as SmartSense, it is less expensive and has more functionality.

The functionalities that make our system more useful to vaccine quality control than this device are:

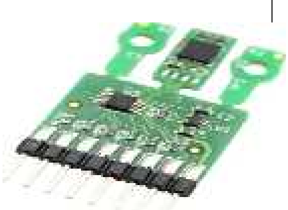
1- The system displays temperature, battery and date on a screen without needing to open the cold storage unit.
2- Our system will send an SMS massage specifying the problem before the call***
3- The system lights a warning light as long as the cold storage unit is open.
4- Our system is affordable.
5- Our system is fail safe and it’s easy to locate the failing component.

[1] "Z Sensor", *SmartSense*, 2019. [Online]. Available: https://www.smartsense.co/products/zigbee-temperature-sensor. [Accessed: 15- Nov- 2019].

2.4 Design options for hardware components**:**

The system consists of two devices. The first device is Transmitting device contains sensors and is kept in cold storage units. The Receiving device and it is kept outside cold storage units and used to monitor readings of the first part and act accordingly, it’s also is connected directly to the network via Ethernet.

Table 2.4.1: requirement analysis

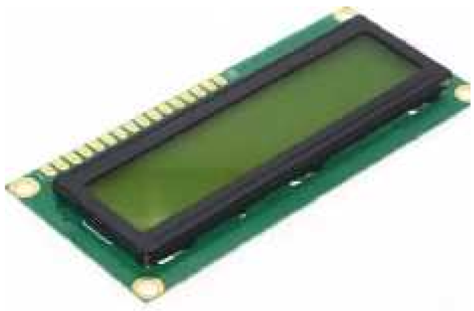
Transmitting device : Microcontrollers	Arduino Uno 	Raspberry PI 	PIC 	Analysis: We chose the ATMega328p because it has the least, energy consumption, least expensive, and we have more experience using it more than any of the other microcontrollers.
Requirements	Options			
1-easy to programming	✔	✔	✘	
2-least expensive	✔	✘	✘	
3- Least power consumption for battery life	✔	✘	✘	
Temperature sensors	TSYS01 	DHT11 	RHT03 	Analysis: We Used DHT11 because it's easier to set up and it is the most widely available and it is not expensive.
Requirements	Options			
1-available	✘	✔	✘	
2-Easiest to use	✘	✔	✘	

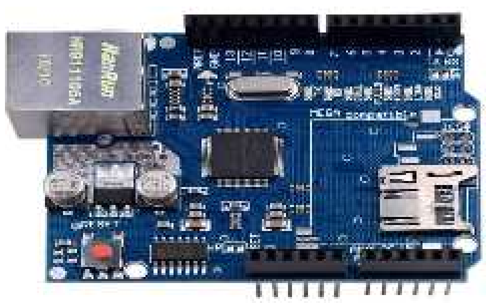
Wireless transmitting /receiving modules	Bluetooth 	Wi-Fi 	XBEE 	Analysis: We chose that sending sensor values would be done wirelessly by using Bluetooth because it's easier to set up has an appropriate size is not expensive and has a less power consumption than the other options it's also the best for public health departments since there's no available Wi-Fi network there.
Requirements	Options			
1-Easiest to use	✔	✘	✘	
2-Most suitable size	✔	✔	✘	
3-Lowest cost	✔	✘	✘	
4-Lowest energy consumption	✔	✘	✘	

Fridge door sensors	LDR 	Ultrasonic 	Analysis: We chose LDR sensor to check if the cold storage unit is closed properly since it's easier to identify if it's open by measuring light intensity in the unit rather than measuring the space between the door and the ultrasonic sensor in that unit. It is also less expensive and considerably smaller.
Requirement	Option		
1-Easiest to use	✔	✘	
2-Lowest cost	✔	✘	
3-Lowest energy consumption	✔	✘	
4-Most suitable size	✔	✘	

Power sources	Lithium Polymer battery	Lithium Polymer	Analysis
			We chose power banks because they are more durable, they will need to be recharged or replaced after a longer usage time than batteries, and are easier to recharge or replace.
Requirement	Option		
1-Large energy	✘	✔	
2-easy to recharge	✘	✔	
3-Suitable size	✘	✔	

Receiving device: Microcontrollers	Arduino mega	Arduino Uno	Arduino NANO	Analysis
				We chose MEGA because it has good processing speed easy to use and has the largest number of pins that we need in order to connect it to other modules
Requirements	Options			
1-Speed of processing	✔	✔	✔	
2- Easy to use	✔	✔	✔	
3-Large # of Pins	✔	✘	✘	

Screens	LCD 	TFT 	Analysis: We chose TFT because it's more practical easier to read and can project a larger number of words.
Requirements	Options		
1-More words space	✘	✔	
2-Easier to read	✘	✔	

Connection to the internet modules	Ethernet Shield 	Wi-Fi Module 	Analysis: We chose the wired way of accessing the internet instead of Wi-Fi because of the lack of Wi-Fi signals in public health clinics so we used Ethernet shield.
Requirements	Options		
1-Supply internet	✔	✔	
2-Easy to use	✔	✔	
3-Wire connection	✔	✘	

SIM card modules	GSM shield 	SIM Module 	Analysis: We chose SIM900 module instead of GSM shield since it's easier to use and it's smaller.
Requirements	Option		
1-Smallest size	✘	✔	
2-Esay to use	✔	✔	
Warning Lights	LED Strip 	RGB LED 	Analysis We want a strong source of light so the health care provider will pay attention to the light and be sure that it lights off by closing the cold storage door correctly
Requirements	Options		
1-Attention Grabbing	✔	✘	

2.5 Design Constrains:

1- The system only covers cold storage units that work on the temperatures 2 to 8 C since these cold storage units are the ones mostly used in public health clinics.
2- The system issues warnings if it is located in public health clinics that have cell coverage.
3- The first device should not be covered by a shadow when the cold storage door is opened.
4- The transmitting device should be within range of 10m from the receiving device in order for the Bluetooth connection to be stable.
5- We need to press the on key for 2 seconds in order turn on the GSM module.
6- The SIM should not be on the pre-paid plan.

Chapter 3: System Design:

3.1 Overview:

This chapter discusses the design of the system. It shows the block diagram of the system, flow charts, wiring diagram and schematic diagrams.

3.2 Detailed System Design:

The system consists of two

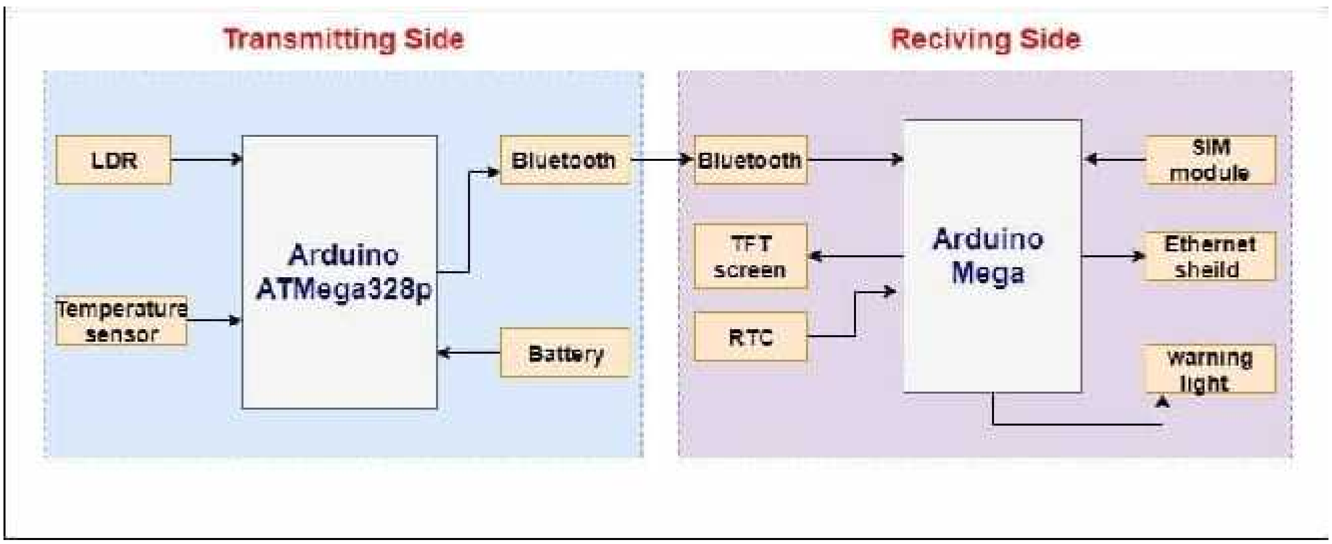


Figure 3.2.1: System Block Diagram

3.3 Flowcharts:

Transmitting Device:

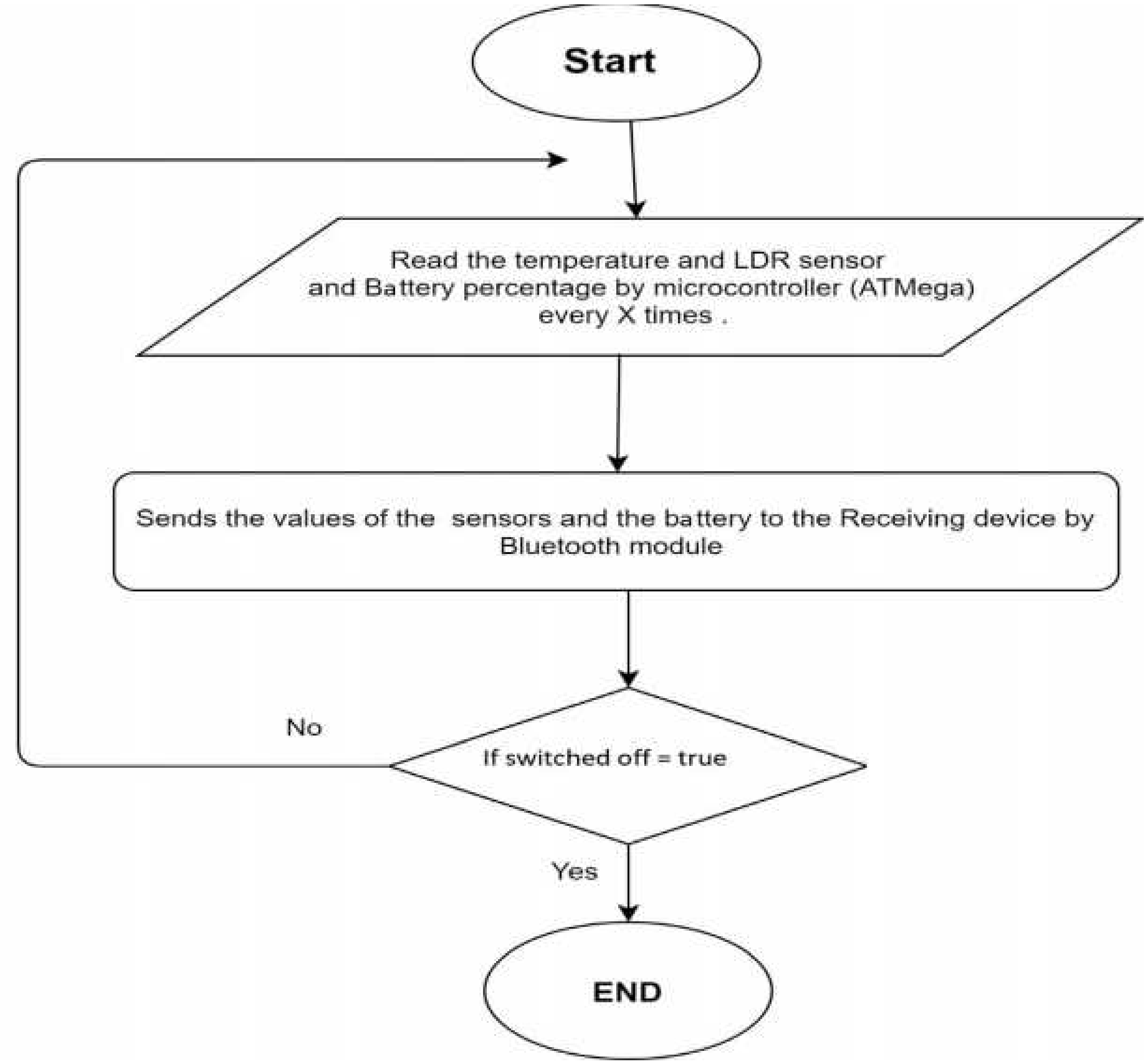
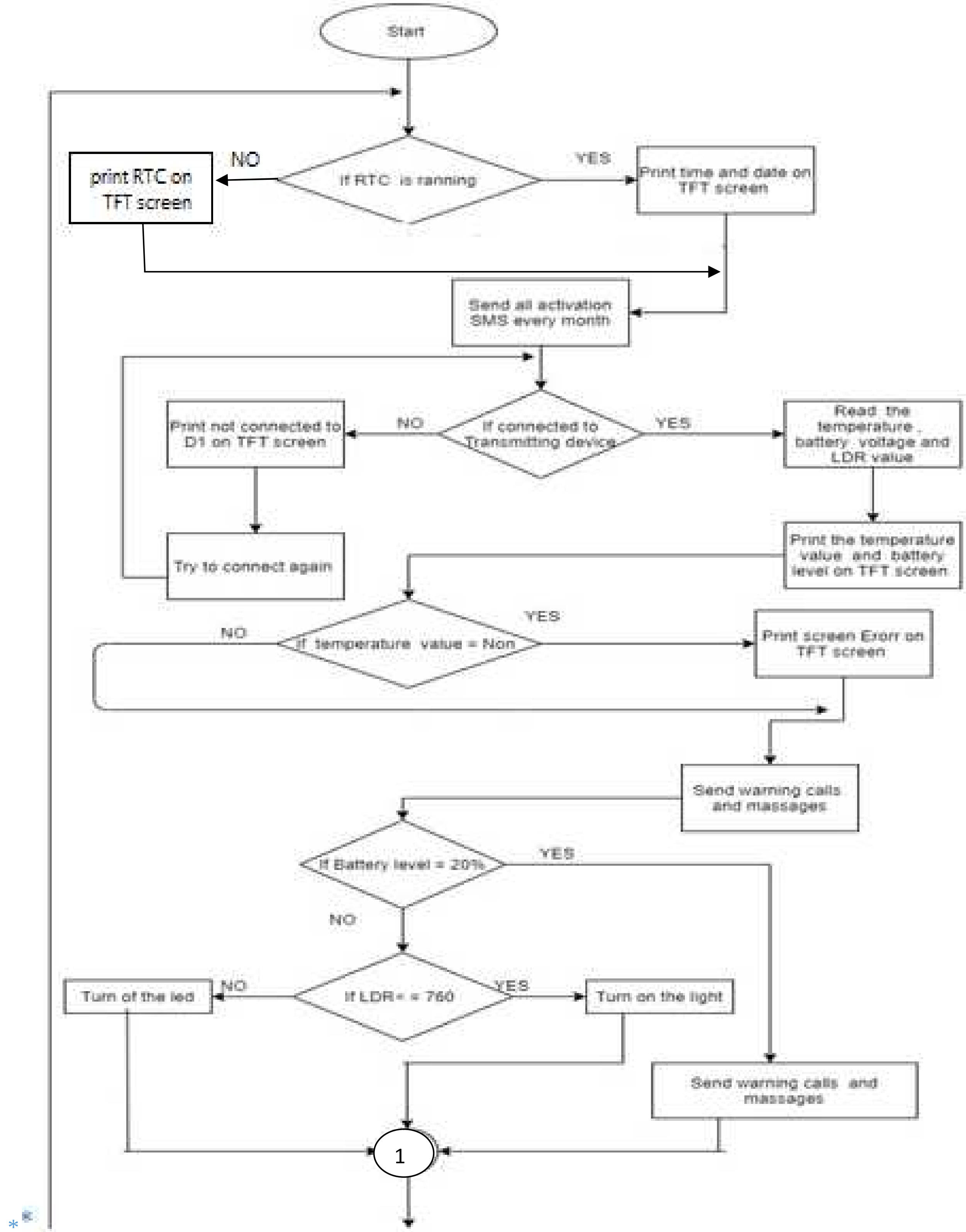


Figure 3.3.1: Transmitting device flowchart

The flowchart of the transmitting device of the system in figure 3.3.1 above shows the steps in it. It Stars by reading the values of temperature sensor on charge of reading temperature values of the vaccine cold storage. LDR values to indicate if the cold storage door open or close, and send them with battery voltage of the battery that powers this part of system together every six seconds via Bluetooth module to the receiving device to do other tasks according them. If the device's off switch is pressed the device is switched off.

Receiving Device:


Start
If RTC is ranning
NO
print RTC on TFT screen
YES
Print time and date on TFT screen
Send all activation SMS every month
If connected to Transmitting device
NO
Print not connected to D1 on TFT screen
Try to connect again
YES
Read the temperature , battery voltage and LDR value
Print the temperature value and battery level on TFT screen
If temperature value = Non
NO
YES
Print screen Erorr on TFT screen
Send warning calls and massages
If Battery level = 20%
YES
NO
If LDR= = 760
NO
Turn of the led
YES
Turn on the light
Send warning calls and massages
1

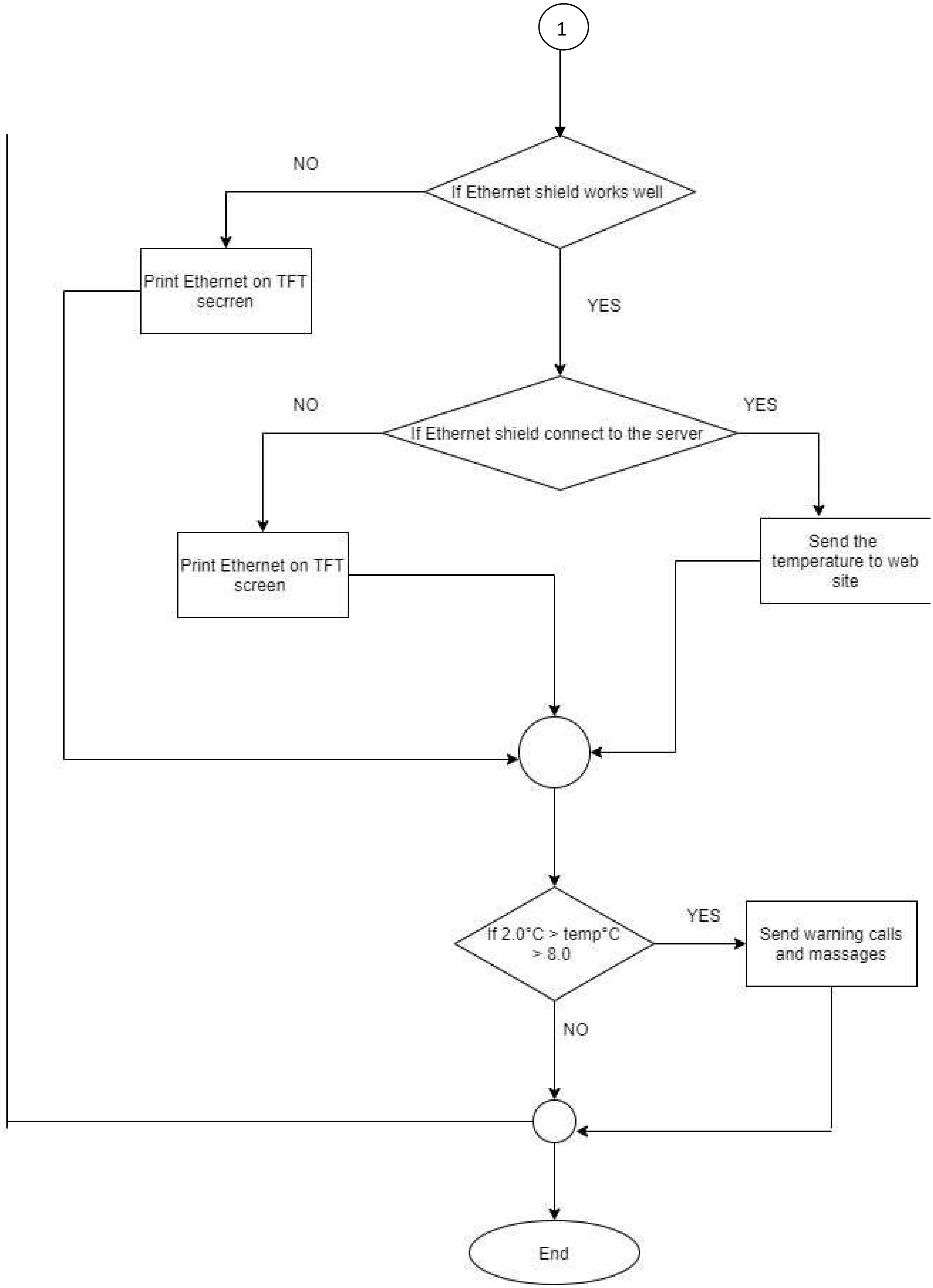


Figure 3.3.2: Receiving device flowchart

The flowchart of the receiving device of the system in figure 3.3.2 above shows the working steps of the device. Starting with reading the date and time from RTC module then print them on the TFT screen, after it checks that it's running. Then, the system sends an activation SMS to ensure that the SIM still works.

Now, the receiving device must be connected to transmitting device via Bluetooth module. If connection is established it must receive the values of sensors and battery voltage. Then, the values of temperature sensor, and percentage of battery are projected on TFT screen. Then check if the temperature value is none then the sensor isn't working so the warning massage is showed on the screen, followed by a call and massages to those persons. Then, checks if the battery percentage is equal 20% warning massages and calls will be sent to same persons to change or recharge the battery ,also check LDR value to ensure that the cold storage door is open if yes, then lights warning light until the door is closed. After that if the Ethernet shield works will and connected to server the temperature value to website; otherwise it will print Eth or Eth ! conn on TFT screen, then it check the temperature range out range the warning calls and massages must be sent. if no data is received from the sensor a warning is shown on the screen..

3.4: System schematic diagrams:

Transmitting Device:

ATmega with Bluetooth module

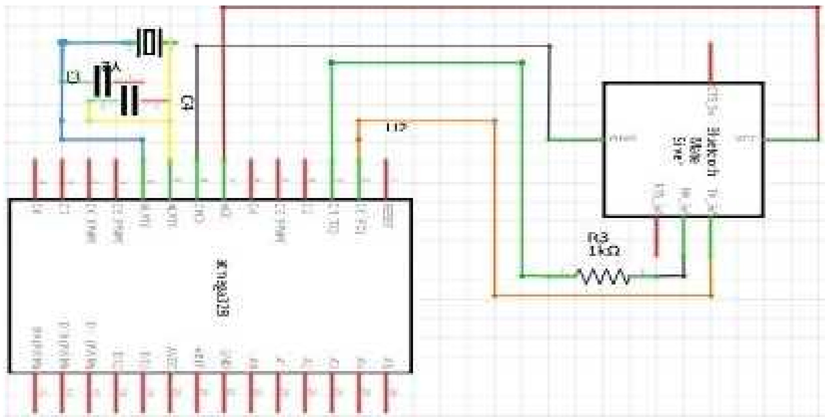


Figure 3.4.1: Schematic diagram of Bluetooth module to ATmega

Figure 3.4.1 shows how to connect Bluetooth module to ATmega.

Table 3.4.1: Interfacing Bluetooth module to ATmega

Bluetooth	ATmega	Analysis
TX	RX	RX and TX pins stand for Receiving and Transmitting pins of Arduino used for Serial communication.
RX	TX	
VCC	VCC	Voltage sourse to BT
GND	GND	Ground

Table 3.4.1 shows the pins connected.

ATmega with LDR:

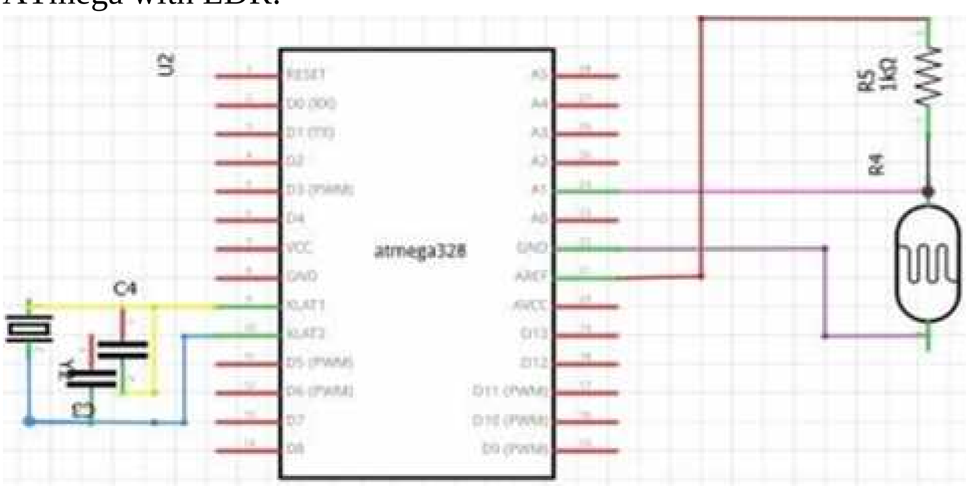


Figure 3.4.2: Schematic diagram of LDR module to ATMega

Figure 3.4.2 shows how to connect LDR to ATMega.

Table 3.4.2: Interfacing LDR module to ATMega

LDR	ATmega	Analysis
+	A1, Resistor	Connected to analog pin one to send analog data
-	GND	Ground

Table 3.4.2 shows the pins connected.

ATmega with DHT11:

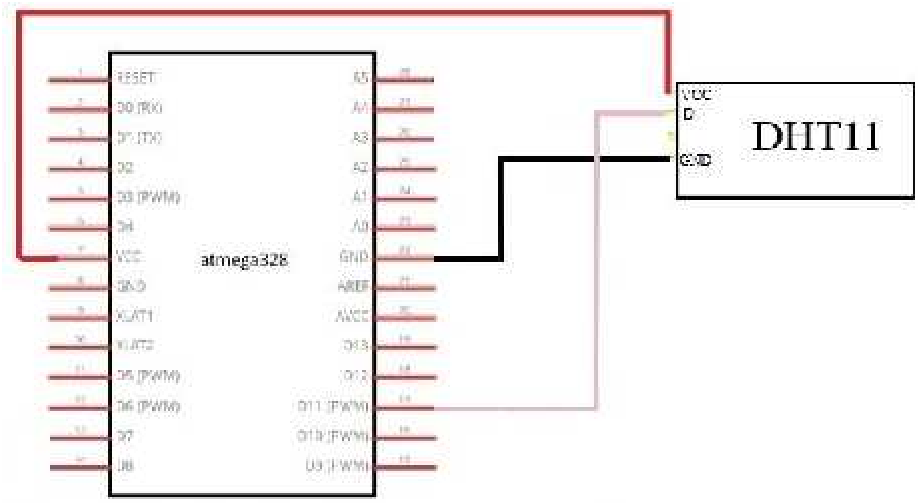


Figure 3.4.3: Schematic diagram of temperature sensor to ATMega

Figure 3.4.3 shows how to connect temperature sensor to ATMega.

Table 3.4.3: Interfacing temperature sensor to ATMega

DHT11	MEGA	Analysis
Vin	3.3V	Voltage sourse to the sensor
GND	GND	Ground
D	D11	(Data Line) – The line that carries thedata values

Table 3.4.3 shows the pins connected.

Receiving Device:

Arduino MEGA with Bluetooth module:

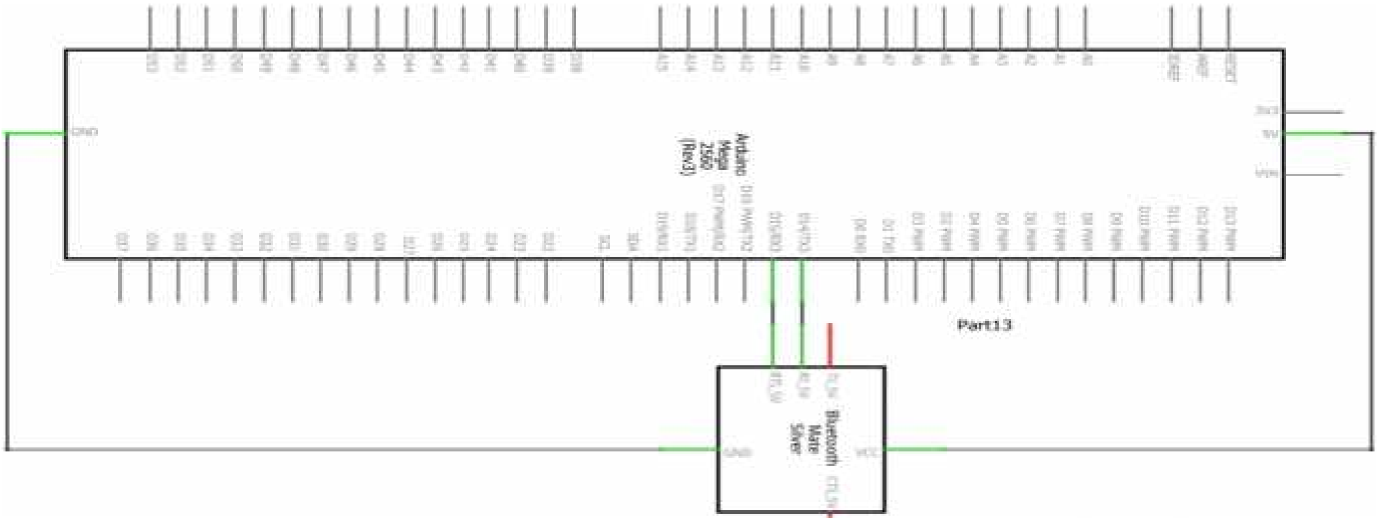


Figure 3.4.4: Schematic diagram of Bluetooth module to Arduino Mega

Figure 3.4.4 shows how to connect Bluetooth module to the microcontroller.

Table 3.4.4: Interfacing Bluetooth module to Arduino Mega

Bluetooth	MEGA	Analysis
TX	RX1	RX and TX pins stand for Receiving and Transmitting pins of Arduino used for Serial communication.
RX	TX1	
VCC	5V	Voltage sourse to BT
GND	GND	Ground

Table 3.4.4 shows the pins connected.

Arduino MEGA with GSM SIM module:

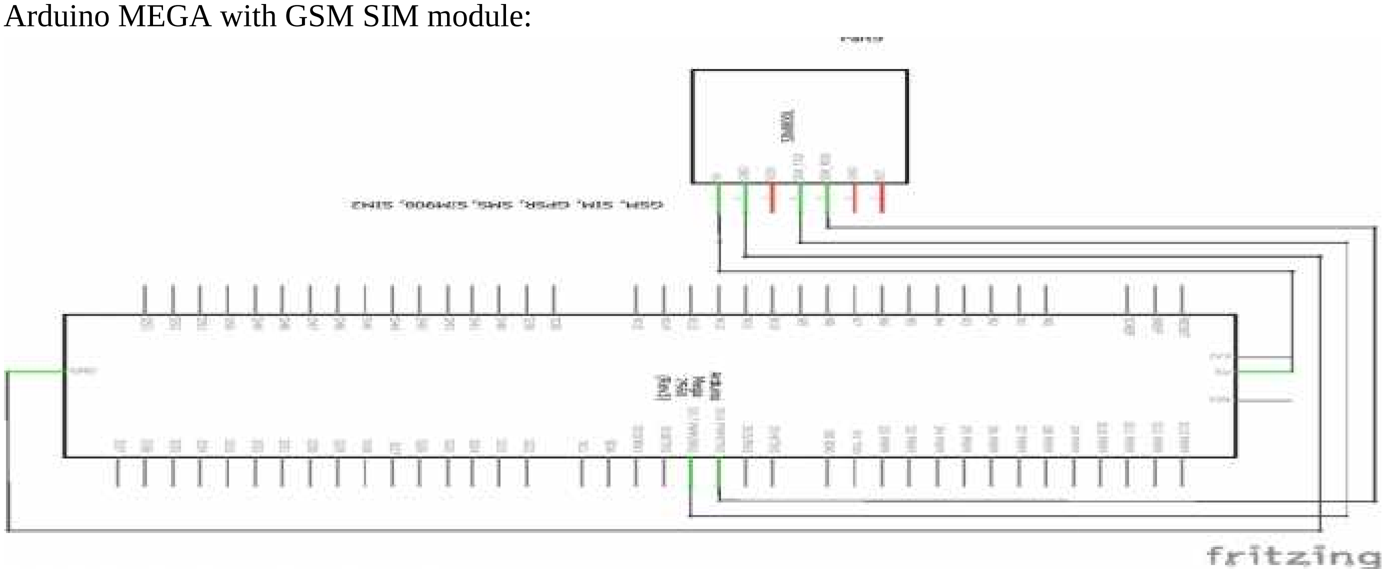


Figure 3.4.6: Schematic diagram of GSM SIM module to Arduino Mega

Figure 3.4.6 shows how to connect GSM SIM module to the microcontroller.

Table 3.4.6: Interfacing GSM SIM module to Arduino Mega

GSM SIM	MEGA	Analysis
TX	35	RX and TX pins stand for Receiving and Transmitting pins of Arduino used for Serial communication.
RX	33	
5V	5V	Voltage sourse to GSM
GND	GND	Ground
DC	—	Extrnal power supply

Table 3.4.6 shows the pins connected.

Arduino MEGA with RTC module:

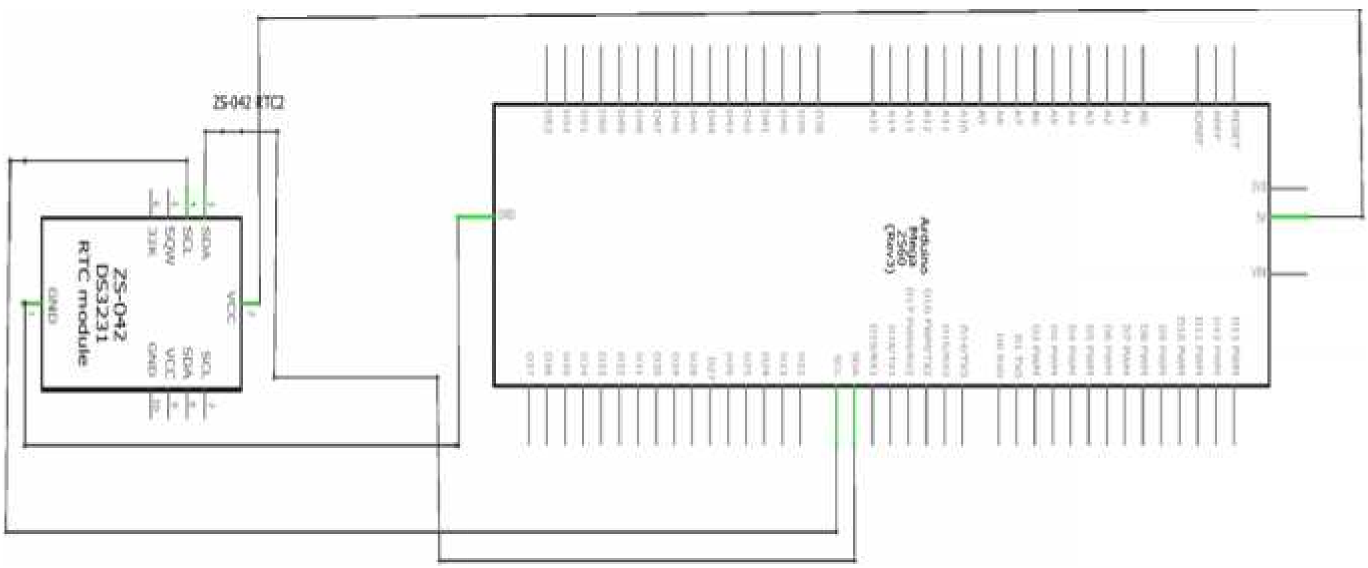


Figure 3.4.7: Schematic diagram of RTC module to Arduino Mega

Figure 3.4.7: shows how to connect RTC module to the microcontroller.

Table 3.4.7: Interfacing RTC module to Arduino Mega

RTC	MEGA	Analysis
SDA	SDA	(Serial Data) – The line for the master and slave to send and receive data
SCL	SCL	(Serial Clock) – The line that carries the clock signal.
VCC	5V	Voltage sourse to RTC
GND	GND	Ground

Table 3.4.7 shows the pins connected.

Arduino MEGA with TFT module:

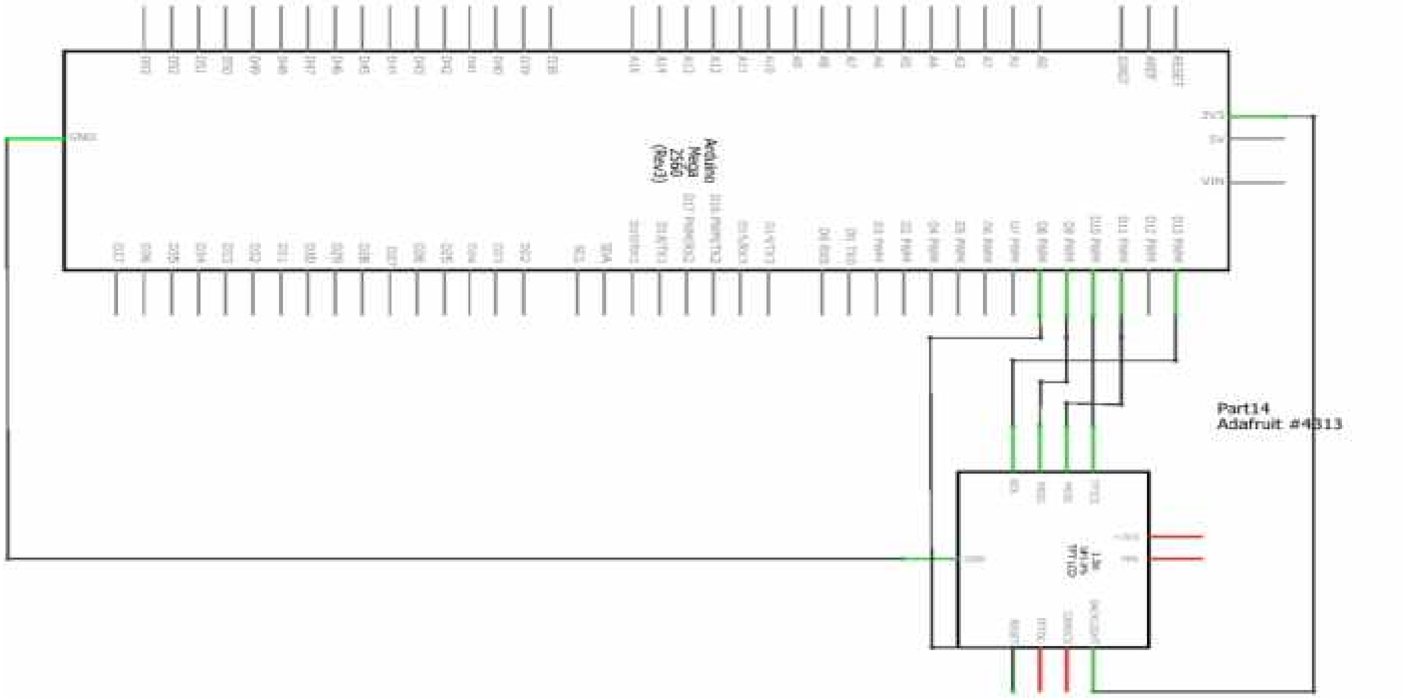


Figure 3.4.8: Schematic diagram of TFT module to Arduino Mega

Figure 3.4.8: shows how to connect TFT module to the microcontroller.

Table 3.4.8: Interfacing TFT module to Arduino Mega

TFT	MEGA	Analysis
BG-light	3.3V	To provide background light
RES	8	Reset
MISO	9	Master In Slave Out. The Slave line for sending data to the master
CS	10	chip select
MOSI	11	Master Out Slave In: The Master line for sending data to the peripherals.
SCK	13	Serial clock: The clock pulses which synchronize data transmission generated by the master
VCC	5V	Voltage sourse to TFT
GND	GND	Ground

Table 3.4.8 shows the pins connected.

Arduino MEGA with Ethernet shield:

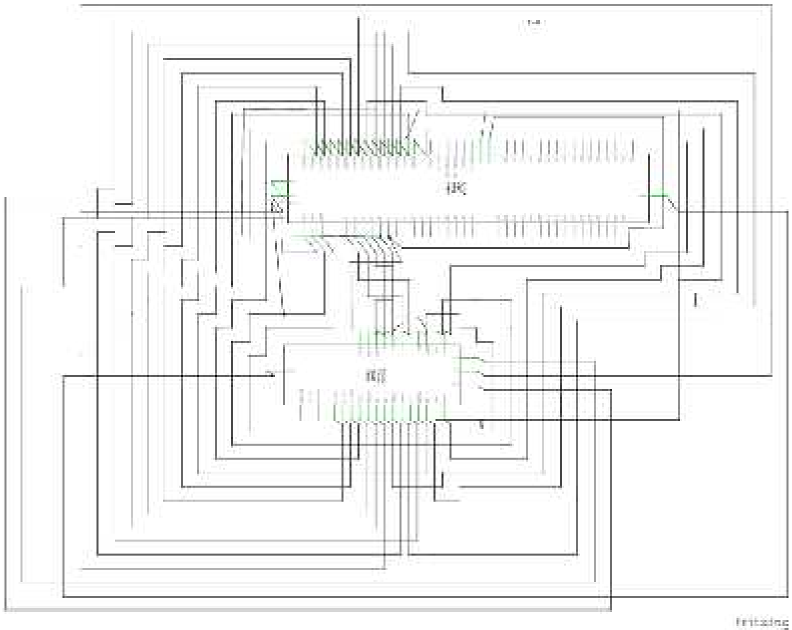


Figure 3.4.9: Schematic diagram of Ethernet shield to Arduino Mega

Figure 3.4.9: shows how to connect Ethernet shield to the microcontroller. The shield goes on top of the Arduino mega.

The shield mounted above the Arduino mega and the pins of the Arduino are available to use by the shield pins except for the pins 4 and 10 that are reserved by the shield.

3.1 Website design :

We created a website using ASP.NET technology on Visual Studio **program** through HTML and C# languages.

The functions of the website are:

to receive data that is sent through Ethernet shield from Arduino Mega and display it in a table and color the temperature values that out of ranges red **.**

In addition, the website contains Home page, directory page, user page, register page, and roles page.

Chapter 4: System Implementation

4.1 Overview:

This chapter describes the implementation of the software and the hardware of this project, such as the circuit connection, microcontroller, the IDEs which is used to build the project codes and Visual Studio program which is used to build the application.

4.2 Description of the implementation

This section will provide some information about the hardware and software implementations done throughout our project:

4.2.1 Software implementation

1- Arduino Software (Arduino IDE):

The code of all hardware components and sensors and their interfaces are written through the use of many functions and libraries since our system consists of two devices. The most noteworthy libraries are as follows:

- Adafruit sensor library and DHT library; we need it in order to read the temperature values and send them to the microcontroller.
- RTC library which enables the functionality for clock reading, clock setting, alarms and timers.
- MCUFRIEND_kbv which enables the 2.4 TFT screen to work properly.

2- Website Software:

We used multiple programs to build and set up the website, and they are shown as follows:

- XAMPP: To control the servers (Apache, mysql) that we need in order to run the website.
- PhpMyAdmin: to construct the logging table to record temperature values that it receives from the Adriano via Ethernet shield.
- Visual Studio: we used this software to design and construct it using (HTML, CSS, PHP, C#).

The web application contains many activities such as:

Login page: This interface of the application enables the user to log in to his account.

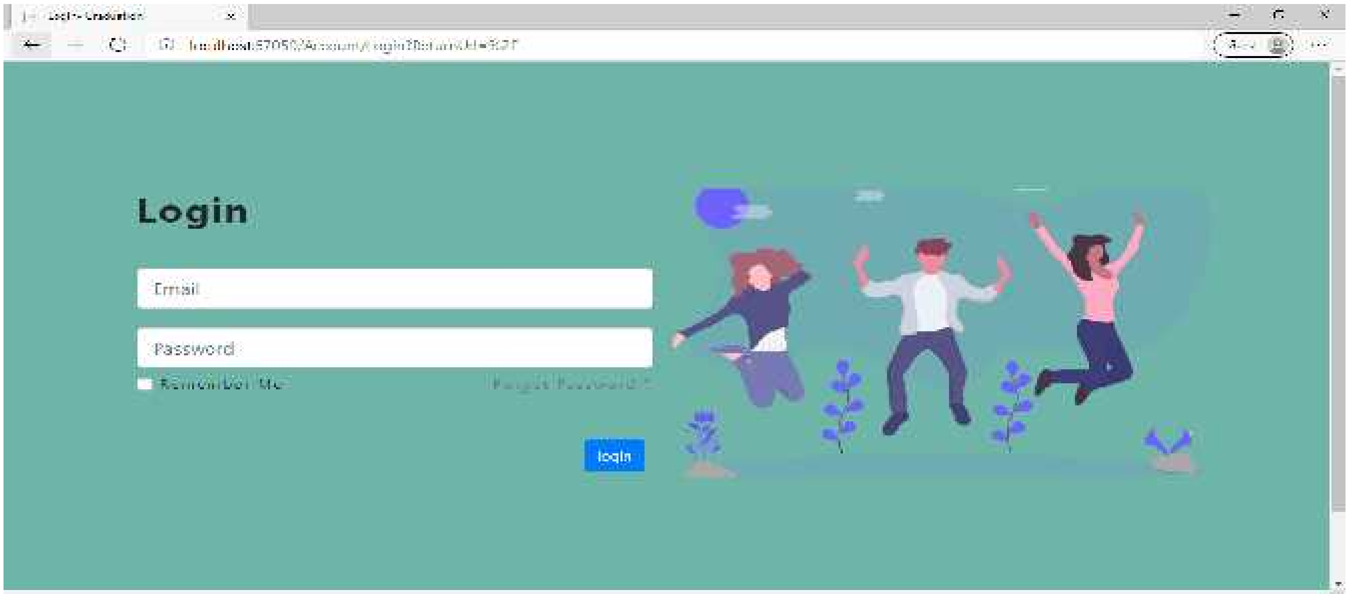


Figure 4.2.1.1: Login page

Home page: The main interface of the application that welcomes the users.

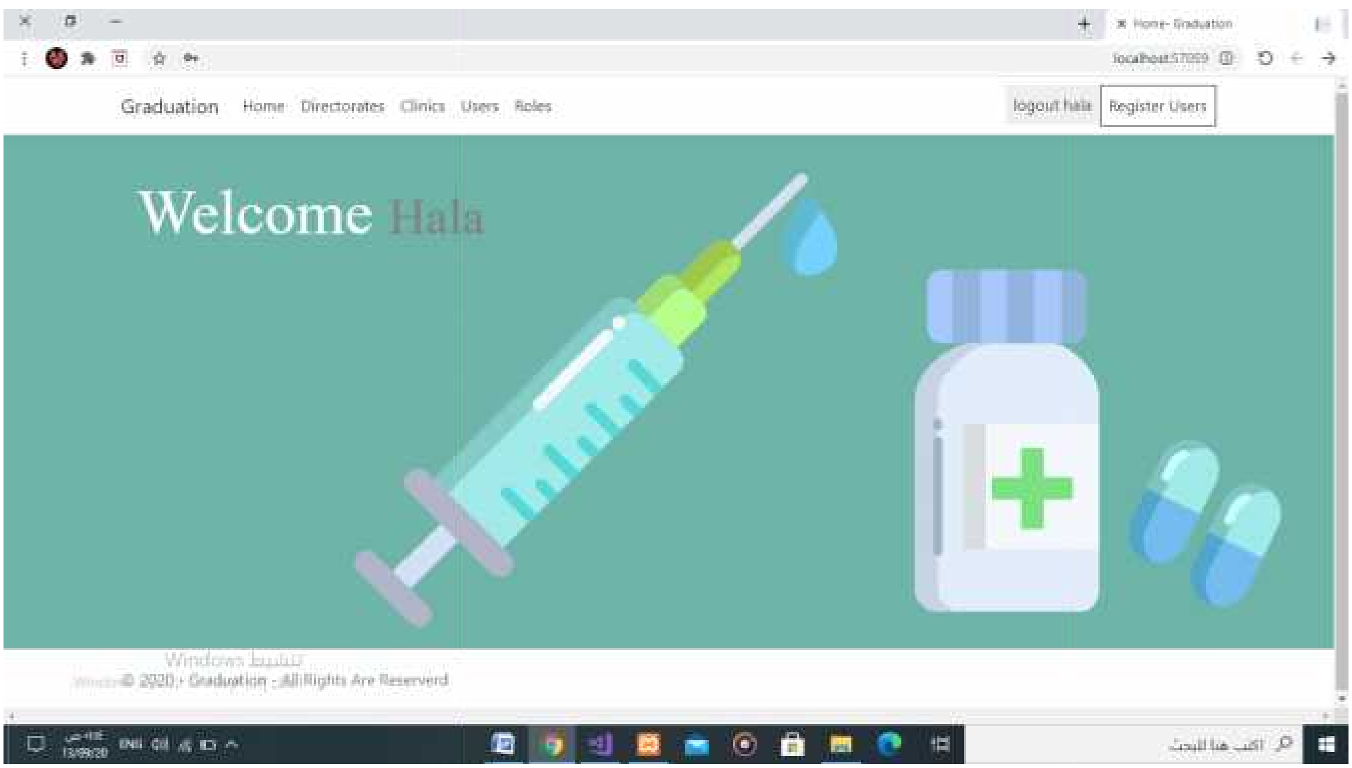


Figure 4.2.1.2: Home page

Directories page: it lists all directories recorded in the website. It is only visible to the Super Admin who created the website.

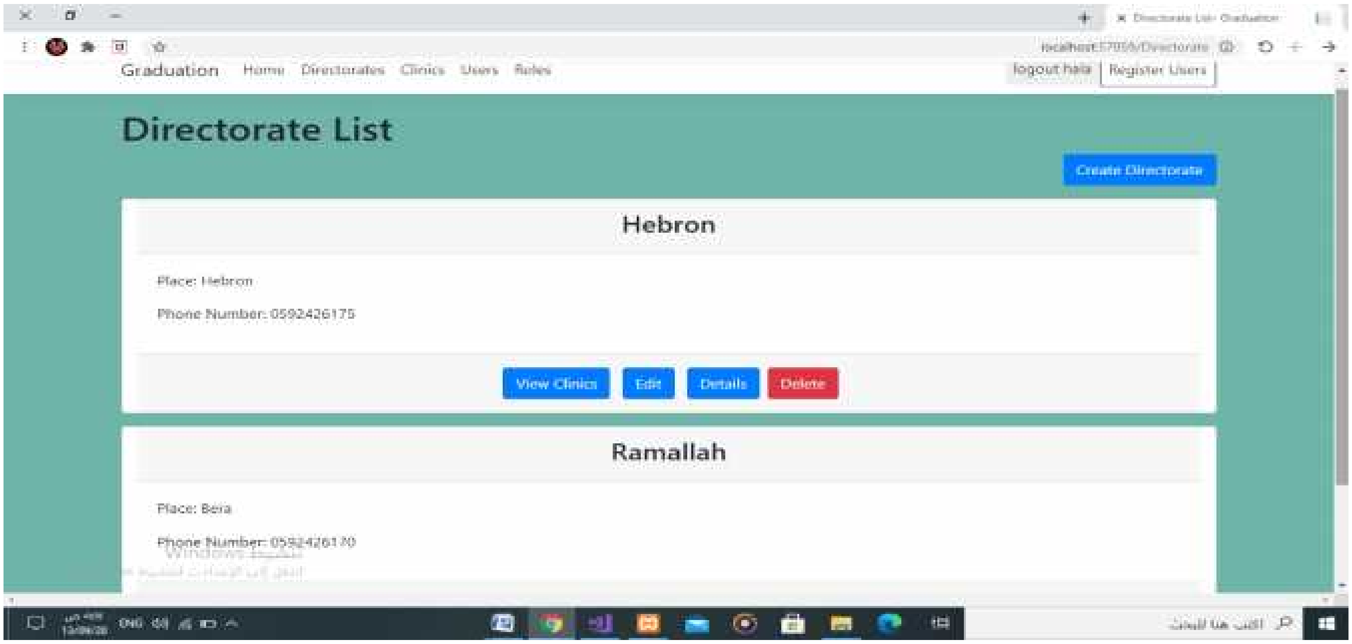


Figure 4.2.1.3: Directories page

Clinics page: it lists all clinics in dedicated directory .all shows by super admin. Directorate manager can see all clinics in his directory and the user can just see the clinics that record in it by directory or super admin.

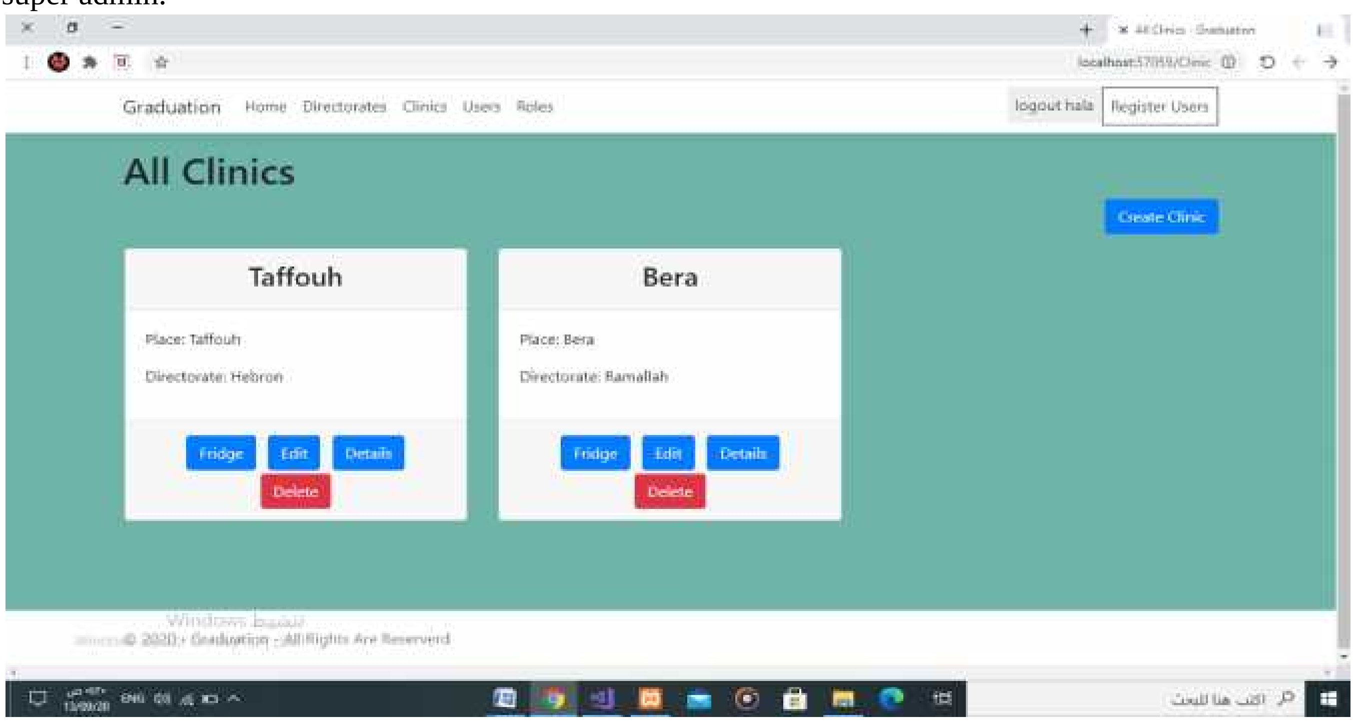


Figure 4.2.1.4: Clinics page

Users: it shows all users that recorded in the website .Accessible just by super admin.

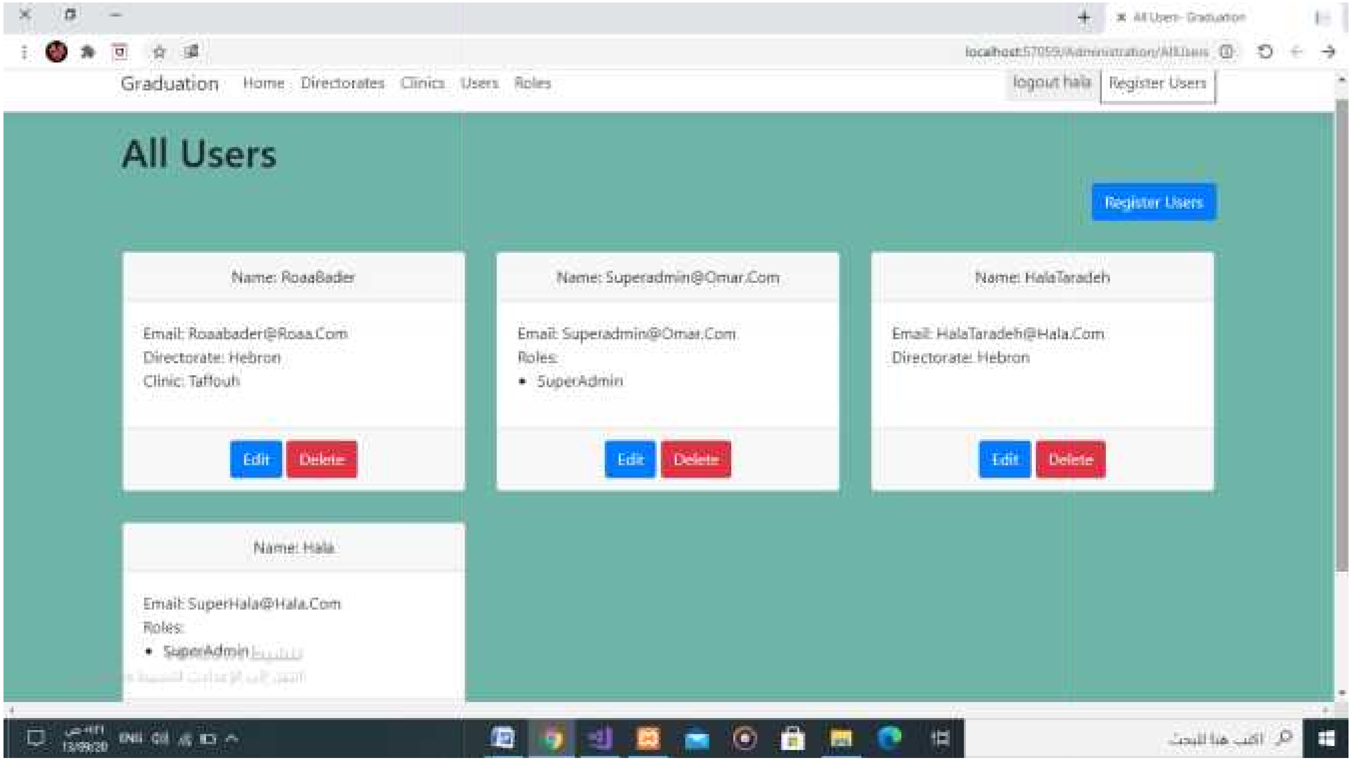


Figure 4.2.1.5: Users page

Fridge page: lists the temperature values of the dedicated clinic every time that receiving device receive the temperature value. If the temperature value is in the normal rang it is colored green, above or below the range it's colored red. If none then it's colored pink.

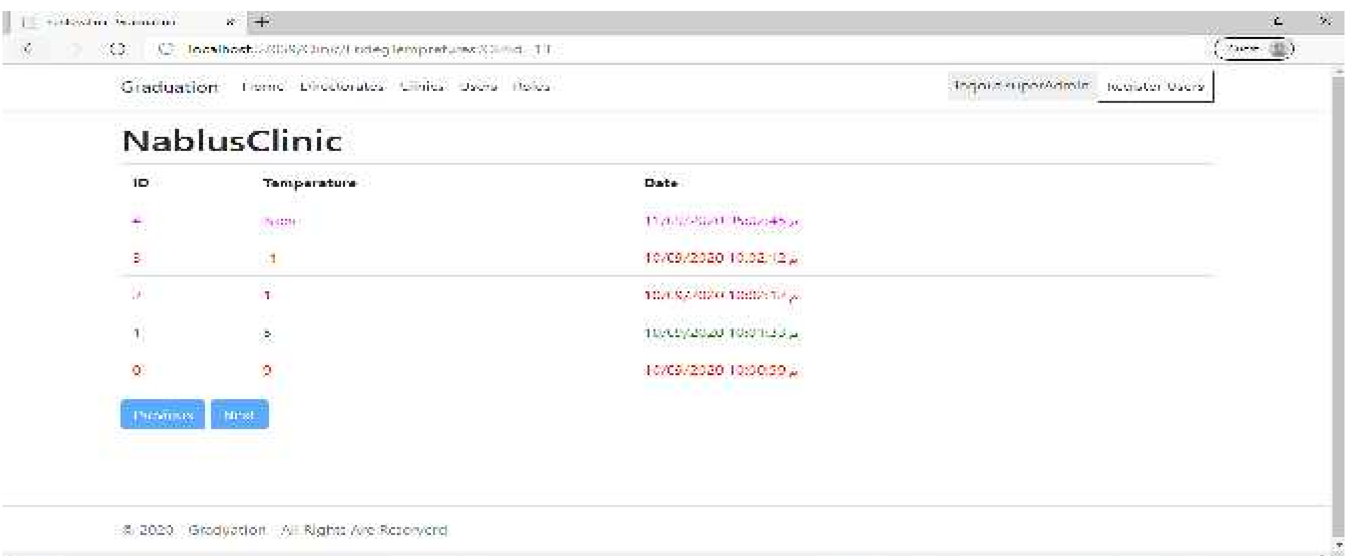


Figure 4.2.1.6: Fridge page

Roles page: this website is role based, it consists of three roles, Super Admin (comes with all the privileges of the website), Directorate (can see all clinics in a single directorate, can also add and delete users in their directorate), and users (can only view their clinic).

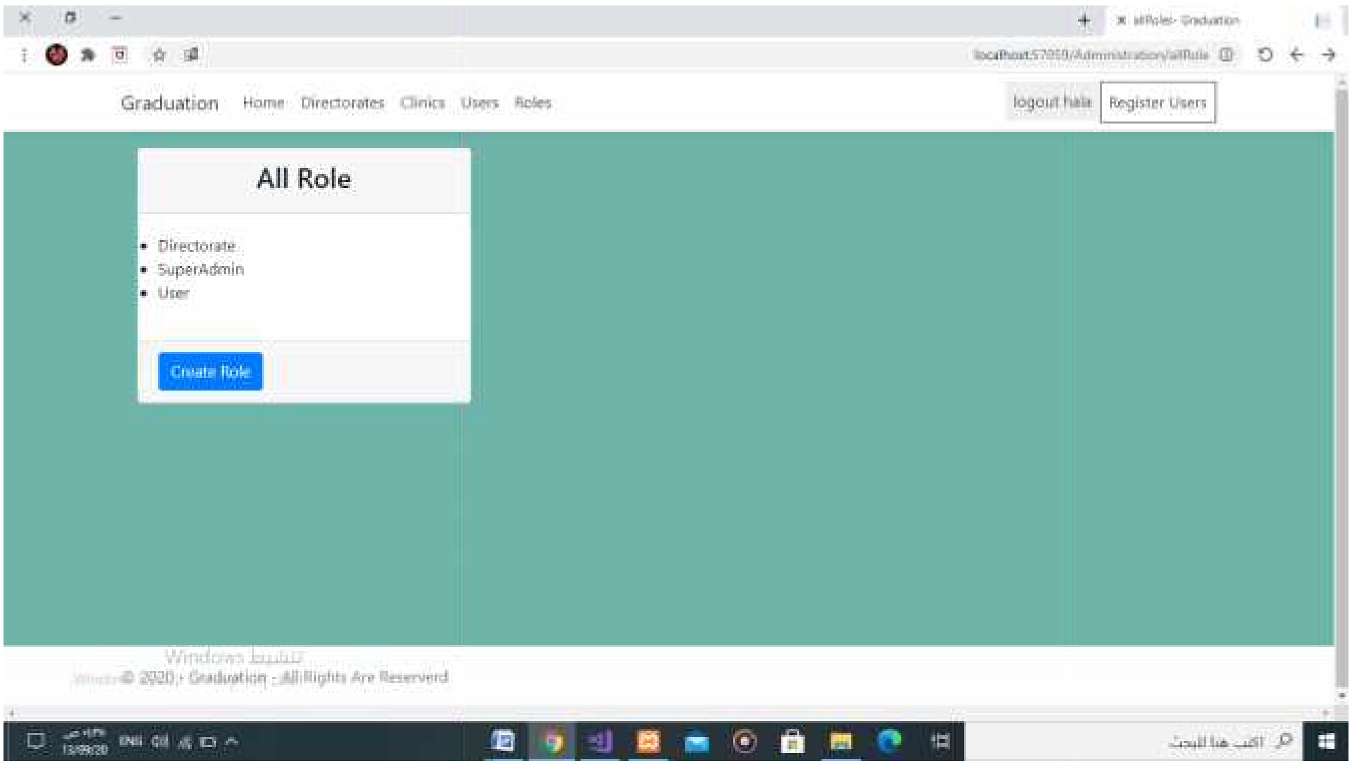


Figure 4.2.1.7: Roles page

Register page: This page is used to register new users into the system. It’s only accessible by Super Admin and Admin role.

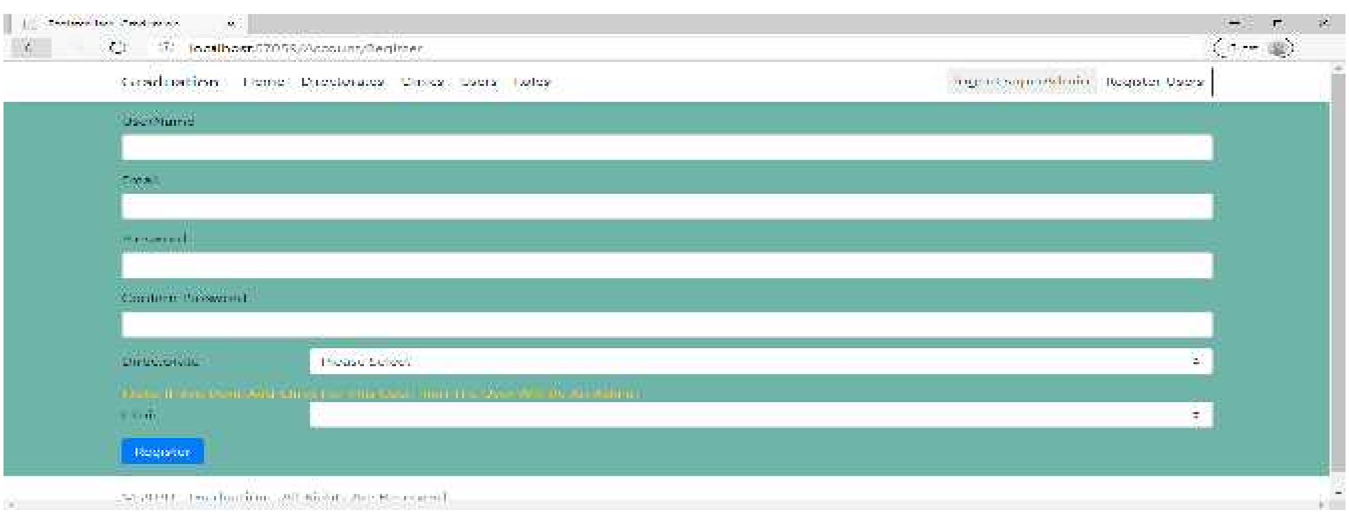


Figure 4.2.1.8: Register page

4.2.1 Hardware implementation:

Hardware Expenses:

Project Budget				
discription	ammount	Quantity	Total	Notes
Atmega328p	1	26.000 ILS	26.000 ILS	For transmitting device
LDR	1	10.000 ILS	10.000 ILS	For transmitting device
Power Supply Module	1	5.000 ILS	5.000 ILS	For transmitting device
DHT11	1	5.000 ILS	5.000 ILS	For transmitting device
Bluetooth	2	40.000 ILS	80.000 ILS	For transmitting device
Soldering Board	1	5.000 ILS	5.000 ILS	For transmitting and receivig device
ArduinoMega	1	60.000 ILS	60.000 ILS	For receivig device
RTC	1	25.000 ILS	25.000 ILS	For receivig device
TFT	1	45.000 ILS	45.000 ILS	For receivig device
Ethernet Shield	1	60.000 ILS	60.000 ILS	For receivig device
GSM SIM900	1	145.000 ILS	145.000 ILS	For receivig device
Wires	3	15.000 ILS	45.000 ILS	Three types (15 wire each)
Adapter	1	20.000 ILS	20.000 ILS	For receivig device
Battery	1	60.000 ILS	60.000 ILS	For transmitting device
Powerbank	1	15.000 ILS	15.000 ILS	For transmitting device
Cables	3	10.000 ILS	30.000 ILS	For transmitting and receivig device
LED strip	1	12.000 ILS	12.000 ILS	For receivig device
Relay	1	10.000 ILS	10.000 ILS	For receivig device
9V Battery	1	10.000 ILS	10.000 ILS	For receivig device
Total ammount:	24	Total expences:	668.000 ILS	

Our system consists of two devices; we started with the transmitting device:

The transmitting device:

Starting with ATMega328, we successfully connected the other system components as follows:

a. DHT11: We connected the temperature sensor to pin D11 on the ATMega328.
   Results: The temperature sensor measured the temperature and sent it to the ATMega328.
b. LDR: We connected the Light Dependent Resistor to pin A1 on the ATMega328.
   Results: The LDR measured the light intensity and sent the value to the ATMega328.
c. Bluetooth: we connected the Bluetooth slave to the ATMega328
   Results: The Bluetooth connected the transmitting device to the receiving device and was used to transmit temperature, battery voltage, and LDR values to the receiving device.

And we welded all the parts on a single circuit board to ensure that they are of an appropriate size for storage units. We put the device in a cardboard box enclosure and made an aperture for the USB power adapter. We also made an opening for the LDR.

The receiving device:

Starting with Arduino Mega, we successfully connected the other system components as follows:

d. Bluetooth: we connected the Bluetooth Master to the Arduino Mega by TX and RX pins. Results: We connect the transmitter to the receiving device to receive temperature, battery voltage and LDR values from the transmitting device.

e. TFT screen: we connected the TFT screen to the Arduino Mega. Results: We became able to view temperature, time, date, and battery percentage on the screen and the name of the components that aren't working successfully.

f. GSM SIM900: we connected an external power supply (5V, 3A) to the GSM SIM900 then we connected it to the Arduino Mega by pins (35,33). Results: We became able to call and send alert messages that contain the temperature values , battery percentage, or DHT11 sensor error in case of an emergency.

g. Relay & LED strip: we connected Relay & LED strip to the Arduino Mega (pin 40) Results: the light is turned on if the LDR values are lower than (900).

h. RTC: we connected RTC the Arduino Mega (SCL, SDA). Results: To get the time and date for display as well as for code functions.

i. Ethernet: we connected Ethernet the Arduino Mega as a shield. Results: we gained the ability to transfer the temperature values to the logging table by Ethernet cable since Wi-Fi is not available in most clinics in our country.

We put the device in a plastic enclosure and made an aperture for the power adapter and another one for the GSM antenna to ensure a strong cellular connection. We also made an opening for the TFT screen and LED strip.

4.3 Implementation Issues:

During the course of the project implementation, we faced many obstacles and had to take several issues to reach to the most suitable design of the system and reach the best properties related to the project's aims. As the summary of these issues and results as the following:

1- Because of the pandemic outbreak every way of ordering or receiving goods online or from outside of the country became invalid so it became very hard to replace certain components that are not available in our country.

2- Some of the electronic components that were ordered were destroyed by the shipping company because we were not able to go and receive it in the given period of time during the nationwide quarantine.

3- Because of the lockdown that was caused as a way to fight the spread of the pandemic the team mates were not able to work together on the hardware implementation and validation till recently.

4- Because our system consists of many components we faced some conflict with pins but we were able to modify the libraries in order to get rid of the conflict.

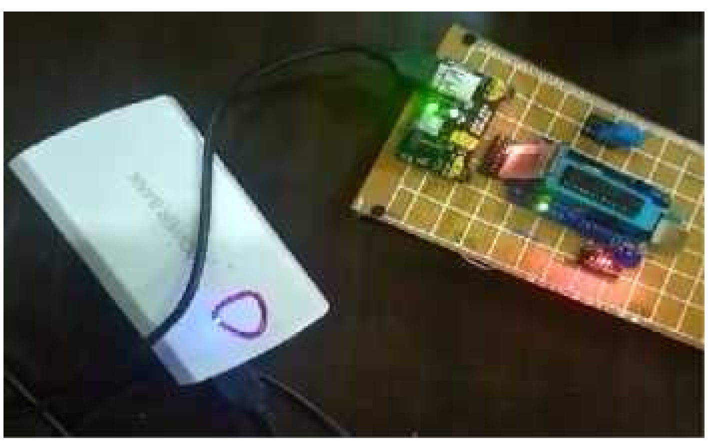
4.5 Implementation Results:

By the end of the implementation process:

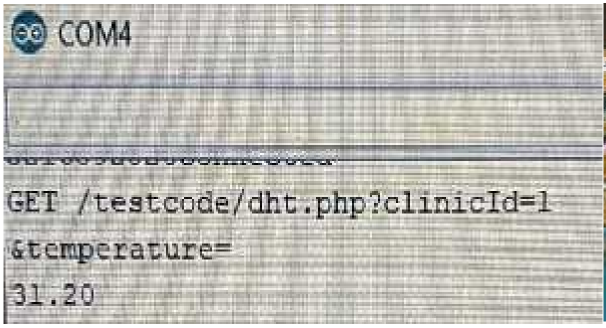
4.5.1 Hardware Testing:

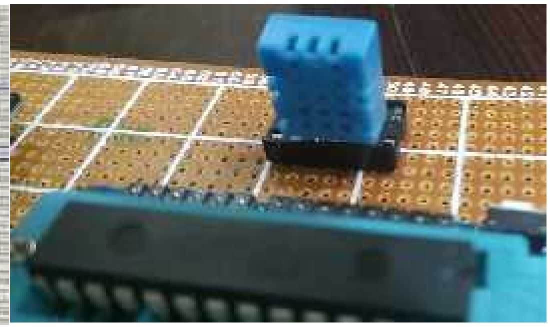
1. Testing The Transmitting Device:

   Starting with ATMega328, we successfully connected the other system components as follows:

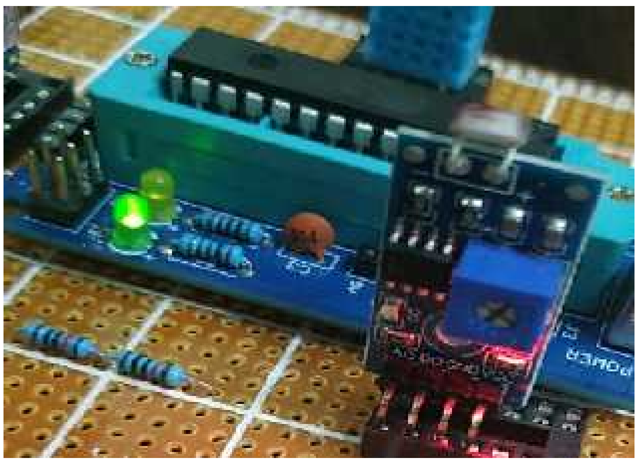
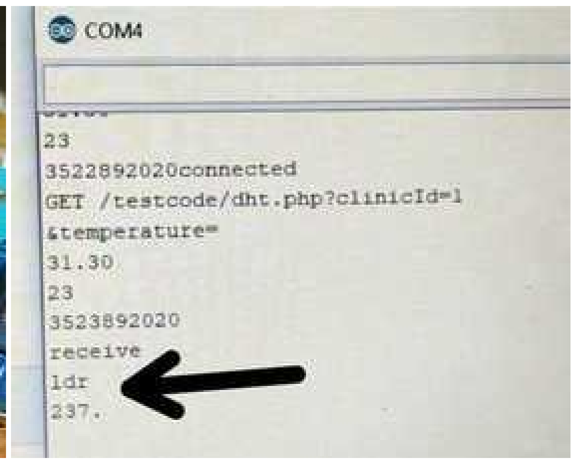


2. DHT11: We tested the DHT11 and connected it to the ATMega328 to measure the temperature value of cold storage units



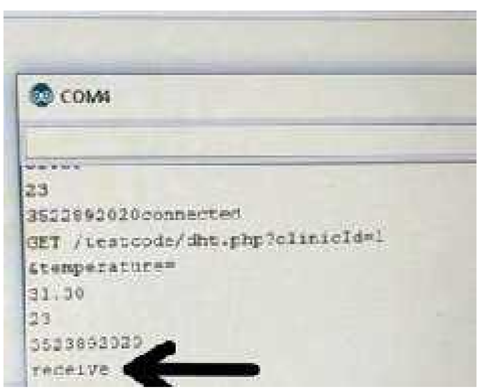


3. LDR: We tested the LDR and connected it to the ATMega328 to measure the resulted resistance.

2. Bluetooth:

We tested the Slave Bluetooth module and connected it to the ATMega328 we set it up using ATcommands. Then we tested the connection between it and the Master Bluetooth module.



3. The receiving device:

Starting with Arduino Mega2560, we successfully connected the other system components as follows:

1. Bluetooth:

   We tested the Master Bluetooth module and connected it to the Mega we set it up using ATcommands. Then we tested the connection between it and the Slave Bluetooth module.

2. TFT:

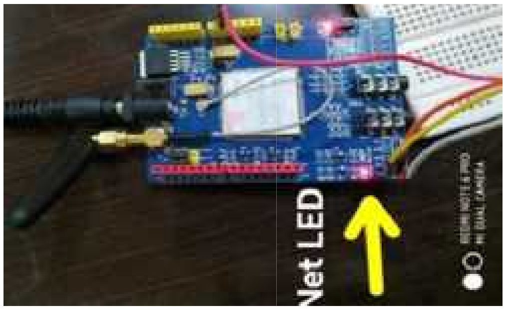
   We set up the TFT and tested it with the graphic testing example and after that we connected it to the Mega.

3. GSM SIM900:

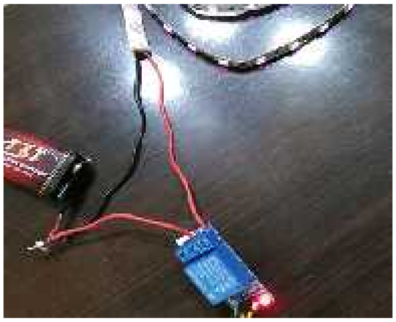
   We connected the GSM SIM900 module to the Arduino Mega then we connected the module to an external power supply and we were able to send both calls and SMS successfully

   We can check if it is connected to the cellular network by noticing the flicker speed of the net light (there should be 3 seconds between each flicker).



4. Relay & LED strip:

   We connected the LED strip to an external battery (9V) and a relay in order to light it when LDR values indicate that the fridge door isn't closed tightly. It lit up when the door was opened and turned off when it was closed, since the value is greater than 900Ω when the door is closed.

5. RTC:

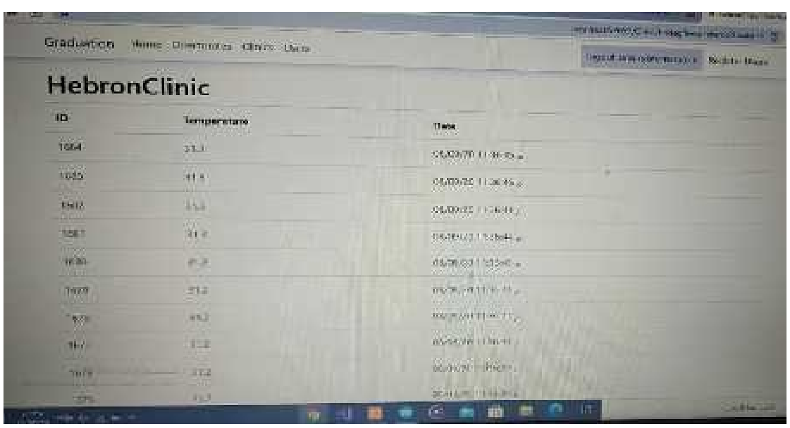
   We connected the RTC to the Mega and got accurate date and time values.

6. Ethernet:

   We connected it as a shield to the Arduino mega. We connected it with a cat6 cable to the router in order to get access to the internet. We set up the logging table and connected the shield to it in order to send temperature values to display them on the website.

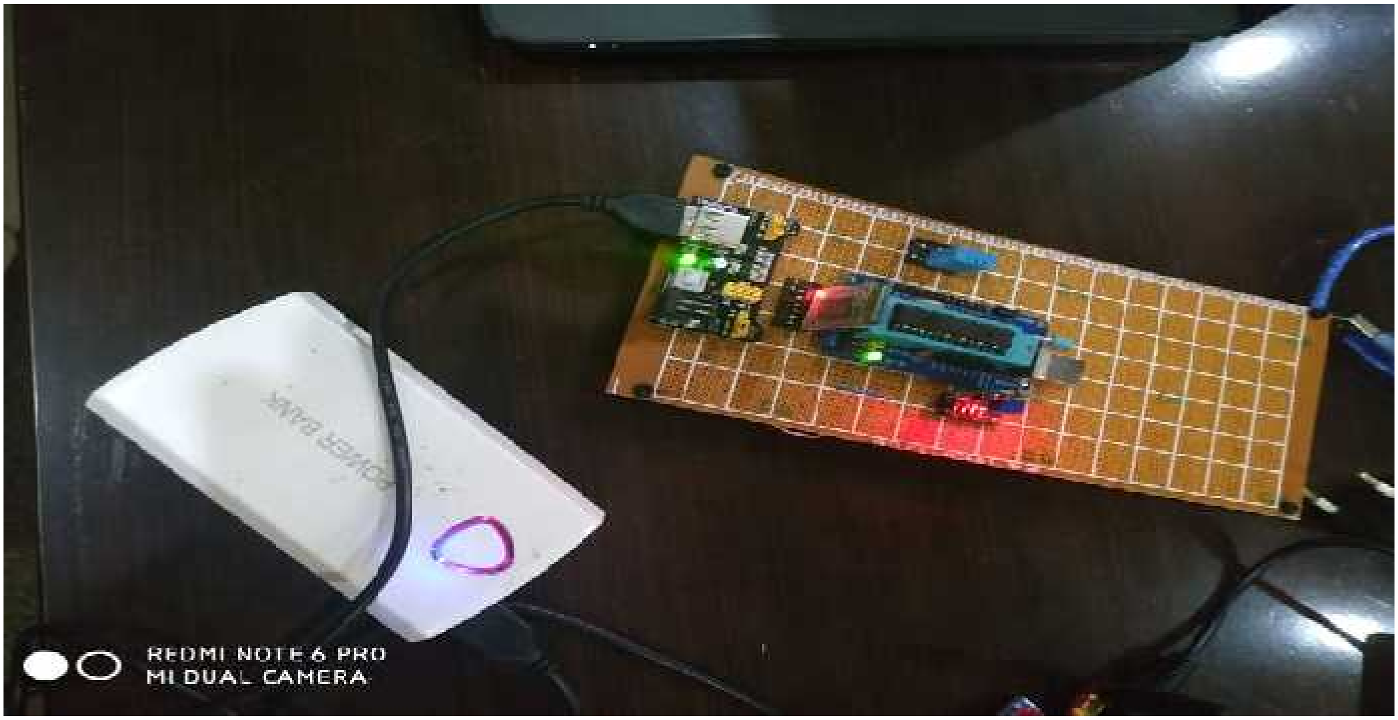
   The values were sent successfully and were added to the logging table.

4.1 Website (Graduation):



System testing:

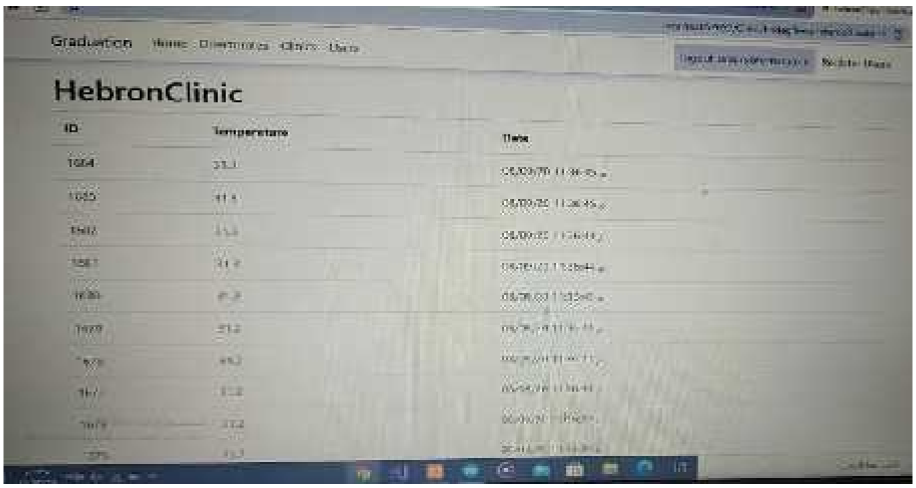
The transmitting device transmits data (temperature values, battery voltage and LDR resistance values) to the receiving device correctly via Bluetooth.



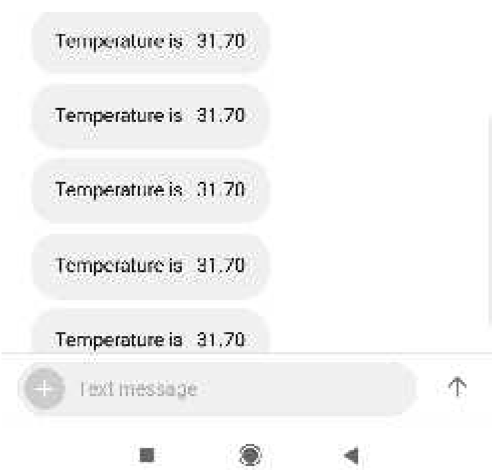
After the Receiving device receives the data and displays it in the following order(date & time, temperature value, battery percentage, connection status and component issues),

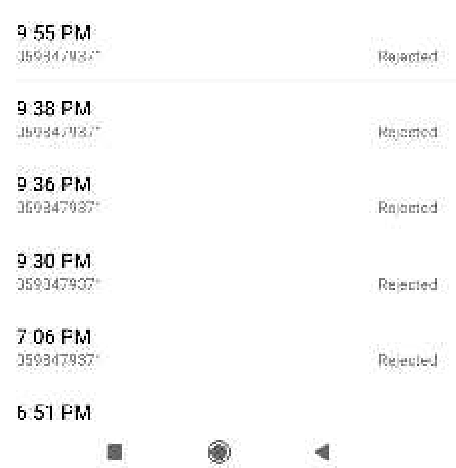
the LED strip lights if the fridge door is open and until it is closed.

The data is successfully uploaded and displayed on the website.



Warnings are issued to all five numbers in form of SMS and calls when the temperature get out of range





the battery percentage reaches 20% charge.

The image will be taken tomorrow.

And if the temperature sensor fail.

Chapter 5: System analysis and discussion

5.1 Overview

This chapter provides analysis and results discussion and system error rate.

5.2 System analysis

After the system implementation:

a- All experiments were done in the university experiment room so that they were tested.

b- The temperature, time, date, warnings and battery percentage are displayed on the screen correctly.

c- In case of an emergency, the system sent alerts (SMS and calls) to the health care providers correctly.

d- Medical staff has been alerted whether the door of the vaccination refrigerator is closed tightly or not by the LED strip light .

e- The daily refrigerator temperature data is displayed correctly on the website (every 6 seconds).

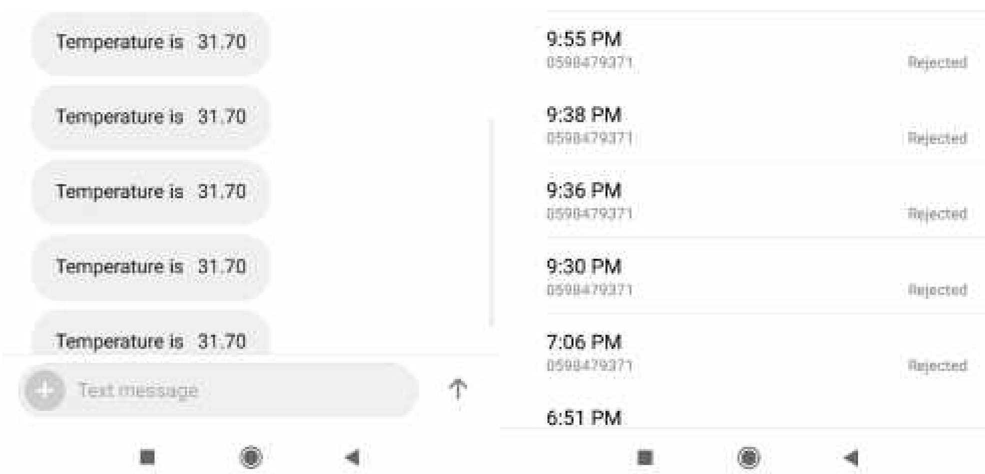
f- In case one of the devices malfunctions, a warning is successfully displayed on the screen or in a call & SMS.

g- In case the battery percentage reaches 20%, the system sent alerts (SMS and calls) to the health care providers correctly.

5.3 Analysis and discussion about the results

- Displaying on the TFT: after receiving the sensor values from the transmitting device via Bluetooth the data from the receiving device is displayed on the TFT along with the date and time retrieved from the RTC module in this order: date, time, temperature, battery percentage. Below these values is an indication of the connection between the Bluetooth modules “connected to D1” or modules “not! connected to D1”. And at the bottom there is a display of the state of the modules after the word “problem:” if there is an issue in any of the modules: its name will be displayed after that word.

- Light indicating storage unit door state: The LDR sensor measures the light intensity in the fridge and the transmitting device sends it to the receiving device vis Bluetooth if it is lower than 900 Ω the microcontroller sends a signal to the relay to turn on the LED strip. When the value measured by the LDR becomes greater than 900 Ω the microcontroller sends a signal to the relay to turn off the LED.
- Website: ?????????????/
- Warnings: after receiving the temperature values from the transmitting device via Bluetooth the Arduino mega checks if the temperature is within the recommended range(2-8C), if not the microcontroller sends a signal to the GSM module to issue messages then calls to personnel in charge of that storage unit. First, to the head of maintenance sector in the health department, then to the health care providers in charge of the clinic where the cold storage unit is located, then to the head nurse in the health department of the city and finally to the head of the department (total of five persons). The warning SMS is shown in the figure bellow.



- Fail safe: We used commands so that in case one or more of the modules stops working its name is displayed at the bottom of the TFT screen as shown in the figure below.

Chapter 6

Conclusion

6.1 Summary

In this project, We aimed to resolve the issue regarding the inability to measure the Temperature of cold storage units and display them remotely, we also acknowledged the need for warnings in case the temperature was not within the recommended range. our project consists of two devices a Transmitting device and a receiving device, the transmitting device is kept in the storage unit to ensure that the unit does not get exposed frequently to the outside temperature. when the health care provider checks the temperature of the unit, we also insure that by indicating whether the storage unit door is closed properly by lighting an LED strip when it's open. The receiving device receives the sensor data and displays it on a screen out side of the unit so it would be easy to monitor by the health care provider. We also made it easy to monitor the unit temperature by creating a website dedicated to monitoring and logging that can be viewed remotely. In case the temperature is not within the recommended range the receiving device issues a SMS detailing the current temperature followed by a call to in charge personnel. The project has fulfilled its intended outcomes.

6.2 Future Work

Ultimately, we want our project to reach highest possible accuracy by replacing the DHT11 sensor with the high sensitivity TSYS01 sensor that we could not acquire before due to the pandemic lockdown. We can also develop our system so it can work on more than one storage unit per receiving device we can also update our website so it would have more than one clinic.

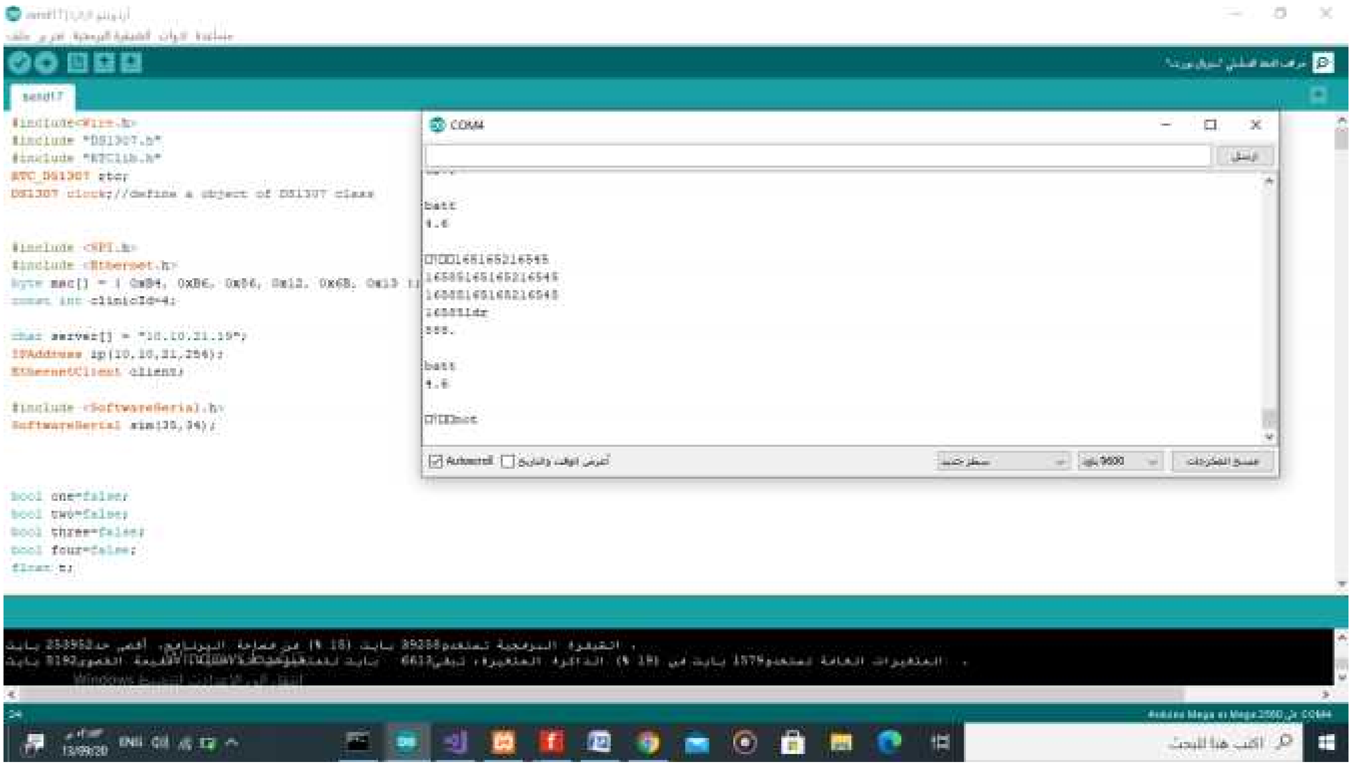
References:

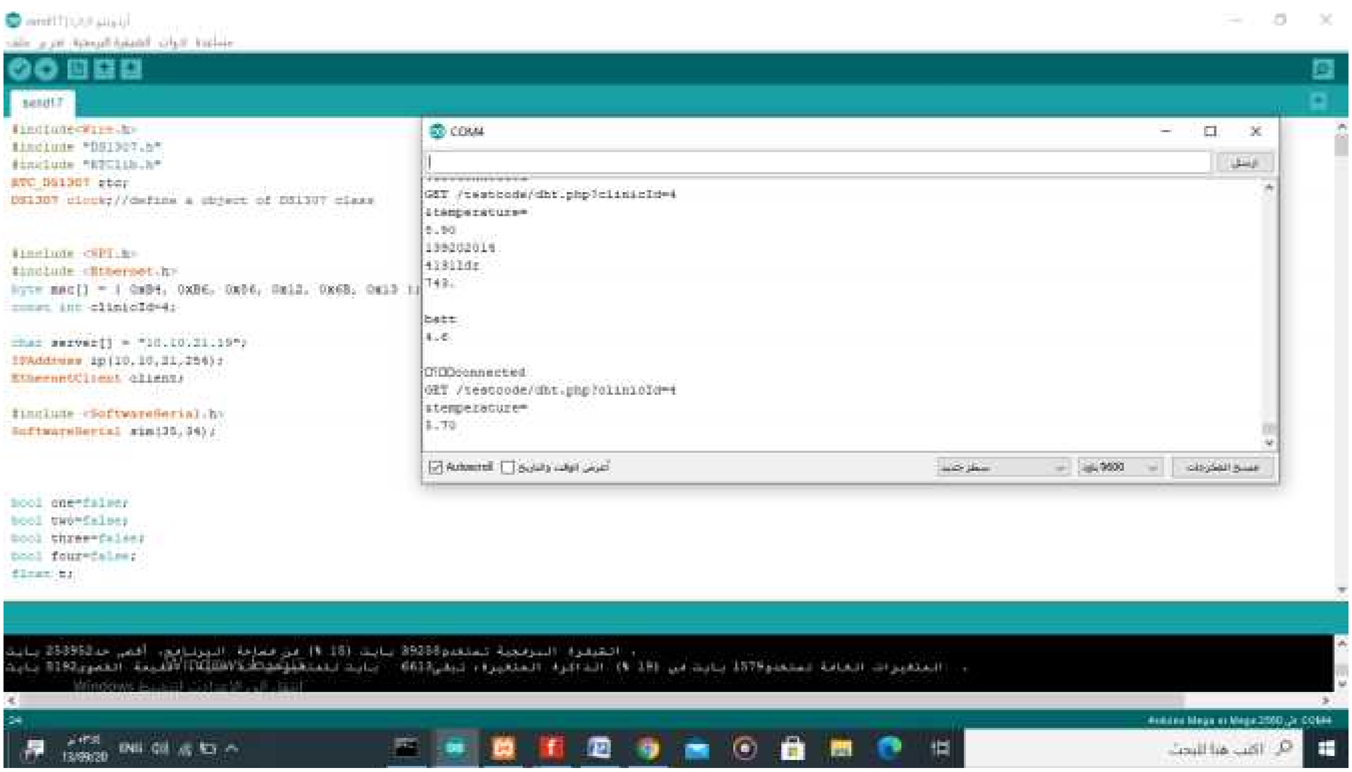
[1] “Sensor Cloud”, *Insights.tempalert.com*, 2019. [Online]. Available: https://insights.tempalert.com/login?__hstc=40690045.dde78eb65371864195c683664fd7ba9b.1576489807052.1576489807052.1576489807052.1&__hssc=40690045.6.1576489807054&__hsfp=3431755086. [Accessed: 16- Dec- 2019].

[2] “Z Sensor”, *SmartSense*, 2019. [Online]. Available: https://www.smartsense.co/products/zigbee-temperature-sensor. [Accessed: 15- Nov- 2019].

[3] “Merriam Webster” Merriam-webster.com. (n.d.). *Definition of VACCINE*. [online] Available at: https://www.merriam-webster.com/dictionary/vaccine [Accessed 15 Nov. 2019].

[4] “W. EVM”, "WHO Vaccine Management Handbook Module VMH-E2", *Apps.who.int*, 2015. [Online]. Available: https://apps.who.int/iris/bitstream/handle/10665/183583/WHO_IVB_15.04_eng.pdf;jsessionid=BBB2570EE392DFDC783D4D3D015B7DD6?sequence=1. [Accessed: 16- Dec- 2019.


sand17
COM4
#include<Wire.h>
#include "DS1307.h"
#include "RTClib.h"
RTC_DS1307 rtc;
DS1307 clock;//define a object of DS1307 class
#include <SPI.h>
#include <Ethernet.h>
byte mac[] = { 0xB4, 0xB6, 0x56, 0x12, 0x6B, 0x13
const int clinicId=4;
char server[] = "10.10.21.19";
IPAddress ip(10,10,21,254);
EthernetClient client;
#include <SoftwareSerial.h>
SoftwareSerial sim(35,34);
bool one=false;
bool two=false;
bool three=false;
bool four=false;
float t;
batt
4.6
batt
4.6
Autoscroll
9600


sand17
COM4
#include<Wire.h>
#include "DS1307.h"
#include "RTClib.h"
RTC_DS1307 rtc;
DS1307 clock;//define a object of DS1307 class
#include <SPI.h>
#include <Ethernet.h>
byte mac[] = { 0xB4, 0xB6, 0x56, 0x12, 0x6B, 0x13
const int clinicId=4;
char server[] = "10.10.21.19";
IPAddress ip(10,10,21,254);
EthernetClient client;
#include <SoftwareSerial.h>
SoftwareSerial sim(35,34);
bool one=false;
bool two=false;
bool three=false;
bool four=false;
float t;
GET /testcode/dht.php?clinicId=4
&temperature=
batt
4.6
connected
GET /testcode/dht.php?clinicId=4
&temperature=
Autoscroll
9600