

Mini Project Report

on

**IOT BASED FOOD GRAIN STORAGE
MONITORING SYSTEM FOR SILOS**

In partial fulfillment of the requirements for the award of the degree of

BACHELOR OF TECHNOLOGY

in

Electronics and Communication Engineering

Submitted By

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CERTIFICATE

This is to certify that the project report titled **IOT BASED FOOD GRAIN STORAGE MONITORING SYSTEM FOR SILOS**, being submitted by **Mudumby Kalyana Ramanuja Swami** bearing register number **19R11A04N1** in partial fulfillment for the award of the Degree of Bachelor of Technology in *Electronics and Communication Engineering* is a record of bona-fide work carried out under my supervision. The results embodied in this report have not been submitted to any other University for the award of any degree.

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With Regards

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SYMBOLS & ABBREVIATIONS

AC	-	Alternating Current
ADC	-	Analog To Digital Converter
AMOLED	-	Active-Matrix Organic Light Emitting Diodes
AWG	-	American Wire Gauge
AWS	-	Amazon Web Services
CO ₂	-	Carbon-Di-Oxide
CPP	-	C++ Programming Language
CPU	-	Central Processing Unit
DAC	-	Digital To Analog Converter
DC	-	Direct Current
DHT11	-	Digital Humidity And Temperature Sensor
GPIO	-	General Purpose Input Output
HTML	-	Hypertext Markup Language
I2C	-	Inter-Integrated Circuit
I2S	-	Inter Integrated Circuit For Sound
IOT	-	Internet Of Things
ITO	-	Indium-Tin Oxide
LED	-	Light Emitting Diode

LCD	-	Liquid Crystal Display
LEC	-	Light-Emitting Electrochemical Cell
LoRa	-	Long Range Radio
MCU	-	Micro Controller Unit
NIR	-	Near Infrared
OLED	-	Organic Light Emitting Diode
PCB	-	Printed Circuit Board
PMOLED	-	Passive-Matrix Organic Light Emitting Diodes
PWM	-	Pulse Width Modulation
RFID	-	Radio Frequency Identification
RPM	-	Revolutions Per Minute
RTC	-	Real Time Clock
SAR	-	Successive Approximation Register
SCL	-	Serial Clock
SD	-	Secure Digital
SDA	-	Serial Data
SPI	-	Serial Peripheral Interface
TFT	-	Thin-Film Transistor
UART	-	Universal Asynchronous Receiver/Transmitter
WiFi	-	Wireless Fidelity

ABSTRACT

Safe food storage has always been a major issue in our country. The changing climatic conditions of India have been posing a great challenge to our farmers who are heavily dependent on seasonal changes in weather. Global warming and rapidly increasing pollution have had a great impact on crop yield for years now. Bad weather conditions often damage the yields beyond repair. Our project “IOT BASED FOOD GRAIN STORAGE MONITORING SYSTEM FOR SILOS” aims to provide a system to maintain silos in a safe and hygienic environment to store food grains by monitoring them at regular intervals, we keep track of the parameters in the silo, such as temperature, humidity and carbon-di-oxide (CO₂) level concentrations. Values recorded at regular intervals of time help us analyse and visualise the data, and observe the effects of these parameters on the food grains stored, while providing protection against pests, rodents and other organisms that can affect the yield. It has also been observed that while the grains are stored in such silos, due to the natural processes we have a lot of CO₂ concentration in the silos which has caused many fatal deaths of farmers. This issue has been mitigated in the project by implementing an emergency procedure which will be activated to open the grain bin and release the toxic gases from the silo. Through our project, we believe we can innovate in the grain storage space and solve the problems faced by the farmers.

1.INTRODUCTION

The cultivation of food crops takes up the highest percentage in the total agricultural production in India. This is due to the fact that India has to supplement its ever-growing population with food in order to keep the growth aspects of its country in a steady state. This leads to cultivation and storage of grains being heavily invested in every budget declaration made by the governments. Since most of the population practises agriculture, it becomes important to have a proper channel through which the produce reaches every citizen. But there are a lot of problems involving the damage to the produce at the fields, during transportation or storage (Figure 1.1). This unfortunately results in 25 to 30 percent wastage due to poor support, lack of cold storages, procurement issues, improper transportation and underdeveloped marketing channels ((Figure 1.2). Food grain wastage cripples a country's economy to an extent that most of us are unaware. When food grains are wasted, there is wastage of water and manpower which is used during cultivation of the food grains. There is also a lot of electric power wasted during the processing of food grains. It also leads to deforestation.



FIGURE 1.1 - Unprotected Bag Storage System



FIGURE 1.2 - Spoiled Canola Due To Poor Storage

Internet of things (IoT) is an approach through which problems can be resolved. The impact that the Internet of Things has in today's world has made people around us intelligent and more perceptive by bringing new changes through combining digital and physical universes. The sensors and communication modules are being equipped into mobile devices with communication technologies like Wi-Fi have penetrated the market making IoT a common research topic.



FIGURE 1.3 - Grain Storage Silos

2.LITERATURE SURVEY

The major developments in the field of agriculture are widely based on the applications of IoT. In recent times, there has been lot of work going on for a storage warehouse system design that is based on the contents coming in and out of the warehouse using RFID tag technology [1]. The prominence of IoT in the agriculture industry can be mentioned by stating few examples which include the supply chain management [2]. Also, there are works which deals with the construction of an IoT-based logistics platform for food based on a IoT three-tier architecture in China [3]. Implementation of the monitoring system with the help of Node-RED visual programming and AWS is another design which comes through as an effective way in realizing the main target of food grain preservation but lacks in the aspect of industry application [4]. Many theoretical realizations and reviews have been provided on how to implement the IoT monitoring system in storage facilities for optimum storage during severe weather conditions. There has been works which dealt with the modelling and architecture of the warehouses for different regions with different weathers and fluctuating environment variables [5]. Technological variations have been introduced where it consisted of implementation of monitoring system using Zigbee transceiver (ETRX357) and buzzer circuit [6]. The PCB implementation of sensors in the monitoring system is quite a different approach fulfilling the same conditions [7]. Usage of computer vision with image analysis toolkit in the monitoring system architecture is a recent concept with technology that can be successfully applied in the inspection and evaluation of grain quality using parametric sensors, automated sampling device and computer interface [8]. The behavior of food crops under sustainable conditions is one of the factors which needs attention while determining the environmental parameters inside the storage warehouses [9]. On an experimental basis, there have been extensive research based on the temperature and spectral responses when the food grains are exposed to different wavelength of light with the parametric variations recorded using NIR spectroscopic analysis [10]. Storing perishable items inside the warehouses has its own limitations. This has been addressed by considering different implementation techniques at different stages of

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food supply chain [11]. There has been works related to the process of multispectral imaging in seed phenotyping and quality monitoring which have provided satisfactory research results [12].

3. HARDWARE

3.1 ESPWROOM32

ESP32-WROOM-32 (Figure 3.1.1) is a powerful, generic Wi-Fi + Bluetooth + Bluetooth LE MCU module that targets a wide variety of applications, ranging from low-power sensor networks to the most demanding tasks, such as voice encoding, music streaming. At the core of this module is the ESP32-D0WDQ6 chip. The chip embedded is designed to be scalable and adaptive. There are two CPU cores that can be individually controlled, and the CPU clock frequency is adjustable from 80 MHz to 240 MHz. The chip also has a low-power coprocessor that can be used instead of the CPU to save power while performing tasks that do not require much computing power, such as monitoring of peripherals. ESP32 integrates a rich set of peripherals, ranging from capacitive touch sensors, Hall sensors, SD card interface, Ethernet, high-speed SPI, UART, I2S and I2C.

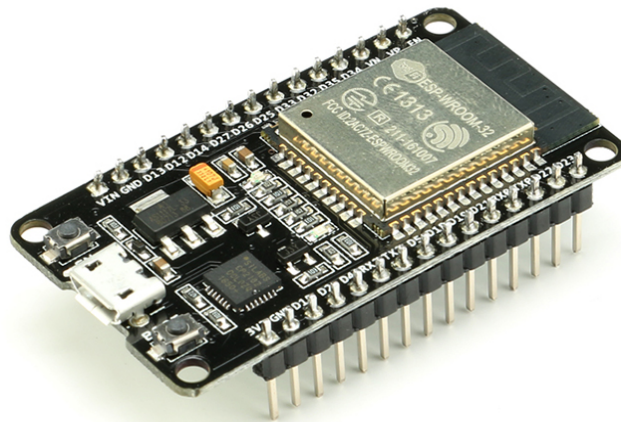


FIGURE 3.1.1 - ESPWROOM32 Microcontroller

3.1.1 Pins of ESPWROOM32

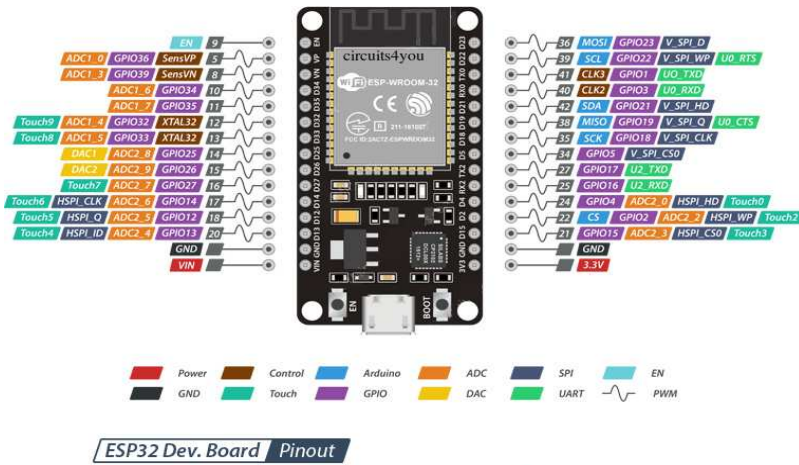


FIGURE 3.1.1.1 - ESPWROOM32 Pin Diagram

GPIO: The GPIO is the peripheral that is most frequently used. Each of the 34 GPIO pins on the ESP32 performs multiple tasks (only one will be active). A pin can be set up in the software as a GPIO, an ADC, or a UART.

The manufacturer-specified pins must be used because ADC and DAC pins are predefined. However, every GPIO pin can have various functions such as PWM, SPI, UART, I2C, etc. assigned to it using software.

RTC GPIO: The 16 RTC GPIOs on the ESP32 are a component of the RTC Low-Power subsystem. These pins can be utilised as an external wake-up source to awaken the ESP32 from a deep sleep.

ADC: Two 12-bit SAR Analog to Digital Converter Modules for the ESP32 are available, each with 8 and 10 channels. Therefore, the combined ADC1 and ADC2 blocks contain 18 channels of 12-bit ADC. The result Digital numbers with 12-bit resolution will fall between 0 and 4093.

DAC: Two separate 8-bit Digital to Analog Converter channels on the ESP32 Microcontroller allow for the conversion of digital values into analog voltage signals.

The power supply serves as the input reference voltage for the DAC's internal resistor network.

DAC functionality is connected to the next two GPIO Pins.

- DAC1 — GPIO25
- DAC2 — GPIO26

Capacitive Touch GPIOs: 10 capacitive-sensing GPIOs on the ESP32 SoC may detect changes in capacitance on a pin as a result of touching or getting close to the GPIO Pin with a finger or stylus. Without any additional hardware, these Touch GPIOs can be utilised to construct capacitive touch pads.

SPI: Three SPI blocks (SPI, SPI2, and SPI3) are available on the ESP32 Wi-Fi chip in both master and slave modes. Flash Memory is interfaced with using SPI.

I2C: I2C is a serial, synchronous, half-duplex communication protocol that allows co-existence of multiple masters and slaves on the same bus. The I2C bus consists of two lines: serial data line (SDA) and serial clock (SCL).

- SDA – GPIO21
- SCL – GPIO22

PWM: 16 separate PWM waveform channels with adjustable frequency and duty cycle make up the ESP32 PWM Controller. LEDs and motors can both be driven using the PWM waveform. The duty cycle, channel, and frequency of the PWM signal are all programmable.

3.2 MQ-135 Gas Sensor

A Sensor as an input device which provides an output (signal) with respect to a specific physical quantity (input). You can find different types of Sensors in our homes, offices, cars etc. working to make our lives easier by turning on the lights by detecting our presence, adjusting the room temperature, detect smoke or fire, make us

delicious coffee, open garage doors as soon as our car is near the door and many other tasks.



FIGURE 3.2.1 - MQ - 135 Gas Sensor

3.2.1 Working of MQ -135 Gas Sensor

The gas sensor module consists of a steel exoskeleton under which a sensing element is housed (Figure 3.2.1.1). This sensing element is subjected to current through connecting leads. This current is known as heating current through it, the gases coming close to the sensing element get ionised and are absorbed by the sensing element. This changes the resistance of the sensing element which alters the value of the current going out of it.

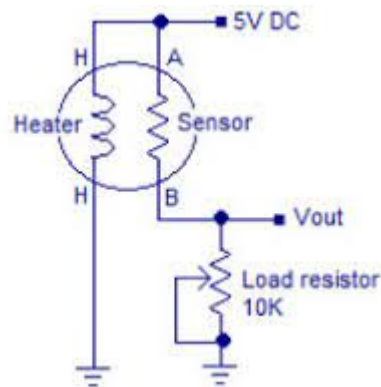


FIGURE 3.2.1.1 - MQ - 135 Gas Sensor Circuit Diagram

To measure or detect the gases, use analog pins or digital pins. Just apply 5V to the module and you can observe that the module's power LED turns ON (glows) and the output LED turns OFF when no gas is detected by the module. This means that the output of the digital pin is 0V. Note that the sensor must be kept for preheating time for 20 seconds before the actual operation.

Now, once when the MQ135 sensor is operated to detect, then the LED output goes high along with the digital output pin. Otherwise, use the potentiometer until the output increases. Whenever the sensor detects a certain gas concentration, the digital pin goes high (5V), otherwise it stays low (0V).

We can also use analog pins to get the same result. The output analog values (0-5V) are read from the microcontroller. This value is directly proportional to the gas concentration detected by the sensor. We can observe the working and reaction of the MQ135 sensor with different gas concentrations and the programming developed accordingly.

3.3 Buzzer

An audio signalling device like a beeper or buzzer may be electromechanical or piezoelectric or mechanical. The main function of this is to convert the signal from audio to sound. Generally, it is powered through DC voltage and used in timers, alarm devices, printers, alarms, computers, etc. Based on the various designs, it can generate different sounds like alarm, music, bell & siren.

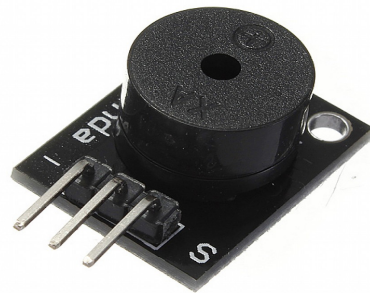


FIGURE 3.3.1 - Buzzer

3.3.1 Working of Buzzer

The working principle of a buzzer depends on the theory that, once the voltage is given across a piezoelectric material, then a pressure difference is produced. A piezo type includes piezo crystals among two conductors. Once a potential disparity is given across these crystals, then they thrust one conductor & drag the additional conductor through their internal property. So this continuous action will produce a sharp sound signal.

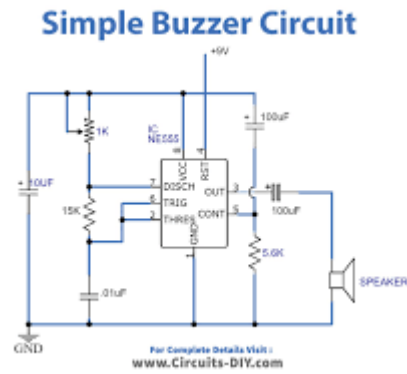


FIGURE 3.3.1.1 - Buzzer Circuit

3.4 Force Sensor

Force sensors (Figure 3.4.1) are devices that are designed to translate applied mechanical forces, such as tensile and compressive forces, into output signals whose value can be used to reflect the magnitude of the force. The signals may be sent to indicators, controllers, or computers to inform operators or serve as inputs to provide control over machinery and processes. They are used in a wide range of products and applications such as bathroom scales, musical instruments, medical applications, automobiles to detect seat occupancy, and process control in manufacturing facilities, to name a few of the many uses for these devices.



FIGURE 3.4.1 - Force Sensor

3.4.1 Working of Force Sensor

The working principle of a force sensor is that it responds to the applied force, as well as converts the value to a measurable quantity. Most force sensors are created with the use of force-sensing resistors. Such sensors consist of electrodes and sensing film.

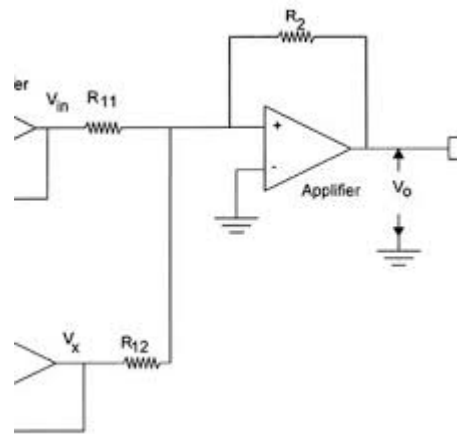


FIGURE 3.4.1.1 - Force Sensor Circuit Diagram

Force-sensing resistors are based on contact resistance. These contain a conductive polymer film, which changes its resistance in a predictable way once force is applied on the surface. This film includes non-conducting, micrometre sized, and electrically conducting particles, which are arranged in a matrix. If force is applied to the film's surface, microsized particles touch the sensor electrodes, which change the film's resistance. The amount of change may alter the resistance value that provides a measure of the applied force. To boost the performance of force-sensing resistors, different efforts are made using several approaches like reducing the drift of polymer electrode configurations being tested with the sensor.

3.5 DHT - 11

Humidity is the measure of water vapour present in the air. The level of humidity in air affects various physical, chemical and biological processes. In industrial applications, humidity can affect the business cost of the products, health and safety of the employees. So, in semiconductor industries and control system industries measurement of humidity is very important. Humidity measurement determines the amount of moisture present in the gas that can be a mixture of water vapour, nitrogen, argon or pure gas etc. Humidity sensors (Figure 3.5.1) are of two types based on their measurement units. They are a relative humidity sensor and Absolute humidity sensor. DHT11 is a digital temperature and humidity sensor.



FIGURE 3.5.1 - DHT - 11

3.5.1 Working of DHT-11

DHT11 uses only one wire for communication. The voltage level with a certain time value defines the logic one or logic zero on this pin. The communication process is divided in three steps, first is to send a request to the DHT11 sensor then the sensor will send a response pulse and then it starts sending data of a total of 40 bits to the microcontroller.

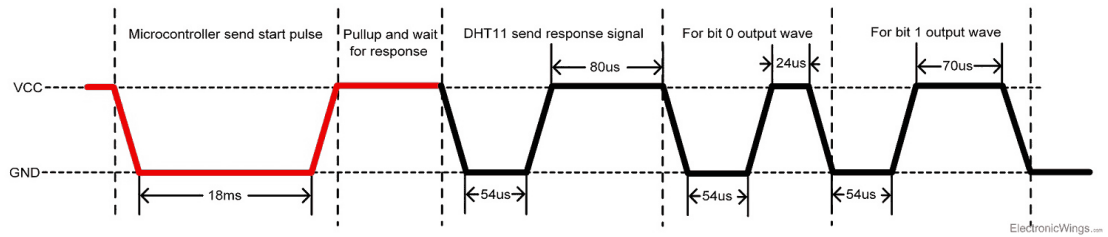


FIGURE 3.5.1.1 - Communication Process

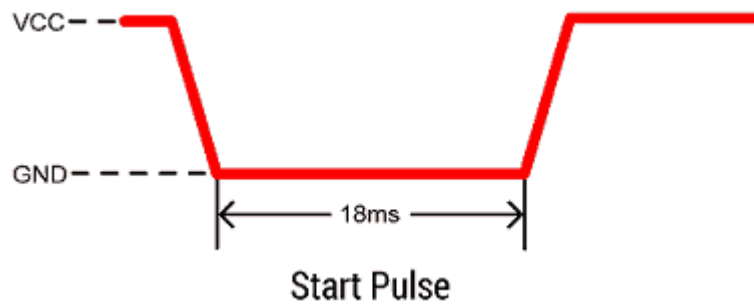


FIGURE 3.5.1.2 - Start Pulse

- To start communication with DHT11, first we should send the start pulse to the DHT11 sensor.
- To provide a start pulse, pull down (low) the data pin minimum 18ms and then pull up, as shown in the diagram.

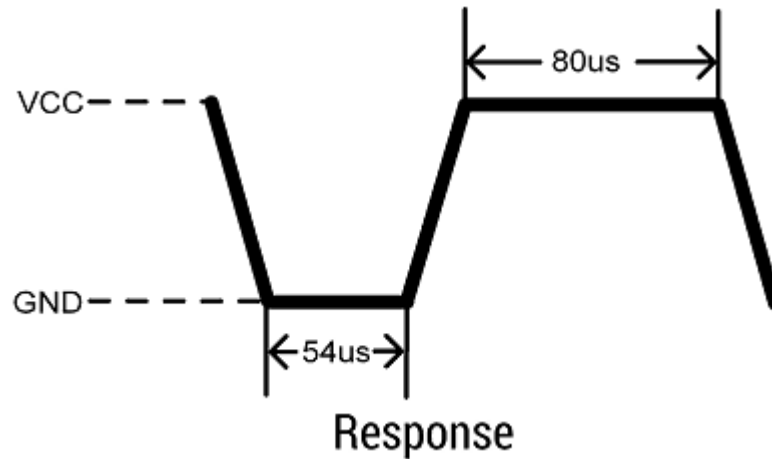


FIGURE 3.5.1.3 - Response

- After getting the start pulse, the DHT11 sensor sends the response pulse which indicates that DHT11 received the start pulse. The response pulse is low for 54us and then goes high for 80us.

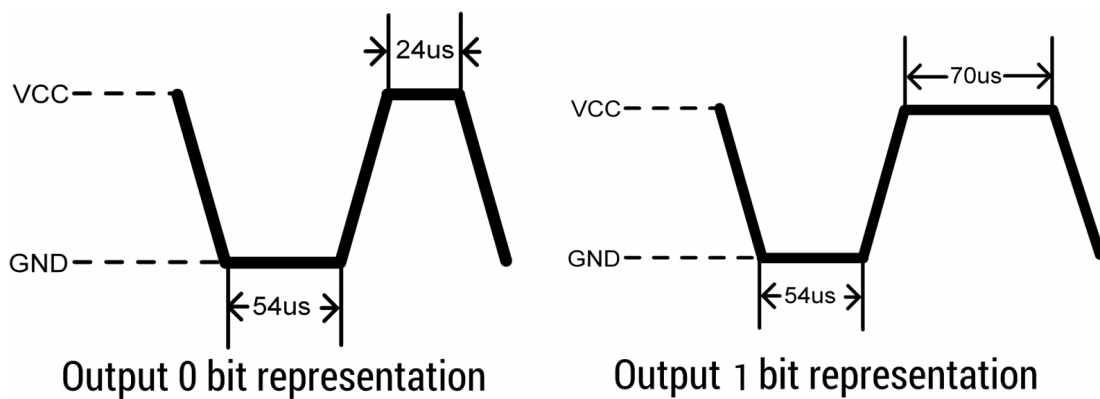


FIGURE 3.5.1.4 - Output Bit Representation

- After sending the response pulse, the DHT11 sensor sends the data, which contains humidity and temperature value along with checksum.

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The data frame is of total 40 bits long, it contains 5 segments (byte) and each segment is 8-bit long.

- In these 5 segments, the first two segments contain humidity value in decimal integer form. This value gives us Relative Percentage Humidity. The 1st 8-bits are the integer part and the next 8 bits are the fractional part. Next two segments contain temperature values in decimal integer form. This value gives us temperature in Celsius form. Last segment is the checksum which holds the checksum of the first four segments.
- Here checksum byte is direct addition of humidity and temperature value. And we can verify it, whether it is the same as checksum value or not. If it is not equal, then there is some error in the received data.
- Once data is received, the DHT11 pin goes into low power consumption mode till the next start pulse.

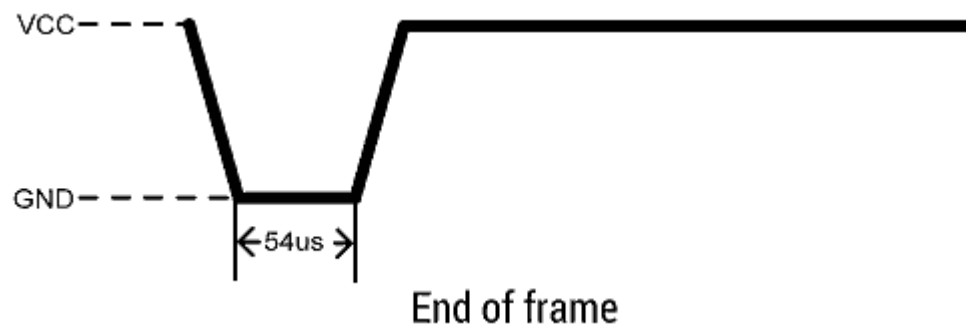


FIGURE 3.5.1.5 - End of Frame

- After sending 40-bit data, the DHT11 sensor sends 54us low level and then goes high. After this DHT11 goes into sleep mode.

3.6 Servo Motor

A servo motor (Figure 3.6.1) is a type of motor that can rotate with great precision. Normally this type of motor consists of a control circuit that provides feedback on the current position of the motor shaft, this feedback allows the servo motors to rotate with great precision. If you want to rotate an object at some specific angles or distance, then you use a servo motor. It is just made up of a simple motor which runs through a servo mechanism. If a motor is powered by a DC power supply then it is called DC servo motor, and if it is AC-powered motor then it is called AC servo motor. Apart from these major classifications, there are many other types of servo motors based on the type of gear arrangement and operating characteristics. A servo motor usually comes with a gear arrangement that allows us to get a very high torque servo motor in small and lightweight packages. Due to these features, they are being used in many applications like toy cars, RC helicopters and planes, Robotics, etc.



FIGURE 3.6.1 - Servo Motor

3.6.1 Working of Servo Motor

A servo consists of a Motor (DC or AC), a potentiometer, gear assembly, and a controlling circuit. First of all, we use gear assembly to reduce RPM and to increase torque of the motor. Say at the initial position of the servo motor shaft, the position of

the potentiometer knob is such that there is no electrical signal generated at the output port of the potentiometer. Now an electrical signal is given to another input terminal of the error detector amplifier. Now the difference between these two signals, one comes from the potentiometer and another comes from other sources, will be processed in a feedback mechanism and output will be provided in terms of error signal. This error signal acts as the input for the motor and motor starts rotating. Now the motor shaft is connected with the potentiometer and as the motor rotates so the potentiometer and it will generate a signal. So as the potentiometer's angular position changes, its output feedback signal changes. After sometime the position of potentiometer reaches a position that the output of potentiometer is the same as the external signal provided. At this condition, there will be no output signal from the amplifier to the motor input as there is no difference between external applied signal and the signal generated at potentiometer, and in this situation the motor stops rotating.

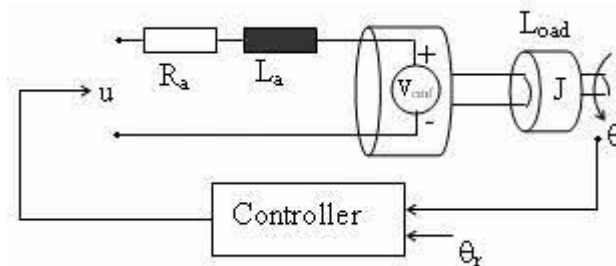


FIGURE 3.6.1.1 - Servo Motor Circuit Diagram

3.7 Jumper Wires

Generally, jumpers (Figure 3.7.1) are tiny metal connectors used to close or open a circuit part. They have two or more connection points, which regulate an electrical circuit board. Their function is to configure the settings for computer peripherals, like the motherboard. Suppose your motherboard supported intrusion detection. A jumper

can be set to enable or disable it. Jumper wires are electrical wires with connector pins at each end. They are used to connect two points in a circuit without soldering.



FIGURE 3.7.1 - Jumper Wires

You can use jumper wires to modify a circuit or diagnose problems in a circuit. Further, they are best used to bypass a part of the circuit that does not contain a resistor and is suspected to be bad. This includes a stretch of wire or a switch. Suppose all the fuses are good and the component is not receiving power; find the circuit switch. Then, bypass the switch with the jumper wire. How much current (I) and voltage (V) can jumper wires handle? The I and V rating will depend on the copper or aluminium content present in the wire.

For an Arduino application is no more than 2A and 250V. We also recommend using solid-core wire, ideally 22 American Wire Gauge (AWG).

3.8 OLED Display

An organic light-emitting diode (OLED or organic LED) (Figure 3.8.1), also known as organic electroluminescent (organic EL) diode, is a light-emitting diode (LED) in which the emissive electroluminescent layer is a film of organic compound that emits light in response to an electric current. This organic layer is situated between two

electrodes; typically, at least one of these electrodes is transparent. OLEDs are used to create digital displays in devices such as television screens, computer monitors, and portable systems such as smartphones and handheld game consoles. A major area of research is the development of white OLED devices for use in solid-state lighting applications.

There are two main families of OLED: those based on small molecules and those employing polymers. Adding mobile ions to an OLED creates a light-emitting electrochemical cell (LEC) which has a slightly different mode of operation. An OLED display can be driven with a passive-matrix (PMOLED) or active-matrix (AMOLED) control scheme. In the PMOLED scheme, each row (and line) in the display is controlled sequentially, one by one, whereas AMOLED control uses a thin-film transistor (TFT) backplane to directly access and switch each individual pixel on or off, allowing for higher resolution and larger display sizes.

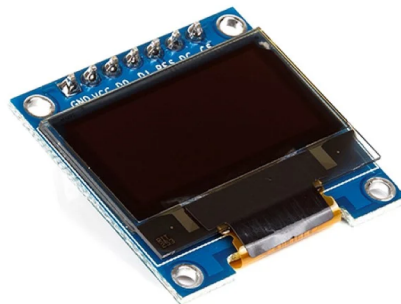


FIGURE 3.8.1 - 128x64 OLED Display

OLED is fundamentally different from LED which is based on a p-n diode structure. In LEDs doping is used to create p- and n- regions by changing the conductivity of the host semiconductor. OLEDs do not employ a p-n structure. Doping of OLEDs is used to increase radiative efficiency by direct modification of

the quantum-mechanical optical recombination rate. Doping is additionally used to determine the wavelength of photon emission.

An OLED display works without a backlight because it emits visible light. Thus, it can display deep black levels and can be thinner and lighter than a liquid crystal display (LCD). In low ambient light conditions (such as a dark room), an OLED screen can achieve a higher contrast ratio than an LCD, regardless of whether the LCD uses cold cathode fluorescent lamps or an LED backlight. OLED displays are made in the same way as LCDs, but after TFT (for active matrix displays), addressable grid (for passive matrix displays) or indium-tin oxide (ITO) segment (for segment displays) formation, the display is coated with hole injection, transport and blocking layers, as well with electroluminescent material after the first 2 layers, after which ITO or metal may be applied again as a cathode and later the entire stack of materials is encapsulated. The TFT layer, addressable grid or ITO segments serve as or are connected to the anode, which may be made of ITO or metal. OLEDs can be made flexible and transparent, with transparent displays being used in smartphones with optical fingerprint scanners and flexible displays being used in foldable smartphones.

4. DESIGN METHODOLOGY

4.1 Block Diagram

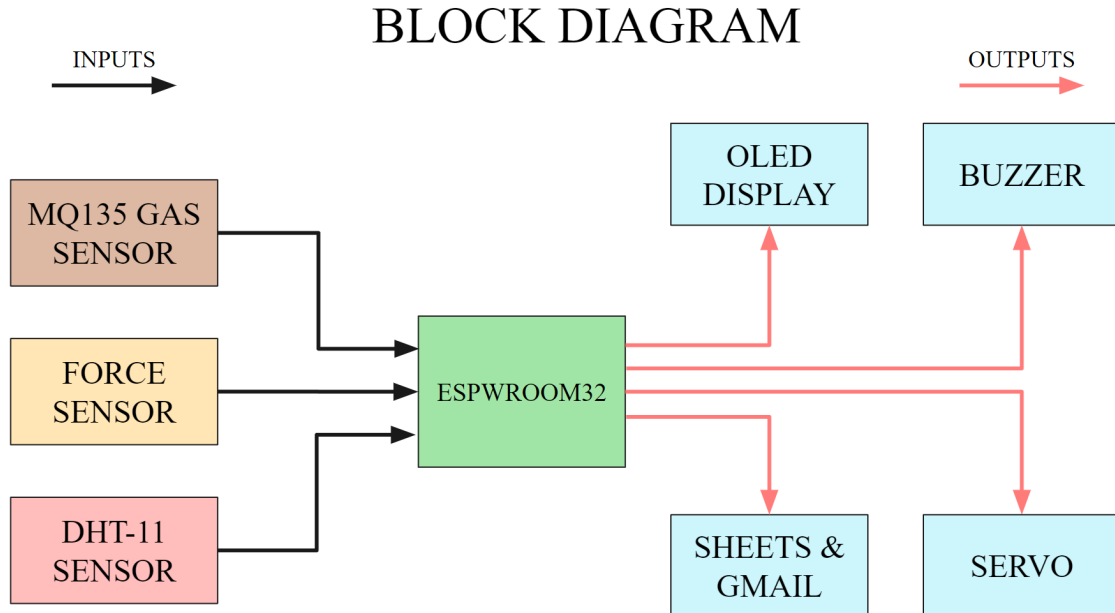


FIGURE 4.1.1 - Block Diagram

The block diagram in Figure 4.1.1 gives us an insight on the working of the project. It consists of the different components used in the hardware of the project, providing us with a design. The block diagram can be broken down into three parts, input elements, functional elements and output elements. In our project, the inputs are the sensors that collect different parameters of the Silo. The MQ-135 gas sensor reads the concentration of carbon dioxide in the silos in PPM (Parts per Million). The force sensor measures the weight of the grains and the DHT-11 gives us the temperature and the relative humidity of the silo. These sensors are interfaced with the ESPWROOM32 to process the data. The microcontroller is programmed in a way that, if any value of the measured parameters exceeds their threshold values, the buzzer is activated and an alert is sent to the user/famer regarding the current status of the silo in the form of an email, If no action is taken and the values reach the maximum threshold then a emergency procedure is executed, which triggers the

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buzzer to go off and by using the servo motor, the grain bin lid will be open to let out the bring the silo back to nominal conditions. We record the values of the silo status for a set interval of time where the ESPWROOM32 contacts the Cloud Application hosted on Google via web POST request, the values from the POST request are parsed by the application and stored on Google Sheets, it is now when we check for the ALERT_PARAM parameter of the POST request as this gives us the clear real-time indication of the silo status, depending on this value we send a mail to the user/farmer.

4.2 ESP32 Program Flowchart

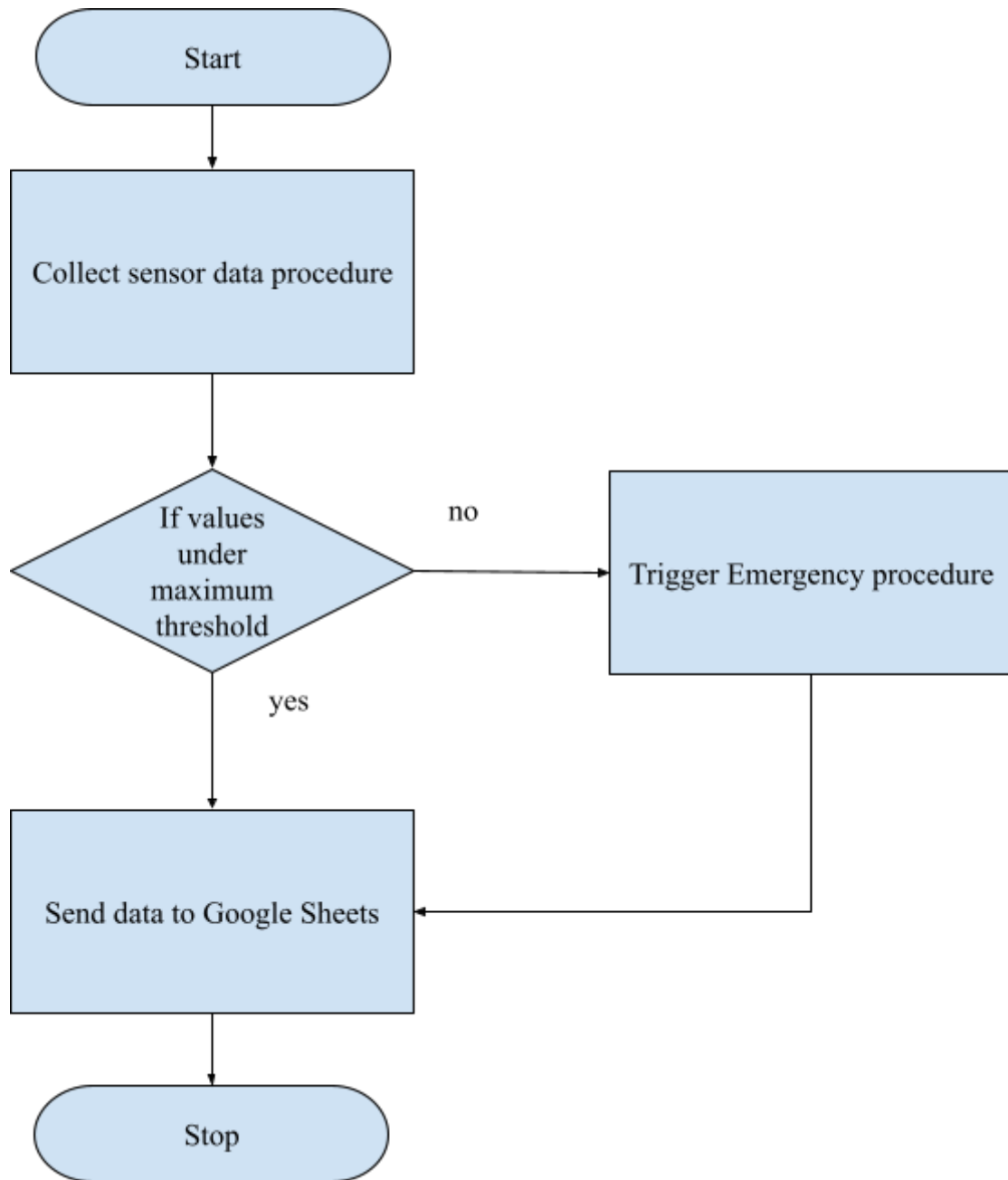


FIGURE 4.2.1 - ESP32 Program Flowchart

4.3 ESP32 Program Code In CPP(c++)

```
// INCLUDE ALL LIBRARIES

#include <DHT.h>

#include <ESP32Servo.h>

#include <Arduino.h>

#include <WiFi.h>

#include <WiFiMulti.h>

#include <HTTPClient.h>

#include <SPI.h>

#include <Wire.h>

#include <Adafruit_GFX.h>

#include <Adafruit_SSD1306.h>

#include <MQUnifiedsensor.h>

// INIT ALL PINS AND PARAMS FOR BETTER READABILITY

// DEFINE DHT PARAMETERS AND OBJECT

#define DHT_PIN 18

#define DHT_TYPE DHT11

// calor -> Heat in Spanish

DHT calor(DHT_PIN, DHT_TYPE);

// DEFINE SERVO AND OBJECT AND STATES

#define SERVO_PIN 17

Servo topLid;

#define OPEN_LID 0
```

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```
#define CLOSE_LID 180

// DEFINE BUZZER PIN

#define BUZZER 16

// DEFINE HTTP and WiFi

WiFiMulti WIFI;

// #define REQUEST

"https://script.google.com/macros/s/AKfycbw9ya_ubtclOguJg2MdQg6p049LXC3TP
_NN1HSJJ0Gwlf6lorxht9qnf6FF-6H1MFkJTA/exec?"

#define REQUEST

"https://script.google.com/macros/s/AKfycbxqsNNCTDZDsVbmvNtU8_yGrKtg_2W
0dsMwheFnP9rFZ0UFduCthMpk-mRJf_H7FijcLQ/exec?"

// DEFINE WIFI SSID AND PASSWORD

#define WIFI_SSID "ESP32"

#define WIFI_PASS ""

// DEFINE DELAYS

#define smallDelay 1000

#define regDelay 3000

#define longDelay 5000

// DEFINE FORCE SENSOR

#define FS_PIN 32

// DEFINE OLED

#define SSD1306_WHITE 1

Adafruit_SSD1306 display(-1);
```

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```
// DEFINE user

#define recipient "19r11a04n1@gcet.edu.in"

// DEFINE MQ135 to detect CO2

#define placa "ESP-32"

#define Voltage_Resolution 3.3

#define pin 35

#define type "MQ-135"

#define ADC_Bit_Resolution 12

#define RatioMQ135CleanAir 3.6

double CO2 = (0);

MQUnifiedsensor MQ135(placa, Voltage_Resolution, ADC_Bit_Resolution, pin,
type);

// ALERT LEVEL

int ALERT_LEVEL=2;

int ALERT_PARAM=3;

void display_OLED(float temp, float humidity, float co2, float weight)

{

// Display Text

display.clearDisplay();

display.setTextSize(1);

display.setTextColor(SSD1306_WHITE);

display.setCursor(0, 0);

display.println("TEMP - ");
```

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```
display.setCursor(0, 8);  
display.println("HUMIDITY - ");  
display.setCursor(0, 16);  
display.println("CO2    - ");  
display.setCursor(0, 24);  
display.println("WEIGHT - ");  
display.setCursor(76, 0);  
display.println(temp);  
display.setCursor(76, 8);  
display.println(humidity);  
display.setCursor(76, 16);  
display.println(co2);  
display.setCursor(76, 24);  
display.println(weight);  
display.display();  
}  
void setup()  
{  
    // put your setup code here, to run once:  
    calor.begin();  
    topLid.attach(SERVO_PIN);  
    Serial.begin(9600);  
    Serial.println("PROGRAM INITIATED");  
}
```

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```
// Add Access Point
WIFI.addAP(WIFI_SSID, WIFI_PASS);

topLid.write(CLOSE_LID);

pinMode(BUZZER, OUTPUT);

// initialise with the I2C address 0x3C
display.begin(SSD1306_SWITCHCAPVCC, 0x3C);

// Clear the buffer.
display.clearDisplay();

// MQ135 sensor

// Set math model to calculate the PPM concentration and the value of constants
Serial.begin(9600);

MQ135.setRegressionMethod(1); // _PPM = a*ratio^b

MQ135.setA(110.47);

MQ135.setB(-2.862);

// Configure the equation values to get NH4 concentration
MQ135.init();

Serial.print("Calibrating please wait.");

float calcR0 = 0;

for (int i = 1; i <= 10; i++)
{
    MQ135.update(); // Update data, the arduino will be read the voltage on the
    analog pin

    calcR0 += MQ135.calibrate(RatioMQ135CleanAir);
}
```


IOT BASED FOOD GRAIN STORAGE MONITORING SYSTEM FOR SILOS

```
Serial.print(".");  
  
}  
  
MQ135.setR0(calcR0 / 10);  
  
Serial.println(" done!.");  
  
if (isinf(calcR0))  
{  
  
    Serial.println("Warning: Connection issue founded, R0 is infinite (Open circuit  
detected) please check your wiring and supply");  
  
    while (1)  
  
        ;  
  
}  
  
if (calcR0 == 0)  
{  
  
    Serial.println("Warning: Connection issue founded, R0 is zero (Analog pin with  
short circuit to ground) please check your wiring and supply");  
  
    while (1)  
  
        ;  
  
}  
  
/***** MQ CALibration  
*****/  
  
MQ135.serialDebug(false);  
  
}  
  
void loop()  
  
{
```

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```
// put your main code here, to run repeatedly:

if (WIFI.run() == WL_CONNECTED)

{

    HTTPClient http;

    Serial.println("CONNECTED TO WIFI NETWORK");

    float sensTemp = calor.readTemperature();

    float sensMoist = calor.readHumidity();

    float force_sensor = analogRead(FS_PIN);

    MQ135.update();      // Update data, the arduino will be read the voltage on
the analog pin

    CO2 = MQ135.readSensor(); // Sensor will read CO2 concentration using the
model and a and b values setted before or in the setup

    // PRINT DATA TO CONSOLE AND DISPLAY ON OLED DISPLAY

    Serial.print("Force: ");

    Serial.println(force_sensor);

    Serial.print("Temperature: ");

    Serial.println(sensTemp);

    Serial.print("Moisture: ");

    Serial.println(sensMoist);

    Serial.print("CO2: ");

    Serial.println(CO2);

    display_OLED(sensTemp, sensMoist, CO2, force_sensor);

    if (CO2 > 8 || sensTemp > 55 || sensMoist > 90){
```

IOT BASED FOOD GRAIN STORAGE MONITORING SYSTEM FOR SILOS

```
// DANGER

if (CO2>8){

    ALERT_PARAM =0;

}

else if (sensTemp>55){

    ALERT_PARAM =1;

}

else if (sensTemp>90){

    ALERT_PARAM =2;

}

ALERT_LEVEL=0;

topLid.write(OPEN_LID);

digitalWrite(BUZZER, HIGH);

delay(longDelay);

topLid.write(CLOSE_LID);

digitalWrite(BUZZER, LOW);

}

else if (CO2> 4 || sensTemp > 40 || sensMoist > 80){

    if (CO2>4){

        ALERT_PARAM =0;

    }

    else if (sensTemp>40){

        ALERT_PARAM =1;

    }

}
```

IOT BASED FOOD GRAIN STORAGE MONITORING SYSTEM FOR SILOS

```
    }  
    else if (sensMoist>80){  
        ALERT_PARAM =2;  
    }  
    ALERT_LEVEL=1;  
    digitalWrite(BUZZER, HIGH);  
    delay(regDelay);  
    digitalWrite(BUZZER, LOW);  
}  
  
String url = String(REQUEST) + "TEMPERATURE=" + String(sensTemp) +  
"&HUMIDITY=" + String(sensMoist) + "&CO2_CON=" + String(CO2) +  
"&WEIGHT=" + String(force_sensor)+ "&LEVEL=" + String(ALERT_LEVEL)+  
"&PARAM=" + String(ALERT_PARAM);  
  
http.begin(url);  
Serial.println(url);  
int HTTP_CODE = http.GET();  
if (HTTP_CODE > 0)  
{  
    String PAYLOAD = http.getString();  
    Serial.println(PAYLOAD);  
}  
}  
else  
{
```

IOT BASED FOOD GRAIN STORAGE MONITORING SYSTEM FOR SILOS

```
Serial.println("WIFI CONNECTION NOT ESTABLISHED, TRYING  
AGAIN");  
  
}  
  
}
```

4.4 Google Apps Script Program Flowchart

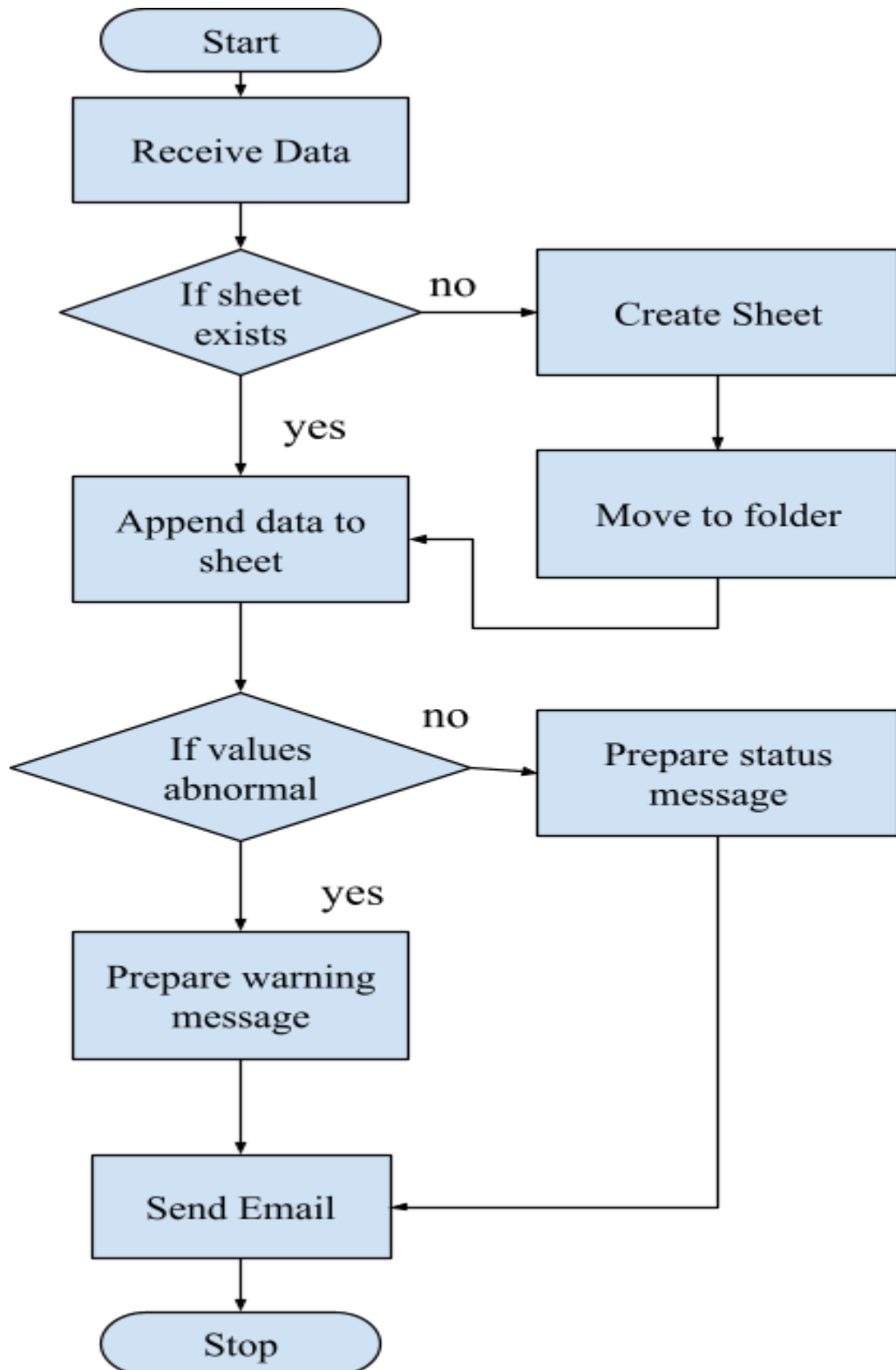


FIGURE 4.4.1 - Google Apps Script Program Flowchart

4.5 Google Apps Scripts Program Code In Google Script(JavaScript)

```

const FOLDER_DUMP = '1rXttMq_gCRJ2TM_2ka71WiCWsq2150od'

function doGet(e) {

    var content = ContentService.createTextOutput(JSON.stringify(e, null, 2));

    console.log(e);

    storeData(e)

    return content;

}

function storeData(values) {

    // function storeData() {

    var date = new Date();

    var current_date = String(date.getDate()).concat("-", (date.getMonth() + 1), '-',
(date.getFullYear()))

    console.log(current_date)

    var folder = DriveApp.getFolderById(FOLDER_DUMP)

    // var current_file_name = String.concat(date.getYear(),"-",date.getMonth())

    // console.log(typeof(date.getMonth()))

    var current_file_name = String(date.getFullYear()).concat("-", (date.getMonth() +
1))

    console.log(current_file_name);

    var current_file = DriveApp.getFilesByName(current_file_name);

    console.log(current_file.hasNext())

```

IOT BASED FOOD GRAIN STORAGE MONITORING SYSTEM FOR SILOS

```
if (current_file.hasNext() == false) {

    var new_SS = SpreadsheetApp.create(current_file_name).getId();

    DriveApp.getFileById(new_SS).moveTo(folder)

    SpreadsheetApp.setActiveSheet(SpreadsheetApp.openById((folder.GetFilesByName(current_file_name).next()).getId()))

    const googleSheet = SpreadsheetApp.getActiveSheet().getSheets()[0];

    googleSheet.setName(current_date);

    googleSheet.appendRow(['DATE', 'TIME', 'TEMPERATURE(C)',
'HUMIDITY(Relative Humidity)', 'CO2 CON(PPM)', 'WEIGHT(N)'])

    var range = googleSheet.getRange(1, 1, googleSheet.getLastRow(), 6);

    range.setHorizontalAlignment('left')

}

else {

    // var current_SS = folder.GetFilesByName(current_file_name).next();
    SpreadsheetApp.setActiveSheet(SpreadsheetApp.openById((folder.GetFilesByName(current_file_name).next()).getId()))

}

// var val = JSON.parse(val)

Logger.log(values)

// COLUMNS

// | DATE | TIME | TEMPERATURE | HUMIDITY | CO2 CON | WEIGHT |

var TEMPERATURE = values['parameter']['TEMPERATURE'];

var HUMIDITY = values['parameter']['HUMIDITY']
```


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```
var CO2_CON = values['parameter']['CO2_CON']

var WEIGHT = values['parameter']['WEIGHT']

var DATA = [current_date, date.toTimeString().split(" ")[0], TEMPERATURE,
HUMIDITY, CO2_CON, WEIGHT]

var PARAM = values['parameter']['PARAM']

var ALERT = values['parameter']['LEVEL']

// var RECIPIENT = values['parameter']['recipient']

// var SUBJECT = PARAMETER.concat("is above threshold values")

const googleSheet = SpreadsheetApp.getActiveSpreadsheet();

var sheet_by_date = googleSheet.getSheetByName(current_date);

if (sheet_by_date == null) {

    var currentDaySheet = googleSheet.insertSheet();

    currentDaySheet.setName(current_date);

    currentDaySheet.appendRow(['DATE', 'TIME', 'TEMPERATURE', 'HUMIDITY',
'CO2 CON', 'WEIGHT'])

}

if (ALERT == "2"){

    var MESSAGE = "NORMAL";

    var COLOUR = "7cfc00";

}

else if (ALERT == "1"){

    var MESSAGE = "WARNING";

    var COLOUR = "ffa500";
```

IOT BASED FOOD GRAIN STORAGE MONITORING SYSTEM FOR SILOS

```
}  
else if (ALERT == "0"){  
    var MESSAGE = "CRITICAL";  
    var COLOUR = "cc0000";  
}  
if (PARAM == "3"){  
    var PARAMETER = "Everything is Normal";  
}  
else if (PARAM == "2"){  
    var PARAMETER = "Humidity levels abnormal";  
}  
else if (PARAM == "1"){  
    var PARAMETER = "Temperature levels abnormal";  
}  
else if (PARAM == "0"){  
    var PARAMETER = "CO2 levels abnormal";  
}  
vals = [MESSAGE, COLOUR, PARAMETER, TEMPERATURE, HUMIDITY,  
CO2_CON, WEIGHT]  
sendMessage(vals)  
var active_sheet = googleSheet.getSheetByName(current_date);  
console.log(DATA);  
active_sheet.appendRow(DATA);
```

IOT BASED FOOD GRAIN STORAGE MONITORING SYSTEM FOR SILOS

```
var range = active_sheet.getRange(1, 1, active_sheet.getLastRow(), 6);

range.setHorizontalAlignment('left')

}

// function sendEmail(String recipient, String subject){

function sendEmailMessage(vals, subject) {

    // var mail = GmailApp.sendEmail(recipient,subject,'hello from the other side')

    var t = HtmlService.createTemplateFromFile('Index');

    // t.value = ['CO2','30.25', '69', '20', '100']

    var date = new Date()

    t.timestamp = String(date.getDate()).concat("-", (date.getMonth() + 1), '-',
(date.getFullYear()), "-",date.getTimeString().split(" ")[0])

    t.alert_level = vals[0];

    t.color = vals[1];

    t.parameter = vals[2];

    t.temperature = vals[3]

    t.humidity = vals[4]

    t.co2 = vals[5]

    t.weight = vals[6]

    GmailApp.sendEmail('19r11a04n1@gcet.edu.in',Report of Silo
,t.evaluate().getContent())

    MailApp.sendEmail({

        to: '19r11a04n1@gcet.edu.in',

        subject: "Report of Silo",
```

IOT BASED FOOD GRAIN STORAGE MONITORING SYSTEM FOR SILOS

```
htmlBody: t.evaluate().getContent(),  
});  
}
```

4.6 Google Apps Script Email Code In HTML

```

<!DOCTYPE html PUBLIC "-//W3C//DTD XHTML 1.0 Transitional//EN"
"http://www.w3.org/TR/xhtml1/DTD/xhtml1-transitional.dtd">

<html xmlns="http://www.w3.org/1999/xhtml"
xmlns:o="urn:schemas-microsoft-com:office:office" style="font-family:arial,
'helvetica neue', helvetica, sans-serif">

<head>

<meta charset="UTF-8">

<meta content="width=device-width, initial-scale=1" name="viewport">

<meta name="x-apple-disable-message-reformatting">

<meta http-equiv="X-UA-Compatible" content="IE=edge">

<meta content="telephone=no" name="format-detection">

<title>New message</title><!--[if (mso 16)]>

<style type="text/css">

a {text-decoration: none;}

</style>

<![endif]--><!--[if gte mso 9]><style>sup { font-size: 100% !important;
}</style><![endif]--><!--[if gte mso 9]>

<xml>

<o:OfficeDocumentSettings>

<o:AllowPNG></o:AllowPNG>

<o:PixelsPerInch>96</o:PixelsPerInch>

</o:OfficeDocumentSettings>

</xml>

```

```
<![endif-->

<style type="text/css">

#outlook a {

    padding:0;

}

.es-button {

    mso-style-priority:100!important;

    text-decoration:none!important;

}

a[x-apple-data-detectors] {

    color:inherit!important;

    text-decoration:none!important;

    font-size:inherit!important;

    font-family:inherit!important;

    font-weight:inherit!important;

    line-height:inherit!important;

}

.es-desk-hidden {

    display:none;

    float:left;

    overflow:hidden;

    width:0;

    max-height:0;
```

IOT BASED FOOD GRAIN STORAGE MONITORING SYSTEM FOR SILOS

```
    line-height:0;
    mso-hide:all;
}

[data-ogsb] .es-button {
    border-width:0!important;
    padding:10px 30px 10px 30px!important;
}

@media only screen and (max-width:600px) {p, ul li, ol li, a {
line-height:150%!important } h1, h2, h3, h1 a, h2 a, h3 a {
line-height:120%!important } h1 { font-size:36px!important; text-align:left } h2 {
font-size:26px!important; text-align:left } h3 { font-size:20px!important;
text-align:left } .es-header-body h1 a, .es-content-body h1 a, .es-footer-body h1 a {
font-size:36px!important; text-align:left } .es-header-body h2 a, .es-content-body h2
a, .es-footer-body h2 a { font-size:26px!important; text-align:left } .es-header-body h3
a, .es-content-body h3 a, .es-footer-body h3 a { font-size:20px!important;
text-align:left } .es-menu td a { font-size:12px!important } .es-header-body p,
.es-header-body ul li, .es-header-body ol li, .es-header-body a {
font-size:14px!important } .es-content-body p, .es-content-body ul li,
.es-content-body ol li, .es-content-body a { font-size:14px!important } .es-footer-body
p, .es-footer-body ul li, .es-footer-body ol li, .es-footer-body a {
font-size:14px!important } .es-infoblock p, .es-infoblock ul li, .es-infoblock ol li,
.es-infoblock a { font-size:12px!important } *[class="gmail-fix"] {
display:none!important } .es-m-txt-c, .es-m-txt-c h1, .es-m-txt-c h2, .es-m-txt-c h3 {
text-align:center!important } .es-m-txt-r, .es-m-txt-r h1, .es-m-txt-r h2, .es-m-txt-r h3
{ text-align:right!important } .es-m-txt-l, .es-m-txt-l h1, .es-m-txt-l h2, .es-m-txt-l h3
{ text-align:left!important } .es-m-txt-r img, .es-m-txt-c img, .es-m-txt-l img {
display:inline!important } .es-button-border { display:inline-block!important }
a.es-button, button.es-button { font-size:20px!important;
display:inline-block!important } .es-adaptive table, .es-left, .es-right {
```

```

width:100%!important } .es-content table, .es-header table, .es-footer table,
.es-content, .es-footer, .es-header { width:100%!important;
max-width:600px!important } .es-adapt-td { display:block!important;
width:100%!important } .adapt-img { width:100%!important; height:auto!important }
.es-m-p0 { padding:0!important } .es-m-p0r { padding-right:0!important } .es-m-p0l {
padding-left:0!important } .es-m-p0t { padding-top:0!important } .es-m-p0b {
padding-bottom:0!important } .es-m-p20b { padding-bottom:20px!important }
.es-mobile-hidden, .es-hidden { display:none!important } tr.es-desk-hidden,
td.es-desk-hidden, table.es-desk-hidden { width:auto!important;
overflow:visible!important; float:none!important; max-height:inherit!important;
line-height:inherit!important } tr.es-desk-hidden { display:table-row!important }
table.es-desk-hidden { display:table!important } td.es-desk-menu-hidden {
display:table-cell!important } .es-menu td { width:1%!important }
table.es-table-not-adapt, .esd-block-html table { width:auto!important } table.es-social
{ display:inline-block!important } table.es-social td { display:inline-block!important }
.es-m-p5 { padding:5px!important } .es-m-p5t { padding-top:5px!important }
.es-m-p5b { padding-bottom:5px!important } .es-m-p5r {
padding-right:5px!important } .es-m-p5l { padding-left:5px!important } .es-m-p10 {
padding:10px!important } .es-m-p10t { padding-top:10px!important } .es-m-p10b {
padding-bottom:10px!important } .es-m-p10r { padding-right:10px!important }
.es-m-p10l { padding-left:10px!important } .es-m-p15 { padding:15px!important }
.es-m-p15t { padding-top:15px!important } .es-m-p15b {
padding-bottom:15px!important } .es-m-p15r { padding-right:15px!important }
.es-m-p15l { padding-left:15px!important } .es-m-p20 { padding:20px!important }
.es-m-p20t { padding-top:20px!important } .es-m-p20r {
padding-right:20px!important } .es-m-p20l { padding-left:20px!important } .es-m-p25
{ padding:25px!important } .es-m-p25t { padding-top:25px!important } .es-m-p25b {
padding-bottom:25px!important } .es-m-p25r { padding-right:25px!important }
.es-m-p25l { padding-left:25px!important } .es-m-p30 { padding:30px!important }
.es-m-p30t { padding-top:30px!important } .es-m-p30b {
padding-bottom:30px!important } .es-m-p30r { padding-right:30px!important }

```


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```
.es-m-p30l { padding-left:30px!important } .es-m-p35 { padding:35px!important }
.es-m-p35t { padding-top:35px!important } .es-m-p35b {
padding-bottom:35px!important } .es-m-p35r { padding-right:35px!important }
.es-m-p35l { padding-left:35px!important } .es-m-p40 { padding:40px!important }
.es-m-p40t { padding-top:40px!important } .es-m-p40b {
padding-bottom:40px!important } .es-m-p40r { padding-right:40px!important }
.es-m-p40l { padding-left:40px!important } .es-desk-hidden {
display:table-row!important; width:auto!important; overflow:visible!important;
max-height:inherit!important } }

</style>

</head>

<body data-new-gr-c-s-loaded="14.1070.0" style="width:100%;font-family:arial,
'helvetica neue', helvetica,
sans-serif;-webkit-text-size-adjust:100%;-ms-text-size-adjust:100%;padding:0;Margin
:0">

  <div class="es-wrapper-color" style="background-color:#FAFAFA"><!--[if gte mso
9]>

      <v:background xmlns:v="urn:schemas-microsoft-com:vml"
fill="t">

          <v:fill type="tile" color="#fafafa"></v:fill>

      </v:background>

    <![endif]-->

    <table class="es-wrapper" width="100%" cellpadding="0"
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cing:0px;padding:0;Margin:0;width:100%;height:100%;background-repeat:repeat;bac
kground-position:center top;background-color:#FAFAFA">

      <tr>
```

IOT BASED FOOD GRAIN STORAGE MONITORING SYSTEM FOR SILOS

```
<td valign="top" style="padding:0;Margin:0">

    <table cellpadding="0" cellspacing="0" class="es-content" align="center"
style="mso-table-lspace:0pt;mso-table-rspace:0pt;border-collapse:collapse;border-spa
cing:0px;table-layout:fixed !important;width:100%">

        <tr>

            <td class="es-info-area" align="center" style="padding:0;Margin:0">

                <table class="es-content-body" align="center" cellpadding="0"
cellspacing="0"
style="mso-table-lspace:0pt;mso-table-rspace:0pt;border-collapse:collapse;border-spa
cing:0px;background-color:transparent;width:600px" bgcolor="#FFFFFF">

                    <tr>

                        <td align="left" style="padding:20px;Margin:0">

                            <table cellpadding="0" cellspacing="0" width="100%"
style="mso-table-lspace:0pt;mso-table-rspace:0pt;border-collapse:collapse;border-spa
cing:0px">

                                <tr>

                                    <td align="center" valign="top"
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                                        <table cellpadding="0" cellspacing="0" width="100%"
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cing:0px">

                                            <tr>

                                                <td align="center" style="padding:0;Margin:0;display:none"></td>

                                            </tr>

                                        </table></td>

                                    </tr>

                                </table></td>

                            </tr>

                        </td>

                    </tr>

                </table>

            </td>

        </tr>

    </table>
```

IOT BASED FOOD GRAIN STORAGE MONITORING SYSTEM FOR SILOS

```
</table></td>

</tr>

</table></td>

</tr>

</table>

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<tr>

<td class="es-m-p0r" valign="top" align="center"
style="padding:0;Margin:0;width:560px">
```

IOT BASED FOOD GRAIN STORAGE MONITORING SYSTEM FOR SILOS

```
<table cellpadding="0" cellspacing="0" width="100%"
style="mso-table-lspace:0pt;mso-table-rspace:0pt;border-collapse:collapse;border-spa
cing:0px">

    <tr>

        <td align="center" style="padding:0;Margin:0;display:none"></td>

    </tr>

</table></td>

</tr>

</table></td>

</tr>

</table></td>

</tr>

</table>

<table cellpadding="0" cellspacing="0" class="es-content" align="center"
style="mso-table-lspace:0pt;mso-table-rspace:0pt;border-collapse:collapse;border-spa
cing:0px;table-layout:fixed !important;width:100%">

    <tr>

        <td align="center" style="padding:0;Margin:0">

            <table bgcolor="#ffffff" class="es-content-body" align="center"
cellpadding="0" cellspacing="0"
style="mso-table-lspace:0pt;mso-table-rspace:0pt;border-collapse:collapse;border-spa
cing:0px;background-color:#FFFFFF;width:600px">

                <tr>
```

IOT BASED FOOD GRAIN STORAGE MONITORING SYSTEM FOR SILOS

```
<td align="left"
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>

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style="mso-table-lspace:0pt;mso-table-rspace:0pt;border-collapse:collapse;border-spa
cing:0px">

<tr>

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<table cellpadding="0" cellspacing="0" width="100%"
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cing:0px">

<tr>

<td align="center"
style="padding:0;Margin:0;padding-top:10px;padding-bottom:10px;font-size:0px"><i
mg
src="https://jtwivw.stripocdn.email/content/guids/CABINET_d0083983c1a429c1d92
72e38a5b350a3/images/1401618430238266.png" alt
style="display:block;border:0;outline:none;text-decoration:none;-ms-interpolation-mo
de:bicubic" width="100"></td>

</tr>

<tr>

<td align="center" class="es-m-txt-c"
style="padding:0;Margin:0;padding-bottom:20px"><h1
style="Margin:0;line-height:46px;mso-line-height-rule:exactly;font-family:arial,
'helvetica neue', helvetica,
sans-serif;font-size:46px;font-style:normal;font-weight:bold;color:#333333"><?=
parameter ?></h1></td>
```

IOT BASED FOOD GRAIN STORAGE MONITORING SYSTEM FOR SILOS

```
</tr>

</table></td>

</tr>

</table></td>

</tr>

</table></td>

</tr>

</table>

<table cellpadding="0" cellspacing="0" class="es-content" align="center"
style="mso-table-lspace:0pt;mso-table-rspace:0pt;border-collapse:collapse;border-spacing:0px;table-layout:fixed !important;width:100%">

<tr>

<td align="center" style="padding:0;Margin:0">

<table bgcolor="#ffffff" class="es-content-body" align="center"
cellpadding="0" cellspacing="0"
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<tr>

<td align="left"
style="padding:0;Margin:0;padding-bottom:10px;padding-left:20px;padding-right:20px">

<table cellpadding="0" cellspacing="0" width="100%"
style="mso-table-lspace:0pt;mso-table-rspace:0pt;border-collapse:collapse;border-spacing:0px">

<tr>
```

IOT BASED FOOD GRAIN STORAGE MONITORING SYSTEM FOR SILOS

```
<td align="left" style="padding:0;Margin:0;width:560px">
    <table cellpadding="0" cellspacing="0" width="100%"
style="mso-table-lspace:0pt;mso-table-rspace:0pt;border-collapse:collapse;border-spa
cing:0px">
    <tr>
        <td align="center"
style="padding:0;Margin:0;padding-top:10px;padding-bottom:20px"><p
style="Margin:0;-webkit-text-size-adjust:none;-ms-text-size-adjust:none;mso-line-hei
ght-rule:exactly;font-family:arial, 'helvetica neue', helvetica,
sans-serif;line-height:21px;color:#333333;font-size:14px"><?= parameter ?>, this
event has occurred at <?= timestamp ?>, please make sure to necessary actions
before the value reaches the threshold value, else emergency measures will be
taken&nbsp;to mitigate critical issues.</p></td>
    </tr>
    <tr>
        <td align="center" style="padding:0;Margin:0"><span
class="es-button-border"
style="border-style:solid;border-color:#2CB543;background:#cc0000;border-width:0
px;display:inline-block;border-radius:5px;width:auto"><a href="" class="es-button"
target="_blank" style="mso-style-priority:100
!important;text-decoration:none;-webkit-text-size-adjust:none;-ms-text-size-adjust:no
ne;mso-line-height-rule:exactly;color:#FFFFFF;font-size:20px;border-style:solid;bord
er-color:#<?= color ?>;border-width:10px 30px 10px
30px;display:inline-block;background:#<?= color
?>;border-radius:5px;font-family:arial, 'helvetica neue', helvetica,
sans-serif;font-weight:normal;font-style:normal;line-height:24px;width:auto;text-alig
n:center"><?= alert_level?></a></span></td>
    </tr>
```

IOT BASED FOOD GRAIN STORAGE MONITORING SYSTEM FOR SILOS

```
</table></td>

</tr>

</table></td>

</tr>

<tr>

<td align="left"
style="padding:0;Margin:0;padding-top:20px;padding-left:20px;padding-right:20px"
><!--[if mso]><table style="width:560px" cellpadding="0" cellspacing="0"><tr><td
style="width:145px" valign="top"><![endif]-->

<table cellpadding="0" cellspacing="0" class="es-left" align="left"
style="mso-table-lspace:0pt;mso-table-rspace:0pt;border-collapse:collapse;border-spa
cing:0px;float:left">

<tr>

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cing:0px">

<tr>

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style="Margin:0;-webkit-text-size-adjust:none;-ms-text-size-adjust:none;mso-line-hei
ght-rule:exactly;font-family:arial, 'helvetica neue', helvetica,
sans-serif;line-height:21px;color:#333333;font-size:14px">TEMPERATURE<br><?=
temperature ?></p></td>

</tr>

</table></td>
```


IOT BASED FOOD GRAIN STORAGE MONITORING SYSTEM FOR SILOS

```
<td class="es-hidden" style="padding:0;Margin:0;width:20px"></td>
</tr>
</table><!--[if mso]></td><td style="width:145px"
valign="top"><![endif]-->
<table cellpadding="0" cellspacing="0" class="es-left" align="left"
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cing:0px;float:left">
<tr>
<td class="es-m-p20b" align="center"
style="padding:0;Margin:0;width:125px">
<table cellpadding="0" cellspacing="0" width="100%"
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cing:0px">
<tr>
<td align="center" style="padding:0;Margin:0"><p
style="Margin:0;-webkit-text-size-adjust:none;-ms-text-size-adjust:none;mso-line-hei
ght-rule:exactly;font-family:arial, 'helvetica neue', helvetica,
sans-serif;line-height:21px;color:#333333;font-size:14px">HUMIDITY</p><p
style="Margin:0;-webkit-text-size-adjust:none;-ms-text-size-adjust:none;mso-line-hei
ght-rule:exactly;font-family:arial, 'helvetica neue', helvetica,
sans-serif;line-height:21px;color:#333333;font-size:14px"><?= humidity
?></p></td>
</tr>
</table></td>
<td class="es-hidden" style="padding:0;Margin:0;width:20px"></td>
</tr>
```

IOT BASED FOOD GRAIN STORAGE MONITORING SYSTEM FOR SILOS

```
</table><!--[if mso]></td><td style="width:125px"
valign="top"><![endif]-->

<table cellpadding="0" cellspacing="0" class="es-left" align="left"
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cing:0px;float:left">

<tr>

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cing:0px">

<tr>

<td align="center" style="padding:0;Margin:0"><p
style="Margin:0;-webkit-text-size-adjust:none;-ms-text-size-adjust:none;mso-line-hei
ght-rule:exactly;font-family:arial, 'helvetica neue', helvetica,
sans-serif;line-height:21px;color:#333333;font-size:14px">CO2 Level<br><?=? co2
?></p></td>

</tr>

</table></td>

</tr>

</table><!--[if mso]></td><td style="width:20px"></td><td
style="width:125px" valign="top"><![endif]-->

<table cellpadding="0" cellspacing="0" class="es-right" align="right"
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cing:0px;float:right">

<tr>
```

IOT BASED FOOD GRAIN STORAGE MONITORING SYSTEM FOR SILOS

```
<td align="center" style="padding:0;Margin:0;width:125px">

    <table cellpadding="0" cellspacing="0" width="100%"
style="mso-table-lspace:0pt;mso-table-rspace:0pt;border-collapse:collapse;border-spa
cing:0px">

        <tr>

            <td align="center" style="padding:0;Margin:0"><p
style="Margin:0;-webkit-text-size-adjust:none;-ms-text-size-adjust:none;mso-line-hei
ght-rule:exactly;font-family:arial, 'helvetica neue', helvetica,
sans-serif;line-height:21px;color:#333333;font-size:14px">WEIGHT<br><?= weight
?></p></td>

        </tr>

    </table></td>

</tr>

</table><!--[if mso]></td></tr></table><![endif]--></td>

</tr>

<tr>

    <td align="left"
style="Margin:0;padding-bottom:10px;padding-top:15px;padding-left:20px;padding-r
ight:20px">

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cing:0px">

            <tr>

                <td align="left" style="padding:0;Margin:0;width:560px">
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IOT BASED FOOD GRAIN STORAGE MONITORING SYSTEM FOR SILOS

```
<table cellpadding="0" cellspacing="0" width="100%"
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cing:0px">

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style="Margin:0;-webkit-text-size-adjust:none;-ms-text-size-adjust:none;mso-line-hei
ght-rule:exactly;font-family:arial, 'helvetica neue', helvetica,
sans-serif;line-height:21px;color:#333333;font-size:14px">Got a
question?&nbsp;Email me&nbsp;at <a target="_blank"
href="mailto:theinhumaneme@gmail.com"
style="-webkit-text-size-adjust:none;-ms-text-size-adjust:none;mso-line-height-rule:e
xactly;text-decoration:underline;color:#5C68E2;font-size:14px">theinhumaneme@g
mail.com</a></p></td>

    </tr>

</table></td>

</tr>

</table></td>

</tr>

</table></td>

</tr>

</table>

<table cellpadding="0" cellspacing="0" class="es-footer" align="center"
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cing:0px;table-layout:fixed
!important;width:100%;background-color:transparent;background-repeat:repeat;back
ground-position:center top">
```

IOT BASED FOOD GRAIN STORAGE MONITORING SYSTEM FOR SILOS

```
<tr>

<td align="center" style="padding:0;Margin:0">

<table class="es-footer-body" align="center" cellpadding="0" cellspacing="0"
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cing:0px;background-color:transparent;width:640px">

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style="Margin:0;padding-top:20px;padding-bottom:20px;padding-left:20px;padding-r
ight:20px">

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cing:0px">

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<tr>

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<table cellpadding="0" cellspacing="0" class="es-table-not-adapt
es-social"
style="mso-table-lspace:0pt;mso-table-rspace:0pt;border-collapse:collapse;border-spa
cing:0px">

<tr>
```

IOT BASED FOOD GRAIN STORAGE MONITORING SYSTEM FOR SILOS

```
<td align="center" valign="top" style="padding:0;Margin:0"></td>
```

```
<td align="center" valign="top" style="padding:0;Margin:0"><a
target="_blank" href="https://www.instagram.com/theinhumaneme/"
style="-webkit-text-size-adjust:none;-ms-text-size-adjust:none;mso-line-height-rule:e
xactly;text-decoration:underline;color:#333333;font-size:12px"></a></td>
```

```
<td align="center" valign="top" style="padding:0;Margin:0"><a
target="_blank" href="https://www.linkedin.com/in/kalyan-mudumby-736a40166/"
style="-webkit-text-size-adjust:none;-ms-text-size-adjust:none;mso-line-height-rule:e
xactly;text-decoration:underline;color:#333333;font-size:12px"></a></td>
```

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</tr>
```

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</table></td>
```

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</tr>
```

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<tr>
```

IOT BASED FOOD GRAIN STORAGE MONITORING SYSTEM FOR SILOS

```
<td align="center"
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style="Margin:0;-webkit-text-size-adjust:none;-ms-text-size-adjust:none;mso-line-hei
ght-rule:exactly;font-family:arial, 'helvetica neue', helvetica,
sans-serif;line-height:18px;color:#333333;font-size:12px">TEAM E-13, Geethanjali
College of Engineering and Technology</p></td>
```

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</tr>
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</table></td>
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</tr>
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</table></td>
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</tr>
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</tr>
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</table>
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cing:0px;table-layout:fixed !important;width:100%">
```

```
<tr>
```

```
<td class="es-info-area" align="center" style="padding:0;Margin:0">
```

```
<table class="es-content-body" align="center" cellpadding="0"
cellspacing="0"
style="mso-table-lspace:0pt;mso-table-rspace:0pt;border-collapse:collapse;border-spa
cing:0px;background-color:transparent;width:600px" bgcolor="#FFFFFF">
```

```
<tr>
```

```
<td align="left" style="padding:20px;Margin:0">
```

IOT BASED FOOD GRAIN STORAGE MONITORING SYSTEM FOR SILOS

```
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```

```
<tr>
```

```
<td align="center" valign="top" style="padding:0;Margin:0;width:560px">
```

```
<table cellpadding="0" cellspacing="0" width="100%" style="mso-table-lspace:0pt;mso-table-rspace:0pt;border-collapse:collapse;border-spacing:0px">
```

```
<tr>
```

```
<td align="center" class="es-infoblock" style="padding:0;Margin:0;line-height:14px;font-size:12px;color:#CCCCCC"><p style="Margin:0;-webkit-text-size-adjust:none;-ms-text-size-adjust:none;mso-line-height-rule:exactly;font-family:arial, 'helvetica neue', helvetica, sans-serif;line-height:14px;color:#CCCCCC;font-size:12px"><a target="_blank" href="" style="-webkit-text-size-adjust:none;-ms-text-size-adjust:none;mso-line-height-rule:exactly;text-decoration:underline;color:#CCCCCC;font-size:12px"></a>No longer want to receive these emails?&nbsp;<a href="" target="_blank" style="-webkit-text-size-adjust:none;-ms-text-size-adjust:none;mso-line-height-rule:exactly;text-decoration:underline;color:#CCCCCC;font-size:12px">Unsubscribe</a>. <a target="_blank" href="" style="-webkit-text-size-adjust:none;-ms-text-size-adjust:none;mso-line-height-rule:exactly;text-decoration:underline;color:#CCCCCC;font-size:12px"></a></p></td>
```

```
</tr>
```

```
</table></td>
```

```
</tr>
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```
</table></td>
```


IOT BASED FOOD GRAIN STORAGE MONITORING SYSTEM FOR SILOS

```
</tr>  
</table></td>  
</tr>  
</table></td>  
</tr>  
</table>  
</div>  
</body>  
</html>
```

5. OPERATING PROCEDURE

In the project, we monitor the parameters of the silo like Temperature, Humidity, CO₂ concentration and weight of the grains using sensors. We monitor the CO₂ concentration of the silo in PPM, using an MQ135 sensor which monitors it as a priority in our readings. The MQ135 sensor works on a resistive element whose resistance changes with respect to the changes in concentration, according to the concentration of the gases which is reflected as an output voltage. This output voltage is in the range of 0-5V which is reduced to 3.3 volts using a voltage divider circuit, as the ESP32 cannot handle more than 3.3 volts as the input voltage. We also read the temperature and the humidity values from the DHT-11 sensor which has a sampling rate of 1 second. The temperature values read from the sensor are in Celsius and the humidity values are in terms of Relative Humidity. We use a round force sensor that gives the total force applied on the sensor. These values are then stored in variables of their specific data type to be stored in the database made using Google Sheets.

We have used Google Sheets as our database as it is very user friendly, cloud based and also has a very generous free tier for our use case. We integrate the ESP32 using Google Apps Script that helps us read values that are sent from the ESP32 using a web POST request. The app reads the values from the parameters sent in the POST request to the app script instance. These apps are run on Google's custom Javascript runtime V8 chrome engines, that have almost 0ms cold start and can be accessed from anywhere in the world. This POST request is processed by the google servers and sent to the application where the data of the parameters is parsed and stored as a new row in the excel sheet/ google sheet. The data is analysed in the code to find out any abnormalities in the values and then processed accordingly. If any abnormality is suspected or identified in the values, an Email using G-mail is sent to the user/farmer which has all the values in the email in a user friendly format. And also when the abnormality occurs, for better understanding about the problem, if the user/ farmer is unable to take any action and any of the values reaches the maximum threshold limit, an emergency procedure initialised automatically on the ESP32 to protect the produce from further damage.

6. RESULTS

After the ESP32 has been turned on for some time we can see that our data is being aggregated in the google sheets (Figure 6.5). The data is inserted into the sheet that corresponds to the google sheet file of that particular month and the subsheet of the google sheet. If the google sheets file of the month doesn't exist, a google sheet file is created and moved into the master folder (Figure 6.3). Similarly, if a subsheet doesn't exist in the google sheet file, it is created and the data is appended, after which we can analyse the data using sheet's inbuilt tools such as graphs and other visual components (Figure 6.4). We can also see the emails that we receive when the parameters in the silo are within limits, status normal (Figure 6.6), over threshold, warning status (Figure 6.7), over maximum status and critical status (Figure 6.8).

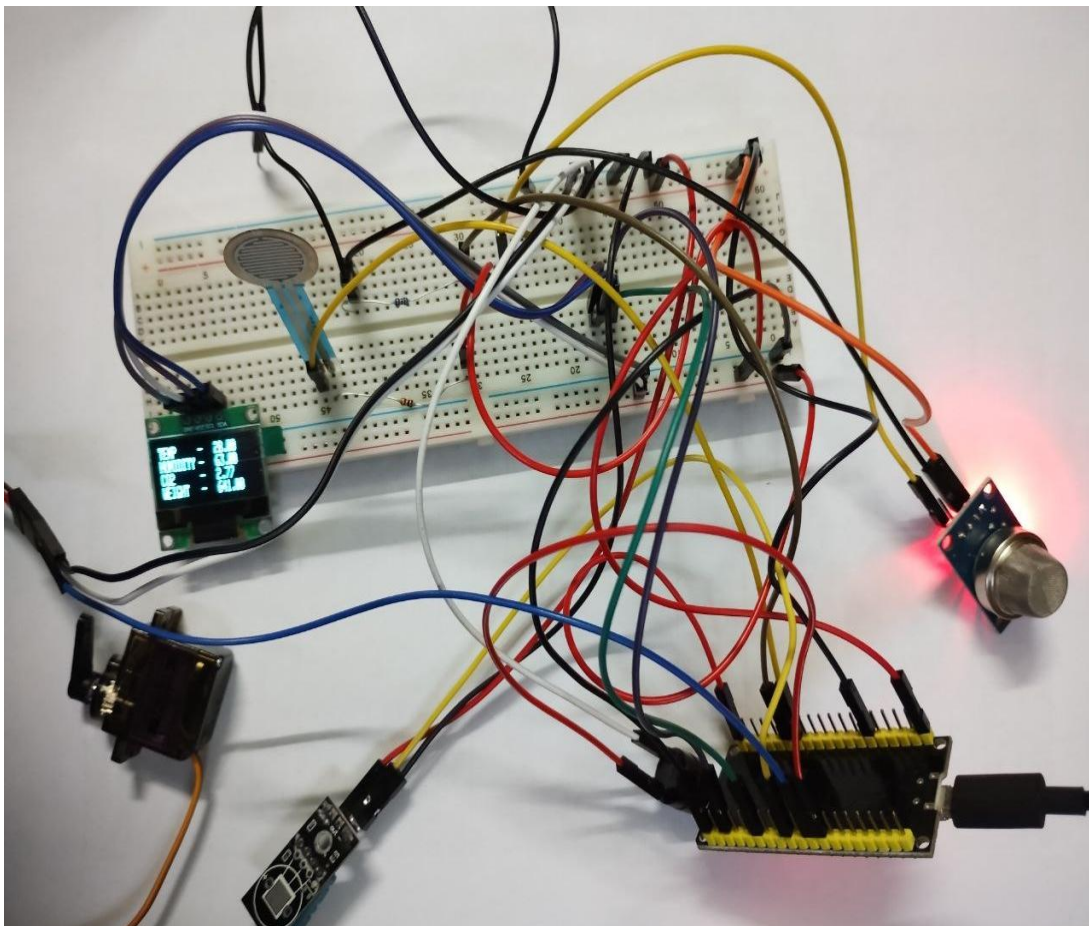


FIGURE 6.1 - Connection of Components

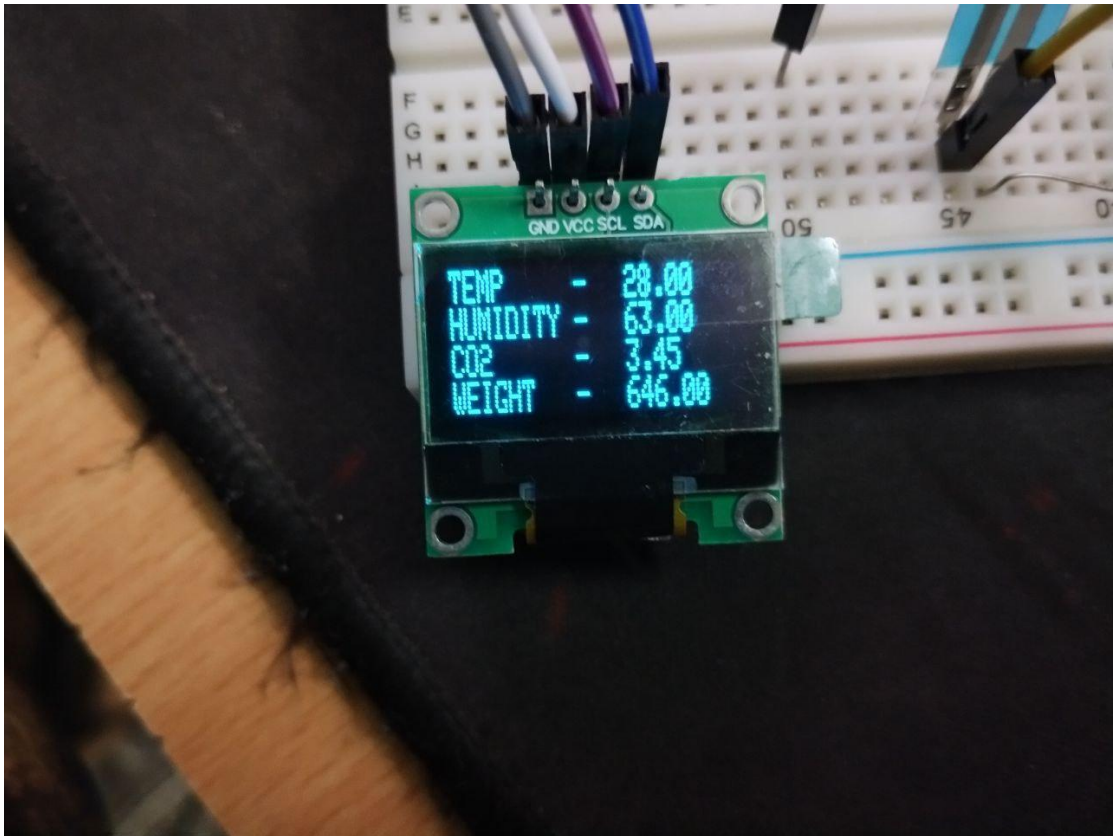


FIGURE 6.2 - Output Values on OLED Display

Name	Owner	Last modified	File size
2022-9	me	3:37 AM me	5 KB
2022-8	me	Aug 31, 2022 me	1 KB

FIGURE 6.3 - Google Sheet Files In Folder



FIGURE 6.4 - Sub Sheets In The Google Sheet

IOT BASED FOOD GRAIN STORAGE MONITORING SYSTEM FOR SILOS

	A	B	C	D	E	F
1	DATE	TIME	TEMPERATURE(in C)	HUMIDITY(Relative Humidity)	CO2 CON(in PPM)	WEIGHT
2	2-9-2022	12:18:04	30.9	66	0.11	82
3	2-9-2022	12:18:12	30.8	66	0.1	0
4	2-9-2022	12:18:18	30.8	66	0.11	0
5	2-9-2022	12:18:23	30.7	66	0.1	11
6	2-9-2022	12:18:29	30.7	66	0.18	0

FIGURE 6.5 - Google Apps Script Results

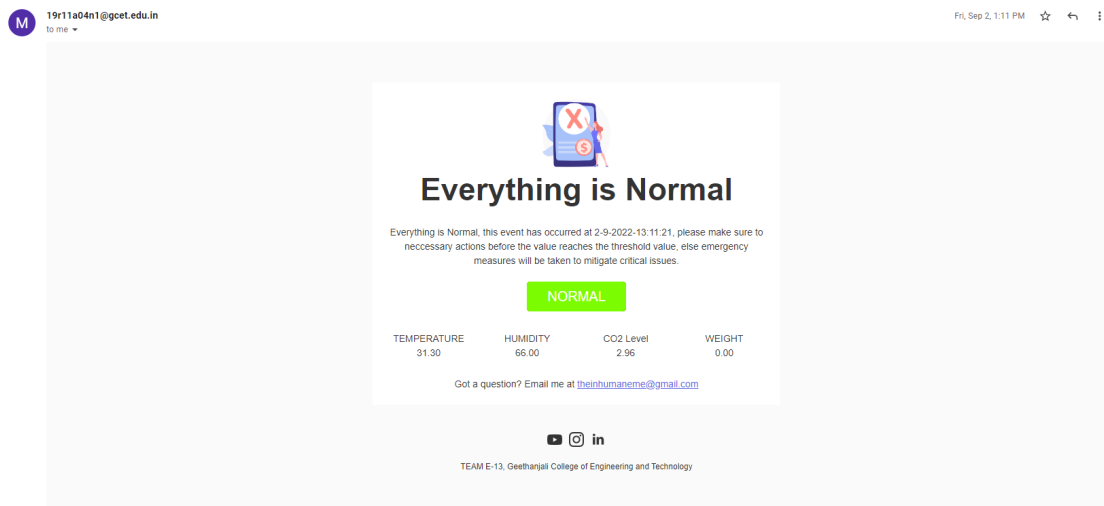


FIGURE 6.6 - Normal Status Email

IOT BASED FOOD GRAIN STORAGE MONITORING SYSTEM FOR SILOS

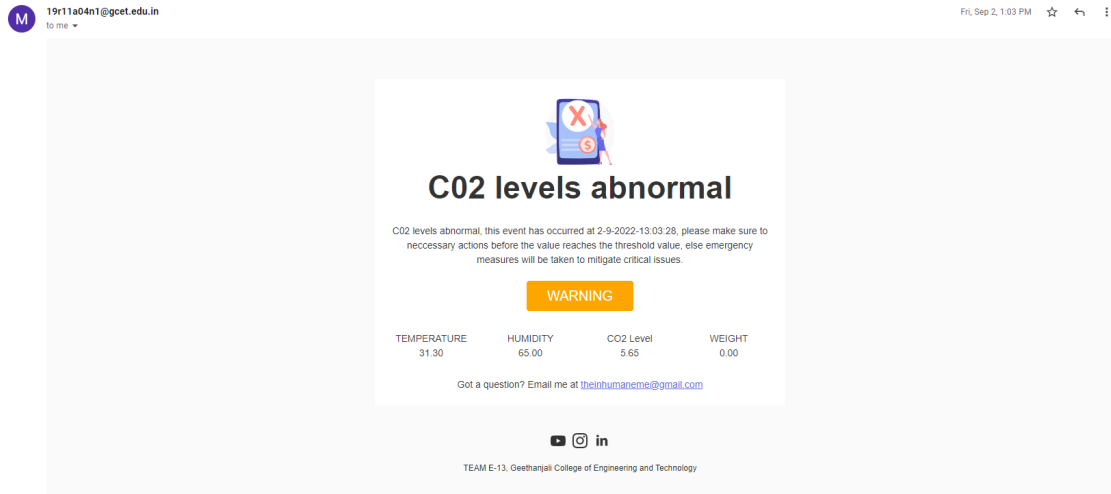


FIGURE 6.7 - Warning Status Email

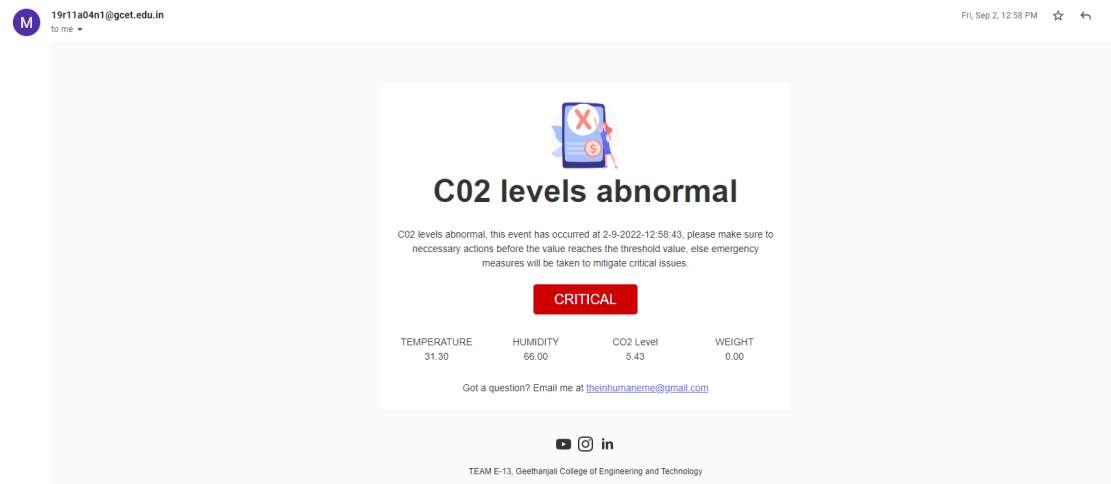


FIGURE 6.8 - Critical Status Email

7. CONCLUSION

By the end of our project “IOT BASED FOOD GRAIN STORAGE MONITORING SYSTEM FOR SILOS”, we have developed a way to monitor the food grains in silos on various parameters such as temperature, relative humidity, Carbon-di-oxide concentration levels and weight of the grain in the silo. By using Google Cloud Platform we have also developed a Data ingest system to aggregate the data from the silo control station and notify the farmer/user about the status of the silo when any parameter is above threshold limits via an email through gmail. This project uses all the possible ways to alert the user/farmer about the abnormalities in the silo, the data ingested is stored on the cloud platform which is reliable which enables us to store and visualise the data to better understand how the grain reacts to the changes of the parameters that are being monitored. The project also makes sure that the grain and the farmer are safe at all times as we have implemented an emergency procedure that is activated automatically when any of the parameters exceeds the maximum threshold value. We believe that this project is highly useful for farmers who cannot spend large sums of money on expensive storage systems to store their harvest. This will help all small-medium scale farmers to sell their grain as they wish and need not depend on any middlemen in the market, helping them get better prices for their produce.

8. FUTURE SCOPE

This project has immense future scope as we can deploy multiple such monitoring systems in multiple silos at the same time. In such mass deployment situations the data ingress point is the same but the control hub needs to be installed in multiple silos. Using WiFi as a means of internet connectivity will get expensive in such deployments, so the data can be transmitted to another machine that acts as a Data Ingress station / Hub, and the control system is a spoke of such a hub. These devices could be connected by a low power, low energy communication such as LoRa technology which can transmit and receive data over large distances, helping us deploy such monitoring systems even in the most remote places of the country at minimal cost. This helps the government analyse and help create better solutions for farmers to store produce and support them by providing subsidies if anything goes wrong. This helps us collect data about various grains in a variety of storage conditions which will aid us in understanding the climatic conditions and the grain better, helping us create a more comprehensive solution in the time to come. As we use Google Cloud Platform in the future, we can also deploy multiple instances on the edge and make the system completely automated and human error free. With this project we can avoid all types of food grain wastage at all levels of its product life cycle.

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