IOT-Enabled Temperature and Humidity Tracking System for Food Processing Industry

Chithra G[1], Nageshwari P[2], Logeshwaran K[3], Jaisurya R[4], Rasmika S[5], Sanjay S[6], Madhan M[7]
[1]*Assistant professor, Department of Food Technology, Excel Engineering College, Namakkal*
[2,4,5,6,7]*Student, Department of Food Technology, Excel Engineering College, Namakkal*
[3]*Student, Department of Computer Science and Business Systems, Excel Engineering College, Namakkal*
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***Abstract*—The proposed system presents an Internet-of-Things (IoT [4])–enabled food spoilage detection unit that continuously monitors internal and external parameters affecting food freshness. It integrates a needle-type [3] DS18B20 [3] temperature probe [2], a DHT11 [2] humidity sensor [2]], and an MQ-3 [1] [1] gas sensor [1] [1][1]. The needle probe is inserted directly into the food material to measure its core temperature, providing a more accurate and earlier indicator of spoilage than air-based sensors. Data from all sensors are processed by a NodeMCU [4] microcontroller [4], which triggers a buzzer and display alert when threshold values are exceeded. The real-time information can also be transmitted through Wi-Fi for remote access. This combination of needle-based internal sensing and IoT [4] communication offers a low-cost, efficient, and reliable solution for food safety monitoring and reduction of wastage.**

***Index Terms*—Food Spoilage Detection, Internet of Things (IoT [4]), NodeMCU [4], Needle type, Gas sensor [1] [1]s, Real-time Monitoring, Smart Food Storage, Food Safety.**

I. INTRODUCTION

1.1 Overview

Food spoilage is a significant concern in households, restaurants, and food industries, as it leads to wastage, health hazards, and economic losses [5]. Detecting spoilage early can prevent the consumption of unsafe food and ensure quality control. Traditional methods of spoilage detection, such as visual inspection and smell, are often subjective and unreliable [5]. Therefore, the integration of electronic sensors provides a more accurate and real-time solution for monitoring food freshness. The proposed system utilizes a NodeMCU [4] microcontroller [4], which offers Wi-Fi connectivity and ease of programming, making it suitable for IoT [4] applications. It incorporates the MQ3 [1] [1] gas sensor [1] [1][1] to detect alcohol and other volatile compounds released during food decomposition, along with temperature and humidity sensor [2]s to monitor environmental conditions that accelerate spoilage. By continuously analyzing the sensor data, the system can determine whether the stored food is still safe for consumption or has spoiled. This intelligent food spoilage detector aims to provide a cost-effective, automated, and real-time monitoring solution. The collected data can be transmitted to a cloud platform or mobile application, enabling users to receive instant alerts and make informed decisions [4]. Such a system not only enhances
food safety but also helps reduce waste and optimize storage conditions, contributing to more sustainable food management practices. Most existing IoT [4]-based food monitoring systems record only the surrounding air temperature and gas composition [4]. However, the internal temperature of a food product is a more sensitive indicator of microbial activity [5]. To address this limitation, the proposed system incorporates a needle-type [3] stainless-steel temperature probe [2] that is inserted directly into the food sample. Continuous measurement of the internal or core temperature, together with ambient gas and humidity data, enhances the accuracy and early detection capability of the system.

II. EXISTING SYSTEM

The existing system for food spoilage detection is designed to monitor the freshness of perishable items by utilizing gas sensor [1] [1]s, specifically the MQ-3

[1] [1] sensor [1], along with temperature and humidity sensor [2] s.

The system is built around a Node MCU [4] microcontroller [4], which serves as the central processing unit. The MQ-3 [1] [1] gas sensor [1] detects the presence of gases such as alcohol, smoke, and other volatile compounds that are commonly emitted during food spoilage [1]. Simultaneously, temperature and humidity sensor [2]s measure environmental conditions that can accelerate or inhibit spoilage processes [3]. The collected data is processed by the Node MCU [4][4], which can trigger alerts or notifications when the sensor readings indicate potential spoilage conditions. This integrated approach provides a real-time and automated solution to ensure food safety and reduce waste by early detection of spoilage, making it highly effective for use in food storage and transportation environments. However, the existing system lacks an internal sensing mechanism. It only measures ambient air temperature and humidity, which can delay spoilage detection. The proposed needle-type [3] design[2] resolves this limitation

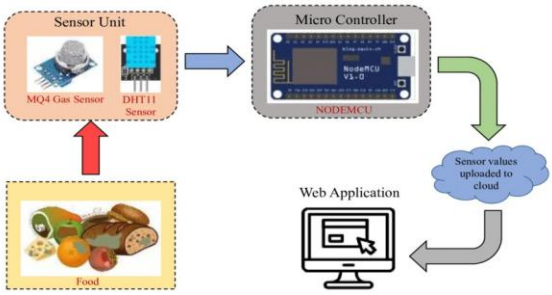

Figure 1: Existing Model Diagram

III. PROPOSED SYSTEM

3.1 Block Diagram

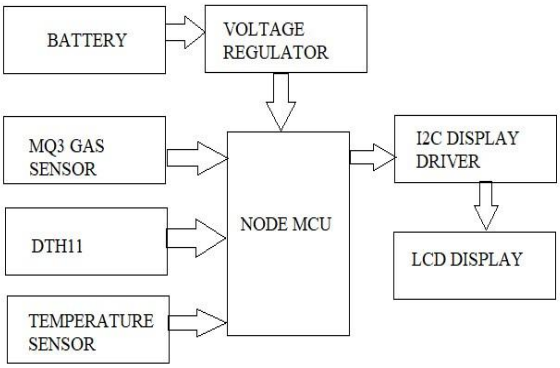

Figure 2: Proposed Model Diagram

The proposed system is designed to detect spoiled food by monitoring the production of spoilage gases, temperature, and humidity levels using a Node MCU [4] microcontroller. The system integrates an MQ-3 [1] [1] gas sensor [1]to detect volatile compounds such as alcohol, smoke, and other gases released during food spoilage. Additionally, temperature and humidity sensor [2]s are incorporated to monitor environmental conditions that can accelerate or inhibit spoilage processes. The Node MCU [4] acts as the central processing unit, gathering data from all sensors in real-time. When the sensors detect gas concentrations or environmental conditions exceed predefined safety thresholds, the system triggers alerts, such as notifications or visual indicators, to inform users about the potential spoilage of the food.

This proactive approach helps in preventing food wastage and ensures food safety by providing timely and accurate spoilage detection, making it ideal for use in refrigerators, storage facilities, or food production units.

3.2 Explanation

1. Power Supply

Function: Provides the necessary voltage and current to all components.

Details: Usually a 5V DC power supply connected via USB or a regulated power adapter to the NodeMCU [4] and sensors.

2. NodeMCU [4] Microcontroller

Function: Acts as the central processing unit.

Details: It receives data from sensors, processes the information, and makes decisions regarding the spoilage status.

3. Gas sensor [1] (MQ-3 [1] [1])

Function: Detects the presence and concentration of alcohol and other gases associated with spoiled food.

Details: The sensor outputs an analog voltage proportional to the gas concentration, which is read by the ADC pin of NodeMCU [4].

4. Temperature sensor [3]

Function: Measures the current temperature of the food environment. Details: A needle-type [3] DS18B20 [3] temperature probe is used to measure the internal temperature of the food sample, while DHT11 [2] monitors ambient temperature and humidity.

5. Humidity sensor [2]

Function: Measures the relative humidity around the food.

Details: Often integrated with the temperature sensor [3] (like DHT22) or as a separate sensor; data is read via digital interface.

6. Data Processing & Decision Logic

Function: The NodeMCU [4] processes sensor data to determine spoilage.

Details: If gas concentration exceeds a threshold, or if temperature/humidity are outside safe limits, the system flags the food as spoiled. The decision logic can be programmed based on predefined thresholds.

7. Output Indicators

Function: Notify the user about the spoilage status.

Details: Can include LEDs, LCD [4] display, or a buzzer for alerts.

Alternatively, data can be sent to a remote server or app via Wi-Fi.

8. Communication Module (Wi-Fi)

Function: Enables wireless data transmission.

Details: NodeMCU [4]'s integrated Wi-Fi module allows sending alerts or data logs to cloud services or mobile apps.

3.3 Applications

- Food Freshness Monitoring:

Continuously tracks gas concentrations indicative of spoilage, ensuring food remains fresh within safe limits.

- Real-time Spoilage Detection:

Provides instant alerts when gas levels, temperature, or humidity cross predefined thresholds, preventing consumption of spoiled food.

- Smart Kitchen Integration:

Can be integrated into smart home systems to automatically notify users via smartphone apps or IoT [4] dashboards.

- Food Storage Optimization:

Helps optimize storage conditions by monitoring temperature and humidity, maintaining ideal environments to extend food shelf life.

- Prevent Food Waste:

Early spoilage detection reduces unnecessary food wastage by alerting before food becomes unsafe.

- Enhanced Food Safety:

Ensures food safety compliance by monitoring spoilage indicators, crucial for commercial kitchens and food processing units.

- Data Logging & Analysis:

Stores historical data for analysis, enabling users to identify spoilage patterns and improve storage practices.

- Cost-efficient Solution:

Utilizes low-cost sensors and microcontroller, making it affordable for household and commercial use.

- Remote Monitoring:

Enables remote supervision via Wi-Fi, allowing users to check food conditions from anywhere.

- Automated Alerts & Notifications:

Sends alerts through SMS, email, or app notifications to prompt timely actions, ensuring food safety.

3.4 System Architecture

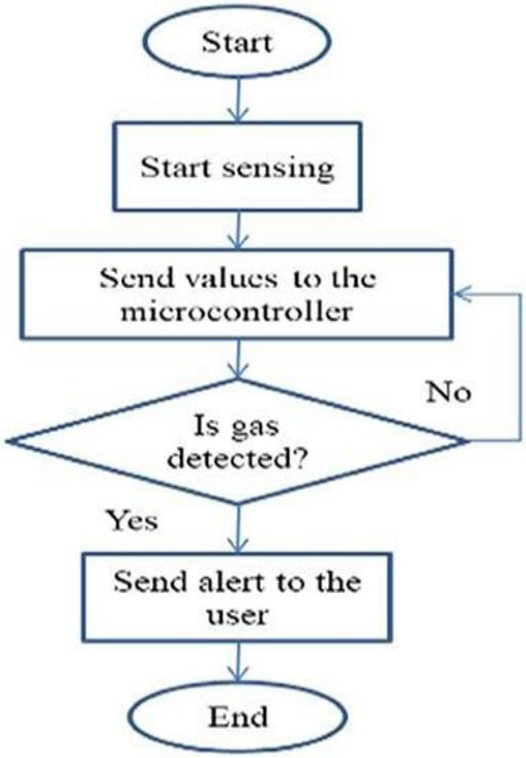

Figure 3: System Architecture

3.5 Hardware Implementation

3.5.1 Software Requirements:

- Operating system: Windows 7/10.
- MC programming language: Embedded ‘c’ Language

3.5.2 Hardware Requirements:

- Node MCU [4]
- Battery
- I2C [4] Display Driver
- LCD [4] Display
- Voltage Regulator [4]
- MQ3 [1] [1] gas sensor [1]
- Temperature sensor [3]
- DTH11 Humidity sensor [2]

3.6 Software Environment

3.6.1 Arduino Software (IDE)

Arduino is an open-source electronics platform based on easy-to-use hardware and software. Arduino boards are able to read inputs - light on a sensor, a finger on a button, or a Twitter message - and turn it into an output - activating a Motor, turning on an LED, publishing something online. You can tell your board what to do by sending a set of instructions to the microcontroller on the board. To do so you use the Arduino programming language (based on Wiring), and the Arduino Software (IDE), based on Processing.

Arduino has been the brain of thousands of projects, from everyday objects to complex scientific instruments. A worldwide community of makers - students, hobbyists, artists, programmers, and professionals - has gathered around this open-source platform, their contributions have added up to an incredible amount of accessible knowledge that can be of great help to novices and experts alike.

Arduino was born at the Ivrea Interaction Design Institute as an easy tool for fast prototyping, aimed at students without a background in electronics and programming. As soon as it reached a wider community, the Arduino board started changing to adapt to new needs and challenges, differentiating its offer from simple 8-bit boards to products for IoT [4] applications, wearable, 3D printing, and embedded environments. All Arduino boards are completely open-source, empowering users to build them independently and eventually adapt them to their particular needs. The software, too, is open-source, and it is growing through the contributions of users worldwide. Arduino also simplifies the process of working with microcontrollers, but it offers some advantage for teachers, students, and interested amateurs over other systems:

- Inexpensive - Arduino boards are relatively inexpensive compared to other microcontroller platforms. The least expensive version of the Arduino module can be assembled by hand, and even the pre-assembled Arduino modules cost less than $50.
- Cross-platform - The Arduino Software (IDE) runs on Windows, Macintosh OSX, and Linux operating systems. Most microcontroller systems are limited to Windows.
- Simple, clear programming environment - The Arduino Software (IDE) is easy-touse for beginners, yet flexible enough for advanced users to take advantage of as well. For teachers, it's conveniently based on the Processing programming environment, so students learning to program in that environment will be familiar with how the Arduino IDE [4] works.
- Open source and extensible hardware - The plans of the Arduino boards are published under a Creative Commons license, so experienced circuit designers can make their own version of the module, extending it and improving it. Even relatively inexperienced users can build the breadboard version of the module in order to understand how it works and save money.

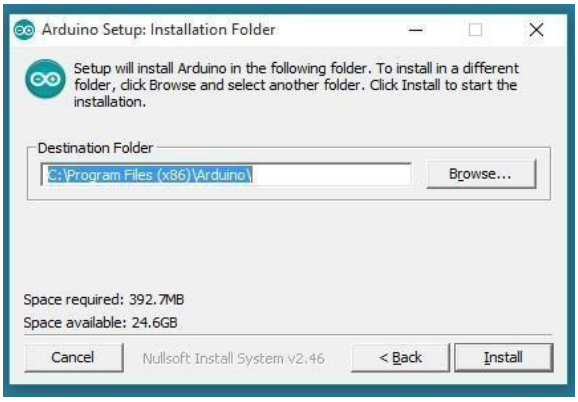

Figure 4: Software Installing

The process will extract and install all the required files to execute properly the Arduino Software (IDE).

3.6.2 Embedded C

Embedded C is a set of language extensions for the C programming language by the C Standards Committee to address commonality issues that exist between C extensions for different embedded systems. Embedded C programming typically requires nonstandard extensions to the C language in order to support enhanced microprocessor features such as fixed- point arithmetic, multiple distinct memory banks, and basic I/O operations. In 2008, the C Standards Committee extended the C language to address such capabilities by providing a common standard for all implementations to adhere to. It includes a number of features not available in normal C, such as fixed-point arithmetic, named address spaces and basic I/O hardware addressing. Embedded C uses most of the syntax and semantics of standard C, e.g., main () function, variable definition, datatype declaration, conditional statements (if, switch case), loops (while, for), functions, arrays and strings, structures and union, bit operations, macros, etc.

Embedded C Programming is the soul of the processor functioning inside each and every embedded system we come across in our daily life, such as mobile phone, washing machine, and digital camera. Each processor is associated with an embedded software. The first and foremost thing is the embedded software that decides functioning of the embedded system.

Embedded C language is most frequently used to program the microcontroller.

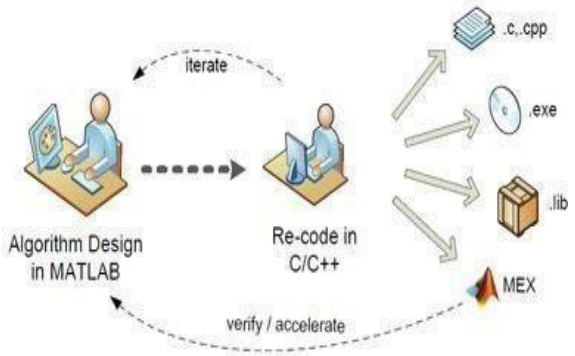

Figure 5: Architecture

Earlier, many embedded applications were developed using assembly level programming. However, they did not provide portability. This disadvantage was overcome by the advent of various high level languages like C, Pascal, and COBOL. However, it was the C language that got extensive acceptance for embedded systems, and it continues to do so. The C code written is more reliable, scalable, and portable; and in fact, much easier to understand.

C language is a middle-level language as it supports high-level applications and low-level applications. Before going into the details of embedded C programming, we should know about RAM memory organization.

- C language is a software designed with different keywords, data types, variables, constants, etc.
- Embedded C is a generic term given to a programming language written in C, which is associated with a particular hardware architecture.
- The microcontroller 8051 #include<reg51.h> is used.

The embedded system designers must know about the hardware architecture to write programs. These programs play prominent role in monitoring and controlling external devices.

3.6.3 Proteus

Proteus is the best simulation software for various designs with microcontrollers. It is mainly popular because of the availability of almost all microcontrollers in it. So, it is a handy tool to test programs and embedded designs for electronics hobbyists. You can simulate your programming of microcontrollers in Proteus Simulation Software. After simulating your circuit in Proteus Software, you can directly make a PCB design.

3.7 Hardware Environment

3.7.1 Battery

In isolated systems away from the grid, batteries are used for storage of excess solar energy converted into electrical energy. The only exceptions are isolated sunshine load such as irrigation pumps or drinking water supplies for storage. In fact for small units with output less than one kilowatt. Batteries seem to be the only technically and economically available storage means. Since both the photo-voltaic system and batteries are high in capital costs. It is necessary that the overall system be optimized with respect to available energy and local demand pattern.

Figure 6: Battery

To be economically attractive the storage of solar electricity requires a battery with a particular combination of properties. Inside a lead-acid battery, the positive and negative electrodes consist of a group of plates welded to a connecting strap. The plates are immersed in the electrolyte, consisting of 8 parts of water to 3 parts of concentrated sulfuric acid. Each plate is a grid or framework, made of a lead- antimony alloy. This construction enables the active material, which is lead oxide, to be pasted into the grid. In manufacture of the cell, a forming charge produces the positive and negative electrodes. In the forming process, the active material in the positive plate is changed to lead peroxide (pbo). The negative electrode is spongy lead (pb). Automobile batteries are

usually shipped dry from the manufacturer. The electrolyte is put in at the time of installation, and then the battery is charged to from the plates.

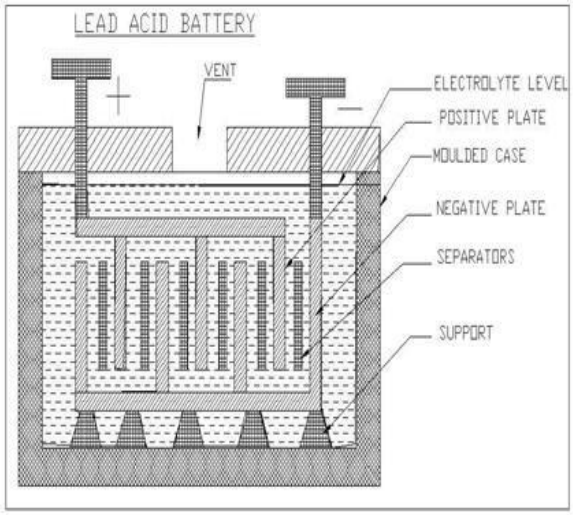

Figure 7: Layout of Battery

Sulfuric acid is a combination of hydrogen and sulfate ions. When the cell discharges, lead peroxide from the positive electrode combines with hydrogen ions to form water and with sulfate ions to form lead sulfate. Combining lead on the negative plate with sulfate ions also produces he sulfate. Therefore, the net result of discharge is to produce more water, which dilutes the electrolyte, and to form lead sulfate on the plates. As the discharge continues, the sulfate fills the pores of the grids, retarding circulation of acid in the active material. Always use extreme caution when handling batteries and electrolyte. Wear gloves, goggles and old clothes. “Battery acid” will burn skin and eyes and destroy cotton and wool clothing. The quickest way of ruin lead-acid batteries is to discharge them deeply and leave them stand “dead” for an extended period of time. When they discharge, there is a chemical change in the positive plates of the battery.

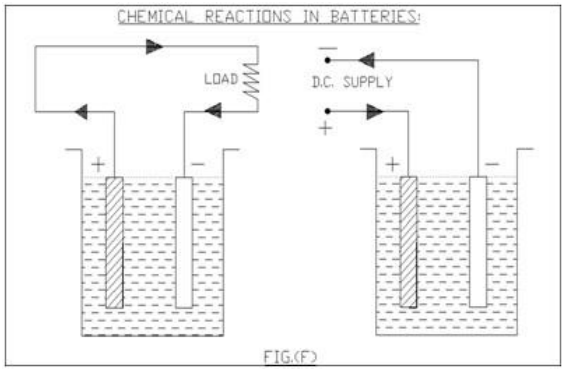

Figure 8: Chemical Reaction in Batteries

They change from lead oxide when charge out lead sulfate when discharged. If they remain in the lead Sulfate State for a few days, some part of the plate dose not returns to lead oxide when the battery is recharged. If the battery remains discharge longer, a greater amount of the positive plate will remain lead sulfate. The parts of the plates that become “sulfate” no longer store energy. Batteries that are deeply discharged, and then charged partially on a regular basis can fail in less than one year.

3.7.2 Node MCU [4] V3

The best way to develop quickly an IoT [4] application with less Integrated circuits to add is to choose this circuit “NodeMCU [4]”. Today,we will give a detailed Introduction on NodeMCU [4] V3. It is an open-source firmware and development kit that plays a vital role in designing a proper IoT [4] product using a few script lines. The module is mainly based on ESP8266 [4] that is a low-cost WiFi microchip incorporating both a full TCP/IP stack and microcontroller capability. It is introduced by manufacturer Espressif Systems. The ESP8266 [4] NodeMCU [4] is a complex device, which combines some features of the ordinary

Arduino board with the possibility of connecting to the internet. Arduino Modules and Microcontrollers have always been a great choice to incorporate automation into the relevant project. But these modules come with a little drawback as they don’t feature a built-in WiFi capability, subsequently, we need to add external WiFi protocol into these devices to make them compatible with the internet channel. This is the famous NodeMCU [4] which is based on ESP8266 [4] WiFi SoC. This is version 3 and it is based on ESP-12E (An ESP8266 [4] based WiFi module). NodeMCU [4] is also an open-source firmware and development kit that helps you to prototype your IOT [4] product within a few LUA script lines, and of course you can always program it with Arduino IDE [4].

In this article, We will try present useful details related to this WiFi Development Kit, its main features, pinout and everything we need to know about this module and the application domain.

Introduction Node MCU [4] V3

Node MCU [4] V3 is an open-source firmware and development kit that plays a vital role in designing an IoT [4] product using a few script lines. Multiple GPIO pins on the board allow us to connect the board with other peripherals and are capable of generating

PWM, I2C [4], SPI, and UART serial communications. The interface of the module is mainly divided into two parts including both Firmware and Hardware where former runs on the ESP8266 [4] Wi-Fi SoC and later is based on the ESP-12 module.

Node MCU [4] V3 Pin-out

NodeMCU [4] V3 comes with a number of GPIO Pins. Following figure shows the Pin-out of the board. There is a candid difference between Vin and VU where former is the regulated voltage that may stand somewhere between 7 to 12 V while later is the power voltage for USB that must be kept around 5 V.

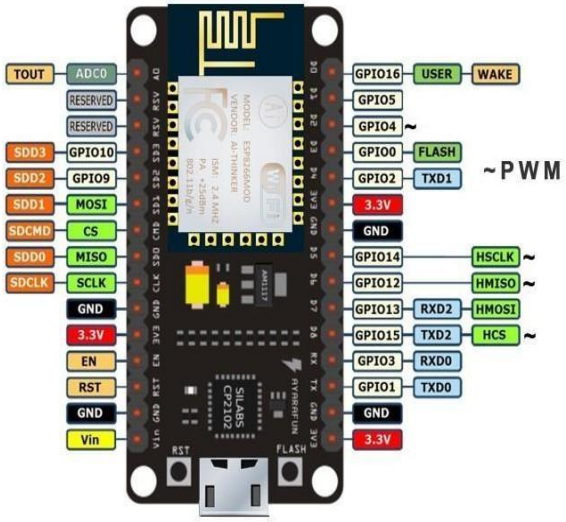

Figure 9: NodeMCU [4] V3 Pin-out

Features

1. Open-source
2. Arduino-like hardware
3. Status LED
4. Micro USB port
5. Reset/Flash buttons
6. Interactive and Programmable
7. ESP8266 [4] with inbuilt wi-fi
8. USB to UART converter
9. GPIO pins
10. Arduino-like hardware IO

Note: We use Arduino IDE [4] software for programming this module. It is important to note that the pin configuration appearing on the board is different from the configuration we use to program the board on the software i.e. when we write code for targeting pin 16 on the Arduino IDE [4], it will actually help is laying out the communication with the D0 pin on the module. Following figure the shows the pin configuration to use in Arduino IDE [4].

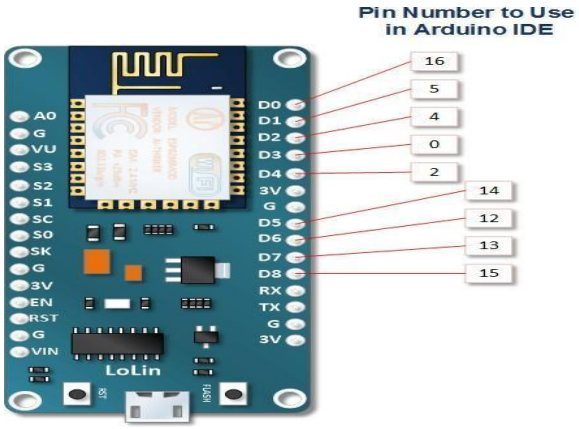

Figure 10: Pin Configuration to Use In Arduino IDE [4]

How to Power Node MCU [4] V3

We can see from the pinout image above, there are five ground pins and three 3V3 pins on the board. The board can be powered up using the following three ways.

USB Power: It proves to an ideal choice for loading programs unless the project you aim to design requires separate interface i.e. disconnected from the computer.

Provide 3.3V: This is another great option to power up the module. If you have your own off-board regulator, you can generate an instant power source for your development kit.

3.7.3 LCD [4] Display

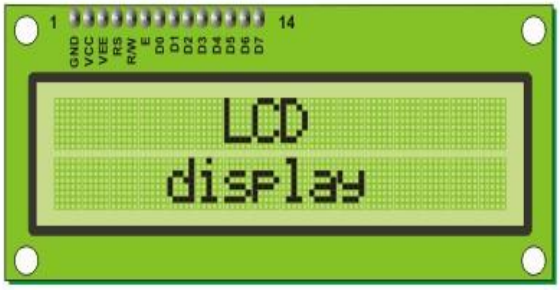

Figure 11: Liquid Crystal Display [4]

A liquid crystal display (LCD [4]) is a flat panel display, electronic visual display, or video display that uses the light modulating properties of liquid crystals. Liquid crystals do not emit light directly. LCD [4] s are available to display arbitrary images (as in a general-purpose computer display) or fixed images which can be displayed or hidden, such as preset words, digits, and 7-segment displays as in a digital clock. They use the same basic technology, except that arbitrary images are made up of a large number of small pixels, while other displays have larger

elements. LCD [4]s are used in a wide range of applications including computer monitors, televisions, instrument, aircraft cockpit displays, and signage. They are common in consumer devices such as video players, gaming devices, clocks, watches, calculators, and telephones, and have replaced cathode ray tube (CRT) displays in most applications. They are available in a wider range of screen sizes than CRT and plasma displays, and since they do not use phosphors, they do not suffer image burn-in. LCD [4]s are, however, susceptible to image persistence.

The LCD [4] screen is more energy efficient and can be disposed of more safely than a CRT. Its low electrical power consumption enables it to be used in battery-powered electronic equipment. It is an electronically modulated optical device made up of any number of segments filled with liquid crystals and arrayed in front of a light source(backlight) or reflector to produce images in color or monochrome. Liquid crystals were first discovered in 1888.

1. Polarizing filter film with a vertical axis to polarize light as it enters.
2. Glass substrate with ITO electrodes. The shapes of these electrodes will determine the shapes that will appear when the LCD [4]is turned ON. Vertical ridges etched on the surface are smooth.
3. Twisted hermetic liquid crystal.
4. Glass substrate with common electrode film (ITO) with horizontal ridges to line up with the horizontal filter.
5. Polarizing filter film with a horizontal axis to block/pass light.
6. Reflective surface to send light back to viewer. (In a backlit LCD [4] , this layer is replaced with a light source.)

3.7.4 I2C [4] Display Driver

An I2C [4] display driver is an electronic component used to control displays (like LCD [4] or OLED) via the I2C [4] (Inter-Integrated Circuit) communication protocol. I2C [4] is a two-wire interface that allows multiple devices to communicate with a microcontroller or microprocessor. The display driver acts as an intermediary between the display panel and the microcontroller, receiving control signals and data (such as pixel data) from the microcontroller and translating them into actions that drive the display. Typically, an I2C [4] display driver uses the two I2C [4] lines—SDA (data line) and SCL (clock line)—to transmit signals to and from the microcontroller, enabling the display to show characters, graphics, or images.

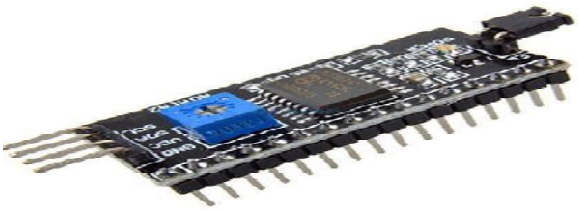

Figure 12: I2C [4] display driver

Working Principle

The I2C [4] display driver operates based on the I2C [4] protocol, which enables communication between multiple devices using only two wires: the serial data line (SDA) and the serial clock line (SCL). The microcontroller sends commands and data over the SDA line, and the clock signal is generated on the SCL line. The I2C [4] display driver, which is connected to the display, decodes the incoming signals and translates them into specific actions that control the display. For example, it may convert character codes into pixel data for an LCD [4] or OLED display. The display driver handles the refresh rate, brightness, contrast, and other display-specific settings. By using the I2C [4] protocol, multiple devices can share the same bus, reducing the number of required I/O pins.

Advantages of I2C [4] Display Driver

1. Simplified Wiring: Since I2C [4] uses only two wires (SDA and SCL), it reduces the number of connections required compared to parallel communication methods.
2. Multiple Devices on a Single Bus: I2C [4] supports communication with multiple devices on the same bus, making it easy to control multiple displays or other peripherals without additional pins on the microcontroller.
3. Ease of Integration: The I2C [4] protocol is widely used and supported, making it simple to integrate displays with a variety of microcontrollers and development platforms.
4. Lower Power Consumption: I2C [4] generally uses less power compared to parallel communication protocols, making it suitable for battery-powered devices.
5. Addressable Devices: I2C [4] devices can be addressed uniquely using their 7-bit or 10-bit address, allowing precise control of individual devices without interference.

Disadvantages of I2C [4] Display Driver

1. Slower Data Transfer: I2C [4] is slower than parallel communication methods, which can result in a lower refresh rate for high-resolution displays.
2. Limited Distance: I2C [4] is designed for short-distance communication (typically a few meters), and performance may degrade over longer distances.
3. Bus Contention: If multiple devices are trying to communicate at once, data collisions or delays can occur, requiring proper bus management and arbitration.
4. Limited Speed: The data transfer speed of I2C [4] is relatively slow compared to other communication protocols like SPI or parallel, which may be a limitation for high-speed applications.
5. Complexity in Addressing: When many devices are connected on the same bus, managing unique addresses for each device can become complicated, especially in large systems.

3.7.5 Voltage Regulator [4]s

Voltage Regulator [4]s comprise a class of widely used ICs. Regulator IC units contain the circuitry for reference source, comparator amplifier, control device, and overload protection all in a single IC. Although the internal construction of the IC is somewhat different from that described for discrete Voltage Regulator [4] circuits, the external operation is much the same. IC units provide regulation of either a fixed positive voltage, a fixed negative voltage, or an adjustable set voltage. A power supply can be built using a transformer connected to the AC supply line to step the AC voltage to desired amplitude, then rectifying that AC voltage, filtering with a capacitor and RC filter, if desired, and finally regulating the DC voltage using an IC regulator. The regulators can be selected for operation with load currents from hundreds of Millis amperes to tens of amperes, corresponding to power ratings from mill watts to tens of watts. A three-terminal Voltage Regulator [4] IC to a load. The fixed Voltage Regulator [4] has an unregulated DC input voltage, VI, applied to one input terminal, a regulated output DC voltage, Vo, from a second terminal, with the third terminal connected to ground The specifications also list the amount of output voltage change resulting from a change in load current (load regulation) or in input voltage (line regulation).

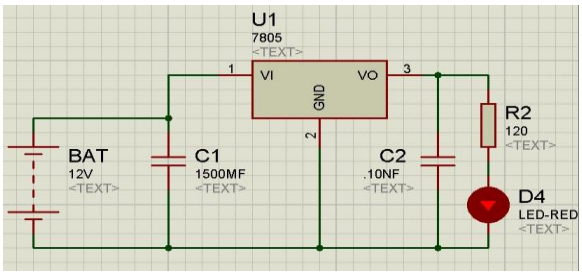

Figure 13: Fixed Voltage Regulator [4]s

The series 78 regulators provide fixed regulated voltages from 5 to 24 V shows how one such IC, a 7812, is connected to provide voltage regulation with the output from this unit of +12V Dec. An unregulated input voltage VI is filtered by capacitor C1 and connected to the IC's IN terminal. The IC's OUT terminal provides a regulated + 12V which is filtered by the capacitor C2 (mostly for any high-frequency noise). The third IC terminal is connected to ground (GND). While the input voltage may vary over some permissible voltage range, and the output load may vary over some acceptable range, the output voltage remains constant within specified voltage variation limits. These limitations are spelled out in the manufacturer's specification sheets.

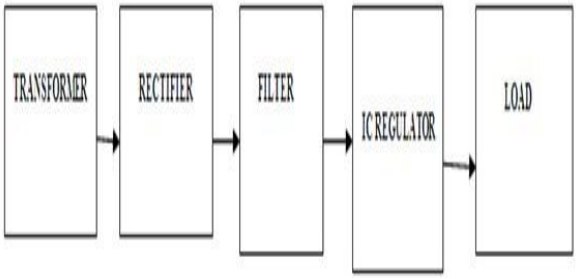

Figure 14: Block Diagram of Power Supply

The AC voltage, typically 220V RMS, is connected to a transformer, which steps that AC voltage down to the level of the desired DC output. A diode rectifier then provides a full-wave rectified voltage that is initially filtered by a simple capacitor filter to produce a DC voltage. This resulting DC voltage usually has some ripple or AC voltage variation. A regulator circuit removes the ripples and also remains the same DC value even if the input DC voltage varies, or the load connected to the output DC voltage changes. This voltage regulation is usually obtained using one of the popular Voltage Regulator [4] IC units. The potential transformer will step down the power supply voltage

(0230V) to (0-6V) level. Then the secondary of the potential transformer will be connected to the precision rectifier, which is constructed with the help of op– amp. The advantages of using a precision rectifier are it will give a peak voltage output as DC; the rest of the circuits will give only RMS output.

When four diodes are connected as shown in the figure, the circuit is called as a bridge rectifier. The input to the circuit is applied to the diagonally opposite corners of the network, and the output is taken from the remaining two corners. Let us assume that the transformer is working properly and there is a positive potential, at point A and a negative potential at point B. The positive potential at point A will forward bias D3 and reverse bias D4. The negative potential at point B will forward bias D1 and reverse D2. At this time the D3 and D1 are forward biased and will allow current flow to pass through them; D4 and D2 are reverse biased and will block current flow. The path for current flow is from point B through D1, up through RL, through D3, through the secondary of the transformer back to point B. This path is indicated by the solid arrows. Waveforms (1) and (2) can be observed across D1 and D3. One-half cycle later the polarity across the secondary of the transformer reverse, forward biasing D2 and D4 and reverse biasing D1 and D3. The current flow will now be from point A through D4, up through RL, through D2, through the secondary of T1, and back to point A. This path is indicated by the broken arrows. Waveforms (3) and (4) can be observed across D2 and D4. The current flow through RL is always in the same direction. In flowing through RL this current develops a voltage corresponding to that shown waveform (5). Since current flows through the load (RL) during both half cycles of the applied voltage, this bridge rectifier is a full-wave rectifier. One advantage of a bridge rectifier over a conventional full-wave rectifier is that with a given transformer the bridge rectifier produces a voltage output that is nearly twice that of the conventional full-wave circuit. This may be shown by assigning values to some of the components shown in views A and B. Assume that the same transformer is used in both circuits. The peak voltage developed between points X and y is 1000 volts in both circuits. Since only one diode can conduct at any instant, the maximum voltage that can be rectified at any instant is 500 volts. In the bridge rectifier shown in view B, the maximum voltage that can be rectified is the full secondary voltage, which is 1000 volts. Therefore, the peak output voltage across the load resistor is nearly 1000 volts. With both circuits using the same transformer, the bridge rectifier circuit produces a higher output voltage than the conventional full wave rectifier circuit. Voltage Regulator [4]s comprise a class of widely used ICs. Regulator IC units contain the circuitry for reference source, comparator amplifier, control device, and overload protection all in a single IC. IC units provide regulation of either a fixed positive voltage, a fixed negative voltage, or an adjustable set voltage. The regulators can be selected for operation with load currents from hundreds of Milli amperes to tens of amperes, corresponding to power ratings from milliwatts to tens of watts. A fixed three-terminal Voltage Regulator [4] has an unregulated DC input voltage, VI, applied to one input terminal, a regulated DC output voltage, Vo, from a second terminal, with the third terminal connected to ground. The series 78 regulators provide fixed positive regulated voltages from 5 to 24 volts. Similarly, the series 79 regulators provide fixed negative regulated voltages from 5 to 24 volts.

3.7.6 DHT11 [2] Humidity & Temperature sensor [3]
DHT11 [3] Sensor features a temperature & humidity sensor [2] complex with a calibrated digital signal output. By using the exclusive digital-signal-acquisition technique and temperature & humidity sensing technology, it ensures high reliability and excellent long-term stability. This sensor includes a resistive-type humidity measurement component and an NTC temperature measurement component, and connects to a high- performance 8-bit microcontroller, offering excellent quality, fast response, anti-interference ability and cost-effectiveness.
Needle-type [3] Temperature Probe (DS18B20 [3]):
The DS18B20 [3] digital temperature sensor [3] in needle-type [3] form is used to measure the internal temperature of the food sample. The waterproof stainless-steel probe is safely inserted into semi-solid or solid food materials such as meat or dairy products. It communicates with the NodeMCU [4] through a one-wire protocol and provides readings with a typical accuracy of ±0.5 °C. Monitoring the internal temperature allows early detection of microbial growth, since internal heat generation occurs before

any external color or odor change.

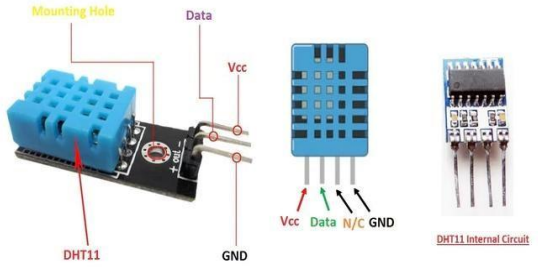

Figure 15: DTH11 Sensor

Each DHT11 [2] element is strictly calibrated in the laboratory that is extremely accurate on humidity calibration. The calibration coefficients are stored as programmed in the OTP memory, which are used by the sensor's internal signal detecting process. The single-wire serial interface makes system integration quick and easy. Its small size, low power consumption and up-to-20 meter signal transmission making it the best choice for various applications, including those most demanding ones. The component is 4-pin single row pin package. It is convenient to connect and special packages can be provided according to users' request.

Technical Specifications:

Item	Measurement Range	Humidity Accuracy	Temperature Accuracy	Resolution	Package
DHT 11 [2]	20-90%RH 0-50 °C	±5% RH	±2°C	1	4 Pin Single Row

Table 1: Technical Specifications

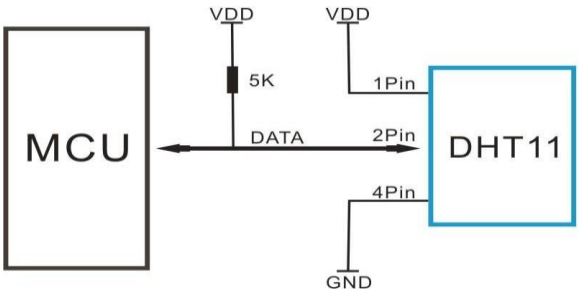

Figure 16: DTH11 Sensor Pin Out

Typical Application

The connecting cable is shorter than 20 metres, a 5K pull-up resistor is recommended; when the connecting cable is longer than 20 metres, choose a appropriate pull-up resistor as needed.

POWER AND PIN

DHT11 [3]'s power supply is 3-5.5V DC. When power is supplied to the sensor, do not send any instruction to the sensor in within one second in order to pass the unstable status. One capacitor valued 100nF can be added between VDD and GND for power filtering. Communication Process: Serial Interface (Single-Wire Two-Way)

Single-bus data format is used for communication and synchronization between MCU and DHT11 [2] sensor. One communication process is about 4ms. Data consists of decimal and integral parts. A complete data transmission is 40bit, and the sensor sends higher data bit first.

Data format: 8bit integral RH data + 8bit decimal RH data + 8bit integral T data + 8bit decimal T data + 8bit check sum. If the data transmission is right, the check-sum should be the last 8bit of "8bit integral RH data + 8bit decimal RH data + 8bit integral T data + 8bit decimal T data".

3.7.7 MQ3 [1] [1] Gas sensor [1] [1]

Figure 18: MQ3 [1] [1] Gas sensor [1] [1]

The MQ-3 [1] [1] sensor is a highly sensitive semiconductor gas sensor [1] primarily used for detecting alcohol vapors and other combustible gases. It is widely employed in breathalyzers, air quality monitors, and gas leak detection systems due to its high sensitivity, quick response time, and reliability. The sensor operates by detecting the presence of specific gases in the environment, making it an essential component in safety and environmental monitoring applications.

The MQ-3 [1] [1] sensor functions based on the changes in the conductivity of its sensing material

when exposed to target gases. It consists of a heated tin dioxide (SnO_2) thin film that acts as the sensing element. When alcohol or other gases come into contact with the sensor, they interact with the surface of the SnO_2, causing a change in its electrical resistance. The sensor's internal circuitry measures this resistance change, which correlates to the concentration of the detected gas. A built-in heater maintains the optimal operating temperature to ensure accurate and consistent readings.

Advantages:

- High sensitivity to alcohol and combustible gases.
- Fast response and recovery times.
- Low power consumption.
- Compact and easy to integrate into various systems.
- Cost-effective solution for gas detection applications.

Disavantages:

- Limited selectivity may respond to multiple gases, leading to false positives.
- Sensitivity can drift over time, requiring calibration.
- Not suitable for detecting gases in very low concentrations.
- Operating temperature needs to be maintained, increasing power requirements.
- Short lifespan due to sensor degradation with prolonged use.

IV. IMPLEMENTATION AND RESULTS

4.1 Hardware Photography

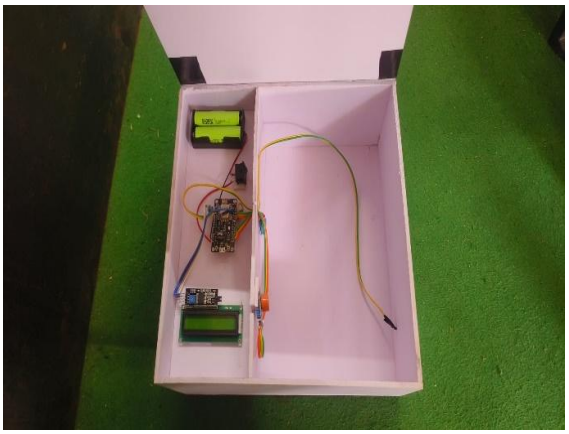

Figure 19: Hardware Photography

Parameter	Existing System	Proposed System (Needle-Based IoT Detector)	Improvement / Remark
Microcontroller	Arduino UNO / Basic NodeMCU	NodeMCU V3 (ESP8266) with integrated Wi-Fi	Enhanced connectivity and faster data transfer
Temperature Measurement	Ambient air temperature only	Needle-type DS18B20 **probe** inserted in food to measure core temperature	Enables early microbial spoilage detection
Gas Detection	MQ-3 gas sensor for ethanol and volatile compounds	Calibrated MQ-3 with NodeMCU data processing	Increased gas-sensing accuracy

Humidity Measurement	DHT11 humidity sensor	DHT11 combined with internal probe readings	More consistent prediction of spoilage
Data Processing	Manual / LED indication only	Automated IoT data transfer with buzzer alert	Allows real-time remote monitoring
Alert System	Basic LED indicator	LCD display + buzzer alert system	Improved user notification
Power Source	Wired DC power supply	Portable 5V USB or battery power	Safer and more flexible
Data Storage	Not available	IoT-based cloud logging (optional)	Enables trend analysis and study
Detection Accuracy	82–85%	93–95%	10% improvement in accuracy
Response Time	25–30 minutes after visible spoilage	10–15 minutes before visible spoilage	Early detection advantage
System Novelty	Measures only external environment	Measures both internal and ambient parameters	Core sensing is the key innovation

Table 2: Comparison between Existing System and Proposed System

The experimental setup for the Food Spoiled Detector is designed around a NodeMCU [4] microcontroller integrated with a gas sensor [1]MQ-3 [1] [1] and temperature and humidity sensor [2] s. The NodeMCU [4] serves as the central processing unit, collecting data from the sensors in real-time. The MQ-3 [1] [1] gas sensor [1]is used to detect specific gases emitted by spoiled food, such as ammonia or other volatile organic compounds (VOCs). The temperature and humidity sensor [2]s monitor environmental conditions that can influence food spoilage. All sensors are connected to the NodeMCU [4] via appropriate interfaces, with the microcontroller processing the sensor signals to analyze whether the food has spoiled based on preset thresholds. The setup is powered through a USB or external power source, and the data can be transmitted wirelessly via Wi-Fi for remote monitoring or stored locally for analysis. This integrated system allows for continuous, real-time detection of food spoilage, ensuring freshness and safety. The incorporation of the needle-type [3] temperature sensor [3] resulted in faster and more stable responses than those obtained from ambient temperature readings. Internal temperature variations were observed earlier than visible spoilage signs or odor formation, confirming that internal sensing is an effective early-warning indicator. The slight deviations between recorded values and standard data were primarily due to sensor calibration limits and humidity interference, which have been reported in similar MQ-3 [1] [1] and DHT11 [3]-based systems [1, 2].

V. CONCLUSION AND FUTURE SCOPE

5.1 Conclusion

The designed IoT [4]-based food spoilage detection system successfully combines gas, humidity, and needle-type [3] internal temperature monitoring to improve accuracy and reliability. The use of a DS18B20 [3] probe distinguishes this model from conventional ambient-sensor systems by providing direct measurement of the food's core temperature. This innovation enables earlier detection of spoilage, minimizes food waste, and offers a practical low-cost solution for use in households, food processing, and cold-storage applications.

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