Department of Electronics and Communication Engineering

National Institute of Technology Srinagar

Hazratbal, Srinagar, Jammu and Kashmir, 190006 (India)

Winter Internship in

Non- destructive method of fruit spoilage detection Projects

Submitted by

AJARUDDIN ANSARI

Enrollment No. - 2021BECE047

Under the guidance of

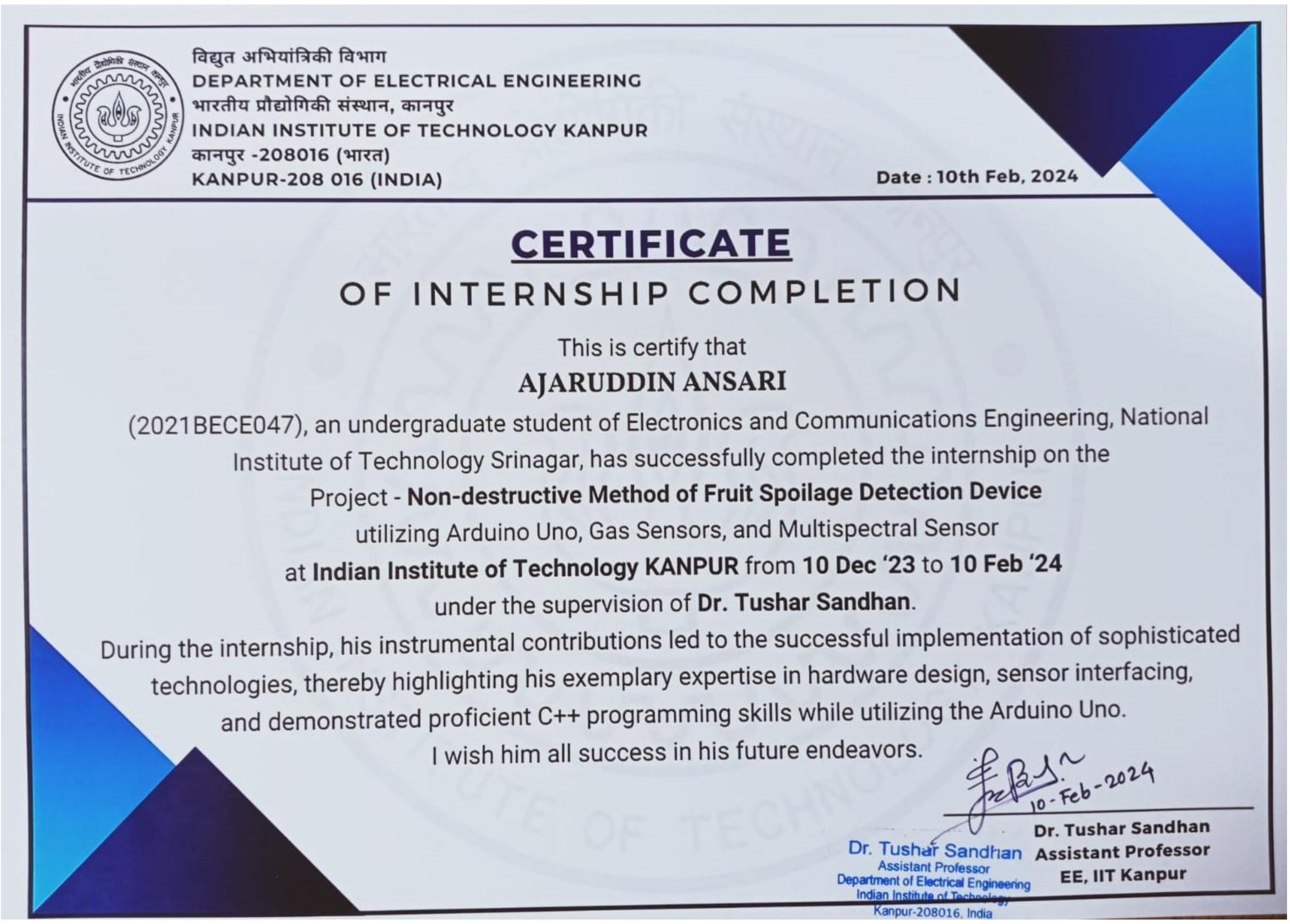
Prof. Tushar sandhan

Department of Electrical Engineering

Indian Institute of Technology, Kanpur

Uttar Pradesh 208016, (India)

(DEC 10th, 2023 - Feb 10th, 2024)



विद्युत अभियांत्रिकी विभाग
DEPARTMENT OF ELECTRICAL ENGINEERING
भारतीय प्रौद्योगिकी संस्थान, कानपुर
INDIAN INSTITUTE OF TECHNOLOGY KANPUR
कानपुर -208016 (भारत)
KANPUR-208 016 (INDIA)

Date : 10th Feb, 2024

CERTIFICATE

OF INTERNSHIP COMPLETION

This is certify that

AJARUDDIN ANSARI

(2021BECE047), an undergraduate student of Electronics and Communications Engineering, National Institute of Technology Srinagar, has successfully completed the internship on the Project - **Non-destructive Method of Fruit Spoilage Detection Device** utilizing Arduino Uno, Gas Sensors, and Multispectral Sensor at **Indian Institute of Technology KANPUR** from **10 Dec '23** to **10 Feb '24** under the supervision of **Dr. Tushar Sandhan**.

During the internship, his instrumental contributions led to the successful implementation of sophisticated technologies, thereby highlighting his exemplary expertise in hardware design, sensor interfacing, and demonstrated proficient C++ programming skills while utilizing the Arduino Uno.

I wish him all success in his future endeavors.

10-Feb-2024

Dr. Tushar Sandhan
Assistant Professor
Department of Electrical Engineering
Indian Institute of Technology
Kanpur-208016, India

Dr. Tushar Sandhan
Assistant Professor
EE, IIT Kanpur

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Hazratbal, Srinagar Jammu and Kashmir, 190006, INDIA

NO: NIT/T&P/INTP/2023-24/BECE/066
Date: 08-11-2023

TO WHOM IT MAY CONCERN

Subject: **Permission of Internship online/offline for student of NIT Srinagar.**

In – Plant/on–the –project internship/Practical Training is an important part of our engineering curriculum. This internship/training is regarded as a vital component of engineering education and is an indicator of extent of field experience, which is very essential for attaining excellence in the technical education. In this context, **Mr. /Ms. Ajaruddin Ansari,** Enrolment No: **2021BECE047** pursuing B. Tech in ELECTRONICS & COMMUNICATIONS ENGINEERING DEPARTMENT (2021-2025) in this Institute has completed his/her 4th semester of the degree (pursuing 5th semester) and is interested in 45 days internship in your esteemed organization.

It will be highly appreciated if your organization provides him/her a chance to get an exposure to some project related to him/her branch of engineering online/offline that is being carried out by your organization during winter vacation from 20th December 2023 to 15th February 2024.

We fervently hope that you will accede to our request and allow him/her to pursue him/her internship in your esteemed organization. The student has been advised to abide by the rules and regulation of your organization. Also, the student has to submit completion report and certificate in the training & placement department after completion of the internship, failing this his/her internship will be deemed incomplete.

Associate TPO (Internships)
Training and Placement
NIT Srinagar

Associate TPO (Internships)
Training & Placement Department
National Institute of Technology
Srinagar, J&K.

Declaration

I, **AJARUDDIN ANSARI**, hereby declare that I have successfully completed a two-month internship at the Indian Institute of Technology Kanpur (IIT Kanpur) under the supervision of Prof. Tushar Sandhan. The internship was started from **10-12-2023 to 10-02-2024** and mainly focused on the project titled "**Non-Destructive Method of Fruit Quality Check**".

During the internship period, I diligently worked on various aspects of the project, including research, experimentation, data collection, analysis, and reporting. I have fulfilled all the responsibilities assigned to me and have actively contributed to the progress and objectives of the project.

I acquired numerous invaluable skills through my involvement in the project. Implementing theoretical knowledge into real-world applications not only enriched my understanding but also equipped me with practical insights crucial for my career advancement.

Engaging with talented minds at the institute proved to be an enlightening journey, fostering an environment conducive to learning and growth. I am confident that the experiences gained during this internship will serve as a solid foundation for my future endeavours.

Acknowledgement:

I am profoundly grateful to Prof. Tushar Sandhan (Assistant Professor, Electrical Engineering department, IIT Kanpur) for his expert guidance and continuous support throughout the whole internship periodat **Indian Institute of Technology, Kanpur**and his visionary ideas always amotivation for me.

It gives me immense pleasure to thank my supervisor, Mr. VijayPandey (PhD Scholar) for providing motivation, guidance and professional advice throughout the internship.

I am also grateful to the entire research team **at Intelligence and Control lab at Electrical Engineering dept** for their collaborationand collective efforts in successful completion of the project in a short duration.

I would also like to extend my sincere gratitude to the Training and Placement cell of National Institute of Technology, Srinagar for permitting me to do the internship at the most prestigious academic institutions in India.

Contents:

Abstract:

This project focuses on the development of a non-destructive method for internal fruit quality detection using gas sensors and spectral sensors.

By integrating these advanced sensor technologies, we aim to provide a reliable and efficient solution for assessing fruit quality without compromising its integrity. The system achieves accurate results by analysing gases emitted and spectral signatures emitted by the fruit, thereby enabling farmers and distributors to make informed decisions regarding fruit quality. Through rigorous testing and optimization, we have demonstrated the effectiveness of our approach in real-world scenarios.

This project not only contributes to advancements in agricultural technology but also highlights the potential for non-destructive methods in enhancing fruit quality assessment processes.

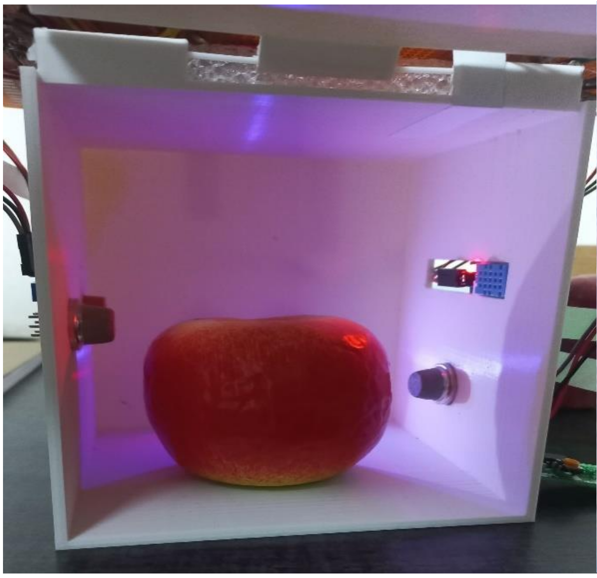
Introduction:

Electronics and Communication Engineering (ECE) is a branch of engineering that deals with the study and application of electronic devices, circuits& communication systems.

During the internship at **Indian Institute of Technology, Kanpur**I have worked on the project **“Non-Destructive method of internal fruit quality check”,** In simple words‘check the freshness of fruit without cutting them internally’.

While working on the project I have gonethrough the different electronic devices, their working principle and their practical application in real world problems.

In this project we have gone through the deep literature of the fruit’s spoilage condition and the factors which plays the vital role in the spoilage of the fruits and the measures & parameters to detect the defective items.

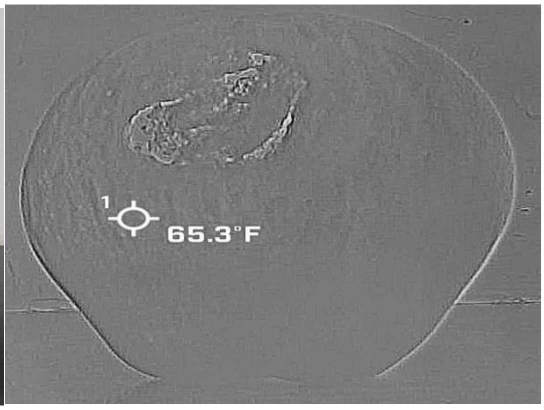


Majorly focuses on the some of the aspect to analyses the fruits (like apple, orange etc.)**:**

- **Thermal IR imaging:**Every object on the earth is made up of the different types of atoms and molecules, so each object has its unique property to absorb and emit the different range of Infrared rays.

Thermal IR imaging detects the heat from the surfaces of the fruits. Due to defective tissues of fruits pulp, the non-uniform temperature difference is observed and sensed on the surface of the fruits.

For getting the images we have used the **Flir one thermal camera.**



1. Thermal camera 2. Gray scale image

- **Gas Sensors:** When the fruits get ripened the concentration of some of the major gases would increase in the proximity of the fruits such as ethylene (C_2H_4), methane (CH_4)and alcohol (C_2H_5OH) etc.

  To measure the concentration of the gases we have implemented some of the gas sensors on the closed **3-D plastic cage** such as MQ-3(Alcohol), MQ-4(Methane), IR, Ultrasonic, Sound, MQ-135, DHT-11(Humidity and temperature) sensor etc.

- **Multispectral Sensors:**Light is a form of electromagnetic radiation, which have the proper electromagneticspectrum of light in nature which consists of different bands with different wavelengths & frequencies.

From low to high frequency different bands are: radio waves,infrared,
visible light, ultraviolet, X-rays, microwaves, and gamma rays.

We have used the **Triad spectroscopy sensor (**AS7265X ICs) designed in the collaboration of two companies, ***Sparkfun& OSRAM***American based electronics and ICs manufacturing company, for observing the 18 different frequencies spectrum ranging from 410nm to 940nmusing Arduino uno.

For implementation of the sensors and getting the proper reading we have also enriches us some the hardwaresuch as Arduino uno, power supply and complex circuits, Softwares like fusion 360 for designing of 3-d model, Eagle CAD for the simulation of complete circuits and tools like Arduino IDE with C^{++} coding.

In this report we will discuss the outlines the working principle, features, application, advantages and limitation different hardware components we have used in our projects.

This report consists of details of successful integration of multiple sensors, including MQ-3, MQ-4, DHT11, Infrared (IR), Ultrasonic, Sound sensors and multispectral sensors with an Arduino Uno on a Zero order PCB to develop a 'non-destructive method for fruit spoilage detection' device which will work efficiently for the detection of internal spoiled fruit.

Here we have also present a comparative analysis of thermal images captured using thermal camera in greyscale, and hot metal colour palettes on apples at two distinct temperatures, **16 degrees Celsius and 26 degrees Celsius.**And will outline the successful integration of the **AS7265x spectral sensor** with an Arduino Uno microcontroller to capture and display 18 different spectral readings using the serial monitor and for observation plot the data on the serial plotter.

Overall,the project utilizing both gas sensors and spectral sensors, demonstrates efficient output with high accuracy, showcasing the practical application of advanced sensor technology in agriculture.

Moreover, the project has provided us with invaluable experience of implementing the theoretical knowledge into the practical problems, expertise in sensor technologies, equipping us for future endeavours in this field.

Vision: Internal spoilage is the big challenge in the commercial fruits industry such as apple and some more pome fruits. So, we plan to collaborate implant the technology of AI and ML, designed a model which will help to identify the spoiled item in early stage automatically.

Gas Sensors

1.MQ3- Alcohol gas Sensor:

The MQ-3 gas sensor is a crucial component in the field of gas detection and monitoring of fruit ripening conditions andspoilage through the emitted gases concentrations like ethanol. This sensor is widely used in applications such as gas leakdetection,breath analysis, and industrial safety.

Working Principle:

The MQ-3 gas sensor operates based on the principle of semiconductor conductivity. It consists of a sensing element made of tin dioxide (SnO2), which exhibits a change in electrical conductivity in the presence of specific gases. When the target gas comes into contact with the sensor, it causes a change in resistance, leading to a measurable electrical signal.

Functional table:

Pin	Function	Unit/Output Example
VCC	Positive power supply	5V
GND	Reference potential (the "ground")	0
A_0	Generates an analog signal proportional to the intensity of methane detected in the air	90
D_0	Generates a digital signal	-

Limitations:

1.Cross-Sensitivity: The MQ-3 sensor may exhibit cross-sensitivity to some gases, leading to potential false readings.

2.Limited Precision: The sensor may not provide the precision required for certain specialized tasks.

2.MQ-4 Methane Gas Sensor:

MQ-4 is a type of gas sensor commonly used for detecting various gases in the environment, particularly methane (CH4), natural gas, propane, and other combustible gases. When the fruits get spoiled it releases the significant amount of this gas in the nearby environment and we will measure that concentration of data which will help us identify the fruit quality check. It operates on the principle of metal oxide semiconductors.

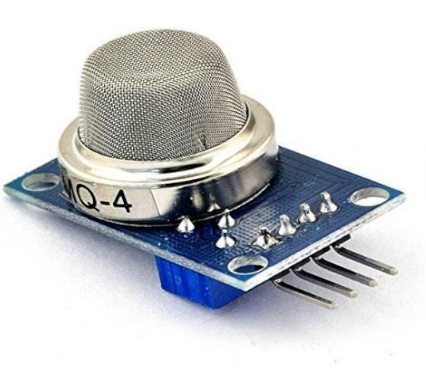
Gas detection:

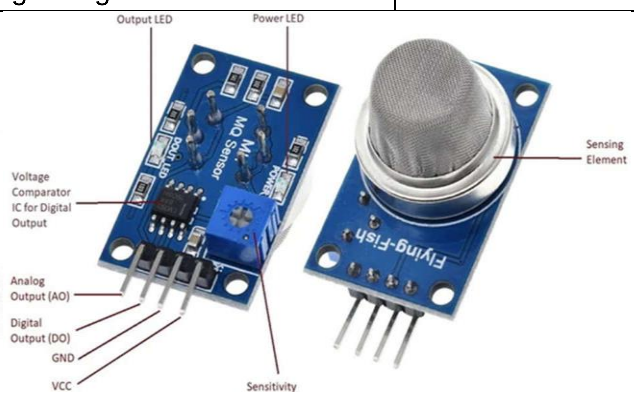
When the sensor is powered on, the heating element heats the metal oxide semiconductor coating on the sensing element. In the presence of target gases such as methane or propane, the conductivity of the metal oxide semiconductor changes. This change in conductivity is due to the chemical reaction between the gas molecules and the metal oxide surface.

It incorporates a sensing element made of tin dioxide (SnO2) that undergoes changes in electrical conductivity when exposed to specific gases. The variation in conductivity is then translated into a measurable electrical signal.
The MQ-4 sensor is capable of detecting various gases, including methane, propane, butane, and other combustible gases.

Pins description:

Pin	Function	Unit/Output Example
VCC	Positive power supply	5V
GND	Reference potential (the “ground”)	0
A_o	Generates an analog signal proportional to the intensity of Alcohol detected in the air	150
D_o	Generates a digital signal	-





Limitations:

The MQ-4 may experience cross-sensitivity to certain gases,leading to false readingsandexternal environmental factors, such as humidity and temperature.

3. MQ-135 Air Quality Gas Sensor:

The MQ-135 is a gas sensor widely used for detecting a variety of airpollutants such as ammonia (NH_3), nitrogen oxides (NO_x), benzene, smoke, and other harmful gases. the MQ-135 includes a built-in heating element, typically made of a fine coil of platinum wire. This heating element heats the sensing element to a specific temperature (usually around 200-400°C) required for the sensor to operate.

Working Principle:

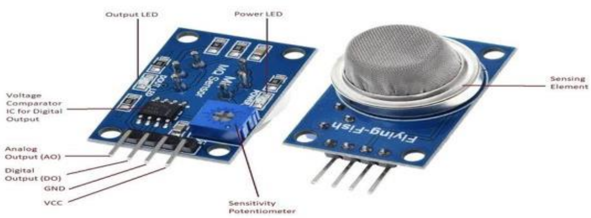
The MQ-135 gas sensor operates based on the principle of semiconductor conductivity. It features a sensing element composed of tin dioxide (SnO_2), capable of detecting a wide range of gases. The interaction of gases with the SnO_2 leads to changes in electrical conductivity, generating measurable signals indicative of the gas concentration.

Pins description:

Pin	Function	Unit/Output Example
VCC	Positive power supply	5V
GND	Reference potential (the "ground")	0
AO	Generates an analog signal proportional to the intensity of Air Content detected in the air	700
DO	Generates a digital signal	-

Output Signal:

The MQ-135 sensor provides an output voltage or current signal that is proportional to the concentration of the target gas in the environment. This signal can be processed and interpreted by a microcontroller or other electronic devices to determine the presence and concentration of the gas.



Applications:

1. Indoor Air Quality Monitoring.
2. Safety Alarms and Industrial Emissions Monitoring.

4.DHT11-Temperature and Humidity Sensor:

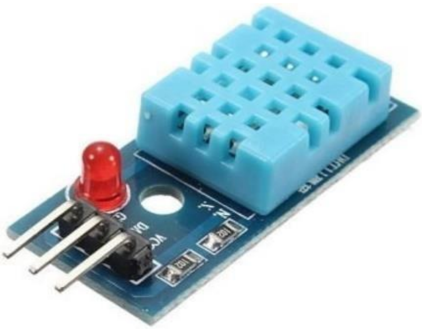
The DHT11 is a widely-used digital temperature and humidity sensor, known for its simplicity, affordability, and reliability. The DHT11 sensor is designed to measure both temperature and humidity in a single device, providing a convenient solution for environmental monitoring.

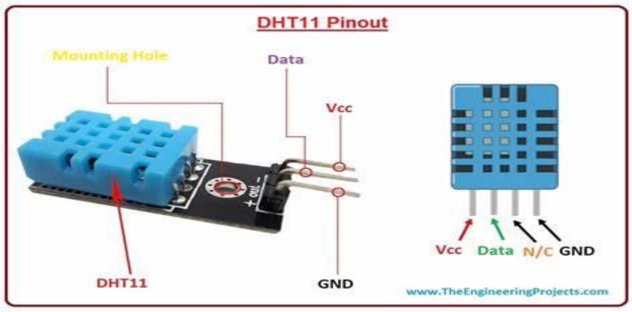
Working Principle:

The DHT11 sensor operates based on a capacitive humidity sensing element and a thermistor for temperature measurement. The humidity sensing element measures changes in capacitance, while the thermistor measures temperature. The sensor converts these measurements into digital signals, providing accurate and easy-to-read data.

Pin description:

Pin	Function	Unit/Output Example
VCC	Positive power supply	5V
GND	Reference potential (the “ground”)	0
A_o	Generates an analog signal proportional to the intensity of Temp. & Humidity detected in the air.	20,5
D_o	Generates a digital signal	-





Features:

1.Combined Temperature and Humidity Sensing:

The DHT11 sensor is designed to measure both temperature and humidity in a single device, providing a convenient solution for environmental monitoring.

2.Digital Output:

The sensor provides a digital signal output, simplifying interfacing with microcontrollers and other digital systems.

3.Cost-Effective:

One of the key advantages is its affordability, making it accessible for a wide range of applications.

Applications:

- **Weather Stations:**
  Utilized in weather stations for monitoring ambient temperature and humidity levels.
- **Home Automation:**
  Integrated into home automation systems for climate control and energy efficiency.
- **Industrial Process Monitoring:**
  Employed in industrial environments for monitoring and controlling processes that are sensitive to temperature and humidity variations.

Advantages:

- **Integrated Solution:**
  The DHT11 provides a cost-effective and straightforward solution for measuring both temperature and humidity, eliminating the need for separate sensors.
- **Wide Operating Range:**
  Capable of operating in a wide temperature and humidity range, making it suitable for diverse environments.
- **Simple Interface:**
  The sensor has a simple digital interface, making it easy to integrate into various projects without complex wiring.

Limitations:

- **Accuracy:**
  While suitable for many applications, the DHT11's accuracy may not meet the requirements of highly precise applications.
- **Response Time:**
  The sensor has a moderate response time, which may not be ideal for applications requiring rapid changes in readings.

Conclusion:

The DHT11 sensor stands as a reliable and cost-effective solution for measuring temperature and humidity in various applications and its simplicity and affordability make it an attractive choice for a wide range of projects.

5.**Infrared Sensors**

Infrared sensors are devices that detect and measure infrared radiation emitted or reflected by objects.

Working Principle:
Infrared sensors operate based on the principle that all objects with temperature above absolute zero emit infrared radiation. These sensors detect this radiation and convert it into an electrical signalthat can be interpreted by electronic devices. The sensor then converts this radiation into an electrical signal, enabling the measurement and analysis of temperature or the presence of objects.

Pin	**Function**	**Unit/Output Example**
VCC	Positive power supply	5V
GND	Reference potential (the “ground”)	0
A_o	Generates an analog signal	-
D_o	Generates a digital signal	-

Applications:

- **Motion Detection:**

  PIR sensors are extensively used in security systems, lighting control, and automatic doors to detect human or animal motion.

- **Object Detection and Ranging:**

  Infrared proximity sensors are employed in robotics, automation, and electronic devices to detect the presence or absence of objects.

- **Night Vision:**

  Infrared imaging sensors are essential in night vision devices for military, security, and surveillance purposes.

Advantages:

- Non-Contact Sensing
- Versatility
- Real-Time Monitoring

Limitations:

1. Environmental Interference 2. Limited Range

6.Ultrasonic Sensors

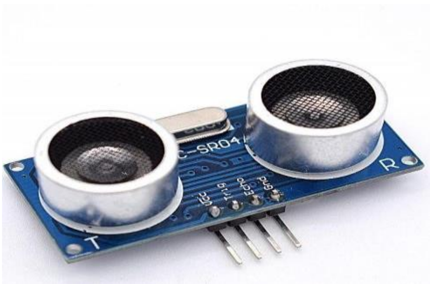
Ultrasonic sensors are devices that use ultrasonic sound waves to detect the presence, distance, and characteristics of objects in their vicinity. Ultrasonic distance sensors measure the distance to an object and are often used in applications such as parking assistance systems, liquid level measurement, and object detection in industrial settings.

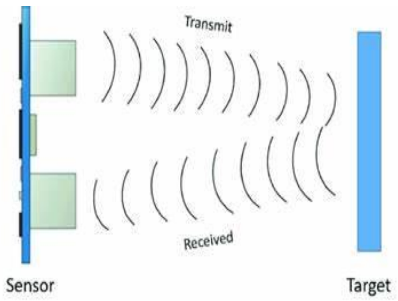
Working Principle:

Ultrasonic sensors emit high-frequency sound waves (ultrasonic waves) and measure the time it takes for the sound waves to bounce back after hitting an object. By calculating the time taken for the sound waves to return and knowing the speed of sound in the medium, the sensor can determine the distance to the object. The basic setup includes a transducer that converts electrical energy into ultrasonic waves and vice versa.

Description table:

Pin	Function	Unit/Output Example
VCC	Positive power supply	5V
GND	Reference potential (the "ground")	0
AO	Generates an analog signal	-
DO	Generates a digital signal	500





Applications:

- **Robotics and Automation:**
  Ultrasonic sensors play a crucial role in robotics and automation for obstacle avoidance, navigation, and precise positioning.
- **Parking Assistance Systems:**
  Used in automotive applications for parking assistance, ultrasonic sensors help drivers avoid collisions by detecting obstacles in their vicinity.
- **Industrial Automation:**

In manufacturing environments, ultrasonic sensors are employed for object detection, quality control, and process monitoring.

- **Medical Imaging:**Ultrasonic sensors are integral to medical imaging technologies such as ultrasound, providing non-invasive imaging for diagnostics.

Advantages:

- **Non-Contact Measurement:**
  Ultrasonic sensors offer non-contact distance measurement, reducing wear and tear and enabling measurements in challenging environments.
- **Versatility:**
  With various types available, ultrasonic sensors are versatile and adaptable to different applications and industries.
- **Accuracy:**
  Ultrasonic sensors provide accurate distance measurements, making them suitable for applications that require precision.

Limitations:

- **Environmental Factors:**

External factors like temperature, humidity, and air pressure can affect the speed of ultrasonic waves, impacting the sensor's accuracy.

- **Limited Range:**
  Ultrasonic sensors may have a limited range compared to other sensing technologies, which may require consideration in certain applications.

Conclusion:

Ultrasonic sensors stand as indispensable tools in a wide array of applications, providing reliable and accurate distance measurement and object detection. As technology advances, their integration with AI, IoT, and ongoing improvements in range and resolution are likely to expand their utility and contribute to further innovation across industries.

7. Sound Sensor:

Sound sensors, also known as sound detectors or acoustic sensors, are essential components in various technological applications, enabling the detection and analysis of sound waves. A sound sensor typically consists of a microphone, a power amplifier, and an output actuator.

The microphone converts the sound signal into an electrical signal, which is then amplified and processed by the power amplifier. The output actuator, such as a loudspeaker, converts the electrical signal back into a sound signal for listening.

Working Principle:
Sound sensors operate based on the conversion of acoustic waves into electrical signals. They typically consist of a microphone or a transducer that converts variations in air pressure caused by sound waves into electrical voltage. The generated electrical signal can then be processed and analysedfor various applications.

Pins description:

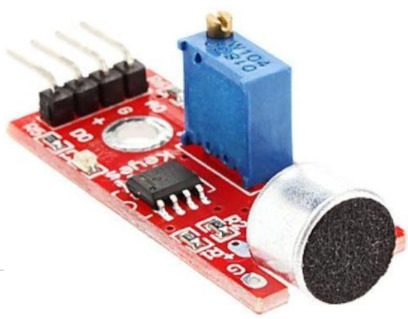
Pin	Function	Unit/Output Example
VCC	Positive power supply	5V
GND	Reference potential (the “ground”)	0
A_o	Generates an analog signal	-
D_o	Generates a digital signal	650

Types of Sound Sensors:

- **Microphone-Based Sound Sensors:**
  Utilizing microphones as the sensing element, these sensors capture variations in air pressure to convert sound into electrical signals.

- **Piezoelectric Sensors:**
  These sensors employ piezoelectric materials that generate voltage in response to mechanical vibrations, including sound waves.

Applications:



- **Noise Monitoring**
- **Security Systems**
- **Consumer Electronics**
- **Industrial Automation**

Arduino Uno Microcontroller

Introduction:

The Arduino Uno is a widely-used open-source microcontroller board that has gained immense popularity in the maker and electronics communities. Developed by Arduino LLC, the Arduino Uno is recognized for its versatility, ease of use, and robust capabilities.

Key Features:

- **Microcontroller:**The Arduino Uno is built around the Atmel ATmega328P microcontroller, providing a clock speed of 16 MHz
- **Digital and Analog I/O Pins:**It features 14 digital input/output pins and 6 analog input pins, offering flexibility for a wide range of projects.
- **USB Interface:**The board is equipped with a USB interface, simplifying the process of programming and power supply.
- **Integrated Development Environment (IDE):**Arduino Uno isprogrammed using the Arduino IDE, providing a user-friendly platform for code development and uploading.

Technical Specifications:

Microcontroller: Atmel ATmega328P
Operating Voltage:5V
Input Voltage:7-12V
Digital I/O Pins:14 (of which 6 provide PWM output)
Analog Input Pins:6
Flash Memory:32 KB (0.5 KB used by bootloader)
SRAM:2 KB
EEPROM:1 KB
Clock Speed:16 MHz

Applications:

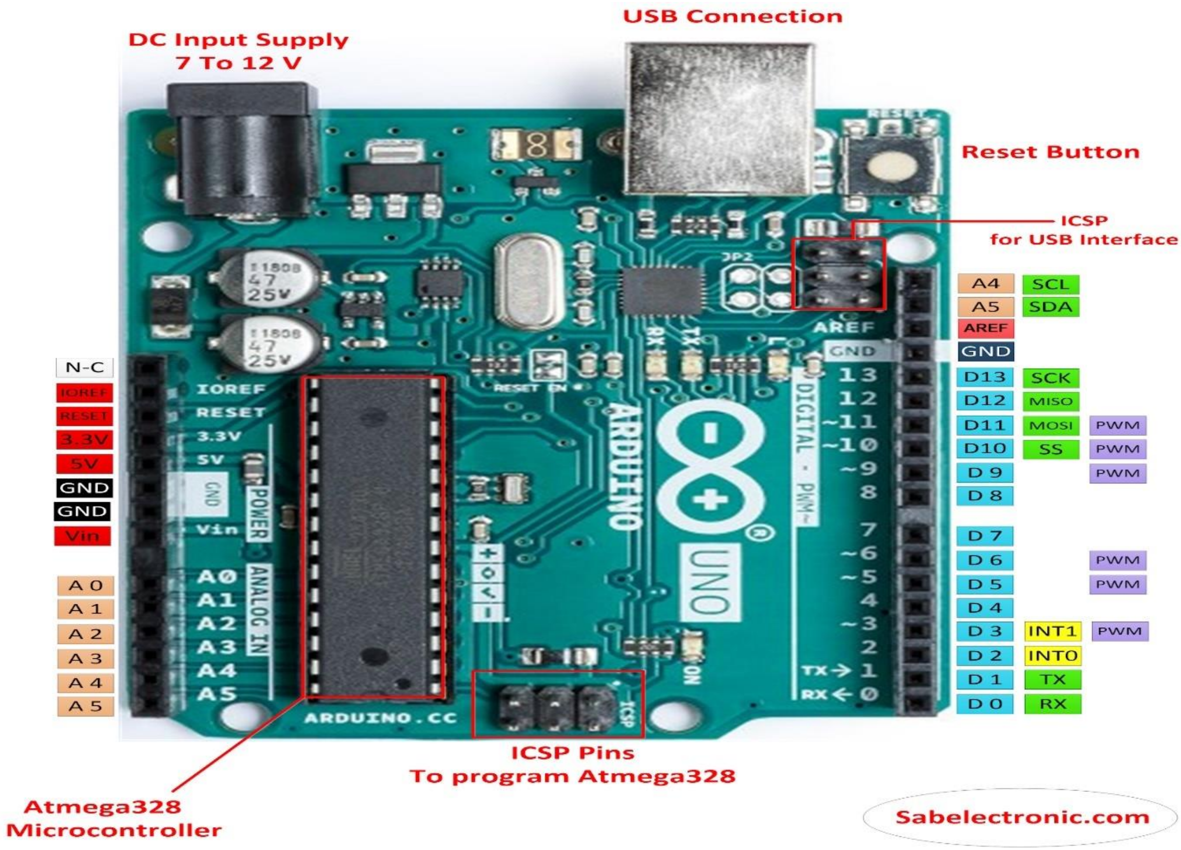
- **Education:**Arduino Uno is widely used in educational settings to teach programming, electronics, and robotics due to its simplicity and ease of learning.
- **Prototyping:**Its flexibility makes it an ideal choice for prototyping electronic projects and systems before moving to more complex microcontrollers.
- **DIY Electronics:**Enthusiasts and hobbyists utilize Arduino Uno for various do-it-yourself electronics projects, including home automation, sensor interfacing, and interactive installations.
- **Embedded Systems:**In the development of small-scale embedded systems, the Arduino Uno serves as a powerful and cost-effective solution.

Advantages:

- **Open-Source Platform:**The Arduino Uno is built on an open-source platform, fostering a vast community of developers who contribute to libraries, tutorials, and projects.
- **Ease of Use:**Its user-friendly IDE, simple programming language, and a wealth of online resources make it accessible even to beginners.
- **Versatility:**The large number of I/O pins, both digital and analog, and compatibility with various sensors and shields make the Arduino Uno versatile for a multitude of applications.

Limitations:

- **Limited Processing Power:**For complex tasks requiring high processing power, the Arduino Uno may be less suitable compared to more advanced microcontrollers.
- **Limited Memory:**Projects with extensive code and data storage requirements may face limitations due to the board's memory constraints.



Impact on the electronics Field:

The Arduino Uno has played a pivotal role in democratizing electronics and programming, enabling individuals with diverse backgrounds to engage in creative and innovative projects. Its open-source nature has led to the development of a vast ecosystem, including a wide array of shields and sensors that extend its capabilities.

The Arduino Uno microcontroller has become a cornerstone in the world of electronics and maker communities. Its simplicity, versatility, and extensive community support make it an ideal choice for beginners, educators, and professionals.

Arduino IDE :

The Arduino IDE (Integrated Development Environment) is a software platform used for programming Arduino microcontrollers. It provides a user-friendly interface for writing, compiling, and uploading code to Arduino boards.

Brief overview of how it works:

Writing Code: Users write code in the Arduino IDE using the Arduino programming language, which is based on C/C++.

Compiling Code: Once the code is written, users can compile it by clicking the "Verify" button in the IDE. The IDE converts the human-readable code into machine-readable instructions that the Arduino board can understand.

Uploading Code: After successfully compiling the code, users can upload it to the Arduino board by clicking the "Upload" button in the IDE. The IDE sends the compiled code to the Arduino board via a USB cable or other communication interface.

Main features:

Cross-Platform Compatibility: The Arduino IDE is compatible with multiple operating systems including Windows, macOS, and Linux, making it accessible to a wide range of users.

Library Manager: Arduino IDE includes a library manager that allows users to easily install and manage libraries, which are collections of pre-written code that extend the functionality of Arduino boards

Serial Monitor: The IDE includes a serial monitor tool that allows users to communicate with Arduino boards in real-time.

Board Manager: Arduino IDE supports a wide range of Arduino-compatible boards.

Serial Plotter: It is a powerful tool within the Arduino IDE that allows users to visualize data in real-time from sensors or other devices connected to an Arduino board.

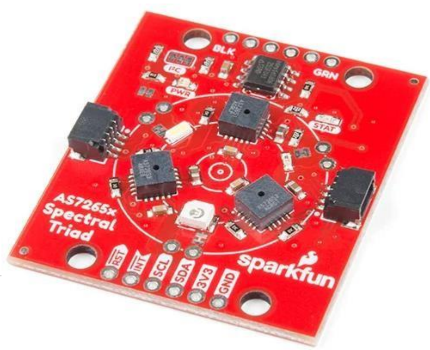
AS7265x Spectral Sensor

The AS7265x is a multispectral sensor designed for spectral analysis, allowing precise measurement of different intensities at various wavelengths of light. Developed by ams AG, this sensor is known for its integration of Eighteen independent optical filters, providing accurate spectral data. The AS7265x is the simplest Triad Spectroscopy Sensor from Sparkfun which can also be called a Spectrophotometer.

The sensor is formed by combining three sensors AS72651, AS72652 & AS72653. The AS72651 is for measuring the visible light spectrum. Similarly, AS72652 is for measuring UV Light. The AS72653 is an IR Sensor for measuring IR Radiation. The sensor also has a 4Mbit EEPROM which is loaded by the firmware which drives the system. The EEPROM is read by the AS72651 at power on.

Working Principle:

The AS7265x Triad Spectroscopy Spectral Sensor detects the light from a wavelength of 410nm to 940nm. The sensor has the ability to measure 18



individual light frequencies with precision down to 28.6 nW/cm2 and accuracy of +/-12%. The sensor operates at a typical voltage of 3.3V. The sensor has I2C pins as SDA (Serial Data) & SCL (Serial Clock) with an I2C address of 0x49. The default baud rate for the sensor is 115200.

Features:

Eighteen Independent Channels: The AS7265x sensor features Eighteen independent spectral channels, covering wavelengths from approximately 410 nm to 940 nm.

Integration of Filters: Each channel includes a filter that allows selective measurement of specific wavelength ranges, enabling accurate spectral analysis.

Digital Interface: The sensor communicates with external devices through an I2C digital interface, facilitating easy integration into various electronic systems.

Applications:

Colour Sensing: The AS7265x is utilized in colour-sensing applications, enabling the precise measurement of RGB values and contributing to colour accuracy in imaging systems.

Spectral Analysis: In scientific research and industrial applications, the sensor is employed for spectral analysis, providing valuable data on the composition of materials.

Agricultural Monitoring: The sensor finds application in agriculture for monitoring crop health, assessing nutrient levels, and optimizing growth conditions based on spectral data.

Advantages:

High Precision: The AS7265x sensor provides high precision in spectral measurements, making it suitable for applications requiring accurate data.

Digital Interface: The I2C digital interface enhances the sensor's compatibility with various microcontrollers and communication protocols.

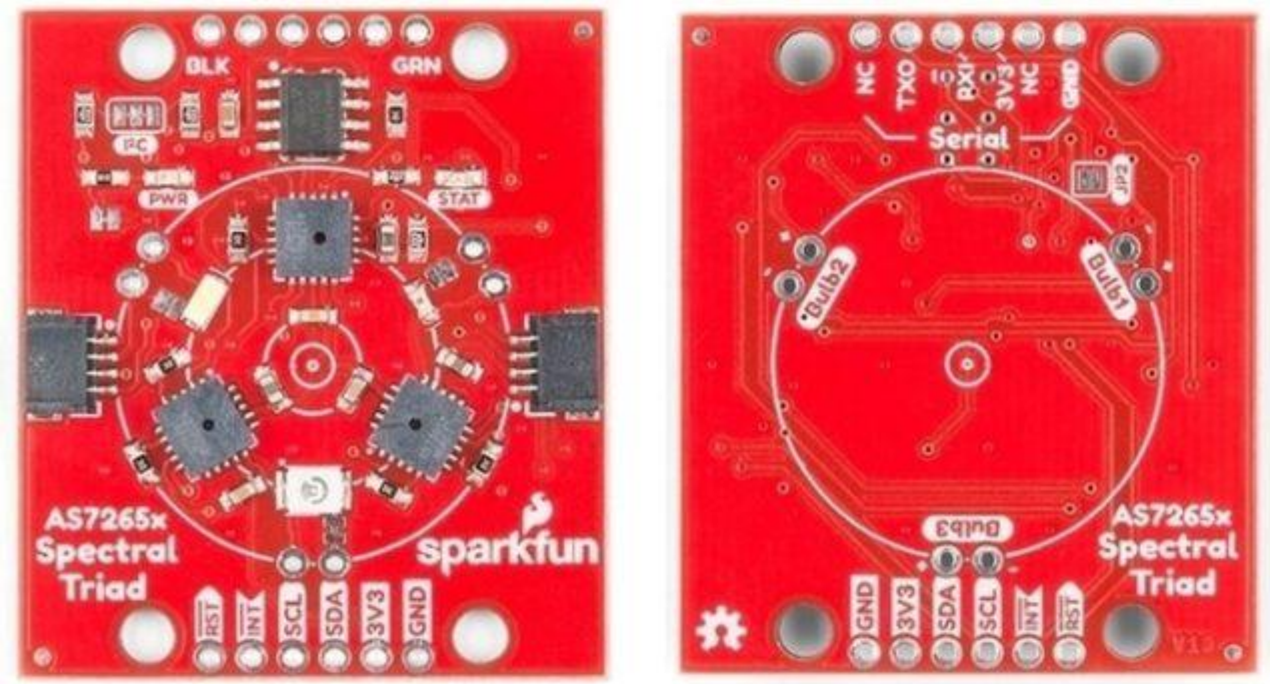
Limitations:

Limited Wavelength Range: While the AS7265x covers a broad range of wavelengths, certain applications may require sensors that extend into the infrared or ultraviolet spectrum.

Cost: The high precision and feature-rich nature of the AS7265x may make it relatively expensive for some budget-sensitive projects.

Conclusion:

The AS7265x spectral sensor stands as a powerful tool for applications demanding high-precision spectral analysis. Its compact design and digital interface make it a versatile choice for various industries, including agriculture, scientific research, and imaging.



Thermal Images by Flir One Camera

The FLIR ONE® Gen 3 is an affordable smartphone attachment thermal imaging camera designed to help professionals find problems faster and get more work done in less time. With MSX® (Multi-Spectral Dynamic Imaging) technology, which enhances thermal images by embossing details from the visual camera onto the thermal image.

FLIR ONE® Gen 3 cameras also provide a OneFit™ connector that adjusts and extends up to 4 mm to fit many popular protective cases. Whether inspecting electrical panels, looking for HVAC problems, or finding water damage, FLIR ONE® Gen 3 thermal imaging cameras enable users of all experience levels to work efficiently while on-the-go. The FLIR ONE Gen 3, FLIR ONE Pro, and FLIR ONE Pro LT are not compatible with iPhone 15 and later models. For iOS customers with USB-C ports, we recommend the FLIR ONE Edge or FLIR ONE Edge Pro. Check mobile devices compatibility.

SPECIFICATIONS:

Thermal Resolution: 80x60

Battery Life: Approximately 1h
Object Temperature Range: -20°C to 120°C (–4°F to 248°F)
Phone:Android
Accuracy :±3°C or ±5%, typical Percent ofthe difference between ambient and scene temperature. Applicable 60s after start-up when the unit is within 15 °C – 35 °C and the scene is within 5 °C – 120 °C.
Operating Temperature: 0°C – 35°C (32°F – 95°F), battery charging 0°C – 30°C (32°F – 86°F)
Spot Meter One spot meter (centered).

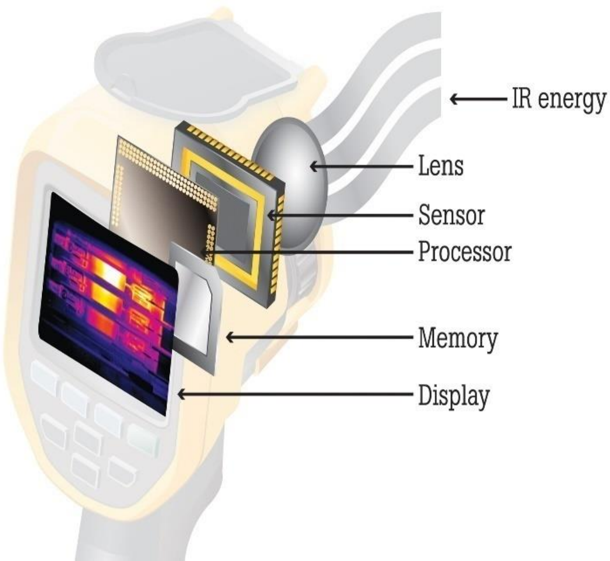
Working:Mainly based on Near infrared rays (NIR)

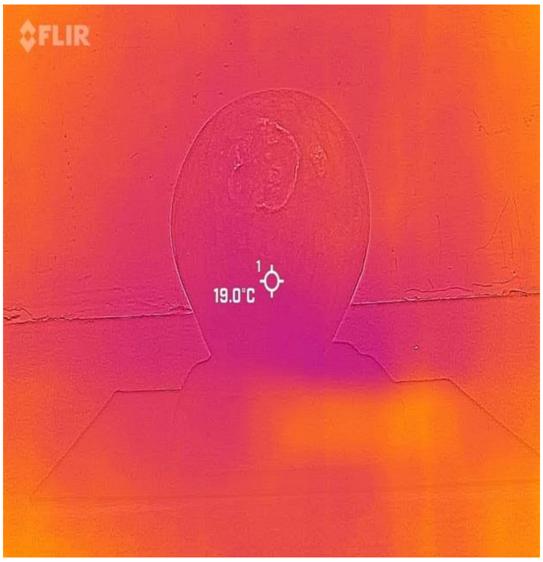
Thermal IR imaging detects the heat from the surface of the fruit. Due to defective tissues of fruit pulp, the non-uniform temperature difference is observed and sensed on the surface of the fruit.

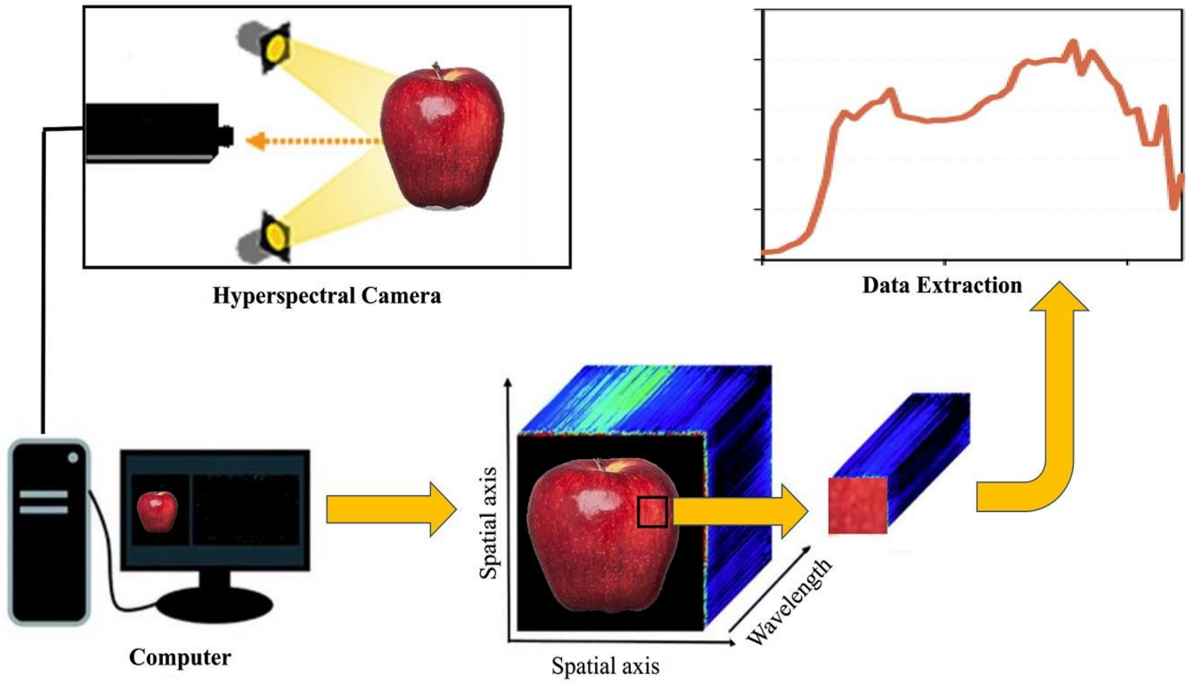
Thermal IR Imaging:

- Infrared Radiation:1. All objects emit infrared radiation. 2. Depends on temperature.
- Sensor Detection: 1. Infrared detectors (e.g., microbolometers). 2. Capture infrared radiation.
- Image Formation: Process electrical signals.
- Temperature Mapping: Assign colours or shades based on temperature.

This is what we have made in our project and for that reference we have attached an image below which depict the working of near infrared rays imaging.







Thermal Imaging of Apples at Varied Temperatures:

Experimental Setup:

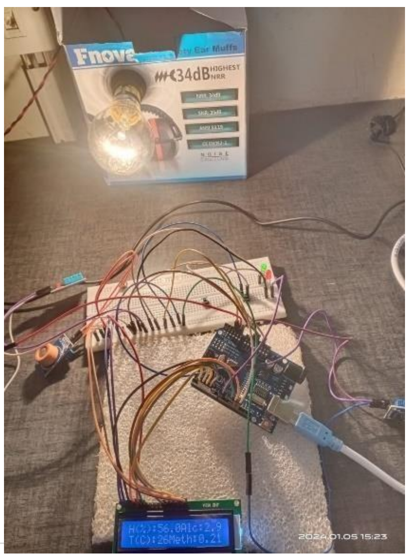
Thermal images were acquired using a thermal imaging camera capable of capturing both greyscale and colour images. Apples were chosen as the subject due to their temperature-sensitive nature and relevance to agriculture and food industries.

Images were captured at two different temperatures,*16 degrees Celsius and 26 degrees Celsius* to simulate conditions relevant to storage and ripening.

A100 Watts bulb is used to varying the temperature in the proximity of apple and temperature is continuously monitored by using the temperature and humidity sensors.The data is continuously observed on the display attached to the Arduino uno board.

RGB, Greyscale, and Hot Metal Imaging:

- RGB Imaging: Traditional RGB images provide a visual representation of the apples with colours corresponding to their surface temperatures. These images serve as a baseline for comparison and are valuable for overall observation.
- Greyscale Imaging: Greyscale images, derived from thermal data, emphasize temperature variations without



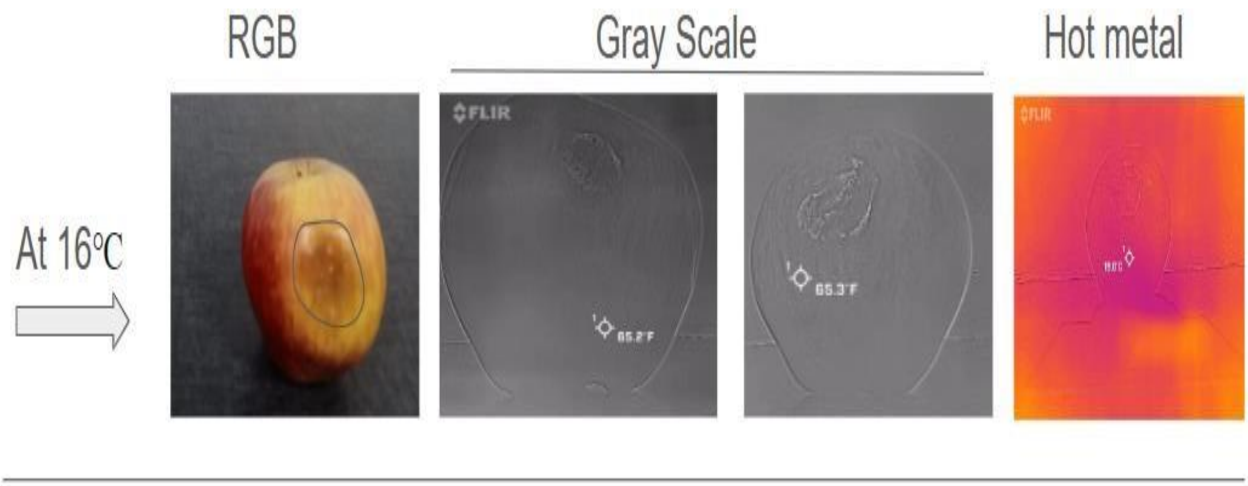
colour distraction. This can offer a clearer representation of temperature distribution.

- Hot Metal Imaging: The hot metal colour palette assigns colours to different temperature ranges, allowing for a vivid and intuitive visualization of thermal patterns on the apples.

Observations:

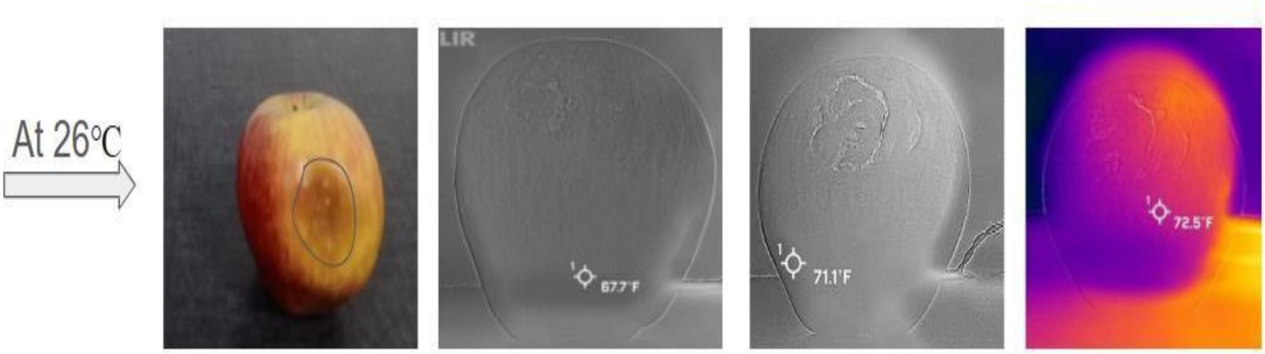
At 16 Degrees Celsius:

- RGB: Apples appear relatively uniform in colour, with subtle variations.
- Greyscale: Temperature variations are more pronounced, revealing nuanced differences in thermal patterns.
- Hot Metal: Vivid colours highlight specific temperature ranges, providing a visually distinct representation of the thermal profile.



At 26 Degrees Celsius:

- RGB: Increased colour intensity indicates higher temperatures, with some apples showing more distinct thermal variations.
- Greyscale: Temperature differences are more evident, emphasizing the impact of increased warmth.
- Hot Metal:The colour palette effectively illustrates temperature variations, aiding in the identification of warmer regions.



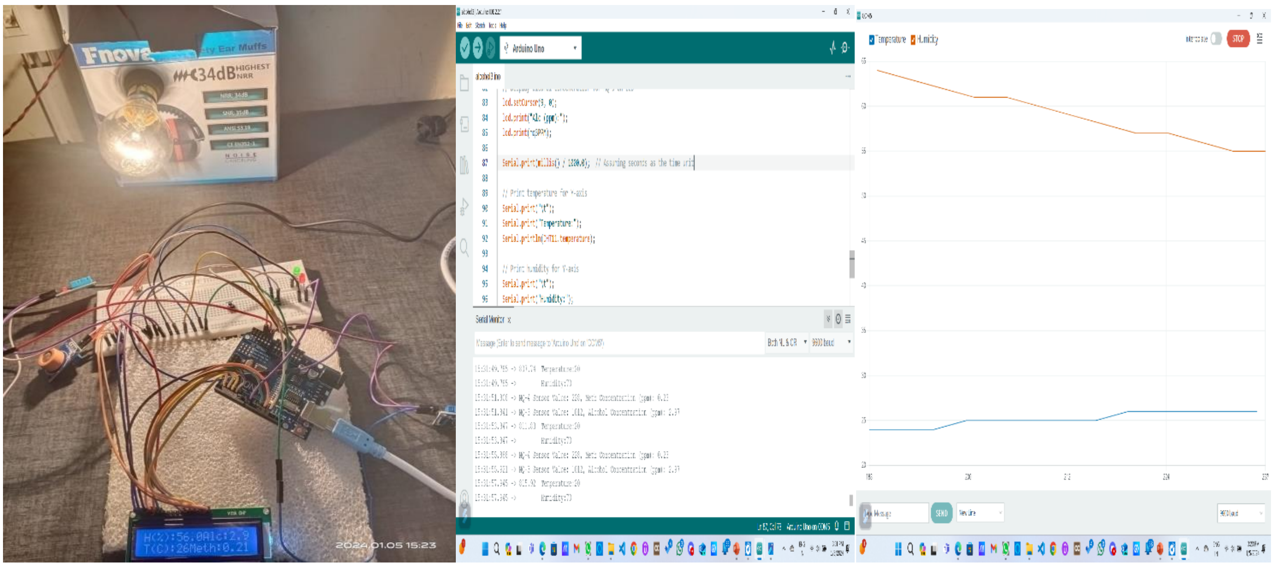
Analysis:

- Temperature Influence: The images at 26 degrees Celsius generally exhibit more pronounced temperature differences compared to those at 16 degrees Celsius, highlighting the impact of temperature on the thermal profile of apples.
- Palette Effectiveness: The hot metal colour palette proves effective in visually conveying temperature variations, offering an intuitive representation that complements traditional RGB and greyscale images.

<u>When bulb is switched ON</u>:

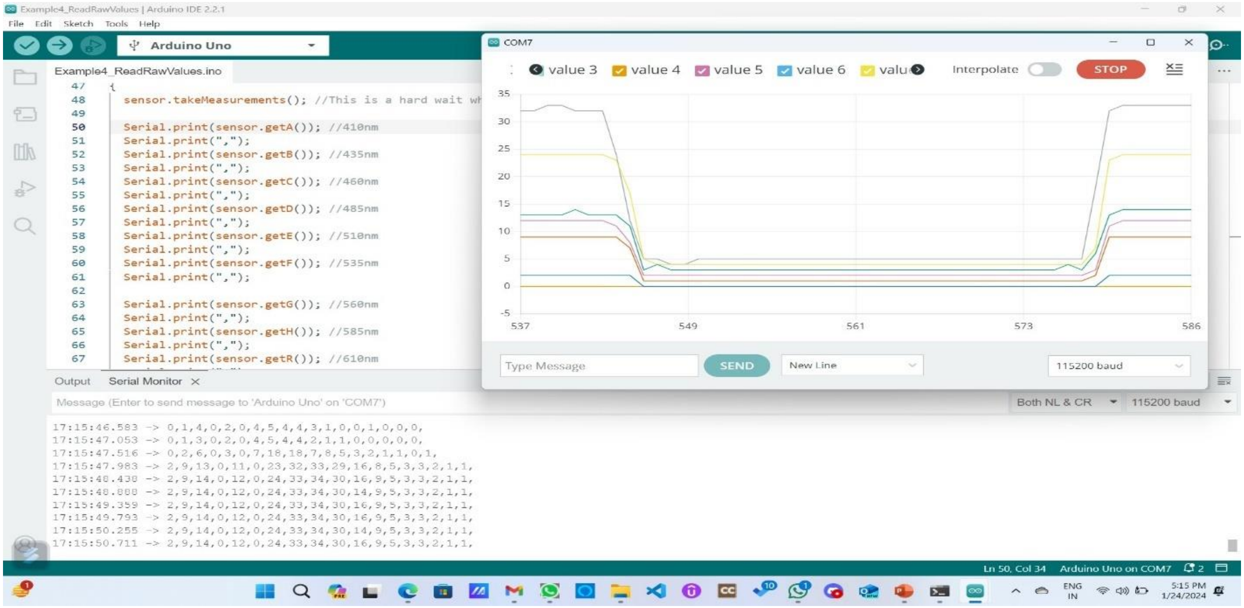
Analyse the data and plot of temperature and humidity.

Data on lcd displayserial monitor serial plotter



<u>Tools and software for Simulation:</u>

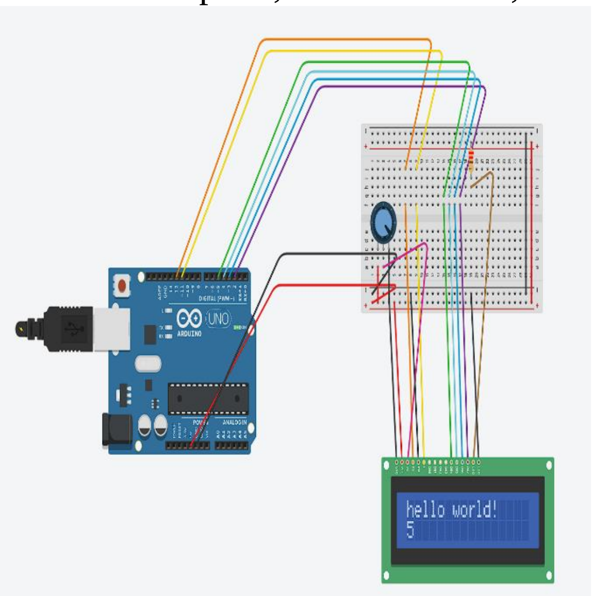
1.Arduino Ide: We have used the integrated development environment of Arduino uno to run the code and analyse the data using its main features such as serial plotter and serial monitor.

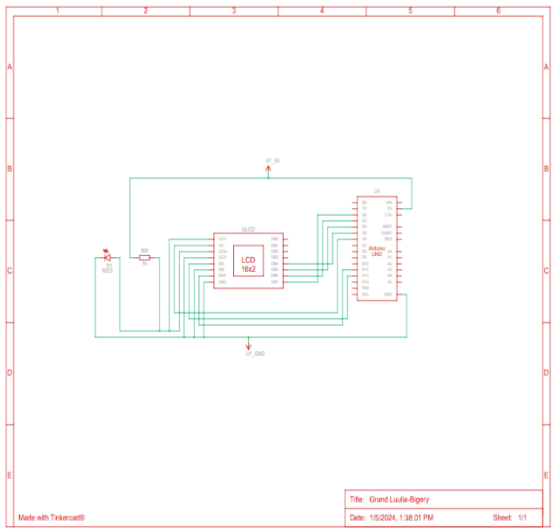


2.Tinker Cad and Wokwisoftware: Tinker Cad is a free-of-charge, online 3D modelling software that runs in a web browser, developed by Autodesk.

Tinker Cad's Circuits section is a browser-based electronic circuit simulator that supports Arduino Uno microcontrollers. Code can be created using graphical CodeBlocks,the software offers pre-built circuits called "Starters" or circuits that can be built using separate components.

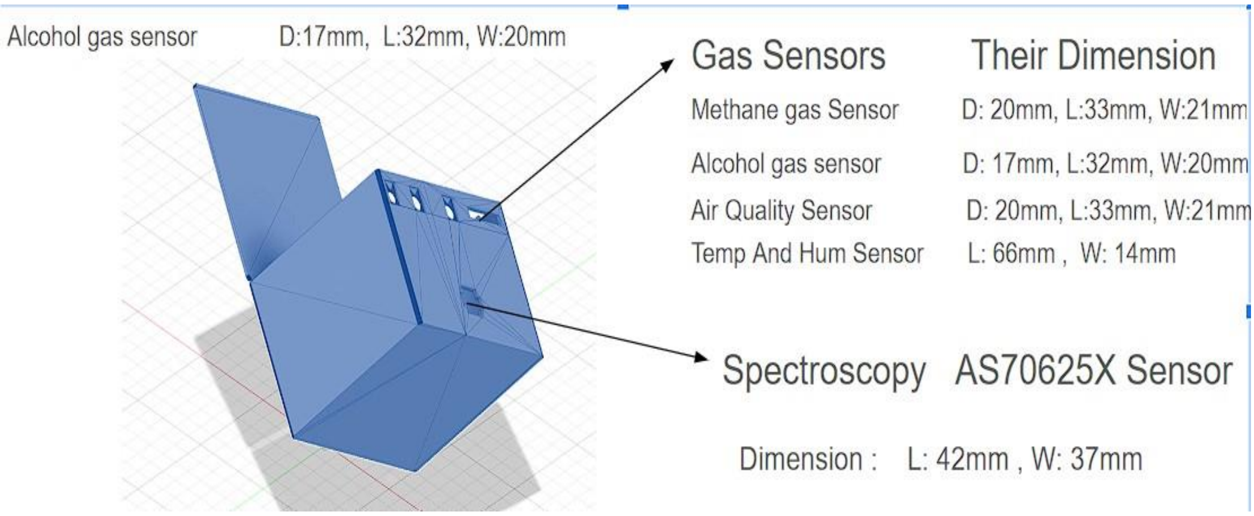
Tinker Cad comes with built-in libraries for popular components, including the Adafruit Neopixel, Arduino Servo, and I2C display libraries.





3.Fusion 360: Fusion 360 is a comprehensive cloud-based 3D modelling software developed by Autodesk. It is widely used by designers, engineers, and manufacturers for creating, simulating, and prototyping various products and components.

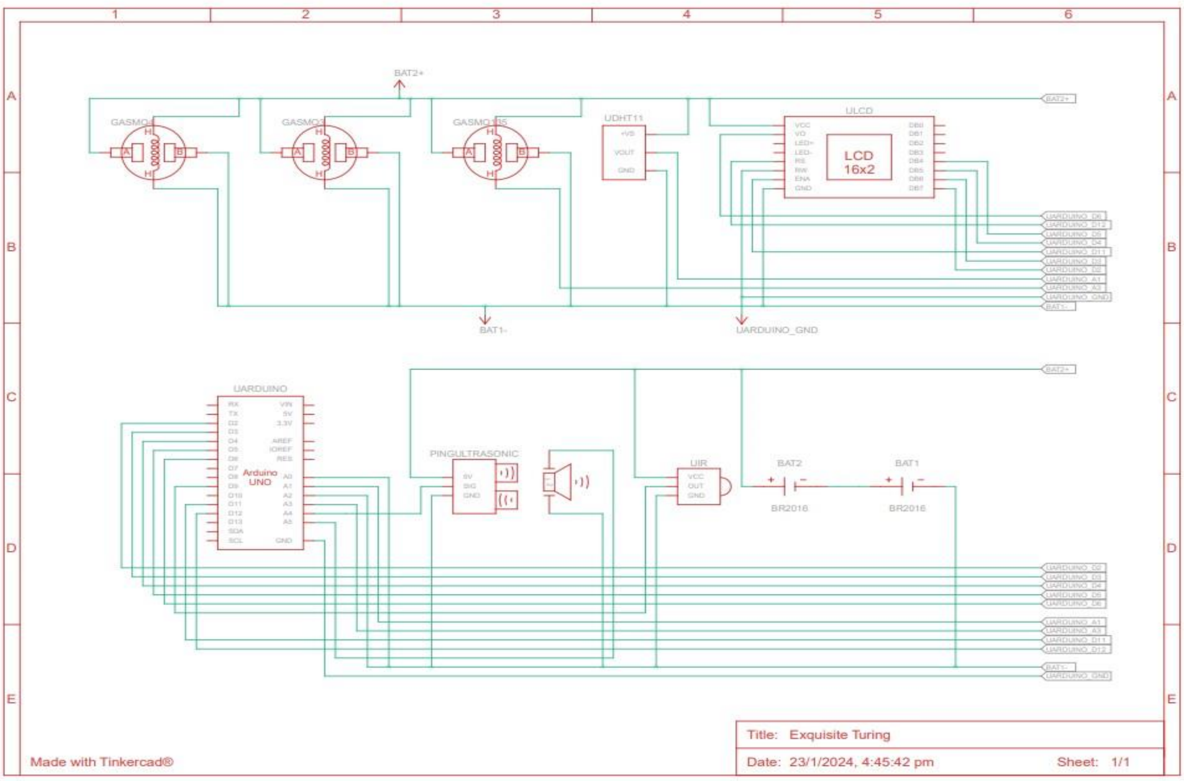
We have used the Fusion 360 designing software to design the model structure.



4.Eagle Cad Software: Used for designing of PCB

EAGLE *(Easily Applicable Graphical Layout Editor)* is a popular electronic design automation (EDA) software developed by Autodesk. It is widely used by engineers, designers, and hobbyists for designing printed circuit boards (PCBs).

It is a versatile and powerful tool for designing PCBs, offering a comprehensive set of features and capabilities to support the entire PCB design process, from schematic capture to manufacturing.



spoilage detection device.

System Architecture:

The integrated system utilizes a breadboard to connect the Arduino Uno with the various sensors. The MQ-3 and MQ-4 sensors detect gases emitted during fruit spoilage, the DHT11 measures temperature and humidity, the IR sensor identifies the presence of objects, the Ultrasonic sensor determines the distance to an object, the Sound sensor captures audio signals indicative of spoilage events and multispectral sensors provides the behaviour of molecules when come across to a range of radiations by observing the plot.

Working Principle:

- MQ-3 Gas Sensors: Detect alcoholic gases released during fruit spoilage, providing early indicators of decay.
- MQ-4 Gas Sensors: Detect methane gas released during fruit spoilage, providing early indicators of decay.
- Temperature and Humidity Sensor (DHT11): Monitors environmental conditions to assess their impact on fruit freshness.
- Infrared Sensor: Detects the presence of objects, helping in identifying the quantity and arrangement of fruits.
- Ultrasonic Sensor:Measures the distance to objects, ensuring optimal sensor placement for accurate readings.
- Sound Sensor: Captures sound waves, analysing them for patterns associated with spoilage events.
- Multispectral Sensors:provides the behaviour of molecules when come across to a range of radiations by observing the plot and variations in the readings.

Data Fusion and Analysis:

The sensor data is collected by the Arduino Uno and processed to create a comprehensive understanding of the fruit storage environment. By analysing the gasconcentrations, temperature, humidity, object presence, distance, and audio signals and the spectral analysis the system can make informed decisions about the freshness and spoilage status of the fruits.

Thresholds and Alerts:

The system incorporates predefined thresholds for each sensor parameter. When readings surpass these thresholds, it triggers alerts to notify users about potential fruit spoilage. These alerts can be visual (LED indicators, buzzer) or transmitted to external devices through communication modules.

Performing the experiment for non-destructive apple spoilage detection involves several steps. Here is a step-by-step guide:

1. Assemble the Hardware:
   - Connect the AS7265x spectral sensor, MQ3, MQ4, DHT11, and infrared obstacle sensor to the Arduino Uno using jumper wires and a breadboard.
   - Connect the LEDs, buzzer, and LCD to the appropriate pins on the Arduino board.

2. Upload the Code:
   - Copy and paste the provided Arduino code into the Arduino Integrated Development Environment (IDE).
   - Connect the Arduino Uno to your computer and upload the code to the board.

3. Verify Connections:
   - Double-check all wiring connections to ensure they match the pin configurations in the code.
   - Confirm that the sensors are correctly placed and oriented.

4. Prepare the Test Environment:
   - Set up a controlled environment for testing, ensuring a consistent temperature for the apples.
   - This may involve using a temperature-controlled chamber or placing the apples in a controlled room.

5. Place the Apples:
   - Position the apples in the testing environment, making sure they are easily accessible to the sensors without any physical interference.

6. Power on the System:
   - Power on the Arduino Uno and allow the sensors to initialize.

7. Press the button present on the device:
   - Press the button on breadboard first time to get the UV spectrum of the fruit.
   - Press the button on breadboard second time to get the visible spectrum of the fruit.
   - Press the button on breadboard third time to get the IR spectrum of the fruit.
   - Press the button on breadboard fourth time to get the reading of Methane gas sensor, alcohol gas sensor, temperature and humidity gas sensor, Air Quality sensor.
   - Press the button on breadboard fifth time to get the reading of IR sensor.

8. Monitor the Serial Output:

- Open the Arduino Serial Monitor to observe real-time readings from the sensors.
- Check for values related to the spectral signature from the AS7265x sensor, gas concentrations from MQ3 and MQ4 sensors, and environmental conditions from the DHT11 sensor.

9. Monitoringthe data on the display:
   - Check the reading on the display.
   - Check for values related to the spectral signature from the AS7265x sensor, gas concentrations from MQ3 and MQ4 sensors, environmental conditions from the DHT11 sensor and detection of the internal quality of freshness of apple.

Spectral Analysis Using AS7265x with Arduino Uno

The successful integration of the AS7265x spectral sensor with an Arduino Uno microcontroller to capture and display 18 different spectral readings using the serial plotter. The AS7265x sensor is a multispectral sensor known for its ability to provide accurate spectral data across various wavelengths. The experiment aimed to demonstrate the functionality of the sensor in conjunction with the Arduino Uno and visualize the spectral readings through the serial plotter.

Experimental Setup:

The AS7265x sensor was connected to the Arduino Uno following the manufacturer's specifications.

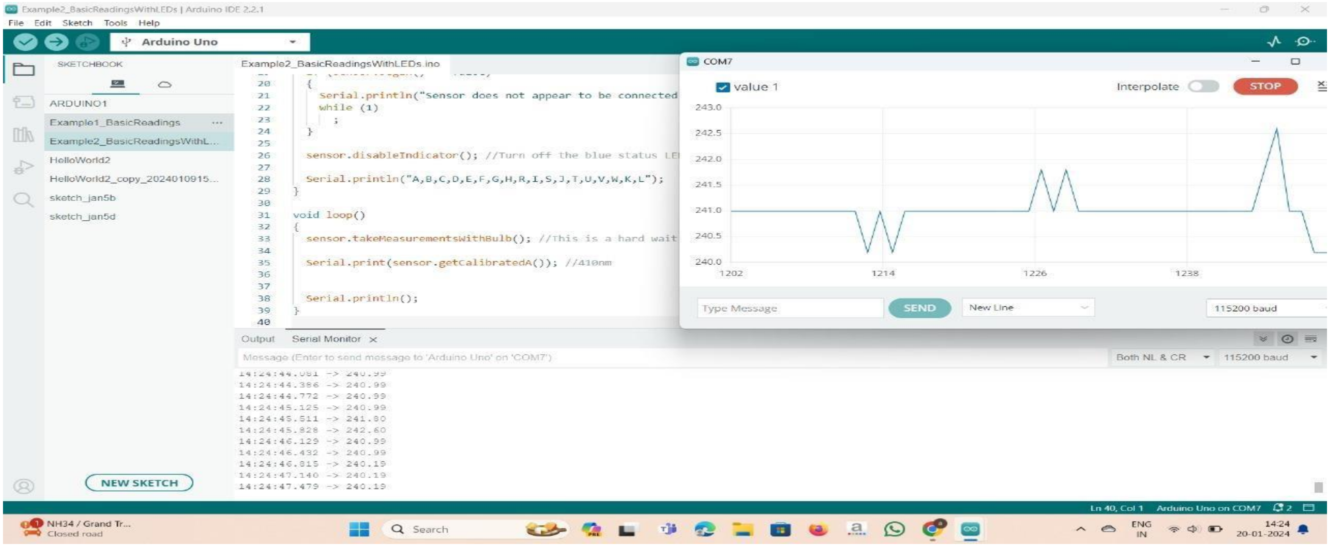
The sensor's spectral readings, covering 18 different wavelength bands, were interfaced with the Arduino Uno, and the data was transmitted to the computer for visualization using the Arduino IDE's serial plotter. The experiment aimed to observe the spectral characteristics of the ambient environment and any specific light sources.

Arduino Code:

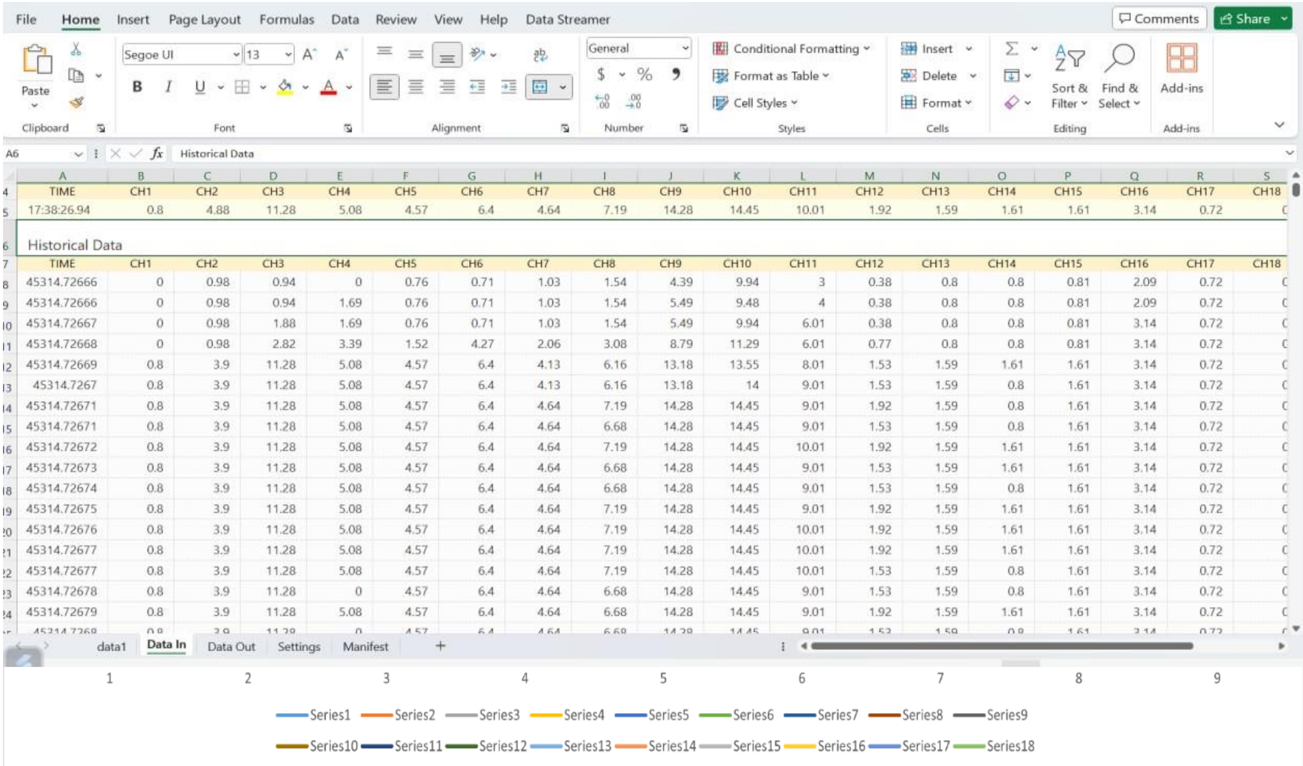
The Arduino code was developed to initialize the AS7265x sensor, read the spectral data, and transmit it serially to the computer. The code utilized the Wire library for I2C communication with the sensor. Each of the 18 spectral bands was read sequentially, and the data was sent to the serial port for real-time visualization.

Spectral Data Visualization:

The serial plotter in the Arduino IDE was employed to visualize the 18 spectral readings. The x-axis represented the different spectral bands, and the y-axis indicated the intensity or amplitude of the spectral response. The resulting plot provided a graphical representation of the light spectrum detected by the AS7265x sensor.



Streaming the data on MS-excel to plot and stored data:



Observations:

The spectral plot revealed distinctive peaks and troughs in the readings, corresponding to the sensor's response to different wavelengths. Peaks indicated higher intensity in those spectral bands, while troughs represented lower intensity. This information could be correlated with known spectral characteristics to identify light sources or environmental factors influencing the spectrum.

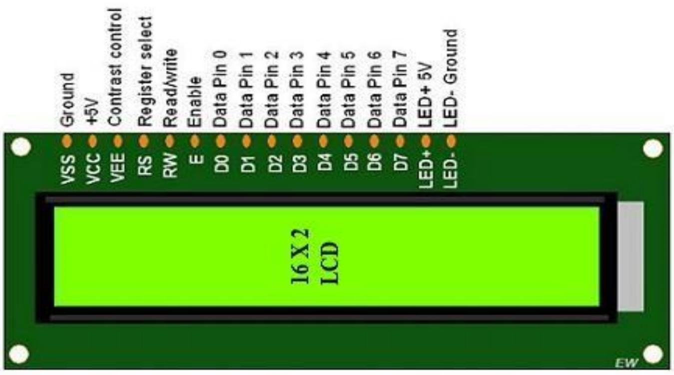
Hardware connections:

Display pins-Arduino pins	Sensor’s o/p pins-Arduino
A-5V	MQ3-A2
K-GND	MQ4-A0
RS-12	MQ135-A3
RO-6	DHT11-A1
RW-GND	IR-9
E-11	Button-1
D4-5	For AS7265x
D5-4	SDA-A4(Serial data)
D6-3	SCL-A5(Serial clock)
D7-2	

Apart from the above connections, The VCC and GND of each sensor will be connected to external supply .

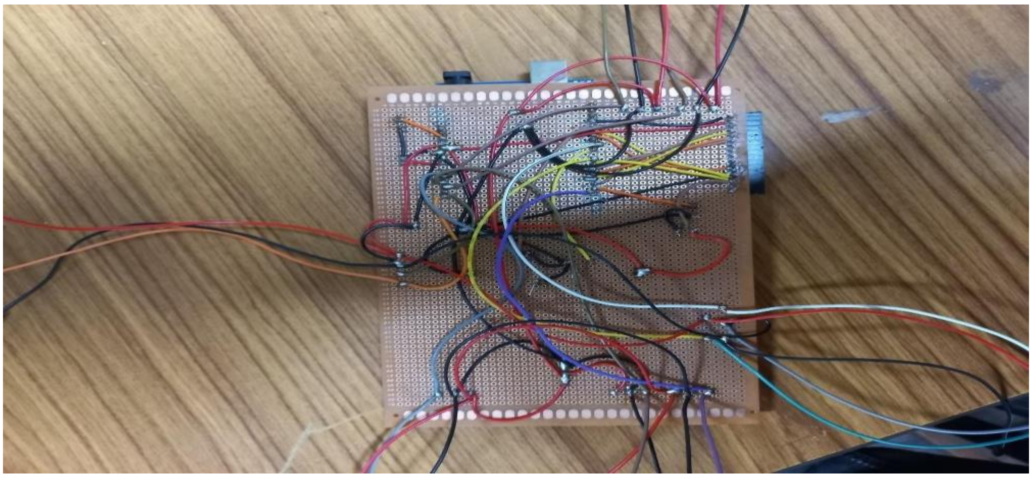
Display to observe the data:

A 16x2display refers to a type of liquid crystal display (LCD) module commonly used in electronics project and devices."16x2" specification indicates that the display has 16 characters positions on each of its two lines, totalling 32 characters.

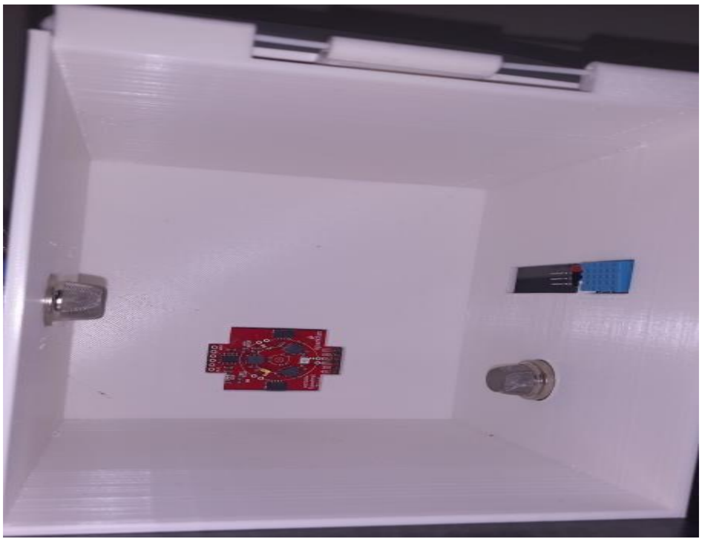


Zero Order PCB:

we have made a zero order PCB according to the connection above, to avoid themess of wires on the breadboard and to give the device a final finish.



Enclosure: We have made an enclosure, and attached all the sensor and display in available slots in the enclosure which is made up of fully white plastic material using 3-D printer.



Arduino IDE Code:

We have written the code using C & C^{++} languageon Arduino ide and install required libraries for getting the output of each of sensors and observe the output for Multi-sensor Non-destructive Spoilage Detection System for Fruits.

Code:

```
#include "SparkFun_AS7265X.h" // Click here to get the library:
http://librarymanager/All#SparkFun_AS7265X
#include <LiquidCrystal.h>
#include <dht11.h>
#include <Wire.h>
#define DHT11_PIN A2
#define MQ3_PIN A1
#define MQ4_PIN A3
#define MQ135_PIN A0
#define MQ3 1
#define MQ4 2
#define ANALOGPIN A2 // Define Analog PIN on Arduino Board
dht11 DHT11;
AS7265X sensor;
int mq3Pin = MQ3_PIN;
int mq4Pin = MQ4_PIN;
int ledPin = 13;
int ledPin1 = 8;
int buzzer = 8 ;
int smokeA0 = A4;
int count = 0;
// Your threshold value.
int sensorThres = 700;
LiquidCrystallcd(12, 11, 5, 4, 3, 2);
int Contrast = 0;
const float MQ3_Ro = 10;
const float MQ4_Ro = 10;
// Function declaration outside the loop
float MQGetGasPercentage(float rs_ro_ratio, int gas_id);
void setup(){
Serial.begin(115200);
```

```
Serial.println("AS7265x Spectral Triad Example");
pinMode(1, INPUT_PULLUP);
Serial.println("Point the Triad away and press a key to begin with
illumination...");
while (Serial.available() == false)
{
}
if (sensor.begin() == false)
{
Serial.println("Sensor does not appear to be connected. Please check wiring. Freezing...");
while (1);
}
sensor.disableIndicator();
Serial.println("A,B,C,D,E,F,G,H,R,I,S,J,T,U,V,W,K,L");
analogWrite(6, Contrast);
lcd.begin(16, 2);
// Serial.begin(9600);

pinMode(ledPin, OUTPUT);
pinMode(ledPin1, OUTPUT);
pinMode(buzzer, OUTPUT);
pinMode(smokeA0, INPUT);
}
void loop()
{
int chk = DHT11.read(DHT11_PIN);

int mq3Value = analogRead(mq3Pin);
int mq4Value = analogRead(mq4Pin);
int analogSensor = analogRead(smokeA0);
float mq3PPM = MQGetGasPercentage(mq3Value / MQ3_Ro, MQ3);
float mq4PPM = MQGetGasPercentage(mq4Value / MQ4_Ro, MQ4);
int val = digitalRead(1);
if (val == 0)
{
count = count + 1;
}
sensor.takeMeasurementsWithBulb(); // This is a hard wait while all 18 channels are measured

switch (count)
{
case 1:
Serial.print(sensor.getCalibratedA()); // 410nm
Serial.print(",");
Serial.print(sensor.getCalibratedB()); // 435nm
```

```
Serial.print(",");
Serial.print(sensor.getCalibratedC()); // 460nm
Serial.print(",");
Serial.print(sensor.getCalibratedD()); // 485nm
Serial.print(",");
Serial.print(sensor.getCalibratedE()); // 510nm
Serial.print(",");
Serial.print(sensor.getCalibratedF()); // 535nm
Serial.print(",");
lcd.clear();
lcd.setCursor(0, 0);
lcd.print("410-535nm");
delay(2000);
lcd.clear();
lcd.setCursor(0, 0);
lcd.print(String(sensor.getCalibratedA()) + " " +
String(sensor.getCalibratedB()) + " " + String(sensor.getCalibratedC()));
lcd.setCursor(0, 1);
lcd.print(String(sensor.getCalibratedD()) + " " +
String(sensor.getCalibratedE()) + " " + String(sensor.getCalibratedF()));
break;
case 2:
Serial.print(sensor.getCalibratedG()); // 560nm
Serial.print(",");
Serial.print(sensor.getCalibratedH()); // 585nm
Serial.print(",");
Serial.print(sensor.getCalibratedR()); // 610nm
Serial.print(",");
Serial.print(sensor.getCalibratedI()); // 645nm
Serial.print(",");
Serial.print(sensor.getCalibratedS()); // 680nm
Serial.print(",");
Serial.print(sensor.getCalibratedJ()); // 705nm
Serial.print(",");
lcd.clear();
lcd.setCursor(0, 0);
lcd.print("560-705nm");
delay(2000);
lcd.clear();
```

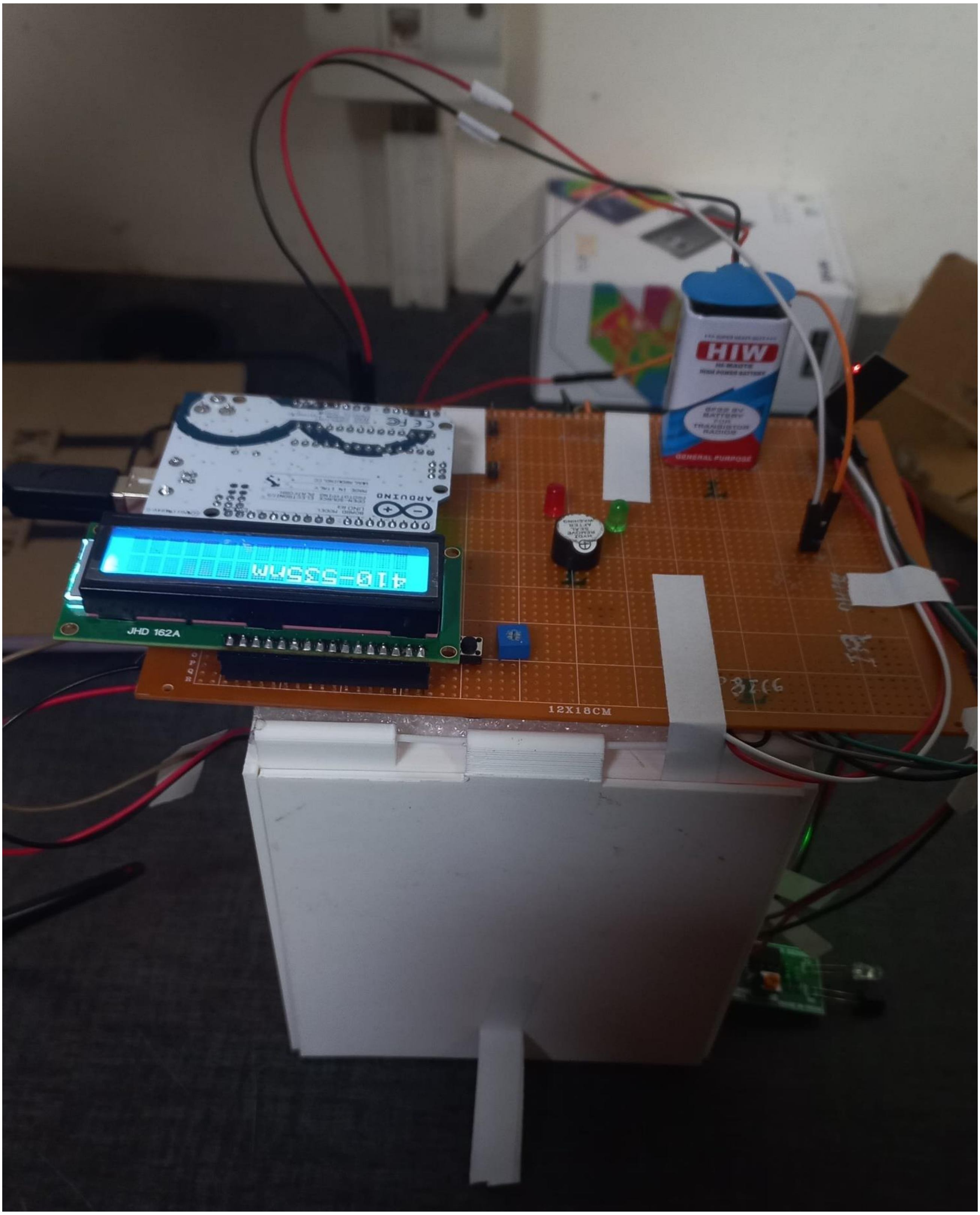
```
lcd.setCursor(0, 0);
lcd.print(String(sensor.getCalibratedG()) + " " +
String(sensor.getCalibratedH()) + " " + String(sensor.getCalibratedR()));
lcd.setCursor(0, 1);
lcd.print(String(sensor.getCalibratedI()) + " " +
String(sensor.getCalibratedS()) + " " + String(sensor.getCalibratedJ()));
break;
case 3:
Serial.print(sensor.getCalibratedT()); // 730nm
Serial.print(",");
Serial.print(sensor.getCalibratedU()); // 760nm
Serial.print(",");
Serial.print(sensor.getCalibratedV()); // 810nm
Serial.print(",");
Serial.print(sensor.getCalibratedW()); // 860nm
Serial.print(",");
Serial.print(sensor.getCalibratedK()); // 900nm
Serial.print(",");
Serial.print(sensor.getCalibratedL()); // 940nm
Serial.print(",");
lcd.clear();
lcd.setCursor(0, 0);
lcd.print("730-940nm");
delay(2000);
lcd.clear();
lcd.setCursor(0, 0);
lcd.print(String(sensor.getCalibratedT()) + " " +
String(sensor.getCalibratedU()) + " " + String(sensor.getCalibratedV()));
lcd.setCursor(0, 1);
lcd.print(String(sensor.getCalibratedW()) + " " +
String(sensor.getCalibratedK()) + " " + String(sensor.getCalibratedL()));
break;
case 4:
```

```
Serial.print("\tMQ3: ");
Serial.print(mq3PPM);
Serial.print("\tMQ4: ");
Serial.print(mq4PPM);
Serial.print("\tSmoke Level: ");
Serial.println(analogSensor - 50);
if (mq4Value > 20){
digitalWrite(ledPin, HIGH);}
else{
digitalWrite(ledPin, LOW);}
if (mq3Value > 10){
digitalWrite(ledPin1, HIGH);}
else{
digitalWrite(ledPin1, LOW);}
delay(1000);
lcd.setCursor(0, 0);
lcd.print("Meth (ppm):");
lcd.print(mq4PPM);
lcd.setCursor(0, 1);
lcd.print("Alc (ppm):");
lcd.print(mq3PPM);
delay(1000);
lcd.clear();
lcd.setCursor(0, 0);
lcd.print("H(%):");
lcd.print((float)DHT11.humidity, 1);
lcd.setCursor(0, 1);
lcd.print("T(C):");
lcd.print((float)DHT11.temperature, 0);
delay(1000);
lcd.clear();
if (analogSensor - 50 >sensorThres){
lcd.setCursor(0, 0);
lcd.print("Alert...!!!");
```

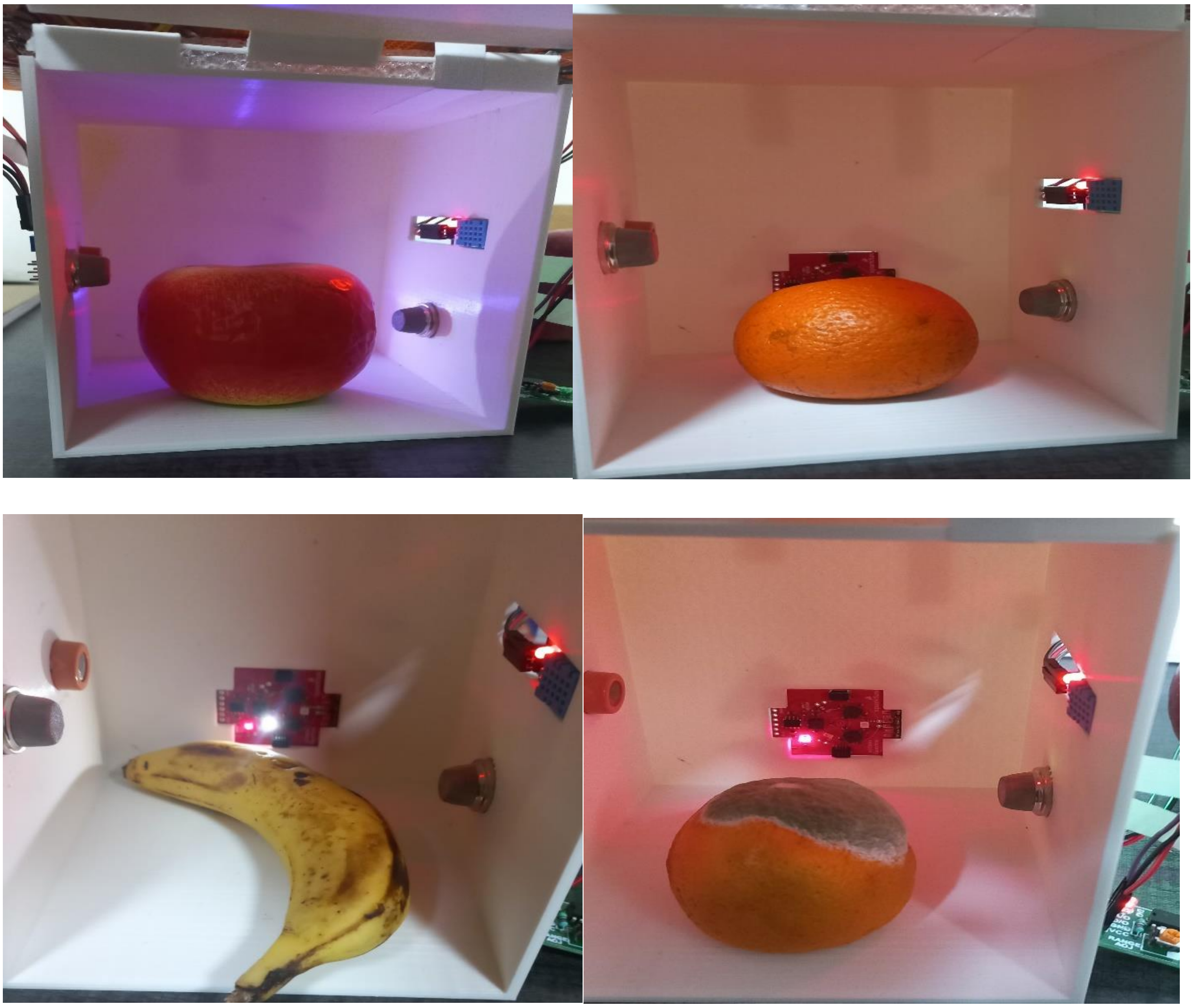
```
tone(buzzer, 1000, 2000);}
else{
lcd.setCursor(0, 0);
lcd.print("....Normal......");
noTone(buzzer);}
delay(1000);
lcd.clear();
break;
case 5:
val = digitalRead(0);
lcd.clear();
if (val == 1){
digitalWrite(13, HIGH); // LED ON
lcd.print("obstacle detected");
Serial.print("obstacle detected");}
else {
digitalWrite(13, LOW); // LED OFF
lcd.print("no obstacle detected");
Serial.print("no obstacle detected");}
break;
default:
Serial.print("Operation ended");
count = 0;}
Serial.println();}
float MQGetGasPercentage(float rs_ro_ratio, int gas_id){
if (gas_id == MQ3){
return pow(10, ((log10(rs_ro_ratio) - 2.174) / (-0.357)));}
else if (gas_id == MQ4)
{return pow(10, ((log10(rs_ro_ratio) - 1.057) / (-0.47)));}
return 0;}
```

Final Device Module

We have successfully completed the device by integrating all the different components and successfully get the data of different fruits.

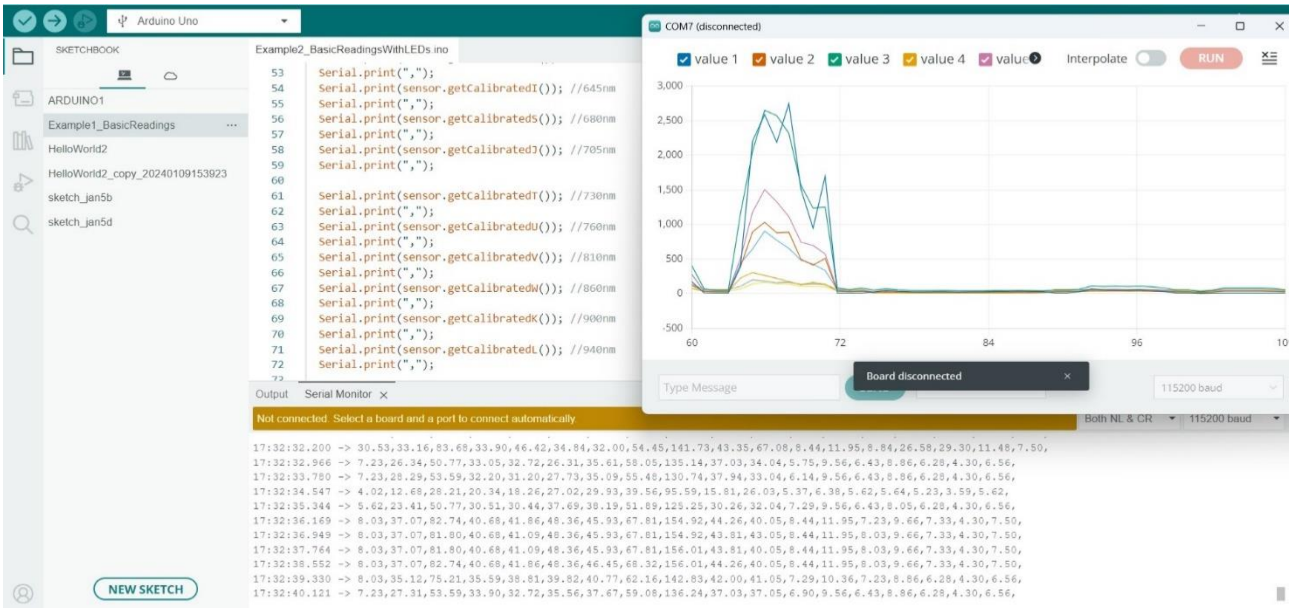


Observations of different fruits and check the quality of freshness:



Rotten banana

Rotten Orange



Observing data on the user interface using wi-fi module:

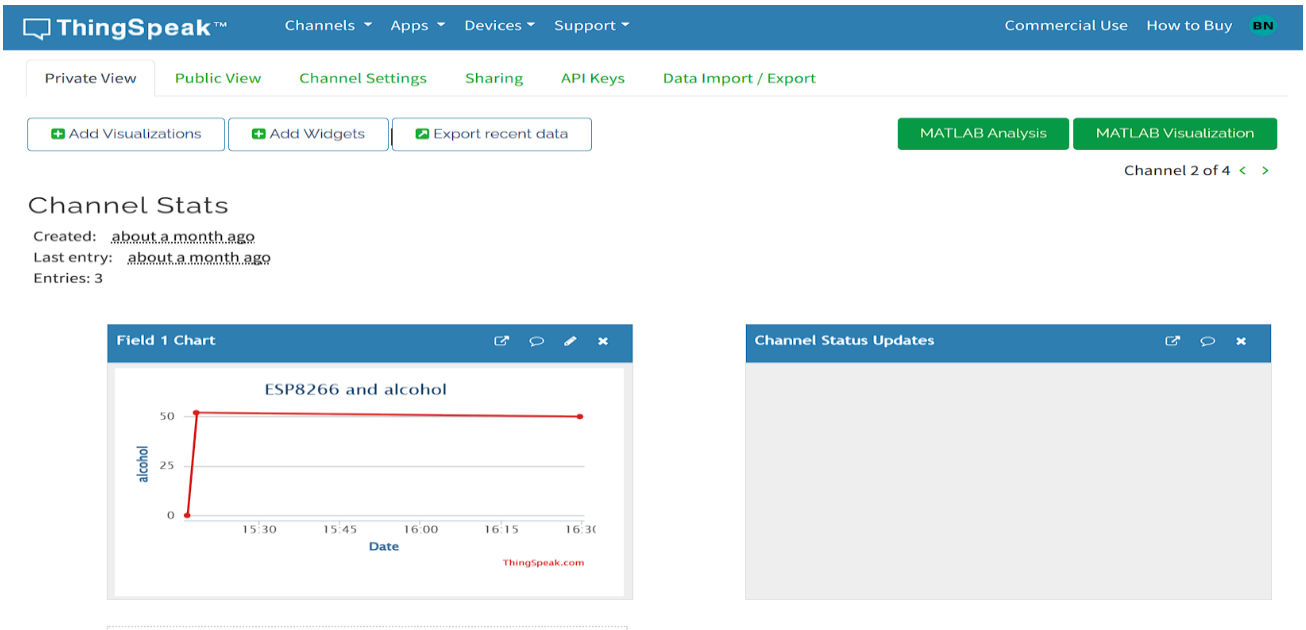
ESP-8266: Wi-fi Module: The ESP8266 is a low-cost Wi-Fi module with an integrated microcontroller, enabling wireless connectivity and control for IoT devices. It offers GPIO pins for interfacing with sensors and actuators, and can be programmed using various languages and development environments. Its affordability, versatility, and low power consumption make it a popular choice for a wide range of projects.

Introduction to ESP8266

We have sent the data on the user web interface using the wi-fi module and monitor the real time data of the fruits.

Thing Speak software: ThingSpeak is an open-source Internet of Things (IoT) platform developed by **MathWorks**. It allows users to collect, store, analyse, and visualize data from IoT devices in real-time. With ThingSpeak, users can create custom IoT applications, monitor sensor data, and remotely control devices. It provides built-in MATLAB analytics for data processing and supports integration with various IoT protocols and devices, making it a versatile platform for IoT development and deployment.

Data monitoring on thing Speak software:



Limitations:

Sensor Calibration: Regular calibration of gas sensors may be required to maintain accuracy.

Interference: Environmental factors like temperature fluctuations and external gases may impact sensor readings.

Accuracy and precision:This is the measure challenge to get the data accurate for the assessment of fruit quality.

Conclusion:

The successful integration of the AS7265x spectral sensor with the Arduino Uno demonstrates the potential for multispectral analysis in a variety of applications. The experiment showcased the ability to capture and visualize 18 different spectral readings in real-time using the Arduino IDE's serial plotter.

The integration of multiple sensors with Arduino Uno on a breadboard for fruit spoilage detection provides a practical and non-destructive solution for monitoring and preserving the freshness of fruits. This system showcases the versatility of Arduino Uno and the potential for addressing complex challenges in the agricultural and food industries. Continuous refinement and future enhancements can further optimize the system for broader applications in food quality monitoring.

In conclusion,our project on the **non-destructive method of internal fruit quality check device,** employing gas and multispectral sensors, represents a significant advancement in agricultural technology. By integrating these sensors, we have developed a solution that enables accurate and efficient assessment of internal fruit quality without compromising the integrity of the fruit.

Through rigorous testing and optimization, we have demonstrated the potential of this approach to revolutionize fruit quality assessment processes, offering benefits such as improved yield prediction, reduced waste, and enhanced product quality. Moving forward, further refinement and deployment of this technology hold promise for enhancing productivity and sustainability in the agricultural industry.

Application and Future Vision:

Application:

Quality Assurance: The device can be employed by farmers, distributors, and food processors to ensure the quality and freshness of fruits before distribution and sale. By detecting internal defects and ripeness levels accurately, it helps maintain product standards and reduces the risk of spoilage.

Sorting and Grading: By analysing internal characteristics such as sugar content, moisture levels, and ripeness, the device enables automated sorting and grading based on predefined quality criteria, enhancing efficiency and consistency.

Post-harvest Management: By monitoring internal fruit quality parameters over time, it facilitates informed decisions regarding storage conditions, shelf-life estimation, and post-harvest treatments, thereby minimizing losses and maximizing product longevity.

Research and Development: The device serves as a valuable tool for researchers and scientists studying fruit physiology, post-harvest biology, and food science, enabling insights into factors influencing fruit maturation, storage behaviour, and nutritional composition.

Future Vision:

Enhanced Sensor Technology: Continued advancements in gas and multispectral sensor technology will lead to improved accuracy, sensitivity, and reliability of internal fruit quality assessments.

IoT Integration: Integration with Internet of Things (IoT) platforms and cloud-based analytics will enable real-time monitoring and data-driven decision-making in fruit production and supply chain management.

Artificial Intelligence and Machine Learning: Adoption of artificial intelligence (AI) and machine learning (ML) algorithms will enable predictive modelling and optimization of fruit quality parameters. By analyzing large datasets of sensor readings and correlating them with environmental factors and production practices, AI/ML models can provide insights into optimal growing conditions, harvest timing, and post-harvest handling protocols.

Industry Adoption and Standardization: Wide-scale adoption of non-destructive fruit quality assessment technologies will require industry collaboration, standardization, and regulatory support.

Literature and Reference:

1.Fruit Defect Prediction Model (FDPM).

Based on: Thermal IR imaging, image processing and deep learning.

Preferred researchpaper:(https://link.springer.com/article/10.1007/s10921-021-00778-6)

Outcomes:

The apple defect detection accuracy by the proposed Naïve Bayes classifier is observed to be 97.6% for thermal IR imaging samples whereas true color (RGB)based achieved only 59% for the same sample.

2.Scio the pocket-sized device

The world's first pocket-sized connected micro-spectrometer." Developed by San Francisco and Israel-based company Consumer Physics. More information: click.
Link for description: SCiO Pocket Molecular Scanner Teardown - SparkFun Learn

Links of those research papers and other links that are relevant to the project are listed below.

- https://tinyurl.com/paper1254
- https://tinyurl.com/paper7410
- Foods | Free Full-Text | Spoilage Monitoring and Early Warning for Apples in Storage Using Gas Sensors and Chemometrics (mdpi.com)
- Electronic nose and visible-near infrared spectroscopy in fruit and vegetable monitoring(degruyter.com)

For project details and demonstration videos:

Git hub project link: prateek1833/Non-Destructive-Method-of-Fruit-Spoilage-Detection (github.com)

Demonstration Video link: click here

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