Introduction

This report outlines the working principle, features, application, advantages and limitation of MQ-3, MQ-4, IR, Ultrasonic, Sound, MQ-135, AS-7265x, DHT-11 sensor and Arduino uno. This report details the integration of multiple sensors, including MQ-3, MQ-4, DHT11, Infrared (IR), Ultrasonic, and Sound sensors with an Arduino Uno on a breadboard to develop a non-destructive method for fruit spoilage detection. This report presents a comparative analysis of thermal images captured using RGB, greyscale, and hot metal colour palettes on apples at two distinct temperatures, 16 degrees Celsius and 26 degrees Celsius. After this, it 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 plotter.

MQ-3 Gas Sensor

Introduction:

The MQ-3 gas sensor is a crucial component in the field of gas detection and monitoring. Designed to detect a variety of gases, this sensor is widely used in applications such as gas leak detection, breath analysis, and industrial safety. This report aims to provide a comprehensive overview of the MQ-3 gas sensor, including its working principle, applications, advantages, limitations, and potential areas for improvement.

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 (SnO_2), 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.

Features:

- Wide Range of Gas Detection:

The MQ-3 sensor is capable of detecting a broad range of gases, including but not limited to alcohol and carbon monoxide.

- High Sensitivity:

The sensor exhibits high sensitivity to the target gases, allowing for the detection of even trace amounts in the air.

- Simple Interface:

The MQ-3 is designed with a straightforward interface, making it easy to integrate into various electronic systems.

Applications:

- Gas Leak Detection:

One of the primary applications of the MQ-3 sensor is in gas leak detection systems for residential and industrial settings.

- Breath Analysis:

The sensor is utilized in Breathalyzer devices to measure alcohol levels, making it a crucial component in law enforcement and automotive safety.

- Industrial Safety:

In industries where the presence of certain gases can pose a threat to human health, the MQ-3 sensor is employed for continuous monitoring.

Advantages:

- Cost-Effective:

The MQ-3 sensor is relatively inexpensive, making it an attractive option for various applications where cost is a significant factor.

- Compact Size:

Its compact size allows for easy integration into different electronic systems and devices.

- Rapid Response Time:

The sensor exhibits a rapid response time, providing real-time data on gas concentrations.

Limitations:

- Cross-Sensitivity:

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

- Limited Precision:

While suitable for many applications, the sensor may not provide the precision required for certain specialized tasks.

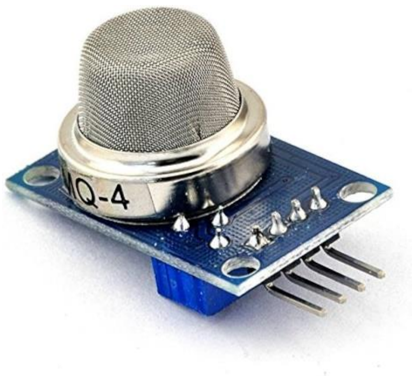
Conclusion:

The MQ-3 gas sensor plays a vital role in gas detection applications, providing a cost-effective and reliable solution for various industries. While it has its advantages, users must be aware of its limitations and consider potential areas for improvement. As technology advances, we can expect further enhancements in gas sensor technology, contributing to improved safety and monitoring capabilities.

MQ-4 Gas Sensor

Introduction:

The MQ-4 gas sensor is a critical component in gas detection systems, widely used for detecting various gases in both industrial and domestic settings. This report provides an in-depth analysis of the MQ-4 gas sensor, covering its working principle, applications, advantages, limitations, and potential areas for improvement.



Working Principle:

Similar to the MQ-3, the MQ-4 gas sensor operates on the principle of semiconductor conductivity. It incorporates a sensing element made of tin dioxide (SnO_2) that undergoes changes in electrical conductivity when exposed to specific gases. The variation in conductivity is then translated into a measurable electrical signal.

Features:

- Multi-Gas Detection:

The MQ-4 sensor is capable of detecting various gases, including methane, propane, butane, and other combustible gases.

- High Sensitivity:

The sensor exhibits high sensitivity, enabling the detection of low concentrations of target gases.

- Simple Integration:

Designed with a straightforward interface, the MQ-4 is easily integrated into diverse electronic systems.

Applications:

-Domestic Gas Leak Detection:

A primary application is in domestic gas leak detection systems, ensuring the safety of households by monitoring for the presence of combustible gases.

-Industrial Safety:

Used in industrial environments to detect flammable gases, the MQ-4 contributes to workplace safety by providing timely alerts.

- Environmental Monitoring:

Employed in environmental monitoring systems to detect the presence of gases that may contribute to air pollution.

Advantages:

- Versatility:

The MQ-4 sensor's ability to detect a range of combustible gases makes it versatile for various applications.

- Cost-Effective:

Like the MQ-3, the MQ-4 is cost-effective, making it a practical choice for applications where cost is a significant consideration.

- Quick Response:

The sensor exhibits a rapid response time, enabling real-time monitoring of gas concentrations.

Limitations:

- Cross-Sensitivity:

Similar to other gas sensors, the MQ-4 may experience cross-sensitivity to certain gases, potentially leading to false readings.

- Environmental Interference:

External environmental factors, such as humidity and temperature, may impact the sensor's performance.

Conclusion:

The MQ-4 gas sensor is a valuable tool for gas detection, finding applications in both domestic and industrial settings. While it offers versatility and cost-effectiveness, users must be mindful of its limitations. Continuous research and development efforts are likely to lead to improvements in selectivity and overall sensor performance, further enhancing its utility in gas monitoring systems.

MQ-135 Gas Sensor

Introduction:

The MQ-135 gas sensor is a key component in gas detection systems, renowned for its versatility in detecting various gases commonly found in the environment.
This report aims to provide a thorough examination of the MQ-135 gas sensor, encompassing its working principle, applications, advantages, limitations, and potential areas for improvement.

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.

Features:

- Wide Range of Gas Detection:

The MQ-135 sensor is designed to detect a variety of gases, including but not limited to ammonia, methane, carbon dioxide, and various volatile organic compounds (VOCs).

- High Sensitivity:

The sensor exhibits high sensitivity, enabling the detection of trace amounts of target gases in the atmosphere.

- Compact Design:

With its compact size, the MQ-135 is suitable for integration into diverse electronic systems and devices.

Applications:

- Indoor Air Quality Monitoring:

A primary application is in indoor air quality monitoring systems, ensuring that enclosed spaces maintain safe levels of various gases.

- Industrial Emissions Monitoring:

Used in industrial settings to monitor emissions and ensure compliance with environmental regulations.

- Safety Alarms:

Incorporated into safety alarms to detect the presence of harmful gases, contributing to the safety of residential and commercial spaces.

Advantages:

- Multi-Gas Detection:

The MQ-135 sensor's ability to detect a broad range of gases makes it versatile for diverse applications.

- Affordability:

Like other MQ series sensors, the MQ-135 is cost-effective, making it a practical choice for widespread deployment.

- Real-time Monitoring:

The sensor provides real-time data on gas concentrations, allowing for prompt response to changes in the environment.

Limitations:

- Cross-Sensitivity:

The MQ-135 may exhibit cross-sensitivity to certain gases, potentially leading to inaccuracies in readings.

- Calibration Requirements:

Periodic calibration may be necessary to maintain accurate and reliable measurements.

Potential Improvements:

- Selective Sensing Enhancements:

  Research efforts could focus on improving the sensor's selectivity to minimize cross-sensitivity.

- Advanced Calibration Methods:

  Implementing advanced calibration techniques may enhance the overall accuracy and stability of the sensor over time.

Conclusion:

The MQ-135 gas sensor stands as a versatile tool for gas detection applications, particularly in monitoring indoor air quality and industrial emissions. While it offers several advantages, users must be aware of its limitations and consider ongoing research for potential improvements in selectivity and calibration methods. As technology advances, the MQ-135 is expected to continue playing a crucial role in maintaining environmental and occupational safety.

DHT11 Temperature and Humidity Sensor

Introduction:

The DHT11 is a widely-used digital temperature and humidity sensor, known for its simplicity, affordability, and reliability. This report aims to provide a comprehensive overview of the DHT11 sensor, covering its working principle, applications, advantages, limitations, and potential areas for improvement.

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.

Features:

-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.

-Digital Output:

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

-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.

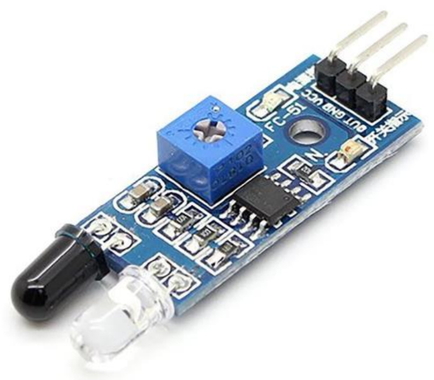
Conclusion:

The DHT11 sensor stands as a reliable and cost-effective solution for measuring temperature and humidity in various applications. While it may not be suitable for highly demanding scenarios, its simplicity and affordability make it an attractive choice for a wide range of projects, from DIY electronics to industrial applications. As technology advances, potential improvements in accuracy and response time could further enhance the sensor's utility in diverse environments.

Infrared Sensors

Introduction:

Infrared (IR) sensors play a crucial role in modern technology, offering a wide range of applications across various industries. This report aims to provide a comprehensive overview of infrared sensors, covering their working principles, types, applications, advantages, limitations, and emerging trends.



Working Principle:

Infrared sensors detect infrared radiation, which is emitted or reflected by objects. The basic principle involves capturing the heat emitted by an object in the form of infrared radiation. The sensor then converts this radiation into an electrical signal, enabling the measurement and analysis of temperature or the presence of objects.

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:

Infrared sensors enable non-contact measurements, reducing the risk of contamination and damage.

- Versatility:

The diverse types of infrared sensors make them versatile for a broad range of applications.

- Real-Time Monitoring:

Infrared sensors provide real-time data, making them suitable for applications that require quick and continuous monitoring.

Limitations:

- Environmental Interference:

Certain environmental conditions, such as extreme temperatures or interference from other infrared sources, may impact sensor accuracy.

- Limited Range:

The effective range of some infrared sensors is limited, requiring careful consideration in specific applications.

Conclusion:

Infrared sensors are integral components in diverse applications, providing non-contact sensing capabilities crucial for modern technology. Their versatility, coupled with ongoing advancements in technology, ensures their continued significance across industries. As miniaturization and integration with IoT continue, the role of infrared sensors is likely to expand, contributing to further innovation in various fields.

Ultrasonic Sensors

Introduction:

Ultrasonic sensors are critical components in various technological applications, offering non-contact distance measurement and object detection capabilities. This report provides an in-depth examination of ultrasonic sensors, covering their working principles, types, applications, advantages, limitations, and emerging trends.

Working Principle:

Ultrasonic sensors operate on the principle of emitting ultrasonic waves and measuring the time it takes for the waves to travel to an object and back. By calculating the time of flight, 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.

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.

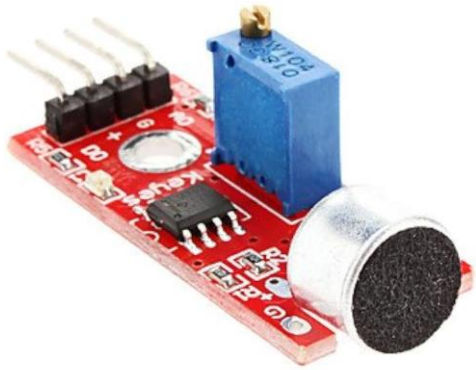
Conclusion:

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.

Sound Sensors

Introduction:

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. This report provides a comprehensive overview of sound sensors, covering their working principles, types, applications, advantages, limitations, and emerging trends.



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 analysed for various applications.

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:

Sound sensors are widely used in environmental noise monitoring systems to measure and analyse noise pollution levels in urban areas.

- Security Systems:

Integrated into security systems for detecting unusual sounds or alarms, sound sensors contribute to intrusion detection and safety.

- Consumer Electronics:

Found in devices like smartphones and voice-activated assistants, sound sensors enable voice recognition and command execution.

- Industrial Automation:

Applied in industrial settings for monitoring machinery sounds, detecting abnormalities, and ensuring equipment safety.

Advantages:

- Real-Time Monitoring:

Sound sensors provide real-time data, making them suitable for applications that require immediate responses.

- Versatility:

The versatility of sound sensors allows them to be used in diverse fields, ranging from consumer electronics to industrial applications.

- Non-Intrusive:

As non-intrusive devices, sound sensors can monitor and detect without physically interfering with the environment.

Limitations:

- Sensitivity to Environmental Factors:

External factors like wind, temperature, and humidity can impact the accuracy of sound sensors.

- Limited Range:

The effective range of sound sensors may be limited, requiring careful consideration in certain applications.

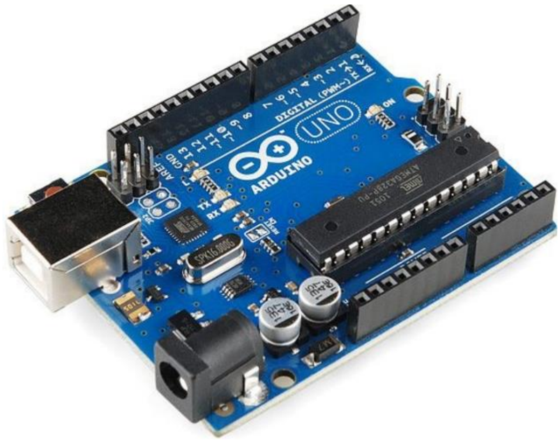
Conclusion:

Sound sensors play a vital role in various applications, providing a means to capture, analyse, and respond to acoustic signals. As technology continues to evolve, their integration with machine learning and IoT is likely to enhance their capabilities and contribute to innovations in noise monitoring, security, and automation. The versatility and real-time monitoring capabilities of sound sensors position them as crucial components in the advancement of various industries.

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. This report aims to provide a comprehensive overview of the Arduino Uno, covering its key features, technical specifications, applications, advantages, limitations, and its impact on the field of electronics.



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 is programmed 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 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.

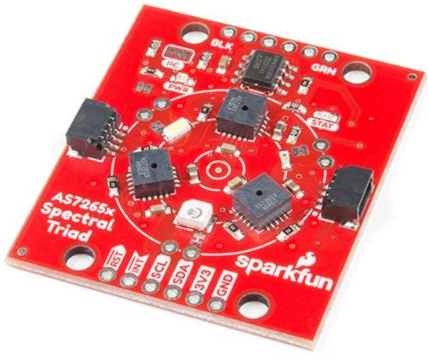
Conclusion:

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 alike. As the field of electronics continues to evolve, the Arduino Uno's impact is likely to persist, fostering creativity and innovation in diverse applications.

AS7265x Spectral Sensor

Introduction:

The AS7265x is a multispectral sensor designed for spectral analysis, allowing precise measurement of various wavelengths of light. Developed by ams AG, this sensor is known for its integration of Eighteen independent optical filters, providing accurate spectral data. This report aims to provide a comprehensive overview of the AS7265x sensor, covering its working principle, features, applications, advantages, limitations, and potential areas for improvement.



Working Principle:

The AS7265x sensor operates based on the principle of spectral analysis. It incorporates Eighteen independent optical filters, each tuned to a specific wavelength range. When light passes through these filters, the sensor measures the intensity of light at each wavelength, providing a spectral signature. The sensor then converts this optical data into digital information for analysis.

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.

- Compact Size: With its compact form factor, the AS7265x sensor is suitable for applications with space constraints.

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.

- Compact Design: Its compact design allows for easy integration into portable devices and space-constrained applications.

- 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. As technology advances, potential improvements in wavelength coverage and cost optimization could further enhance the sensor's appeal in a wider range of applications.

Integration of all Sensor

Introduction:

Fruit spoilage is a significant concern in the agriculture and food industries. Detecting spoilage at an early stage is crucial to prevent the consumption of contaminated or deteriorated fruits. the integration of multiple sensors, including MQ-3, MQ-4, DHT11, Infrared (IR), Ultrasonic, and Sound sensors with an Arduino Uno on a breadboard to develop a non-destructive method for fruit spoilage detection.

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, and the Sound sensor captures audio signals indicative of spoilage events.

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.

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 gas concentrations, temperature, humidity, object presence, distance, and audio signals, 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.

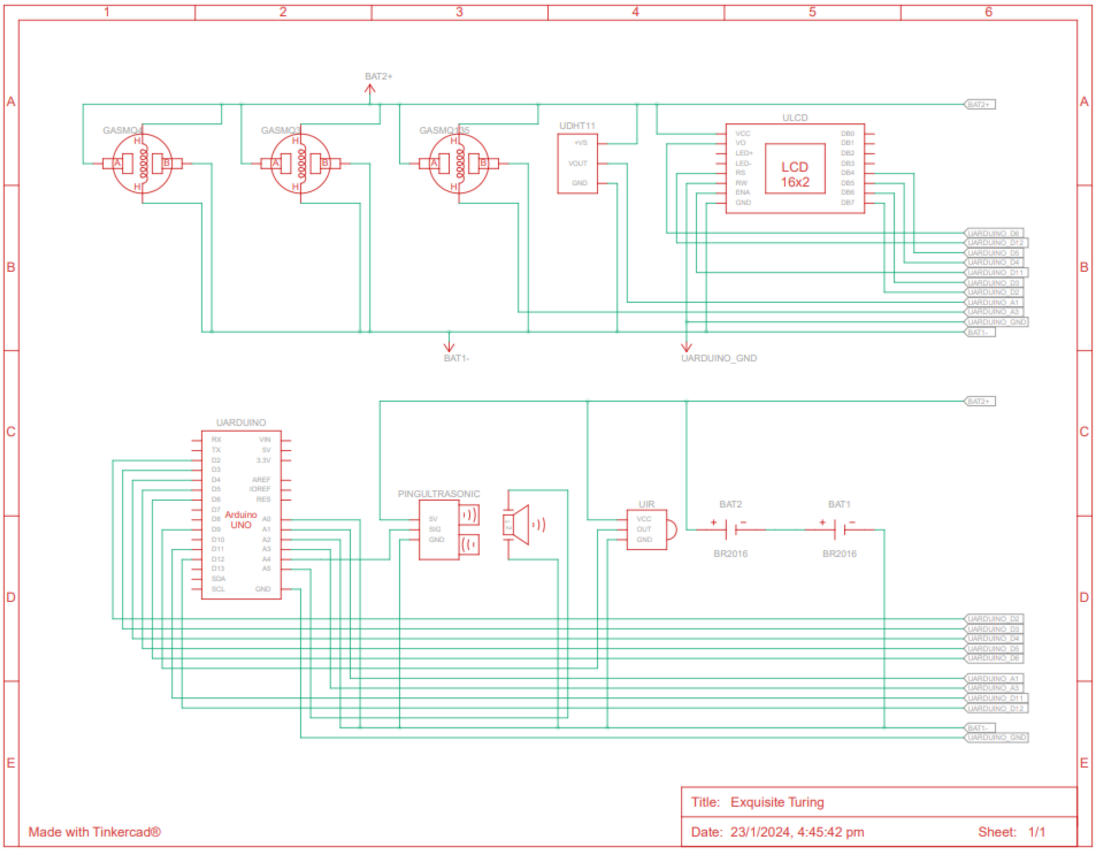
Limitations:

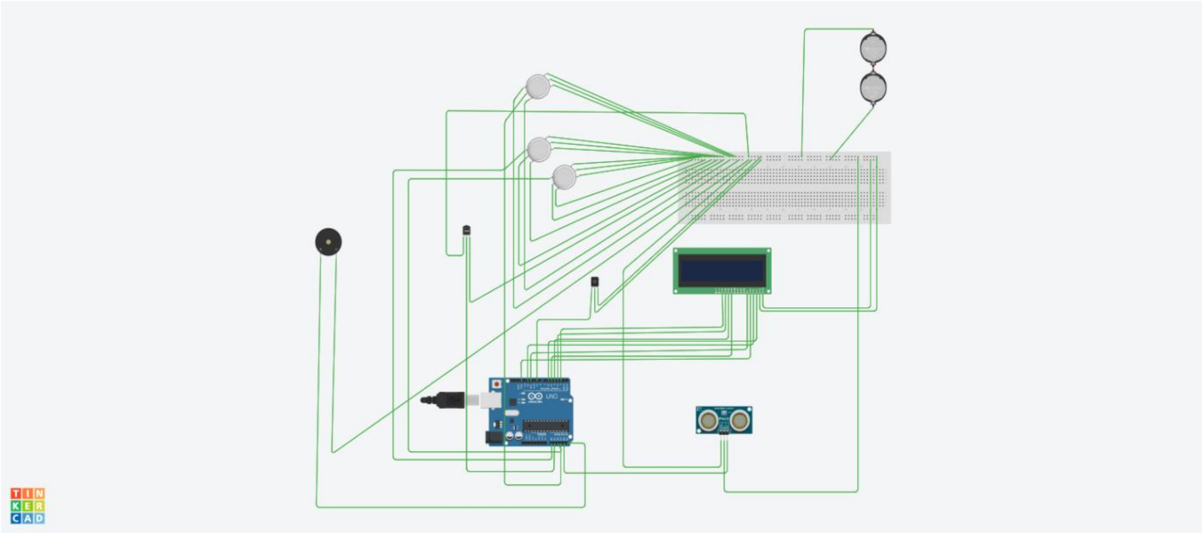
- Sensor Calibration: Regular calibration of gas sensors may be required to maintain accuracy.

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

Conclusion:

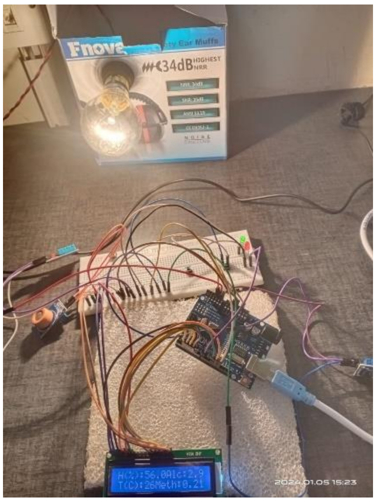
The integration of multiple sensors with Arduino Uno on a breadboard for fruit spoilage detection provides a practical and non-destructive solution for monitoring and preserving the freshness of fruits. This system showcases the versatility of Arduino Uno and the potential for addressing complex challenges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





Thermal Imaging on 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.

RGB, Greyscale, and Hot Metal Imaging:

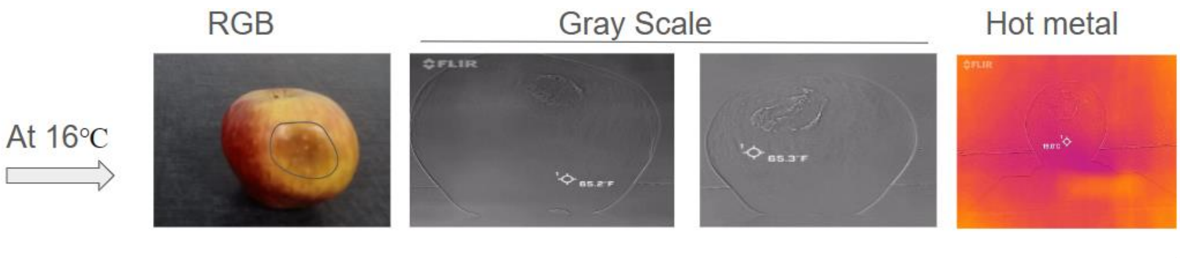
- RGB Imaging: Traditional RGB images provide a visual representation of the apples with colours corresponding to their surface temperatures. These images serve as a baseline for comparison and are valuable for overall observation.

- 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:

- 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.

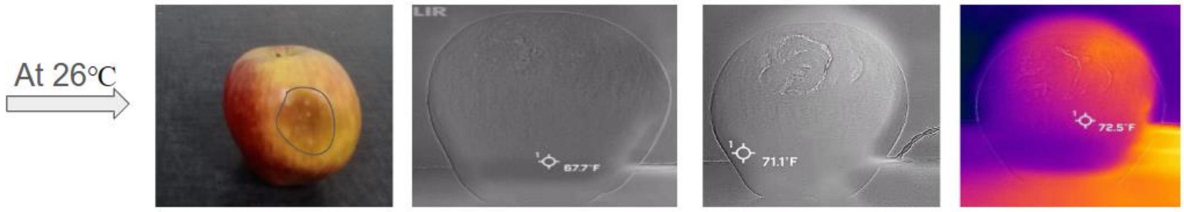


- **26 Degrees Celsius:**

  - 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.

Spectral Analysis Using AS7265x with Arduino Uno

Introduction:

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:

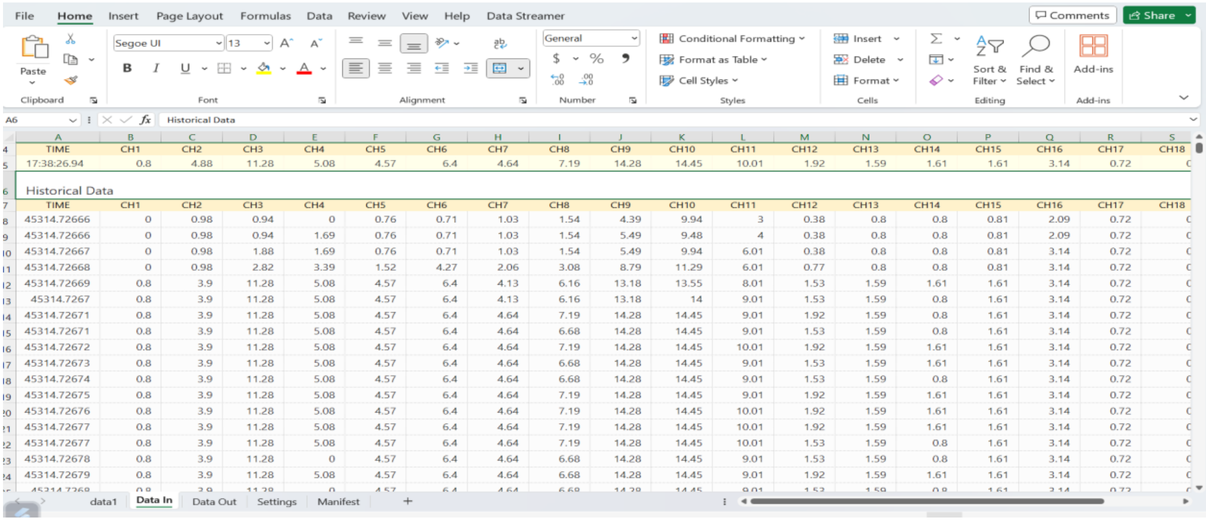
The serial plotter in the Arduino IDE was employed to visualize the 18 spectral readings. The x-axis represented the different spectral bands, and the y-axis indicated the intensity or amplitude of the spectral response. The resulting plot provided a graphical representation of the light spectrum detected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

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.

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.

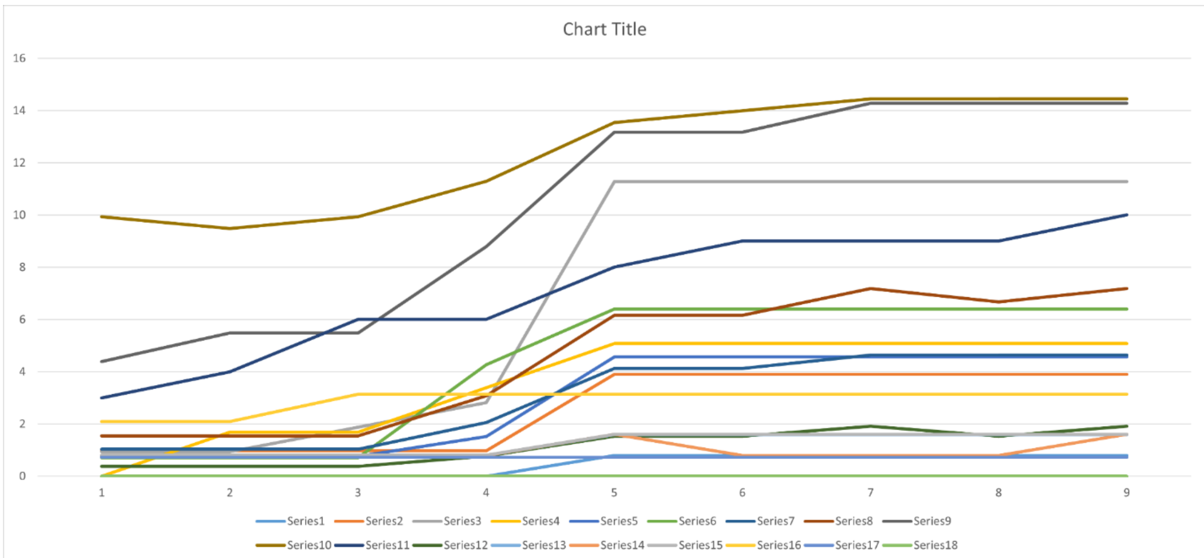
Streaming the data on MS-excel to plot and store.

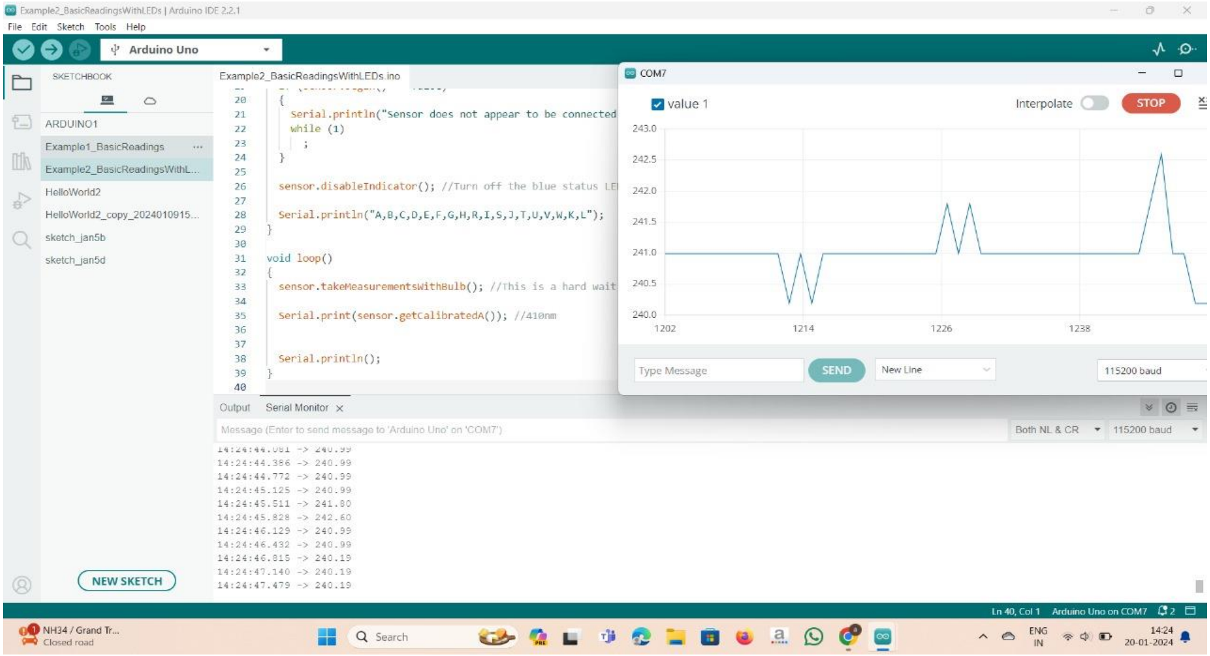


TIME	CH1	CH2	CH3	CH4	CH5	CH6	CH7	CH8	CH9	CH10	CH11	CH12	CH13	CH14	CH15	CH16	CH17	CH18
17:38:26.94	0.8	4.88	11.28	5.08	4.57	6.4	4.64	7.19	14.28	14.45	10.01	1.92	1.59	1.61	1.61	3.14	0.72	

Historical Data

TIME	CH1	CH2	CH3	CH4	CH5	CH6	CH7	CH8	CH9	CH10	CH11	CH12	CH13	CH14	CH15	CH16	CH17	CH18
45314.72666	0	0.98	0.94	0	0.76	0.71	1.03	1.54	4.39	9.94	3	0.38	0.8	0.8	0.81	2.09	0.72	
45314.72666	0	0.98	0.94	1.69	0.76	0.71	1.03	1.54	5.49	9.48	4	0.38	0.8	0.8	0.81	2.09	0.72	
45314.72667	0	0.98	1.88	1.69	0.76	0.71	1.03	1.54	5.49	9.94	6.01	0.38	0.8	0.8	0.81	3.14	0.72	
45314.72668	0	0.98	2.82	3.39	1.52	4.27	2.06	3.08	8.79	11.29	6.01	0.77	0.8	0.8	0.81	3.14	0.72	
45314.72669	0.8	3.9	11.28	5.08	4.57	6.4	4.13	6.16	13.18	13.55	8.01	1.53	1.59	1.61	1.61	3.14	0.72	
45314.7267	0.8	3.9	11.28	5.08	4.57	6.4	4.13	6.16	13.18	14	9.01	1.53	1.59	0.8	1.61	3.14	0.72	
45314.72671	0.8	3.9	11.28	5.08	4.57	6.4	4.64	7.19	14.28	14.45	9.01	1.92	1.59	0.8	1.61	3.14	0.72	
45314.72671	0.8	3.9	11.28	5.08	4.57	6.4	4.64	6.68	14.28	14.45	9.01	1.53	1.59	0.8	1.61	3.14	0.72	
45314.72672	0.8	3.9	11.28	5.08	4.57	6.4	4.64	7.19	14.28	14.45	10.01	1.92	1.59	1.61	1.61	3.14	0.72	
45314.72673	0.8	3.9	11.28	5.08	4.57	6.4	4.64	6.68	14.28	14.45	9.01	1.53	1.59	1.61	1.61	3.14	0.72	
45314.72674	0.8	3.9	11.28	5.08	4.57	6.4	4.64	6.68	14.28	14.45	9.01	1.53	1.59	0.8	1.61	3.14	0.72	
45314.72675	0.8	3.9	11.28	5.08	4.57	6.4	4.64	7.19	14.28	14.45	9.01	1.92	1.59	1.61	1.61	3.14	0.72	
45314.72676	0.8	3.9	11.28	5.08	4.57	6.4	4.64	7.19	14.28	14.45	10.01	1.92	1.59	1.61	1.61	3.14	0.72	
45314.72677	0.8	3.9	11.28	5.08	4.57	6.4	4.64	7.19	14.28	14.45	10.01	1.92	1.59	1.61	1.61	3.14	0.72	
45314.72677	0.8	3.9	11.28	5.08	4.57	6.4	4.64	7.19	14.28	14.45	10.01	1.53	1.59	0.8	1.61	3.14	0.72	
45314.72678	0.8	3.9	11.28	0	4.57	6.4	4.64	6.68	14.28	14.45	9.01	1.53	1.59	0.8	1.61	3.14	0.72	
45314.72679	0.8	3.9	11.28	5.08	4.57	6.4	4.64	6.68	14.28	14.45	9.01	1.92	1.59	1.61	1.61	3.14	0.72	





Connections

Display to Arduino

- RS-12
- RO-6
- RW-GND
- E-11
- D4-5
- D5-4
- D6-3
- D7-2
- A-5V
- K-GND

Sensors to Arduino

- MQ3-A2
- MQ4-A0

- MQ135-A3
- DHT11-A1
- IR-9
- Button-1
- AS-7265x
    1. SDA-A4
    2. SCL-A5

Other than this , the VCC and GND of each sensors will connected to external supply .

Code for Multi-sensor Non-destructive Spoilage Detection System for Fruits

```
#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 A1
#define MQ3_PIN A2
#define MQ4_PIN A0
#define MQ135_PIN A3
#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;
LiquidCrystal lcd(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(2, 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 > 110)
    {
      digitalWrite(ledPin, HIGH);
    }
    else
    {
      digitalWrite(ledPin, LOW);
    }
```

```
  if (mq3Value > 1010)
  {
    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(9);
    lcd.clear();
    if (val == 1)
    {
      digitalWrite(7, HIGH); // LED ON
      lcd.print("obstacle detected");
      Serial.print("obstacle detected");
    }
    else
    {
      digitalWrite(7, 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;
}
```

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

-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.

8. Monitor 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 apple.

Reference

We have read few research papers to initiate our project.

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

- https://elibrary.asabe.org/azdez.asp?search=1&JID=5&AID=48072&CID=spo2017&v=&i=&T=1&urlRedirect=%5Banywhere%3D&keyword=&abstract=&title=on&author=&references=&docnumber=&journals=All&searchstring=&pg=&allwords=&exactphrase=&OneWord=&Action=Go&Post=Y&qu=%5D&redirType=newresults.asp&utm_source=TrendMD&utm_medium=cpc&utm_campaign=Journal_of_the_ASABE_TrendMD_0
- Identification of the apple spoilage causative fungi and prediction of the spoilage degree using electronic nose - Guo - 2021 - Journal of Food Process Engineering - Wiley Online Library
- 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)