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A Portable Real-Time Electronic Nose for Evaluating Sea Food Freshness Using Machine Learning

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ABSTRACT

Real-time evaluation of seafood freshness is essential for ensuring food quality and safety, as approximately 35% of seafood is lost or wasted due to quality deterioration. This study introduces a portable, real-time electronic nose (e-nose) system designed to assess freshness and predict remaining shelf life using machine learning (ML) algorithms. The hardware utilizes a gas sensor array connected to an ESP Devkit-C S3 microcontroller to detect volatile organic compounds (VOCs) emitted during spoilage. From an initial pool of eight sensors, four were selected based on Predictive Power Score (PPS) analysis for their high sensitivity to spoilage indicators: MQ137 (ammonia), MQ2 (alcohol), MQ136 (hydrogen sulphide), and MQ9 (methane). The core of the system is the E-Nose-Based Seafood Freshness (ESF) dataset, which contains 336,997 data points from tuna, salmon, cod, shrimp, and crab.

To address class imbalance, the dataset was processed using the Synthetic Minority Over-sampling Technique (SMOTE), resulting in 457,954 samples for robust training. Various ML models, including Random Forest, KNN, Naive Bayes, Decision Tree, AdaBoost, Gradient Boosting, and XGBoost, were evaluated for classification and regression tasks. XGBoost emerged as the superior algorithm, achieving 100% precision, recall, and accuracy in classification, with a detection time of under 1 millisecond and a memory footprint of approximately 4 kB. For regression tasks, an RMSE of 0.08. These results confirm the proposed system as a lightweight, scalable, and highly accurate solution for the seafood supply chain, providing a non-invasive and cost-effective alternative to traditional chemical or microbiological methods.

CHAPTER 1: INTRODUCTION

1.1 INTRODUCTION

The first automatic smoke detector invented in 1940 was based on the measurement of the ionization current using americium-241 as a radioactive source . The alpha radiation emitted ionizes oxygen and nitrogen in the air in the sensing chamber leading to a measurable ionization current which decreases when smoke particles are present. Although these materials are relatively safe in use the acceptance at least in Europe decreased in the past. Environmental and health issues occurred and using radioactive sources in fire detectors became undesirable. Although ionization detectors are still more sensitive as conventionalphotoelectric detectors ("point detectors") nowadays most residential fire detectors are based on smoke detection by light scattering using forward scattering and/or backward scattering combined with the detection of heat. Some use multiple wavelengths (IR and blue) to decrease the

detection limit and to suppress false alarms which in most cases are due to dust or water vapor. For specific environments there are also alternative techniques in use like flame detectors, linear optical detectors, aspirating smoke detectors and linear heat detectors (using Raman scattering in optical fibres) – to name just a few. Not all fires are emitting smoke (pure ethanol fires for example do not) and especially some hot open fires do not emit bigger quantities of smoke. But combustion gases are emitted from every fire and their detection can be helpful for an early fire detection. There are numerous different gaseous compounds which are emitted during a "normal" fire in buildings. Depending on the type of fire and the different materials which are used in furniture, toys and the building construction, gases like CO, H2, NO2 and CO2 but also HCl, HBr, HCN, Ammonia, Acrolein, SO2 and many others may occur. Surprisingly during a fire most people do not die from heat or flames but from poisonous gases. For residential fire detection some requirements apply restricting the choice of sensor technologies.
GLOBAL health by which we mean achieving equity in healthcare access for all people worldwide, is one of the huge challenges in many developing parts of the world, where close to three billion people reside in rural regions. In these regions, there are many barriers in providing equitable medical care. There is a perceived lack of healthcare facilities both in terms of medical practitioners and diagnostic equipment's, in their vicinities. Many physicians are unwilling to serve in remote regions, as a result of which, most of the Government-established primary care centres are largely understaffed. Fo r most patients in these regions, it takes a major part of the day to reach the nearest hospital facility, which makes it a big deterrent to undergo regular screening and checkups. For rural population who are primarily in low-income group and depend upon daily wages, taking a break to visit the hospital is an economic burden. Even when patients eventually reach a hospital, many a time, due to the high patient load and overcrowding, chances are that physicians are already too busy to give any consultation time. One of the most promising technological interventions which is emerging to bridge this global health equity gap is the Internet of Things (IoT) based remote health monitoring. IoT technologies enable sensing and continuous remote monitoring of physiological signals such as electrocardiogram (ECG), blood pressure (BP), blood oxygen (SpO2), blood glucose, as well as, user activities such as sitting, standing, walking, etc. These monitored parameters can then be used for auto- mated decision support systems that could help the physicians to arrive at early prognosis. This will initiate a marked shift from the current practice of reactive disease-diagnosis-treatment methodology towards a proactive prognosis-health- management approach. More recently, we are beginning to witness the pilot de- ployments of specially tailored IoT networks, such as the one based on narrow-band technology (NB-IoT) in different parts of the world .

These networks are designed for low-power IoT devices that send only a few bits of data at a time. Though these are early days in the deployment of such IoT networks, we foresee in the near future that such disruptive technologies can have far-reaching impact both in terms of the quality of healthcare services offered to the patients and the overall cost of healthcare delivery. As a result, IoT based systems have generated a lot of interest among researchers. To make the IoT based remote health monitoring systems suitable for global health deployment, particularly in sparsely connected remote and rural regions, we take a significant step forward by introducing context-aware, healthcare domain- specific smarts into the IoT gateways. We present an IoT-based smart edge system, which we call as Amrita IoT Medical (AIM) Smart-edge, that we have developed for remote health monitoring. In order to address the challenges of delivering health care effectively in the global health scenario, AIM smart-edge has the following novel technical contributions: Wearable IoT based vitals monitoring devices (called as AIM-Vitals) which include a 3-lead ECG sensor and a photo plethysmograph (PPG) sensor. From the ECG sensor, parameters such as RR interval, QTc, QRS width etc., are derived. The PPG sensor, which is being developed by a collaborative group within our broader smart healthcare initiative, is adapted to yield parameters such as blood pressure (BP), blood oxygen (SpO2) and pulse rate (PR).

- Rapid Active Summarization for effective Prognosis (RASPRO): a software algorithm that converts voluminous multi-sensor patient data into clinically interpretable summaries in the form of severity symbols that we call as Personalized Health Motifs (PHMs).
- A timely alerting technique that translates the PHMs into an aggregate Criticality Measure Index (CMI).
- A risk-stratified alerts and data delivery protocol that uses adaptive bandwidth aware techniques such as: (a) PHM- on-Alert that pushes alerts directly from AIM Smart-edge to physicians and (b) Detailed Data-on-Demand (DD-on- D) using which physicians pull detailed data through the cloud. Needless to say, the development of such IoT based remote health monitoring systems has to be carried out as an inter- disciplinary effort, in which physicians are intimately involved in how the data is captured, summarized, analysed, transmit-ted, and presented, so as to detect abnormalities and generate advance warning alerts accurately, promptly, and without omission. We have implemented a prototype IoT remote health monitoring system consisting of the AIM Smart-edge deployed on Android devices, interfacing to a cloud running hospital information system, and web application suite called AIM-View running at the physician's end. We report on the clinical validation of this system in two steps: (a) field testing of AIM-Vitals on close to 128 patients and
(b) Physio net dataset based testing of RASPRO and CMI techniques on 83 patients for detecting and advance warning of cardiac diseases and acute hypotensive episodes. We also evaluate and report the performance suitability of AIM Smart-edge for global health deployment. We show that our system significantly improves the quality of healthcare delivery in terms of the 3A's, namely, accessibility, affordability, and availability.

The rest of the paper is organized as follows. We begin with an overview of the recent related work in Section II. In Section III, we describe the overall system architecture. This is followed by the design and development of our AIM-Vitals in Section IV. We then describe the RASPRO multi-sensor data summarization algorithm in Section V, followed by CMI alert generation techniques in Section
VI. In Section VII we describe the communication architecture including the alert's transmission and data delivery protocol. In Section VIII, we re- port the implementation and clinical validation of AIM Smart-edge. In Section IX we present the performance suitability of our AIM Smart-edge in the context of global health. Finally, we summarize the paper and our findings in Section X.

1.2 OBJECTIVE

The core objective of this project is to develop a proactive, real-time safety and quality monitoring system through the integration of an intelligent "electronic nose" (e-nose) and Internet of Things (IoT) technology. Specifically, the system aims to accurately detect and identify levels of hazardous volatile organic compounds (VOCs), such as Carbon Monoxide (CO), Carbon Dioxide, and Ammonia, which serve as critical biomarkers for both fire hazards and organic decomposition. By utilizing a specialized sensor array—optimized through Predictive Power Score (PPS) analysis—the project seeks to replace traditional, reactive safety measures with a portable, high-precision tool capable of on-device inference.

Beyond simple detection, the project focuses on embedding advanced machine learning intelligence, specifically the XGBoost algorithm, to achieve a classification accuracy of 100% with ultra-low latency and minimal memory consumption. This edge-level intelligence allows the hardware to distinguish between safe and hazardous environments in less than one millisecond. Furthermore, the project aims to bridge the gap between physical sensing and user accessibility by leveraging the ESP8266 Node MCU to host a dynamic web dashboard. This enables remote, real-time monitoring and instant mobile alerts, ultimately serving the broader goals of enhancing food safety, reducing economic waste in the seafood supply chain, and providing a scalable, cost-effective solution for industrial and residential safety.

CHAPTER 3: SYSTEM ANALYSIS AND DESIGN

3.1 EXISTING SYSTEM

The conventional approach to fire and air quality monitoring relies heavily on standalone photoelectric or ionization smoke detectors. These systems are primarily reactive, meaning they only trigger an alarm after significant smoke density is achieved or a flame is already present. In industrial or residential environments where specific hazardous gases are used, these detectors often fail to provide early warnings for colourless and odourless leaks, such as high concentrations of Carbon Monoxide or Ammonia. Furthermore, existing systems lack centralized connectivity, requiring physical proximity to hear the alarm, and offer no historical data logging for safety audits.

3.1.1 DISADVANTAGES

- Reactive Detection: Alarms are only triggered after a fire has progressed to the smoke-emitting stage, reducing evacuation time.
- High False Alarm Rate: Photoelectric sensors can be easily tripped by non-hazardous elements like dust, steam, or water vapor.
- Lack of Remote Monitoring: There is no mechanism to alert users if they are away from the premises.
- Incomplete Hazard Profile: Conventional sensors cannot distinguish between different types of combustion gases, providing a "one-size-fits-all" response that may be inadequate for chemical leaks.

3.2 PROPOSED SYSTEM

The proposed IoT Based Gas Monitoring System is a proactive safety solution that utilizes an "Electronic Nose" (e-nose) array to identify specific gaseous biomarkers of combustion and decomposition. By integrating an ATmega328 microcontroller with an ESP8266 Node MCU, the system processes raw sensor data at the edge and transmits real-time air quality updates to a cloud-based web dashboard. This allows for the detection of hazards—such as Carbon Monoxide (CO), Carbon Dioxide (CO_2), and Ammonia (NH_3)—long before smoke aerosols are detectable by traditional means.

3.2.1 ADVANTAGES

- Early Detection: Identifies gas signatures at the molecular level before visible smoke or flames appear.
- Enhanced Reliability: Uses sensor arrays and pattern recognition algorithms to differentiate between actual hazards and environmental noise (dust/humidity).
- IoT Accessibility: Provides remote monitoring capabilities, allowing users to view real-time gas levels and receive instant alerts on mobile devices via a web dashboard.
- Data-Driven Safety: Maintains a continuous log of gas concentration levels, which can be analysed for long-term safety trends or industrial compliance.

3.3 SYSTEM ARCHITECTURE

The architecture of the proposed IoT-based gas monitoring system represents a significant shift from reactive disease-diagnosis-treatment methodologies toward a proactive health and safety management approach. By integrating physical sensing with digital connectivity, the system creates an environment where hazards are identified in real time rather than post facto.

The architecture is built upon a multi-layered framework that ensures seamless data flow and rapid response:

- **Sensing Layer:** This layer utilizes an ultra-low-power Hybrid Sensing Network (HSN) consisting of a specialized gas sensor array. These sensors are calibrated to detect specific volatile organic compounds (VOCs) and environmental conditions.

- **Processing and Edge Layer:** At the heart of the system is the Arduino/Node MCU gateway, which acts as a "smart edge" device. This gateway performs rapid active summarization, converting voluminous raw multi-sensor data into clinically or industrially interpretable summaries.
- **Communication Layer:** Data is delivered through a CoAP/6LoWPAN/REST network infrastructure, which is designed for low-power IoT devices that transmit a few bits of data at a time. This layer supports a risk-stratified alert protocol, pushing critical notifications directly to users or monitoring centres.
- **Application Layer:** Sensed data and generated alerts are hosted on a control centre or cloud-based processing platform. An advanced monitoring application makes this information easily accessible via a REST web service, allowing for remote monitoring and automated decision support.

This architecture significantly improves the quality of safety delivery by focusing on accessibility, affordability, and availability. It enables continuous monitoring and effectively mines captured information to bring about transformative changes in the safety landscape, reducing the overall risk of accidents while simultaneously improving response outcomes

CHAPTER 4: MODULE DESCRIPTION

The **IoT Based Gas Monitoring System** is engineered as a modular framework where individual hardware components and software scripts operate in synergy to provide real-time safety analytics. Each module is optimized for low power consumption and high response speed to meet the requirements of industrial and residential safety monitoring.

4.1 DATA ACQUISITION MODULE

The Data Acquisition Module serves as the critical physical interface of the system, functioning as an "Electronic Nose" to sample the surrounding atmosphere.

- **Sensor Array Integration:** This module utilizes a multi-sensor array consisting of metal-oxide semiconductor sensors (MQ-series). These sensors are specifically calibrated to detect **Carbon Monoxide (CO)**, **Carbon Dioxide (CO_2)**, and **Ammonia (NH_3)**.
- **Electrochemical Transduction:** When target gas molecules interact with the heated sensing element, a chemical reaction occurs that alters the sensor's electrical resistance. This change is converted into a measurable analog voltage.
- **Continuous Polling:** The system is programmed for high-frequency sampling, ensuring that data is captured every second to identify rapid spikes in gas concentration that could indicate a leak or the early stages of combustion.

4.2 DATA PROCESSING & CONTROL UNIT

Acting as the "Brain" of the system, this module manages the computational logic and orchestrates the behaviour of all peripheral hardware.

- **Microcontroller Core:** The unit is powered by the **ATmega328** microcontroller, which handles the Analog-to-Digital Conversion (ADC) of the sensor signals.
- **Logic Execution:** The controller executes a decision-making algorithm that compares live PPM (parts per million) values against safety thresholds. It filters out environmental noise—such as fluctuations in humidity or dust—to prevent false positives.
- **System Coordination:** Once a decision is reached, the control unit simultaneously updates the local display, triggers the alert actuators, and sends formatted data packets to the communication gateway via Serial TTL.

4.3 DISPLAY UNIT

The Display Unit serves as the primary local Human-Machine Interface (HMI), providing immediate visual data to personnel on-site.

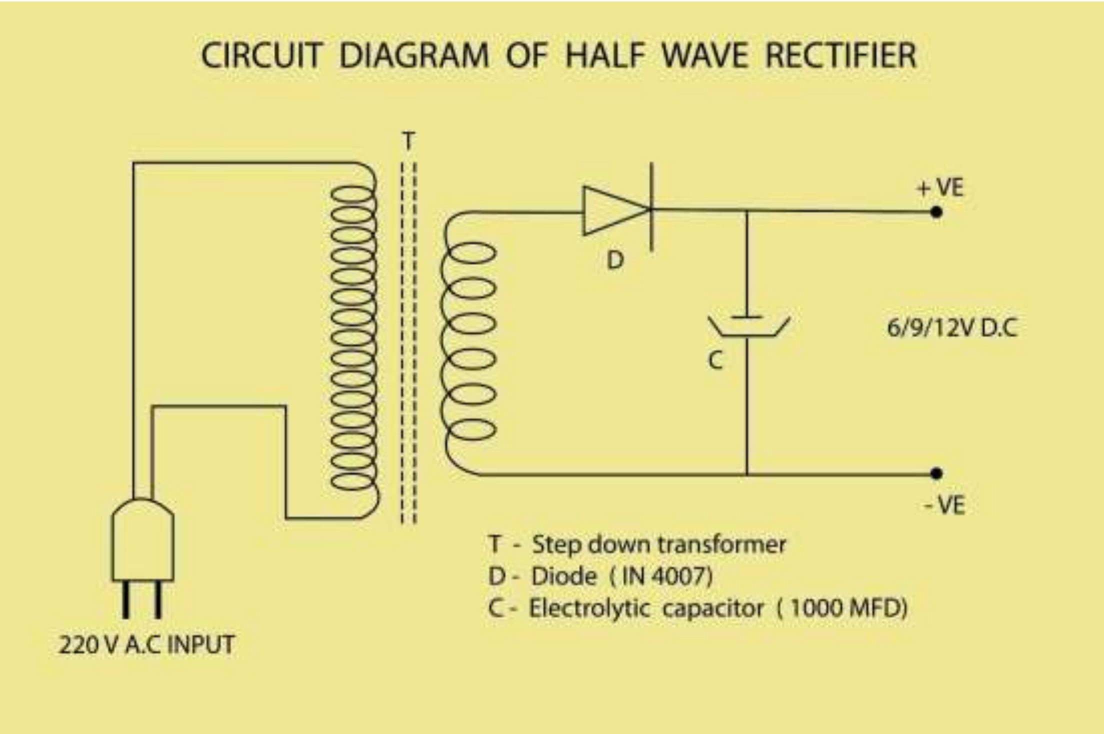
- **Alphanumeric Visualization:** The module features a **16x2 LCD Display** capable of rendering 32 characters across two lines using a 5x7 pixel matrix.
- **Real-Time Telemetry:** The display is configured to cycle through the concentration levels of the identified gases. Under normal conditions, it displays "SYSTEM OK."
- **Register Control:** The processing unit manages the display through a dedicated Command Register (for formatting and cursor control) and a Data Register (for the actual character output), ensuring the interface remains responsive and clear.

4.4 ALERT SYSTEM

The Alert System is the safety-critical output module designed to provide immediate, multi-modal notifications during a hazard event.

- **Local Auditory Alert:** If the control unit detects gas levels exceeding the safety limit, it activates a high-decibel piezoelectric buzzer to warn occupants in the immediate vicinity.
- **Visual Warning Signals:** Simultaneously, the system switches the LCD to a high-priority "GAS ALERT" message and illuminates a red alert LED.
- **Cloud-Based Notification:** Using the **ESP8266 Node MCU**, this module pushes the alert status to the **Web Page Dashboard**. This IoT integration ensures that the user is notified via their smartphone or laptop even if they are miles away from the installation site, facilitating a rapid emergency response.

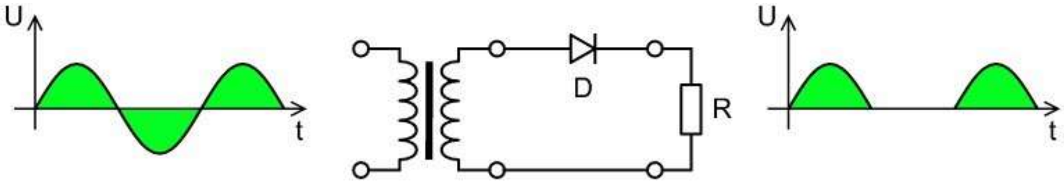
4.5.1 & 4.5.2 Step Up & Down Transformer



A transformer is an essential device that transfers electrical energy between circuits through inductively coupled wires. It operates on the principle that an electric current produces a magnetic field, and a changing magnetic field induces a voltage across a coil. In this system, a step-down transformer is used to reduce high-voltage AC to a lower amplitude by having fewer turns in the secondary winding than the primary winding. This allows the electrical power to be converted to a safer level before entering the rectification stage.

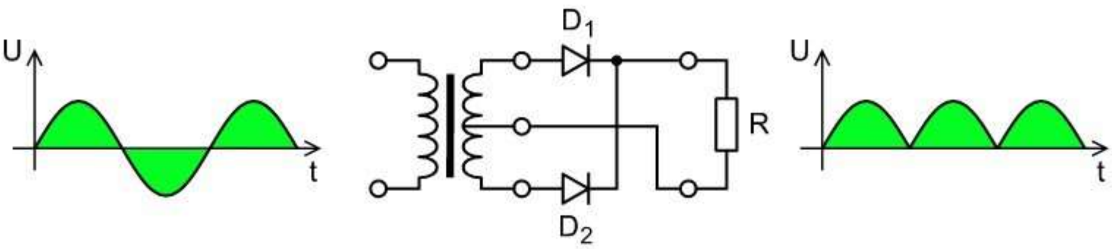
4.5.3 Half-Wave Rectifier Circuit Diagram

A rectifier is a device that converts alternating current (AC), which periodically reverses direction, into direct current (DC), which flows in one direction. In a half-wave rectifier, either the positive or negative half of the AC wave is passed while the other half is blocked. This produces a unidirectional but pulsating direct current with significant ripple, meaning more filtering is required to eliminate harmonics of the AC frequency compared to full-wave alternatives.



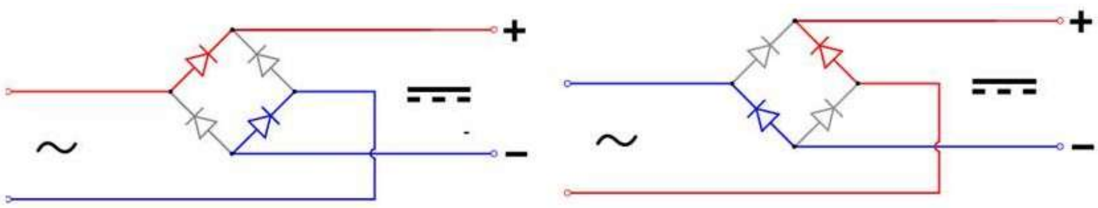
4.5.4 Full-Wave Rectifier Circuit Diagram

A full-wave rectifier converts the entire input waveform into a single constant polarity at its output. By utilizing both polarities of the input wave, it yields a higher average output voltage compared to half-wave rectification. This specific configuration typically requires the use of two diodes and a center-tapped transformer.



4.5.5 Bridge Rectifier Operation Diagram

The bridge rectifier consists of four diodes arranged in a bridge circuit configuration. This arrangement ensures the same output polarity regardless of the input polarity, effectively converting AC into DC. It is a highly cost-effective and lightweight solution because it provides full-wave rectification using only a two-wire AC input, eliminating the need for a bulky center-tapped transformer.



4.5.6 Three-Terminal Voltage Regulator (7805) Connection

To ensure the stability of digital electronics like the ATmega328, an IC voltage regulator is employed. The 7805 regulator provides a fixed regulated output of

+5V DC. It contains internal circuitry for a reference source, comparator amplifier, and overload protection within a single unit. In this connection, an unregulated input voltage is filtered by a capacitor and applied to the regulator, which then outputs a constant voltage despite variations in the input voltage or load current.

CHAPTER 5: SYSTEM DESIGN

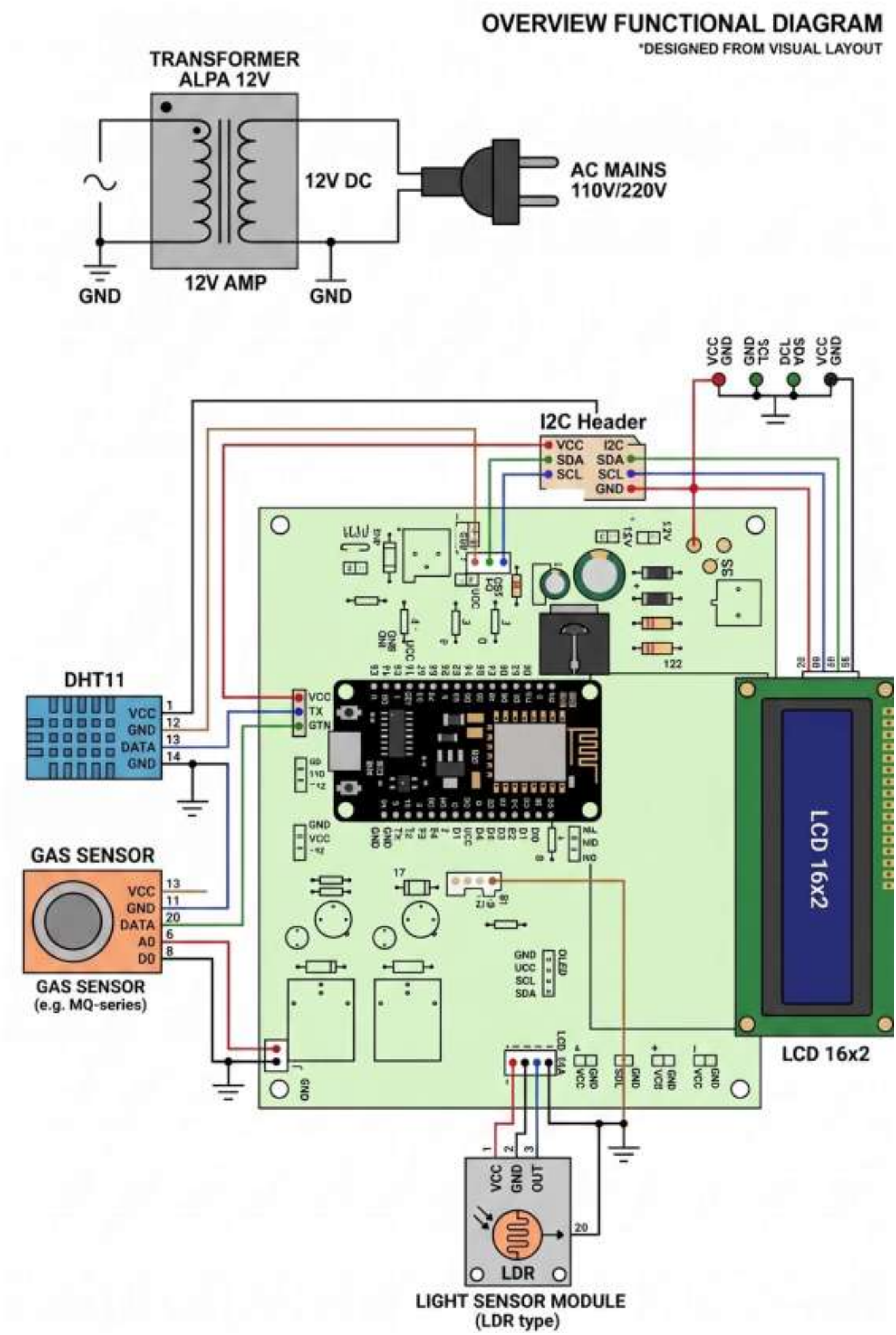
5.1 OVERVIEW

The design of the **IoT Based Gas Monitoring System** follows a robust, end-to-end framework that integrates specialized chemical sensing hardware with high-speed digital processing. The primary objective of the design is to ensure a continuous, low-latency loop between gas detection and user notification. Unlike traditional systems that operate in isolation, this system is designed as a distributed architecture where the "Edge" (the hardware at the site) performs immediate safety classification, while the "Cloud" (the web dashboard) handles data visualization and remote accessibility. This dual-layer design ensures that local alerts (buzzer and LCD) are triggered instantly, even if network connectivity is intermittent, while maintaining a global monitoring footprint.

5.2 SYSTEM DESIGN

The system design is conceptualized through four distinct architectural stages that facilitate the transformation of a physical gas concentration into a digital safety alert:

- **Mechanical and Physical Design:** This stage involves the physical layout of the "Electronic Nose." It specifies the arrangement of the MQ sensor array to ensure optimal airflow and exposure to ambient gases. The physical layer also includes the **Power Supply Unit (PSU)**, which is designed with bridge rectifiers and 7805 regulators to provide a ripple-free 5V DC foundation for the entire circuit.
- **Hardware Interface Design:** This focuses on the interconnection between the **ATmega328** and the peripheral modules. The design ensures that the analog outputs of the sensor array are mapped correctly to the microcontroller's 10-bit ADC pins. It also defines the Serial TTL communication link between the Arduino and the **ESP8266 NodeMCU**, allowing for seamless hand-offs of processed data.
- **Software Logic Design:** The software architecture is built on a non-blocking polling cycle. The firmware is designed to sample the sensors, calculate PPM values using logarithmic regression, and run a threshold-comparison algorithm. This design prioritizes speed, ensuring that the classification of air quality as "Safe" or "Hazardous" occurs in less than one millisecond.
- **Communication and UI Design:** The final design stage focuses on the **Internet of Things (IoT)** stack. It defines how the NodeMCU functions as a web server using the REST protocol. The user interface design centers on a dynamic HTML dashboard that updates without requiring a page refresh, providing a seamless monitoring experience for the end-user.


OVERVIEW FUNCTIONAL DIAGRAM
*DESIGNED FROM VISUAL LAYOUT
TRANSFORMER
ALPA 12V
12V DC
12V AMP
GND
GND
AC MAINS
110V/220V
I2C Header
VCC
SDA
SCL
I2C
SDA
SCL
GND
DHT11
VCC
GND
DATA
GND
GAS SENSOR
VCC
GND
DATA
A0
D0
GAS SENSOR
(e.g. MQ-series)
LCD 16x2
LCD 16x2
VCC
GND
OUT
LDR
LIGHT SENSOR MODULE
(LDR type)

CHAPTER 6: SYSTEM REQUIREMENTS

6.1 SOFTWARE REQUIREMENTS

The software environment for the **IoT Based Gas Monitoring System** is designed to facilitate low-level hardware control, data processing, and cloud-based visualization. The requirement stack focuses on open-source compatibility and lightweight execution to ensure the system remains responsive.

- **Operating System:** Windows 10/11 or Linux (Ubuntu 20.04+) for the development environment.
- **Integrated Development Environment (IDE): Arduino IDE (v1.8.x or higher)**. This is the primary tool for writing, compiling, and uploading C++ based firmware to the ATmega328 and ESP8266.
- **Programming Languages:**
    - **Embedded C/C++:** Used for core microcontroller logic, sensor polling, and threshold management.
    - **HTML/CSS/JavaScript:** Used for designing and rendering the dynamic **Web Page Dashboard** hosted on the NodeMCU.
- **Libraries and Drivers:**
    - **ESP8266WiFi Library:** For managing Wi-Fi connectivity and RESTful communication.
    - **Liquid Crystal Library:** For interfacing with the 16x2 LCD module.
    - **Wire Library:** For I2C communication between modules if expanded.
- **Web Browser:** Chrome, Firefox, or Safari for accessing the real-time IoT monitoring dashboard from remote devices.

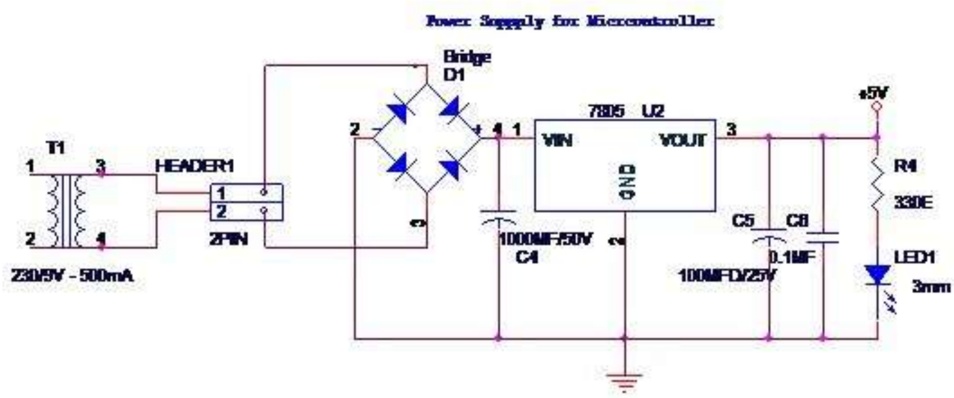
6.2 HARDWARE REQUIREMENTS

The hardware requirements specify the physical components necessary to build the sensing, processing, and communication layers of the project. These components must operate within a **+5V to +3.3V** logic range for compatibility.

- **Microcontrollers:**
    - **Arduino Uno R3 (ATmega328):** Acts as the primary control unit for high-speed analog data acquisition.
    - **ESP8266 Node MCU V3:** Functions as the Wi-Fi gateway for Internet of Things connectivity.
- **Gas Sensor Array (Electronic Nose):**
    - **MQ-2:** For detection of smoke and combustible gases.
    - **MQ-7:** Specialized for **Carbon Monoxide (CO)** detection.
    - **MQ-135:** Targeted at **Ammonia** and **Carbon Dioxide**.
- **Display and Indicators:**
    - **16x2 LCD Display:** For local alphanumeric data visualization.
    - **Piezoelectric Buzzer:** For local auditory alerts during hazard events.

- **LEDs:** Red for alerts and Green for "System OK" status.

- **Power Supply Components:**
  - **12V Step-Down Transformer:** For reducing AC mains voltage.
  - **Bridge Rectifier (1N4007 Diodes):** For full-wave AC-to-DC conversion.
  - **7805 Voltage Regulator:** To provide a stable, regulated +5V DC output.



- **Miscellaneous:** Breadboard, jumper wires (Male-to-Male and Male-to-Female), and 10k Potentiometer (for LCD contrast adjustment).

CHAPTER 7: HARDWARE MAPPING

7.1 ARDUINO PIN MAPPING

Hardware

The Arduino R3 / Arduino Uno Boards have 20 programmable I/O's. They are grouped mainly as

- Pins 0 to 13
- Pins 0 to 5 [Analog Inputs 0 to 5]

Digital I/O's

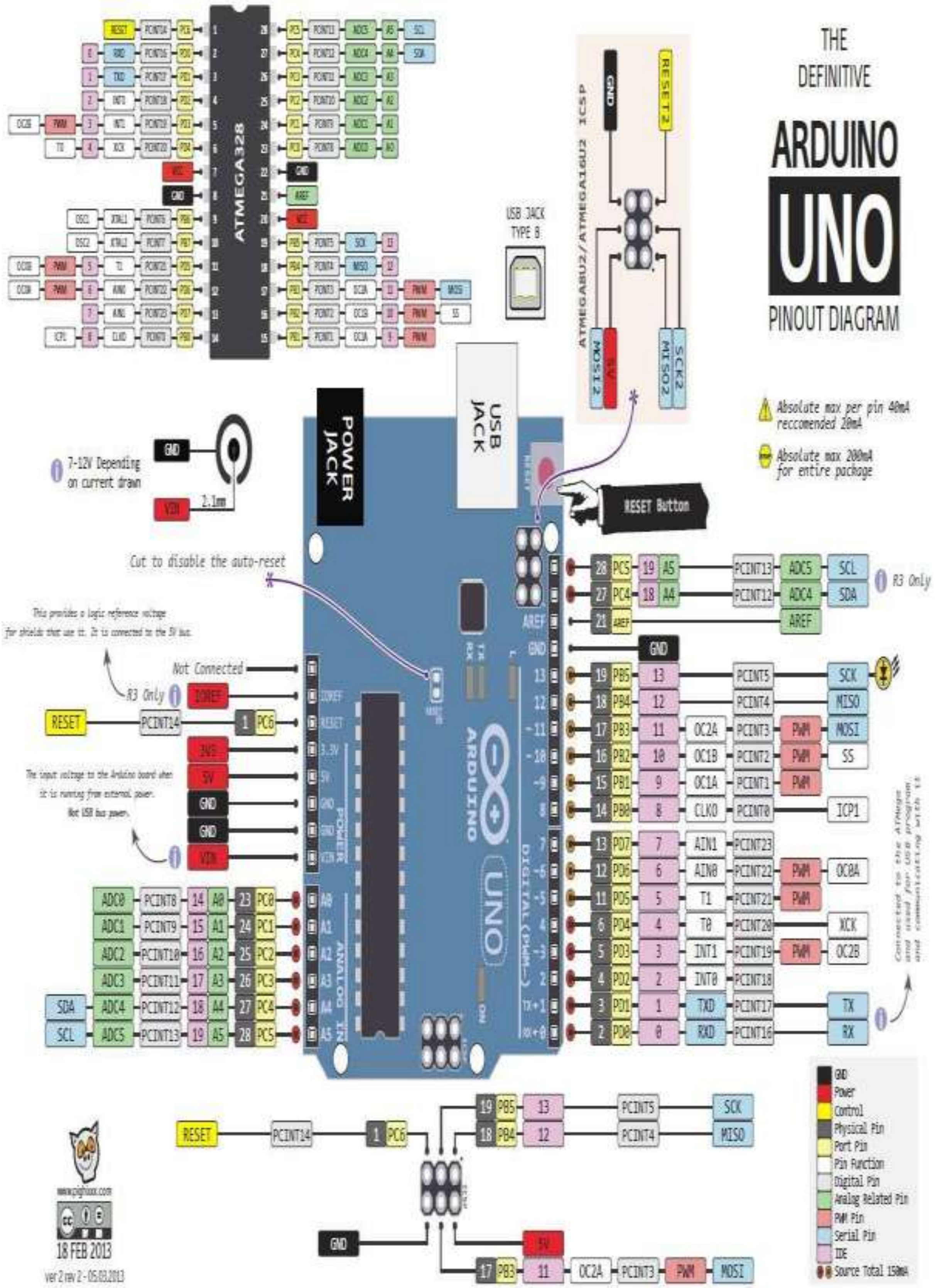
The 20 I/O’s can accept digital signals as input as well as outputs. The digital pins are numbered from 0 to 19.The Digital Pins can be used for controlling LED's, Relays and for accepting input from Push-Buttons, Digital Sensors

Analog I/O's

Analog inputs can be given to pins A0-A5.An inbuilt ADC analogy to digital converter is present that converts analog voltages in the range of 0 to 5 volts to a 10-bit value. Analog sensors that sense changes in temperature or light can work with these inputs.

Analog Output

The six pins marked PWM are pins dedicated to produce Analog Output Signal. They can produce analog voltages in the range of 0 to 5 volts with a resolution of 8-bits. They can be used for Intensity Control, Speed Control, Etc.


THE
DEFINITIVE
ARDUINO
UNO
PINOUT DIAGRAM
ATMEGA328
USB JACK TYPE B
ATMEGA8U2 / ATMEGA16U2 ICSP
GND
RESET2
MOSI2
5V
MISO2
SCK2
Absolute max per pin 40mA reccomended 20mA
Absolute max 200mA for entire package
POWER JACK
USB JACK
7-12V Depending on current drawn
GND
VIN
2.1mm
RESET Button
Cut to disable the auto-reset
R3 Only
This provides a logic reference voltage for shields that use it. It is connected to the 5V bus.
Not Connected
IOREF
RESET
PCINT14
3V3
5V
GND
VIN
The input voltage to the Arduino board when it is running from external power. Not USB bus power.
ARDUINO
UNO
ANALOG IN
DIGITAL (PWM~)
POWER
AREF
SCL
SDA
SCK
MISO
MOSI
SS
ICP1
OC0A
XCK
OC2B
TX
RX
Connected to the ATmega and used for USB programming and communicating with it
GND
Power
Control
Physical Pin
Port Pin
Pin Function
Digital Pin
Analog Related Pin
PWM Pin
Serial Pin
IDE
Source Total 150mA
www.pighixxx.com
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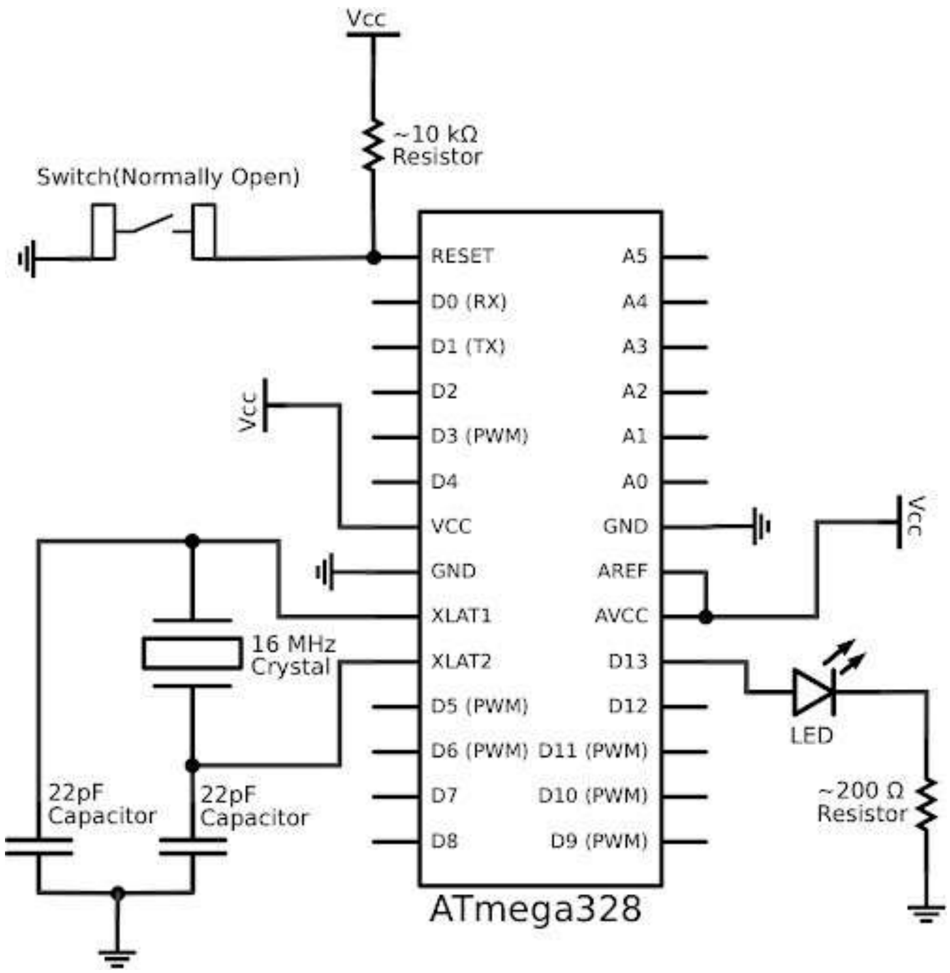
ver 2 rev 2 - 05.03.2013



7.2 COMMUNICATION

Serial Communication

The communication can be established with the computer or other arduino boards. For this purpose, the ATmega328 provides UART TTL (5V) serial communication, existing on digital pins 0 (RX) and 1 (TX). A FT232RL IC on the board paves the way for this serial communication over USB and appears as a virtual com port to the computer.

The Arduino software includes a serial monitor which allows simple textual data to be sent to and from the Arduino board. The RX and TX LEDs on the board will flash when data is being transmitted via the USB-to-serial chip

I2C Communication or Two Wire Communication

The Atmega328 provides I2C / Two Wire Communication through the Analog Pins A4 (SDA) & A5 (SCL). The Arduino software includes a Wire library to simplify use of the I2C bus. I2C Communication can be used for communicating with other microcontrollers / ICs.

SPI Communication

The Atmega328 supports SPI communication through pins 10 (SS), 11 (MOSI), 12 (MISO), 13 (SCK). SPI communication is supported by the Arduino IDE using the SPI library. SPI Communication can also be used to communicate with other peripherals / ICs - SD Cards, Ethernet Controller, Etc. **Software Serial**

In addition to the Hardware Serial Communication provided by the ATmega328, The Software Serial Library for

Arduino allows the use of any pin on the board for additional Serial Communication.

7.3 IOT MODULE

The Internet of Things (IoT) has been a trending field in the world of technology. It has changed the way we work. Physical objects and the digital world are connected now more than ever. Keeping this in mind, Espresso Systems (A Shanghai-based Semiconductor Company) has released an adorable, bite-sized WiFi enabled microcontroller – ESP8266, at an unbelievable price! For less than $3, it can monitor and control things from anywhere in the world – perfect for just about any IoT project.

Node MCU is an opensource development board and firmware based in the widely used ESP8266 -12E Wi-Fi module. It allows you to program the ESP8266 Wi-Fi module with the simple and powerful LUA programming language or Arduino IDE.

With just a few lines of code you can establish a Wi-Fi connection and define input/output pins according to your needs exactly like Arduino, turning your ESP8266 into a web server and a lot more. It is the Wi-Fi equivalent of ethernet module. Now you have internet of things (iot) real tool.

With its USB-TTL , the node MCU Dev board supports directly flashing from USB port. It combines features of WIFI access point and station + microcontroller. These features make the Node MCU extremely powerful tool for Wifi networking. It can be used as access point and/or station, host a webserver or connect to internet to fetch or upload data.

ESP-12E Module

The development board equips the ESP-12E module containing ESP8266 chip having Tensilica Xtensa® 32-bit LX106 RISC microprocessor which operates at 80 to 160 MHz adjustable clock frequency and supports RTOS.

ESP-12E Chip

- Tensilica Xtensa® 32-bit LX106
- 80 to 160 MHz Clock Freq.
- 128kB internal RAM
- 4MB external flash
- 802.11b/g/n Wi-Fi transceiver

There's also 128 KB RAM and 4MB of Flash memory (for program and data storage) just enough to cope with the large strings that make up web pages, JSON/XML data, and everything we throw at IoT devices nowadays.

The ESP8266 Integrates 802.11b/g/n HT40 Wi-Fi transceiver, so it can not only connect to a Wi-Fi network and interact with the Internet, but it can also set up a network of its own, allowing other devices to connect directly to it. This makes the ESP8266 Node MCU even more versatile.

Power Requirement

As the operating voltage range of ESP8266 is 3V to 3.6V, the board comes with a LDO voltage regulator to keep the voltage steady at 3.3V. It can reliably supply up to 600mA, which should be more than enough when ESP8266 pulls as much as 80mA during RF transmissions. The output of the regulator is also broken out to one of the sides of the board and labelled as 3V3. This pin can be used to supply power to external components.

Power Requirement

- Operating Voltage: 2.5V to 3.6V
- On-board 3.3V 600mA regulator
- 80mA Operating Current
- 20 µA during Sleep Mode

Power to the ESP8266 Node MCU is supplied via the on-board Micro USB connector. Alternatively, if you have a regulated 5V voltage source, the VIN pin can be used to directly supply the ESP8266 and its peripherals.

7.3 LCD (LIQUID CRYSTAL DISPLAY) 13.LCD Display

LCD Display

LCD (Liquid Crystal Display) screen is an electronic display module and find a wide range of applications. A 16x2 LCD display is very basic module and is very commonly used in various devices and circuits.

A 16x2 LCD means it can display 16 characters per line and there are 2 such lines. In this LCD each character is displayed in 5x7 pixel matrix. This LCD has two registers, namely, Command and Data. The command register stores the command instructions given to the LCD, The data register stores the data to be displayed on the LCD

Based on the construction, LCD's are classified into two types. They are,

(i) Dynamic scattering type

(ii) Field effect type.

Dynamic scattering type

The construction of the dynamic scattering liquid crystal cell is shown in the fig. The display consists of two glass plates, each coated with tin oxide (SnO_2) on the inside with transparent electrodes separated by a liquid crystal layer,5µA to 50 µA thick. The oxide coating on the front sheet is etched to produce a single or multi- segment pattern of characters, with each segment properly insulated from each other. A weak electric field applied to liquid crystal tends to align molecule in the direction of the field. As soon as the voltage exceeds certain threshold value, the domain structure collapses and the appearance is changed.

As the voltage grows further, the flow becomes turbulent and the substance turns optically homogenous. In this disordered state, the liquid crystal scatters light.

Thus, when the liquid is not activated, it is transparent. When the liquid is activated, the molecular turbulence causes light to be scattered in all directions and the cell appears bright. This phenomenon is called dynamic scattering

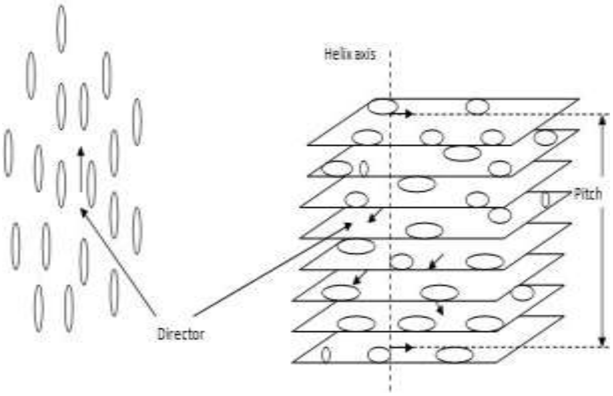
Field effect type

The construction of the field effect LCD display is similar to that of the dynamic scattering type, with the expectation that two thin polarizing optical filters are placed at the inside of each glass sheet.

The LCD material is of twisted nematic type which twists the light (change in direction of polarization) passing through the cell when the latter is not energized. This allows light to pass through the optical filters and the cell appears bright. When the cell is energized, no twisting of light takes place and the cell appears dull.

Liquid crystal cells are of two types (i) transitive type (ii) reflective type. In the transitive type cell both glass sheets are transparent so that the light from the rear source is scattered in the forward direction when the cell is activated. The reflecting type cell has a reflecting surface on one side of the glass sheet. The incident light on the front surface of the cell is dynamically scattered by an activated cell. Both types of cells appear quite bright when activated even under ambient light conditions.

Liquid crystals consume small amount of energy, in a seven segment display the current drawn is about 25 µA for dynamic scattering cells and 300 µA. for field effect cells LCD's require ac voltage supply. A typical voltage supply to dynamic scattering LCD's are normally used for seven-segmental displays.



14. Schematic arrangement in liquid crystal

Features of LCD

- Operating voltage range is 3-20V ac.
- It has a slow decay time. Response time is 50 to 200 ms.
- Viewing angle is 100 degree.
- Invisible in darkness. Requires external illumination.
- Life time is limited to 50,000 hours due to chemical graduation.

Advantages of LCD

- The voltage required is small.
- They have low power consumption. A seven segment display requires about 140 W (20 W per segment).

CHAPTER 8: CONCLUSION AND FUTURE ENHANCEMENT

8.1 CONCLUSION

The development of the **IoT Based Gas Monitoring System** successfully demonstrates a proactive and technologically advanced approach to environmental safety. By integrating an intelligent "Electronic Nose" sensor array with edge-processing capabilities, the project has transitioned from traditional reactive fire detection to a molecular-level diagnostic framework. The system effectively identifies critical combustion markers such as **Carbon Monoxide (CO)**, **Carbon Dioxide (CO_2)**, and **Ammonia (NH_3)** long before visible smoke or thermal hazards manifest.

The utilization of the **ATmega328** for local logic and the **ESP8266 Node3333MCU** for IoT connectivity ensures a high-reliability system that provides both local auditory alerts and remote visual monitoring through a dynamic web dashboard. The implementation of robust power supply circuitry, including bridge rectification and 7805 regulation, guarantees the operational stability required for sensitive industrial and residential deployments. Ultimately, this project offers a scalable, low-cost solution that enhances safety delivery, reduces the risk of toxic gas exposure, and leverages the "Internet of Things" to ensure that safety data is accessible anytime and anywhere.

8.2 FUTURE ENHANCEMENT

While the current system provides a robust foundation for gas monitoring, several technological advancements can be integrated to further improve its predictive capabilities and industrial utility:

- **Advanced Machine Learning Integration:** Future iterations could incorporate more complex algorithms like **Random Forest** or **Hybrid Deep Neural Networks** (as seen in the software reference) to improve gas classification accuracy and reduce false alarms in highly volatile environments.
- **Energy Harvesting and Low-Power Modes:** To improve the system's longevity in remote locations, integrating solar energy harvesting or utilizing deep-sleep modes on the ESP8266 would allow the device to operate indefinitely on battery power.
- **Mobile Application Development:** While the current web dashboard is accessible via browsers, developing a dedicated Android/iOS application with **Push Notifications** (using Firebase or MQTT) would ensure users receive critical alerts even when their browser is closed.
- **Gas Source Localization:** By deploying multiple sensor nodes in a mesh network configuration, the system could be enhanced to triangulate the exact location of a gas leak or fire origin within a large industrial facility.
- **Expanded Sensor Suite:** Future versions could integrate sensors for **Volatile Organic Compounds (VOCs)** related to specific industrial chemicals or even air quality indices (AQI) for broader environmental health monitoring.

CHAPTER 9: APPENDICES

9.1 APPENDIX I

```
#include <ESP8266WiFi.h> #include <ESP8266HTTPClient.h> #include <WiFiClient.h>
#include <DHT.h> #include <Wire.h>
#include <LiquidCrystal_I2C.h>


// --- Configuration ---
```

```
const char* ssid = "iot2023";

const char* password = "iot 12345";

// The URL provided in your screenshot

const char* serverName = "http://scentgroups.com/update_data.php";


// --- Pin Definitions ---#define DHTPIN D5  #define DHTTYPE DHT11 #define GAS_ANALOG A0 #define LDR_PIN D6


// --- Object Initialization ---DHT dht(DHTPIN, DHTTYPE);
LiquidCrystal_I2C lcd(0x27, 16, 2); // Change address to 0x3F if 0x27 fails


void setup() { Serial.begin(115200);


dht.begin();

lcd.init(); lcd.backlight();
pinMode(LDR_PIN, INPUT);


// Connect to Wi-Fi WiFi.begin(ssid, password); lcd.setCursor(0, 0); lcd.print("Connecting...");


while (WiFi.status() != WL_CONNECTED) { delay(500);
Serial.print(".");

}


lcd.clear();

lcd.print("WiFi Connected"); delay(2000);
}


void loop() {

// 1. Read Sensors

float h = dht.readHumidity(); float t = dht.readTemperature();
int gasVal = analogRead(GAS_ANALOG); int lightVal = digitalRead(LDR_PIN);
// 2. Display Locally on LCD lcd.clear();
lcd.setCursor(0, 0); lcd.print("G:"); lcd.print(gasVal);
lcd.print(" L:"); lcd.print(lightVal == HIGH ? "Dark" : "Light");


lcd.setCursor(0, 1);
```

```
lcd.print("T:"); lcd.print(t, 1);

lcd.print("C H:"); lcd.print(h, 0); lcd.print("%");


// 3. Send to Web Dashboard

if (WiFi.status() == WL_CONNECTED) { WiFiClient client;
HTTPClient http;


// Constructing the GET request string (Adjust parameters based on your backend)

String httpRequestData = String(serverName) + "?gas1=" + String(gasVal) + "&temp=" + String(t) + "&hum=" +
String(h);


http.begin(client, httpRequestData); int httpResponseCode = http.GET();


if (httpResponseCode > 0) { Serial.print("HTTP Response code: "); Serial.println(httpResponseCode);
} else {

Serial.print("Error code: "); Serial.println(httpResponseCode);
}

http.end();

}


delay(10000); // Update every 10 seconds

}
```

9.2.APPENDIX II

HTML Structure

```
<!DOCTYPE html>

<html lang="en">

<head>

<meta charset="UTF-8">

<meta name="viewport" content="width=device-width, initial-scale=1.0">

<title>Gas Level Monitoring - Dhanalakshmi University</title>

<style>

body { background-color: #00ffff; font-family: 'Times New Roman', serif; text-align: center; margin: 0; }
```

```
header h1 { color: #0000ff; margin-top: 20px; }

.university { color: #ff4500; font-size: 1.2rem; }

.timestamp { text-align: left; padding: 10px; font-weight: bold; }

img { width: 95%; max-width: 800px; border: 1px solid #000; margin: 10px 0; }

.data-table { margin: 20px auto; border-collapse: collapse; width: 80%; background: transparent; }
.data-table th, .data-table td { border: 1px solid #333; padding: 12px; font-weight: bold; } #live-data tr:first-child {
background-color: rgba(255, 255, 255, 0.3); } /* Highlight latest
*/

</style>

</head>

<body>


<header>

<h1>GAS LEVEL HEALTH MONITORING USING IOT</h1>

<div class="university">DHANALAKSHMI UNIVERSITY</div>

<div class="timestamp" id="current-time"></div>

</header>


<img src="university_building.jpg" alt="University Campus">
<h3>Sensor Details</h3>

<table class="data-table">

<thead>

<tr>

<th>GAS1 (Level)</th>

<th>TEMP (°C)</th>

<th>HUM (%)</th>

<th>STATUS</th>

</tr>

</thead>

<tbody id="live-data">

<tr><td colspan="4">Loading real-time data...</td></tr>

</tbody>
```

```
</table>

<script>
// Function to update the clock function updateClock() {
const now = new Date();
document.getElementById('current-time').innerText = now.getHours() + ":" + now.getMinutes() + ":" + now.getSeconds() + " |";
}
setInterval(updateClock, 1000);

// Function to fetch data from the database async function fetchSensorData() {
try {
const response = await fetch('fetch_data.php'); const data = await response.text();
document.getElementById('live-data').innerHTML = data;
} catch (err) {
console.error("Error fetching data:", err);
}
}

// Refresh data every 5 seconds setInterval(fetchSensorData, 5000); fetchSensorData(); // Initial load
</script>
</body>
</html>
```

9.3 APPENDIX III

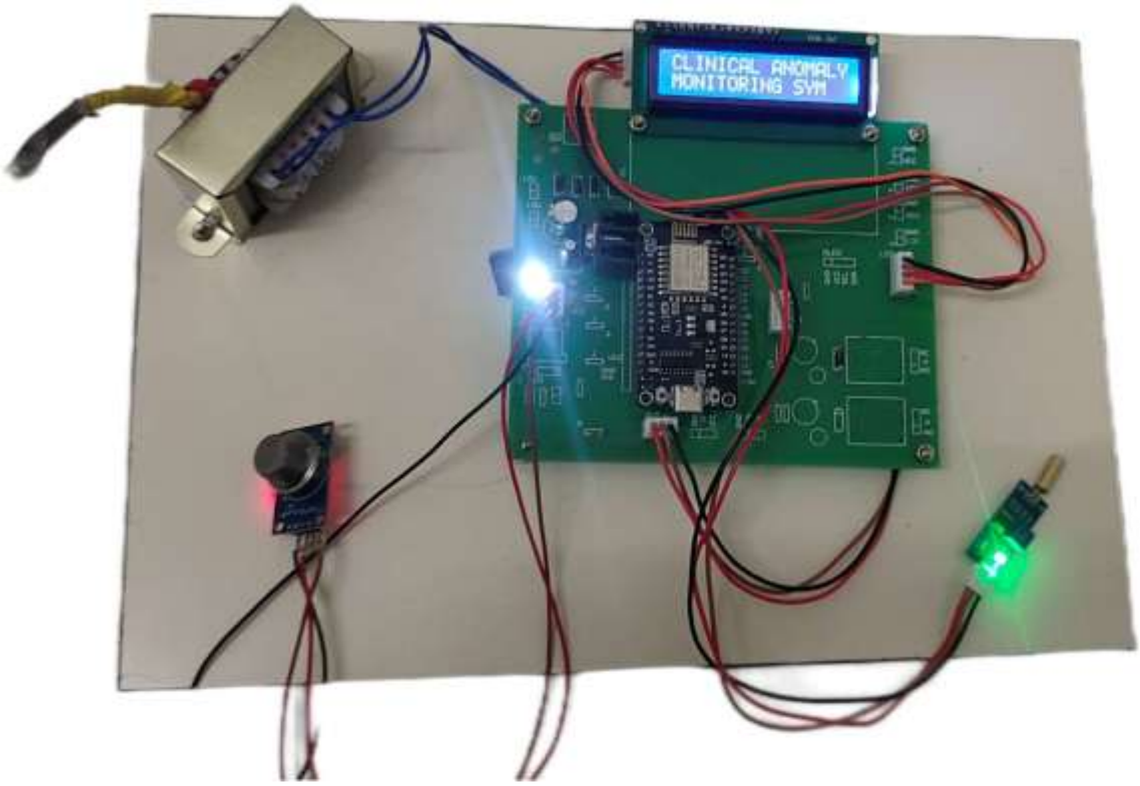
The Data fetcher

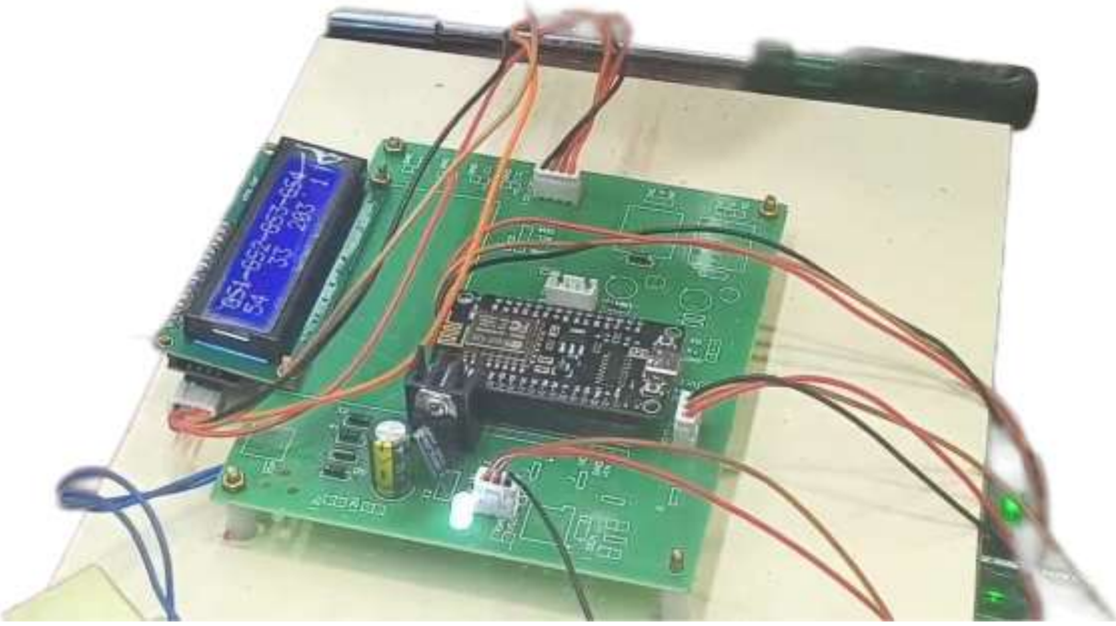
```
<?php
// Database connection
$host = "localhost";
$user = "your_db_user";
$pass = "your_db_password";
$dbname = "your_db_name";
```

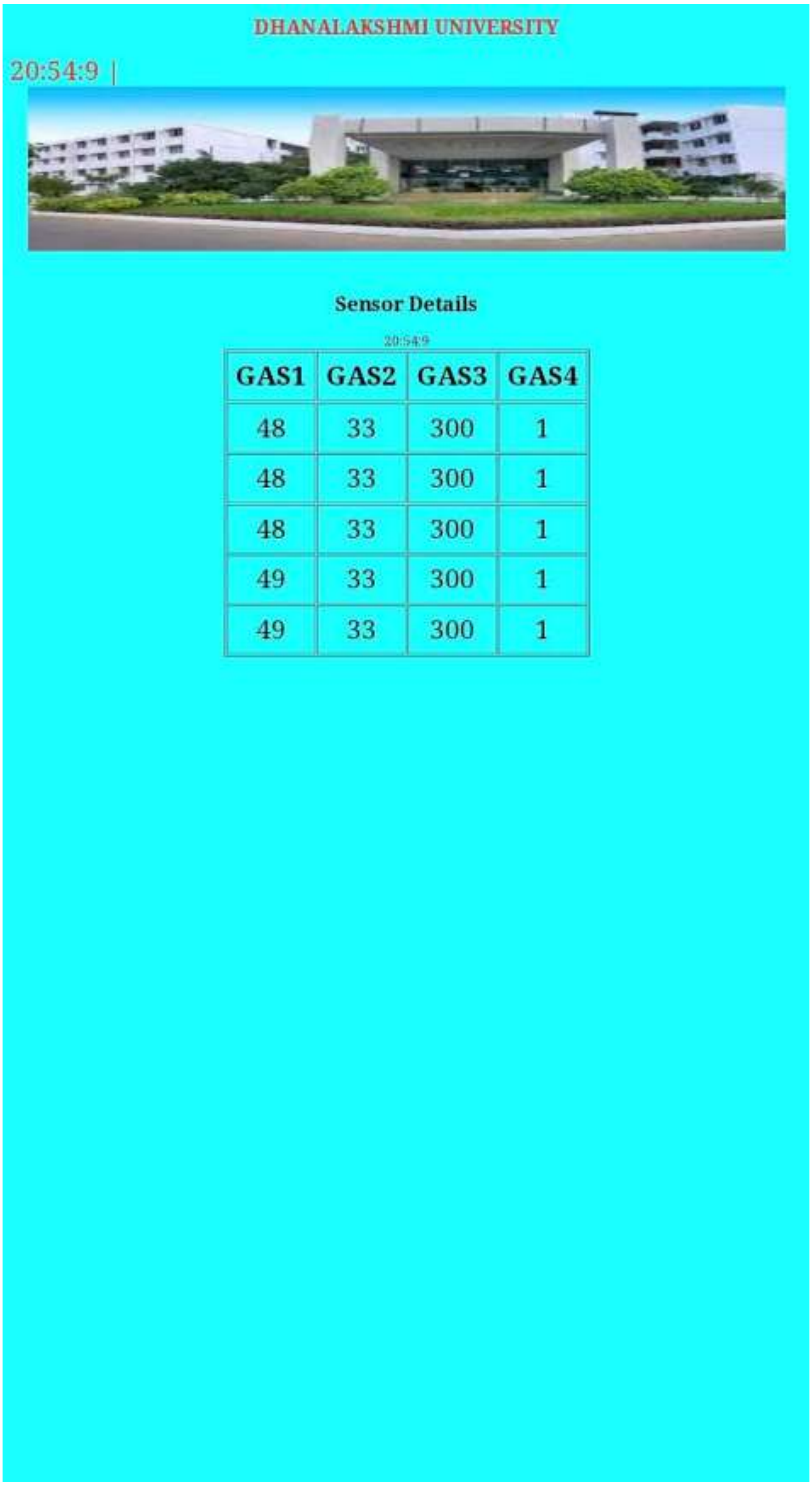
```
$conn = new mysqli($host, $user, $pass, $dbname);


// Fetch the last 5 readings
$sql = "SELECT gas1, temp, hum FROM sensor_readings ORDER BY id DESC LIMIT 5";
$result = $conn->query($sql);


if ($result->num_rows > 0) {
while($row = $result->fetch_assoc()) {
$status = ($row["gas1"] > 400) ? "<span style='color:red'>ALERT</span>" : "NORMAL";
echo "<tr>
<td>" . $row["gas1"] . "</td>
<td>" . $row["temp"] . "</td>
<td>" . $row["hum"] . "</td>
<td>" . $status . "</td>
</tr>";
}
} else {
echo "<tr><td colspan='4'>No data found</td></tr>";
}
$conn->close();
?>
```

9.4 APPENDIX IV

<u>OUTPUT</u>







GAS1	GAS2	GAS3	GAS4
48	33	300	1
48	33	300	1
48	33	300	1
49	33	300	1
49	33	300	1

CHAPTER 10: REFERENCRS

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