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Development of Microcontroller-Based Smart Device for Substance Detection in University Environment

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***Abstract*— The rising concerns over substance abuse particularly involving Indian hemp (marijuana) and alcohol among university students in Nigeria poses significant health and social concerns, and necessitate innovative solutions for detection, effective monitoring and intervention strategies. Substance abuse among university students has become a pressing issue, negatively impacting academic performance, contributing to increased cultism, and compromising overall student well-being. The lack of effective monitoring mechanisms within universities has allowed these behaviours to persist, with students often evading detection due to limited oversight and enforcement by university authorities. This research proposed the development microcontroller- based smart device designed specifically for detecting smoking and drinking activities on university campuses. Upon detecting suspicious activities associated with smoking or drinking activities, the device will immediately notify university law enforcement in the university and provide them with precise GPS coordinates of the location where the activity was detected. The device utilizes an MQ3 sensor for alcohol and smoke detection, a GPS sensor for location tracking, and a GSM module for real-time alerting and monitoring. This integrated system enables proactive intervention and swift response to substance-related incidents on campus.**

Keywords—Substance Detection, Microcontroller, Smart device, Monitoring

I. Introduction

According to the National Drug Law Enforcement Agency (NDLEA) 2023 report, it is estimated that over 14.3 million Nigerians are involved in drug abuse, with youths aged between 18 and 35 accounting for 40% of this figure [1]. Substance abuse among university students can be attributed to various factors, including stress, peer pressure, curiosity, family challenges and undue exposure to drugs and alcohol [2]. Academic pressures and the transition to independent living away from home can also contribute to increased experimentation with substances. Also lack of awareness about the risks associated with drug and alcohol misuse, coupled with limited access to right counselling and support services from the university, can further exacerbate the problem among students [3]. In response to this pressing concern, technologically innovative approaches are needed to effectively monitor and combat substance abuse activities. In order to be able, detect different substances within alcohol family, [4] proposed classification of alcohol type using MQ3 gas sensor. The findings were able to classified the ethanol content from the methanol and showed that selectivity increased when the detection was combined from the response of MQ3 gas sensor. However, the smoke detection of the gas sensor was not considered. This research introduced microcontroller based smart device designed to accurately sense Indian hemp smoke and alcohol level, offering a non-invasive, efficient, and user-friendly approach to substance detection. Traditional methods of substance detection often involve invasive procedures or laboratory-based tests, which are time-consuming, expensive, and impractical for widespread use [5][6]. The proposed device addresses these challenges by leveraging advanced sensor technology and algorithms to detect marijuana and alcohol accurately. The MQ3 sensor detects both alcohol content and smoke levels in the area, relaying the location data obtained via the GPS sensor to the University's law enforcement department in real-time through the GSM module. Installing the device in strategic areas around the university where such activities are suspected, university authorities can receive immediate feedback on Indian hemp and alcohol consumption and pinpoint the locations within the campus where these activities are taking place.

II. Theoretical Analysis

A. *MQ 3 Gas Sensor*

The MQ3 sensor used in this research exhibits sensitivity and selectivity in detecting alcohol and smoke concentrations [7]. Its sensitivity enables it to respond to even low levels of alcohol vapors and smoke particles in the surrounding environment. However, this sensitivity is balanced by its selectivity, which allows it to distinguish between alcohol and smoke based on their chemical compositions [8]. Fig. 1 shows the internal configuration of MQ 3 gas sensor.

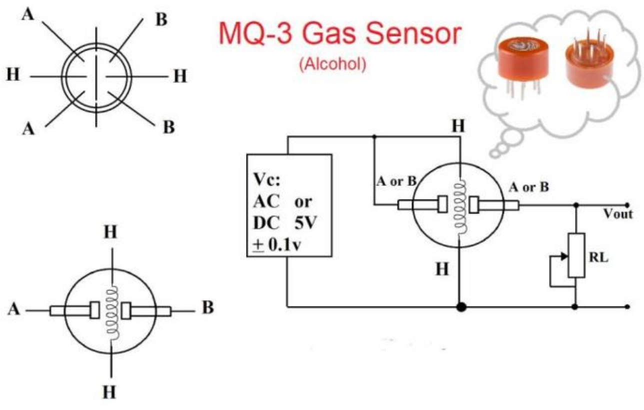

Fig. 1: MQ 3 Sensor Circuit

The sensor sensitivity equation is given by [9]:

$$S = \frac{\Delta RL}{\Delta PPM}$$

Where S is the sensor sensitivity, ΔRL is the change in sensor resistance (Ohms) and ΔPPM is the change in alcohol concentration (Parts Per Million).

TABLE I: List of substances with detecting range in PPM

S/N	Substances	Detection Range
1	Ethanol	100 ppm - 1000 ppm
2	Methanol	50 ppm - 300 ppm
3	Smoke	200ppm-10000 ppm.
4	Carbon Monoxide	10 ppm - 1000 ppm
5	LPG	200ppm- 10000 ppm

Table I shows the substances with detecting range in Part Per Million (PPM) and the sensor's analog resistive output RL correlates with alcohol concentration. As alcohol gas concentration rises, the sensor's conductivity increases proportionally. The MQ-3 sensor relies on a chemical reaction to detect gases. It utilizes a moderate heating element to elevate the temperature of its metal oxide semiconductor (MOS) sensor [10]. When exposed to alcohol fumes in the atmosphere, the MOS sensor undergoes a chemical reaction, altering its electrical resistance. Additionally, the MQ-3 sensor exhibits operational flexibility, performing effectively within a temperature range of 10°C to 70°C [11]. Its functionality is supported by a heating element, with the heater coil drawing a current of 150 mA [12].

III. SYSTEM DESIGN

The Fig. 2 shows the block diagram of the proposed system. The system's hardware consists of five primary components: ATMEGA328 Microcontroller, power supply unit, MQ3 sensor, GSM and GPS module.

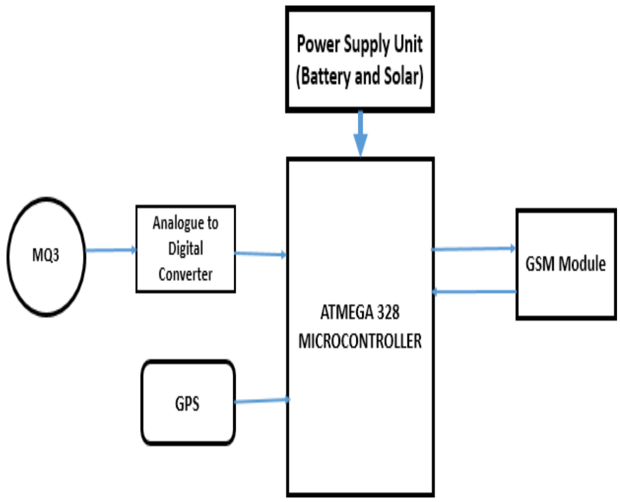

Fig. 2: Block Diagram

A. THE HARDWARE COMPONENTS

The system's hardware design incorporates essential components including MQ3 sensor, ATMEGA 328 microcontroller, GPS module, GSM module, and other electronic components. The MQ3 serves the purpose of detecting the alcohol and smoke produced by the marijuana. The sensor output is fed into the analog-to-digital converter (ADC) of the microcontroller. Upon detecting the smell of alcohol or the smoke from marijuana, the device automatically sends the source information and transmits its location to law enforcement of the university for appropriate action.

a. ATMEGA 328 Microcontroller

At the core of the system lies the ATMEGA328 microcontroller, responsible for data processing and control logic. As shown in Fig. 3, this 8-bit microcontroller belongs to the Atmel AVR family and is known for its versatility, being widely utilized in diverse applications from hobbyist projects to industrial automation and robotics [13]. Operating on the Harvard architecture, it features separate program memory (Flash) and data memory (SRAM), with a clock speed of 8 MHz and the ability to execute most instructions in a single clock cycle. The ATMEGA328 offers 32KB of Flash program memory, 2KB of SRAM data memory, and 1KB of EEPROM for non-volatile data storage. Its comprehensive set of peripherals includes digital I/O pins, analog-to-digital converters (ADCs), timers/counters, UART communication, and PWM channels, making it highly adaptable for interfacing with a wide range of sensors, actuators, and communication devices [14].

With 23 general-purpose digital I/O pins, including PWM-capable pins, the ATMEGA328 offers extensive flexibility for connecting external devices, while its 10-bit ADC with multiple input channels allows for the conversion of analog signals from sensors into digital values for further processing. Additionally, its support for UART communication is essential for interfacing with various external devices [15].

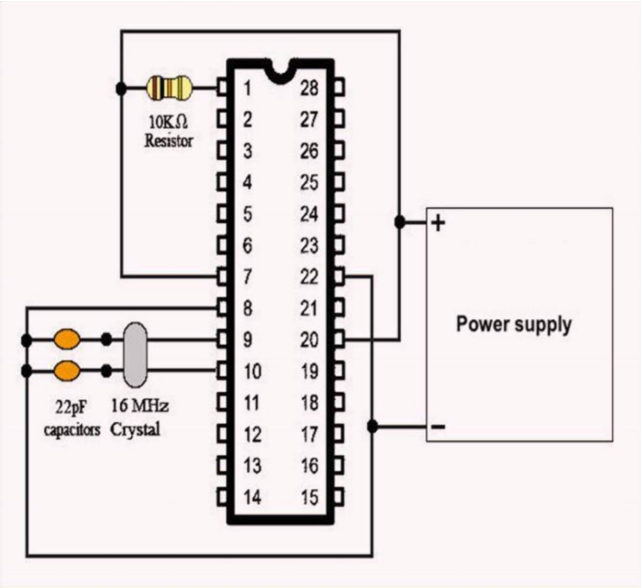

Fig. 3: ATMEGA 328 Circuit Connection

The ATmega328 microcontroller plays a pivotal role in the proposed smart device design by serving as the central processing unit. It coordinates the functions of the MQ3 sensor for detecting alcohol and smoke, the GPS sensor for accurate location tracking, and the GSM module for real-time alerting and monitoring. Through its programming, the ATmega328 enables the device to detect suspicious smoking and drinking activities on university campuses, promptly notifying law enforcement with precise GPS coordinates for immediate action.

b. MQ3 Sensor

The MQ-3 sensor, illustrated in Fig. 4, is a conductometric Metal Oxide Semiconductor (MOS) gas sensor known for its rapid response times and high sensitivity to alcohol. Despite its strong sensitivity to alcohol, the sensor shows reduced responsiveness to other gases like benzene, methane, hexane, propane, and carbon monoxide.

Fig. 4: MQ3 Sensor

The sensor's sensitive material consists of a thin film of SnO2, or tin dioxide, which has low electrical conductivity in clean air. Classified as an n- type MOS sensor, the MQ-3 sensor's conductivity increases proportionally with alcohol concentration, allowing it to detect alcohol levels ranging from 0.05 mg/l to 10 mg/l [16].

c. GSM Module (SIM 800)

As shown in Fig. 5, the SIM800 module operates using the AT command set, a collection of standard commands designed for controlling and configuring modem-like devices. These commands enable functionalities like sending text messages, making phone calls, and accessing the internet. Users can transmit data or messages by issuing specific AT commands to the module, which then encodes and sends the information over the GSM network to the desired recipient. Conversely, when data or messages are received, the module decodes the information, making it available for further processing by the host system [17]. Utilizing the GSM network infrastructure, the module ensures reliable communication, making it a valuable component in applications such as remote monitoring, telematics, and IoT devices. Its ease of use and compatibility with standard AT commands have contributed to its widespread adoption in various projects and applications [18].

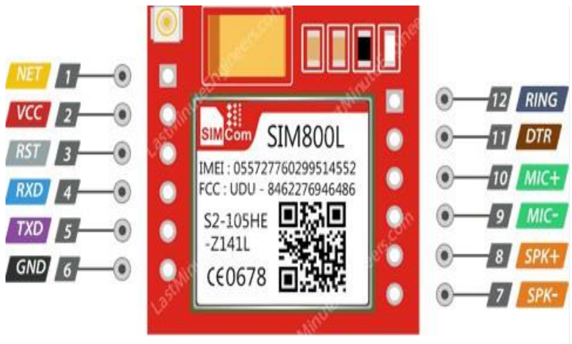

Fig. 5: SIM 800 GSM Module

The SIM800 module functions as the communication interface in the proposed smart device design, facilitating real-time alerting and monitoring capabilities. It enables the device to transmit notifications to university law enforcement via SMS or call functionalities upon detecting suspicious smoking and drinking activities. Additionally, the SIM800 module allows for remote monitoring and control of the device's operation through cellular networks.

d. GPS Module

The Fig.6 shows the GPS (Global Positioning System) module receives signals from satellites to determine its precise location on Earth [19]. It calculates its position by measuring the time it takes for signals from multiple satellites to reach the module. These signals contain information about the satellite's position and the exact time the signal was transmitted. By triangulating this data, the GPS module can determine its latitude, longitude, and altitude coordinates. In this proposed device, the GPS module plays a crucial role in identifying the exact location where the microcontroller-based smart device installed. When the device detects the presence of alcohol or smoke, the GPS module captures the geographical coordinates of that location [20].

Fig. 6: GPS Module

The GPS module plays a crucial role in the smart device design by providing precise location tracking capabilities. It enables the device to accurately pinpoint the location where suspicious smoking and drinking activities are detected on university campuses. By incorporating GPS functionality, the device ensures that university law enforcement receives detailed location information, facilitating swift and targeted responses to such activities.

B. PROPOSED CIRCUIT DESIGN AND SIMULATION

As shown in Fig. 7, the circuit consists of an ATMEGA328 microcontroller, GPS module, GSM module, and MQ-3 gas sensor. The GPS module determines precise location coordinates, while the MQ-3 sensor detects alcohol presence. The ATMEGA328 manages data acquisition, processing, and transmission tasks. It reads signals from the MQ-3 sensor and GPS module, processes the data, and sends it to the GSM module. The GSM module facilitates communication over the cellular network, enabling data transmission to a remote server. Overall, this circuit forms a smart monitoring system capable of detecting substance use, tracking location coordinates, and transmitting data for real-time monitoring and intervention. This proposed device will play a vital role in detecting substance use among university students. It provides accurate location tracking where alcohol is detected, allowing for immediate alerts to authorities. The integration of GPS ensures precise geographical data, while the GSM module enables swift communication for timely interventions. This combined functionality enhances campus safety by offering real-time information on substance use activities, enabling proactive measures to be taken, and facilitating enforcement actions when necessary.

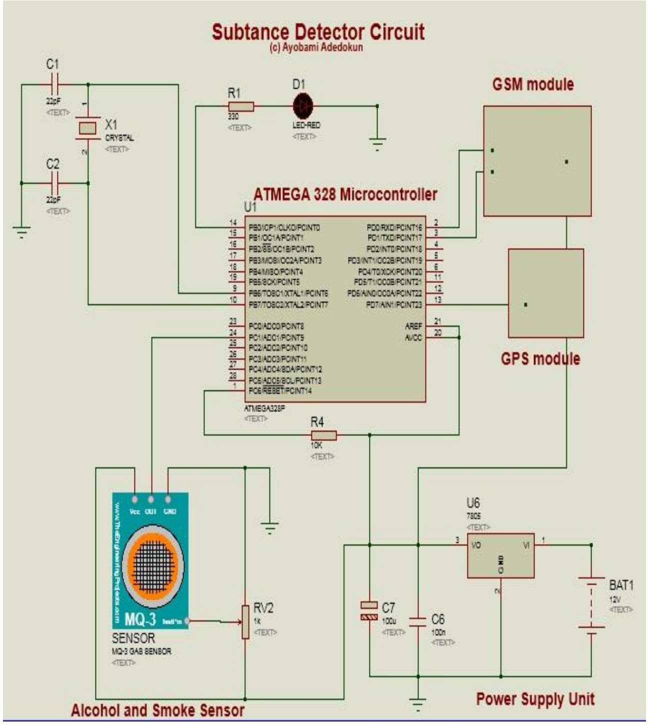

Fig. 7: System Circuit Simulation Diagram

In the proposed smart device, the interconnection of sensors, including the MQ3 sensor for alcohol and smoke detection, the GPS sensor for location tracking, and the SIM800 module for communication, forms a cohesive system for detecting and reporting suspicious activities on university campuses. Firstly, the MQ3 sensor detects the presence of alcohol and smoke, triggering the microcontroller, which processes the sensor data. Simultaneously, the GPS module continually tracks the device's location, providing real-time coordinates. When suspicious activities are identified, the microcontroller activates the SIM800 module, which sends alerts to university law enforcement via SMS or calls, incorporating precise GPS coordinates. This integration enables prompt responses to smoking and drinking activities, enhancing campus safety and security.

IV. RESULTS AND DISCUSSION

Table II illustrates the testing phase of the device concerning the detection of various substances. The sensitivity range spans from 200 parts per million (ppm) to 10,000 ppm, specifically tailored for detecting alcohol and smoking activities. Should the concentration fall outside this calibrated scope, the device may fail to register it. This calibration ensures the device's effectiveness in accurately identifying targeted substances within the specified range, enhancing its reliability for intended applications. Through meticulous calibration, the device strives to maintain precision and efficacy in its detection capabilities, contributing to its overall utility and trustworthiness in practical scenarios.

TABLE II Substances Testing Phase

S/N	PPM	Substances Detected
1	10	No substance detected
2	20	No substance detected
3	50	No substance detected
4	100	Alcohol Detected
5	150	Alcohol Detected
6	200	Smoke Detected
7	250	Smoke and Alcohol Detected
8	300	Smoke and Alcohol Detected
9	350	Smoke and Alcohol Detected
10	400	Smoke and Alcohol Detected

As shown in Fig.8, the complete design and construction of the device are detailed comprehensively. Upon detecting the presence of smoke or alcohol, the device initiates an automatic alert system. This alert system sends a notification containing the exact location and timestamp of the detected activity directly to the authorities. The device is designed to operate discreetly, ensuring that no external alarms are triggered to alert the culprit. This discreet operation allows for swift and covert intervention by the authorities, facilitating immediate action without alarming the individual being monitored. The integration of this advanced alert mechanism enhances the device's effectiveness in monitoring and

Fig. 8: Device Fabrication

V. CONCLUSION

In conclusion, the developed microcontroller-based smart substance detector offers a promising solution for detecting alcohol and smoke presence in university environments. The integration of GPS and GSM modules enables real-time location tracking and immediate communication with authorities upon detection of substance use. The device's discreet operation ensures covert monitoring without alerting the culprits, facilitating swift and effective interventions. This innovative system has the potential to significantly enhance campus safety by providing actionable insights into substance use activities, enabling proactive measures and enforcement actions to be taken.

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