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Review Article

# Automation of Power Windows by CAN-based Integrated Sensing System for Rain and Toxic Gases

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## ABSTRACT

A CAN-based integrated sensing system, which can auto control the car window's opening/closing status by the integrated consideration of rain and toxic gases presence inside the vehicle's cabin, is implemented in this work. The ability of this single system to decide the closing/opening of windows during both rainfall and the presence of a high amount of toxic gases, adds to the smarter automation and cost-effectiveness. Two STM microcontrollers (MCs) are used out of which, one works to sense the rainfall/existence of hazardous gases, and another works to control power windows based on the sensed information by the first MC. The data collected by the sensor MC is sent to the actuator MC through CAN bus protocol. The gas sensor used in this work is MQ9, which mainly measures carbon monoxide (CO) and other flammable gases. A resistive rain sensor is used to detect rainfall.

**Keywords:** Controlled Area Network (CAN); outdoor air quality (OAQ); indoor air quality (IAQ).

## INTRODUCTION

Motor vehicles, which are the prime sources of transportation, emit different air pollutants (such as carbon monoxide (CO), nitrogen oxides, etc.) in the environment by the process of combustion of fuels. Such pollutants are mostly colorless, odorless and toxic. Continual exposure of these gases to humans may lead to different health issues such as dizziness, fatigue, headache, nausea, etc. Moreover, a higher concentration of these pollutants in the air is so toxic that it may cause vomiting, breathing difficulty, loss of consciousness, brain damage, heart irregularity, and even death [1-4]. Thus, it is clear that to avoid any sort of health damage, the proportion of these toxic gases in the air should be detected and controlled to the safety standard defined by the World Health Organization (WHO) [5].

The research dedicated to the detecting and controlling of various toxic gases out of motor vehicles can be performed considering two types of air quality: outdoor air quality (OAQ) and indoor air quality (IAQ). OAQ refers to the open-air standard located outside of the vehicle; whereas IAQ refers to the quality of the air located inside the vehicle. The study of OAQ is very significant, as it gives an overall insight into the measure of air pollution produced by vehicles of a particular region [6-7]. Also, such a study helps to monitor the various proportions of air substances regularly; thus, by using the findings of this research, effective measures can be taken to keep the OAQ safe enough for humans and other living creatures. On the other hand, the study of IAQ is related to the investigation of the air substances contained in the small confined cabin inside a vehicle. Most of the vehicles have very small space and therefore, a low volume of air, inside themselves. Consequently, the chance of rapid contamination of air located inside a car or any type of vehicle, due to the addition of various hazardous gases through either ventilation or windows, is very high. Moreover, since most of these gases are odorless and colorless, a person sitting inside a car cannot physically sense the presence of such gases. This fact may result in a deadly scenario, where, the long-duration inhaling of such toxic gases by that person can cause serious health problems to him or her. Many pieces of research have been performed for detecting such deadly contaminants in the air and thus, maintaining the IAQ up to the safety level to avoid any kind of health risk [8-12].

In today's automotive industry, we can notice that various automation has been implemented in the car or other vehicles to make the driving task safe and comfortable. One example of such advancement is the realization of power windows, which support the automatic closing of the vehicle's window glasses upon the detection of raindrops [13-14]. We may consider a

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realistic case, where the air inside a car is highly contaminated by poisonous gases such as CO; and at the same time, owing to the sensing of raindrops, windows and doors have been closed automatically. Now, if a person stays in such a deadly exposure for a long time, then they may suffer from major health problems due to the intake of CO into their body. Therefore, smarter automation, which can take effective decisions on window closing by the consideration of the collective state of both the cases, toxic gases as well as rain, is required to be implemented under such a scenario.

The Controller Area Network (CAN), introduced by BOSCH in 1986, is one of the most successful network protocol, which is used in almost every passenger cars and other types of vehicles [15]. The wide-versatility of CAN's application domain, excellent reliability, and low cost of CAN-based system implementation are the two attractive features working behind gaining the huge popularity of this network protocol around the globe to date [15]. The use of CAN protocol can also be found in many published works [16-19], where various control architectures have been developed to intelligently control the car doors and windows. Again, the rain-sensing system using CAN for power windows was implemented in [20]. However, this work has not analyzed the combined scenario in which the air inside a car contains toxic gases while it is raining. CO gas leakage detector is based on a gas sensor and a logic detector circuit has been implemented in [21-23]. But, the analysis for sensing of other flammable gases, the significant presence of which can cause explosions, has not been discussed.

In this work, a CAN-based single integrated sensing system for both rain, as well as CO and other flammable gas, was developed using resistive rain sensor and MQ9 gas sensor. As this implemented system integrates the functionality of both, rain and gas sensors, therefore it will be cost-effective to use such a sensor instead of using the individual sensor for individual detection of rain or gases.

## System functionality

Depending on the functionality, the implemented system can broadly be divided into two sub-systems: hardware and software. Further, the hardware part can be split into the power supply section, the CAN communication section, the two controllers (called nodes), and the sensor module.

### Hardware functionality

**Power Supply Section:** The voltage levels required for circuits are 5V and 12V DC source. The 12V DC supply has been used for controlling the motor of the power window, whereas the 5 V DC source was used for driving the other modules such as LED, controller, and buzzers. The voltage level can be reduced to the minimum that is the required levels by using the voltage regulator IC 7805.

**CAN Communication Section:** The CAN frame format is of two types: CAN 2.0A and CAN 2.0B [15]. CAN 2.0A is the base format, which is consisted of an 11-bit identifier; whereas CAN 2.0B, also known as an extended frame of CAN 2.0A, is a 29-bit frame format [15]. In this work, CAN 2.0A was used.

**Nodes:** Two nodes; NODE 1 and NODE 2 are used in this work. For both of the nodes, two STM32F407VG controllers were used. Every data transferred between both of the nodes will be encoded with a unique value which is known as an identifier. When the sensor node (NODE 1) sends data through the CAN bus, the actuator node (NODE 2) receives it and identifies the RX frame. Then, the data received is further processed in the actuator node.

**Sensor module:** Two main sensor modules used in the prototype are the rain and gas sensor. The rain sensor is a resistive grid sensor in which the electrodes are made on the sensor plates. When rainwater falls on such electrodes, a short circuit happens; which helps to indicate the presence of rain. The MQ9 gas sensor, which mainly detects the CO gas, is used as the gas sensor.

Fig.1 presents the system block diagram, in which two STM32F407VG controllers are used. NODE 1 and NODE 2 are used as a sensor and actuator module, respectively.

The reason to create two unique nodes is to create a work environment similar to an actual vehicle. Both the modules communicate with each other through the CAN bus protocol. The CAN communication can be directly established using the terminating diode and resistor circuit (for short-distance communication) or by using the trans-receiver IC (for long-distance communication). Since this work has been accomplished for a short distance, only diodes, and resistors were used for implementing CAN communication. Rain and gas sensors are connected to NODE 1. The analog outputs of both of these sensors are further be applied to an analog-to-digital converter (ADC) for converting them to digital signals and then fed as input to the microcontroller (MC) for continual monitoring. MC checks the outputs obtained from the sensor using the polling technique. The change in the state of the input is sent to the actuator section (NODE 2). The LEDs and motor are connected to NODE 2. The motor is connected to the node through the motor driver IC L293D. The received data is processed in the NODE 2 and then the visual outputs are generated to inform the user.

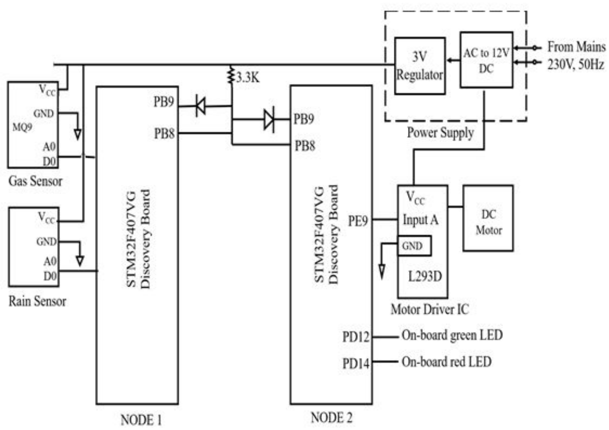
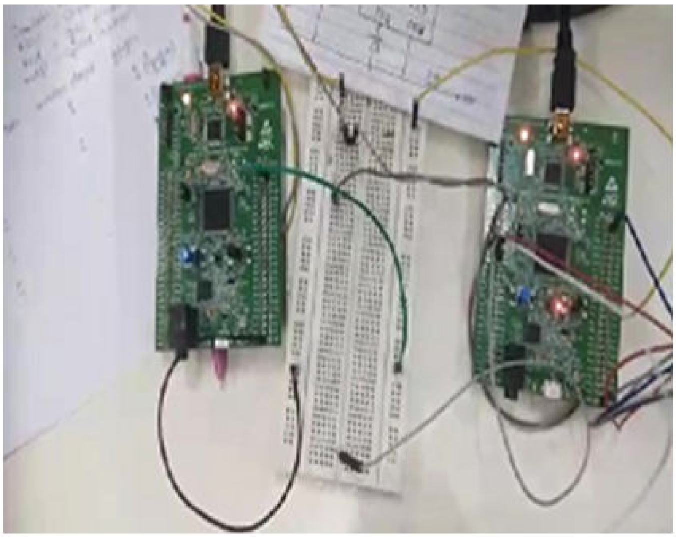



**Figure 1:** System block diagram

The actual implementation of the block diagram (Fig. 1) on the proto circuit is shown in Fig. 2.



## Software functionality

When the vehicle is in ignition on-state, the implemented sensing system will become active; otherwise, it will be turned off. One green and red LED is used in NODE 2 to indicate the status of rain and toxic gases, respectively.

The output of the green and red LED is indicated by G and R, respectively. Two sensors (rain and gas) work independently.

The illumination of LEDs indicates the presence of rain and a high amount of toxic gases. Fig. 3 presents the workflow diagram of the implemented system, which consists of four different scenarios, which are described below:

- (NR + NG): no rain and a low amount of toxic gases
- (NR + G): no rain and a high amount of toxic gases
- (R + NG): rain and a low amount of toxic gases
- (R + G): rain and a high amount of toxic gases.

In the first scenario (NR + NG), rain as well as a high amount of toxic gases will not occur; thus both the LED outputs G and R will be zero. And, consequently, no action (NA) will be performed i.e. window will maintain its previous status. In (NR + G), though rainfall is absent, a high amount of toxic gas is present. Thus, G = 0 and R = 1. Therefore, the system will send a signal to open windows (OW) to improve the IAQ. Next is (R + NG), in which rain is present and the IAQ is good. Thus, the close windows (CW) command will be provided by the system.

In the last scenario (R + G), both rain and a high amount of toxic gas are present. But, the priority of the decision-making basis of windows' closing/opening will be given to the improvement of IAQ.

Thus, despite the presence of rain, windows will be kept open (active window/AW) by the system. The system stops working when the vehicle stops running. The test table of the work is also explained in Table 1.

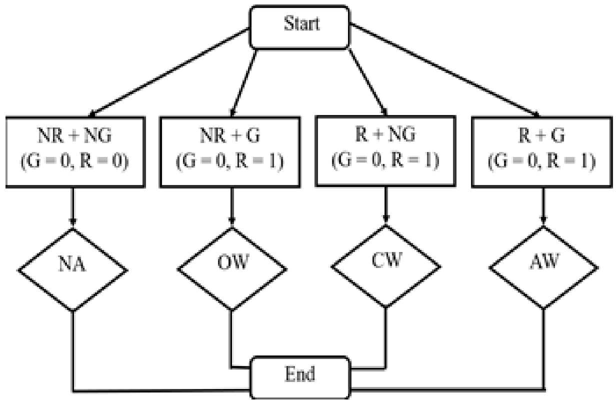



Fig. 3. Workflow diagram

**Table 1:**Test table

| State of sensor | | Action performed |
|---|---|---|
| **Rain** | **Gas** | |
| 0 | 0 | No action (NA) |
| 0 | 1 | Open window (OW) |
| 1 | 0 | Close window (CW) |
| 1 | 1 | Keep window open (AW) |

## CONCLUSION

The implemented system in this work helps to avoid prolonged exposure of a high amount of hazardous gases inside a vehicle by opening windows, even in presence of rain. Since, the proto circuit of the system was implemented using simple components such as STM microcontrollers, MQ9 gas sensor, resistive rain sensor, and CAN communication protocol, it will be cost-effective and easy to design.

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