# Vehicle Gas Leakage Detector.

**A. Che Soh, M.Sc.; M.K. Hassan, M.Eng.; and A.J. Ishak, M.Sc.**

Department of Electrical and Electronic Engineering, Faculty of Engineering, Universiti Putra Malaysia.

E-mail: azura@eng.upm.edu.my

## ABSTRACT

This paper presents the design of a Carbon Monoxide (CO) gas leakage detector in vehicles. The number of sudden death incidents due to excessive CO inhalation has recently increased. Many cases are due to driver habits and awareness, for instance, air conditioning switches remain on while they are sleeping in the car. This habit is not a good practice because if there were gas leakage into the cabin, especially CO, the situation could result in sudden death. Basically the driver feels sleepy when excessive CO concentrations occur in the cabin. Based on that, a vehicle gas leakage detector system has been developed using a gas sensor and logic detector circuit. Subsequently, the signal from the sensor is fed to an 8-bit PIC16F84 microcontroller on-board system via appropriate interfacing devices, which will run on pre-programmed instructions.

(Keywords: gas leakage detector, carbon monoxide, CO, gas sensor circuit, logic detector circuit)

## INTRODUCTION

The main driver behind this research relates to real cases which occurred in recent years in Malaysia. The first case was reported in Johor Bahru, Malaysia [1], where a young couple died due to Carbon Monoxide (CO) inhalation. This case occurred after lethal doses of the gas speeded into the car's inner chamber through its extractor exhaust system, which was found to have been modified. An examination of the bodies showed that there is no sign of trauma.

In a second case involving the hazardous CO gas occurred in Kulai, Johor. This accident involved a family with three children. As reported in the newspaper account [2] the leakage of CO managed to flow through the ventilation system when the engine of the car was left in the running condition for about 3 hours. T

In a third case, a couple also died because they inhaled a large quantity of CO which leaked from the air conditioning unit. The couple slept in the car without stop the engine or shutting off the air conditioning system [3].

In the last case detailed here, a person tried to kill himself by using CO supplied from the car's exhaust using a pipe attached to the exhaust system [4, 5, 6]. These cases represent an illustration that CO gas is poisonous and can represent a serious danger when introduced into a vehicle's cabin.

As reported in [7, 8] all cases mentioned above were due to CO gas leakage in a car cabin. Carbon Monoxide is a colorless, odorless, and tasteless gas that is poisonous and potentially lethal. CO is a by-product of incomplete combustion. It is a product from flammable fuels such as natural gas, propane gas, heating oil, kerosene, coal, charcoal, gasoline, or wood burn with insufficient oxygen. All cases as discussed can be avoided if the gas leakage detector could be installed in the users' car.

CO leakage normally happens due to one of two events. First, the original exhaust system has been altered for a certain reason. Usually, a standard car has a long exhaust system but modified exhaust systems are usually a bit shorter. Due to this, it is believed that the CO manages to seep into the car's inner chamber through its extractor exhaust system more easily compared to a standard exhaust. Second, the air conditioning system in a car operates by filtering air from the outside before it is used. However, it is recommended not to turn on the air condition system while the engine idles or while the car is stall. Car air conditioners may gather CO gas while the engine idles. The possible conditions for gas leakage as discussed above are shown as in Figure 1.

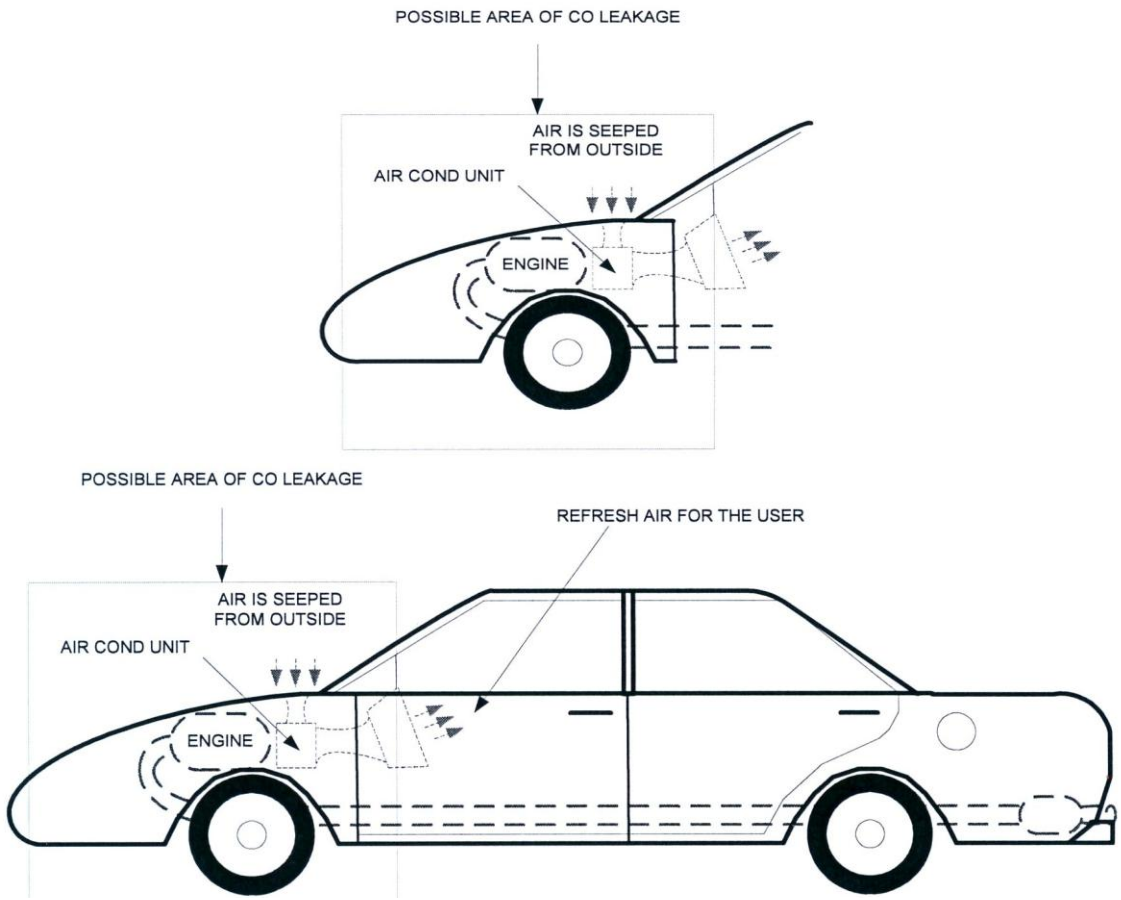


**Figure 1**: The Possible Situation of Leakage Carbon Monoxide Gas in a Car.

The developments of gas detection sensors such as for methane, propane, or any harmful gases in the automotive industry have been very encouraging. Such examples include the monitoring of carbon dioxide ($CO_2$) concentration in cabin. A high-precision spectroscopic gas sensor measuring $CO_2$ for harsh environmental conditions of automotive applications was developed and investigated [9]. Sensors for explosive gas leakage recognition [10] and a compact wireless gas sensor using a carbon nanotube/PMMA thin film chemiresistor were also recently developed [11]. Such examples illustrate the importance of gas detection systems as embedded components in engine management systems for the safety of vehicle operators and cabin passengers.

The application of gas leakage detectors to vehicles is relatively new research which has been applied in the transportation engineering and also automotive engineering fields especially in Malaysia. To authors' knowledge, there have been no applications of gas leakage detectors in vehicles or other transportation. Moreover, the authors believe that this is the first study in Malaysia that introduces a CO gas leakage detector as one of the security system in the vehicles. However, alarm activation, type of alarm, detector location, and gas detector maintenance are not covered in this particular paper.

## MATERIALS AND METHOD

The vehicles gas leakage detector system can be divided into the hardware and software system development. The hardware system development can be divided four parts, which are 1) the gas sensor circuit, 2) microcontroller on-board system, 3) logic detector circuit, and 4) alarm system. The sensor circuit is used to detect the gas leakage in the car. Output from the gas sensor circuit will then interrupt the microcontroller to send a signal to logic detector circuit. The logic detector circuit is used to check whether the presence of the gas leakage in the car and lastly send to alarm system.

Figure 2 shows the block diagram of vehicle gas leakage detector system. The source sample of CO gas is taken from a motorcycle. CO is a by-product of combustion when fuel is burned. Common home appliances, such gas refrigerators, oil furnaces, or gas/wood burning stoves, etc. produced it. Fumes from automobiles and gas powered lawn movers also contain CO gas and the gas can enter inside a house through walls or doorways if an engine is left running in an attached garage. Therefore, to obtain a sample of CO gas, the exhaust produced by a motorcycle engine was used in this study.

The first part of this system is the schematic of the gas sensor circuit (Figure 3). In this system, the NEMOTO semiconductor type of gas sensor NAP-11A is used as the gas sensor in this circuit. This type of sensor (NAP-11A) is able to detect a very low concentration range of CO generated by stoves or other stoking equipment in rooms. NAP-11A is widely used as a detector because of its superb stability against noise gases and ambient temperature and humidity. The other important feature in the choice of the NAP-11A sensor is the sensor's highly sensitive to a low concentration of CO gas. After the gas sensor circuit has been successfully implemented, the output signal has been fed to microcontroller on-board system [12].

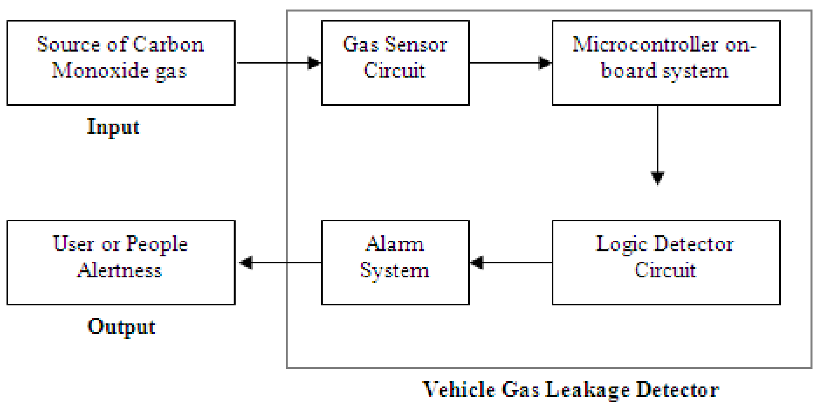


**Figure 2:** Block diagram of vehicle gas leakage detector system.

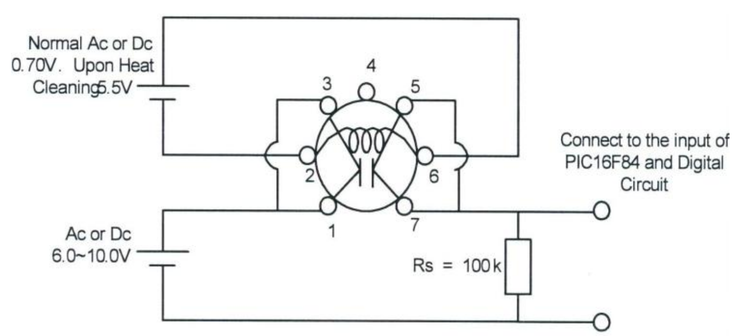


**Figure 3:** Schematic of gas sensor circuit

The heart of the system is an 8-bit microcontroller of PIC16F84, which will run on pre-programmed instructions. The microcontroller (PIC16F84) has 18 pin terminals. In this hardware design, the new version of this family microcontroller is used, PIC16F84A. These pins can divide into PORTA (5 bits) and PORTB (8 bits). The design of this microcontroller is quite the same as PIC16F84.

The AC/DC adapter provides the power supply to microcontroller on-board system. To obtain stable a voltage, IC voltage regulator (7805CT) provides the voltage regulation on-board component. Diode is used as reverse polarity protection when the power system is supplied to the microcontroller on-board system with incorrect polarity [13, 14, 15].

The PIC16F84 microcontroller must be programmed to detect gas leakage and interrupt the system automatically. Then a detector signal will be sent to logic detector circuit; the output signal from logic detector circuit sends to the alarm system. The microcontroller PIC16F84 on-board system is an interface part between the gas sensor circuit and logic detection circuit, before the alarm system is activated.

The heart of the system is an 8-bit microcontroller of PIC16F84, which will run on pre-programmed instructions. The microcontroller (PIC16F84) has 18 pin terminals. In this hardware design, the new version of this family microcontroller is used, PIC16F84A. These pins can divide into PORTA (5 bits) and PORTB (8 bits). The design of this microcontroller is quite the same as PIC16F84.

The AC/DC adapter provides the power supply to microcontroller on-board system. To obtain stable a voltage, IC voltage regulator (7805CT) provides the voltage regulation on-board component. Diode is used as reverse polarity protection when the power system is supplied to the microcontroller on-board system with incorrect polarity [13, 14, 15].

The PIC16F84 microcontroller must be programmed to detect gas leakage and interrupt the system automatically. Then a detector signal will be sent to logic detector circuit; the output signal from logic detector circuit sends to the alarm system. The microcontroller PIC16F84 on-board system is an interface part between the gas sensor circuit and logic detection circuit, before the alarm system is activated.

The logic detector circuit consists of two units NOT logic gate. NOT gate is chosen because it has a single input, and its output logic level is opposite to the logic level of this input. This NOT gate is more commonly called an inverter. The output from the gas sensor circuit is also connected to the logic detector circuit. Any detected signal will allow the logic detector circuit to operate and vice versa. Figure 4 shows the schematic of the logic detector circuit, which consists of two units of NOT gate used in series order and the output of the logic detector circuit is then connector to the alarm system.

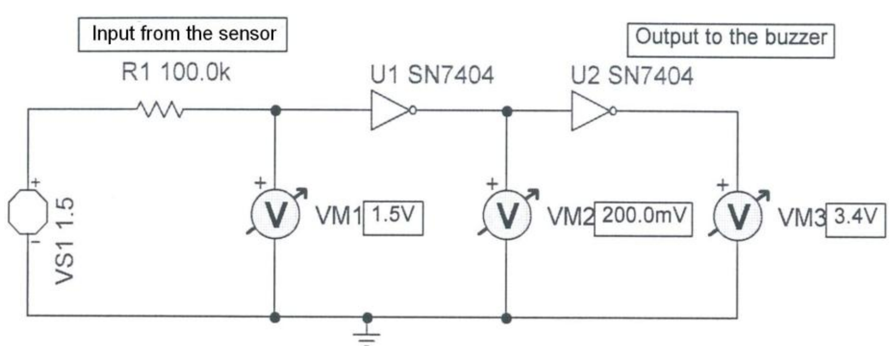


**Figure 4:** Schematic of Logic Detector Circuit.

In this vehicle leakage detector system, the alarm system contains two units of buzzer and two units of LED display (green and red). A buzzer is a device that produces a high frequency sound. Therefore, the buzzer can catch the attention of the user if the sensor is detecting any leakage of CO gas. The buzzer's terminal is connected through PIC16F84 at port B2. The other buzzer is connected directly to the logic detector circuit.

The green LED only operates at normal condition to show no indication of any CO gas present. Any signal of detection, the red LED lights and the buzzer operates, both working simultaneously. A direct current of range 1.5V to 12.0V can be used as voltage supply to ensure smooth operation. As the voltage increases, the sound magnitude of the buzzer becomes much louder. The buzzer connected to the logic detector circuit only operates when signal is transferred from the sensor circuit. Whereas, as the signal is transferred, the buzzer connected with the detector circuit will immediately operate. The buzzer is in an off state when no signal is transferred.

From the discussion above, the complete circuit of the vehicle sensor leakage system is shown in Figure 5. The hardware development is easy to implement and inexpensive. The hardware system cannot work without software development. The software development designs a program for the system to detect automatically and give alertness if the gas leakage in the car.

The software for this project is written in C language and developed using MPLab v6.30 to convert to machine code before downloaded to PIC16F84A using 1C Program 1.05A software application. The program is designed to interrupt PIC16F84 when the input port A will equal to zero, there is no CO gas is detected and no change of voltage from gas sensor circuit. The output signal is used to indicate any presence of Carbon Monoxide gas in the cabin. At this state, the green LED operates smoothly, while the red LED and buzzer are in the OFF condition.

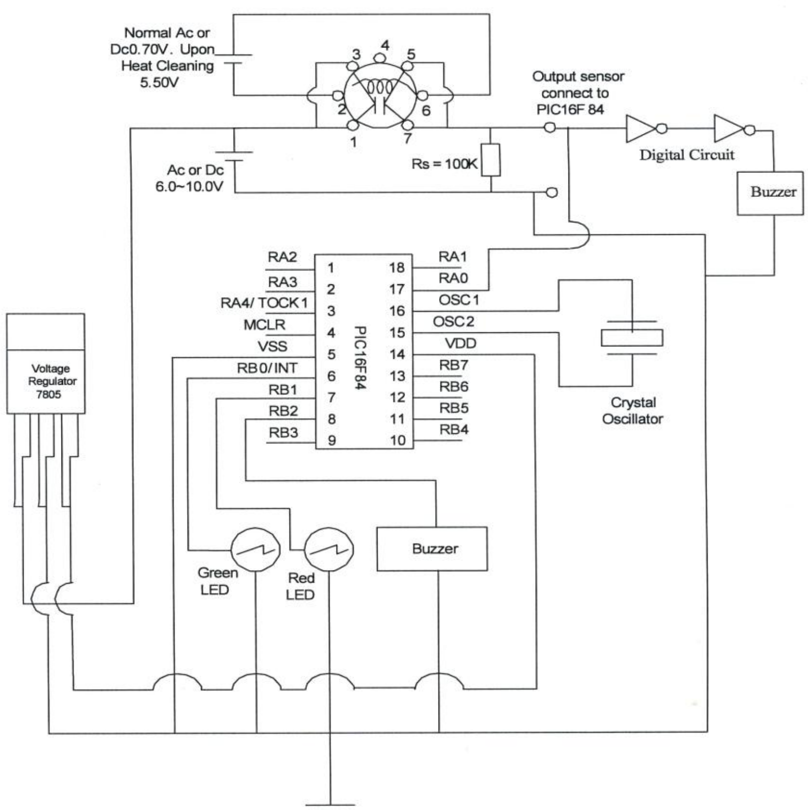


**Figure 5**: Schematic of Vehicle Gas Leakage System.

**Table 1:** Logic Digital Value Representation the Sate of Alarm System.

| Input Pin | Output Pin |
|---|---|
| '0' | - No voltage changes in the gas sensor circuit. No signal is transferred.<br>- Green LED lights on.<br>- Red LED lights off.<br>- Buzzer is at off state. |
| '1' | - A voltage changes occurs. Signal is transferred.<br>- Green LED lights off<br>- Red LED is on<br>- Buzzer operates |

In another situation, if the gas sensor circuit detects the CO gas leakage in the car, the voltage change will be used as the signal input for the PIC16F84A. At this state, the voltage changes will equal to magnitude of '1'. In the situation there is no signal, the magnitude is equal to '0' and lights on the green LED [16]. Table 1 shows the value of digital value representation the state of alarm system.

## RESULTS AND DISCUSSIONS

Using TINA software, the DC analysis of the logic detector circuit has been designed and shown in Figure 6. This analysis has been done to indicate that any signal transferred from the gas sensor circuit, will trigger logic detector and hence will turn on the buzzer. The voltage required for logic detector circuit to operate at 1.5V. In case of transition from presence of Carbon Monoxide gas to normal operation, the analysis has been done and shown in Figure 7. This stage, the voltage required for logic detector operates is 1.2V and this voltage is known as voltage critical.

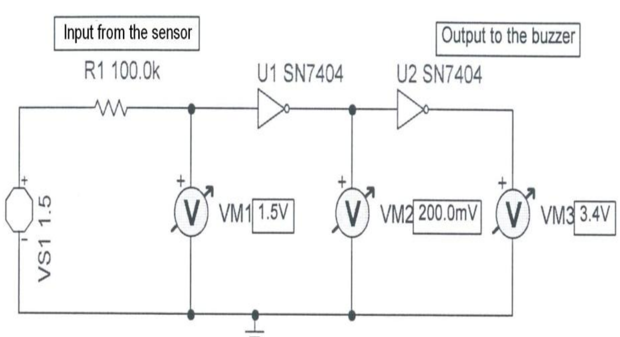


**Figure 6:** Schematic of Logic Detector Circuit Analysis for 1.5V using TINA.

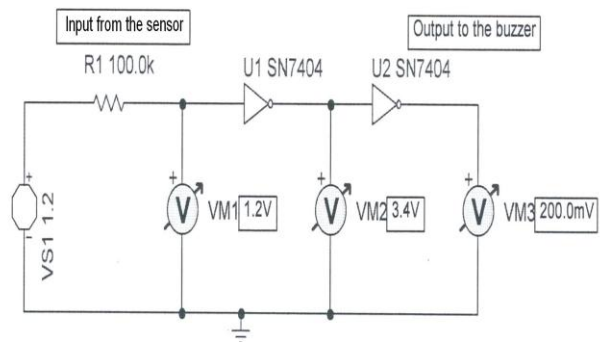


**Figure 7:** Schematic of Logic Detector Circuit Analysis for 1.2V using TINA.

The microcontroller on-board system can be represented by the combinational logic as shown in Figure 8 and the output of system can be seen in Figure 9. From the waveform in Figure 8, when the input from the sensor and voltage regulator is high, the red LED and the buzzers will operate. In another case, when the input from sensor and voltage regulator is low, only the green LED will be on. This combinational logic in Figure 8 is made accordingly to the programming in the PIC16F84A.

To test the functionality of the software application, written program downloaded in PIC16F84A is performed and the expected simulation result as shown in Figure 10.

The source of the CO gas is used in this project are fumes from the exhaust of a motorcycle. During the normal operation, the readings of various part of the circuit can be seen as shown in Table 2.

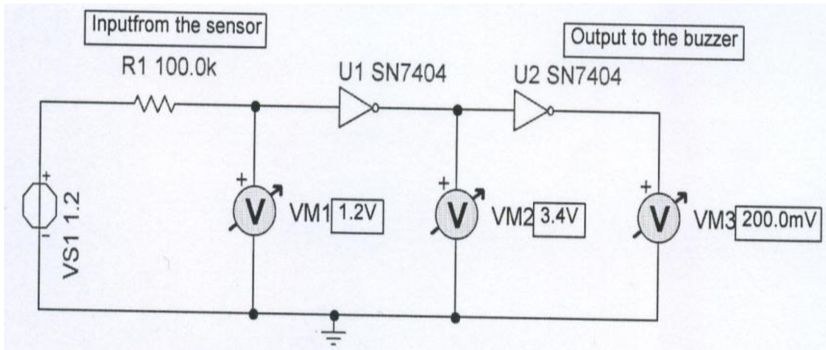


**Figure 8:** Schematic of Logic Detector Circuit Analysis for 1.2V using TINA.

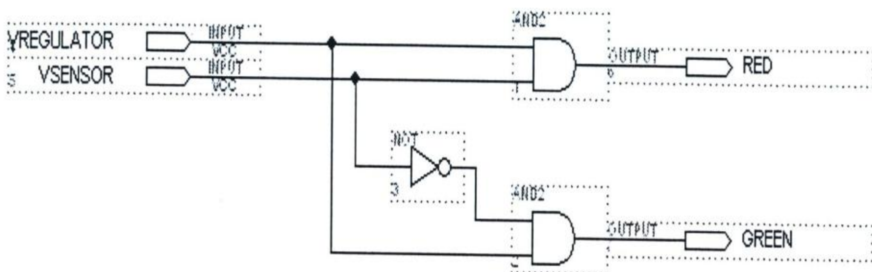


**Figure 9:** Combinational Logic Circuit for Microcontroller On-Board System.

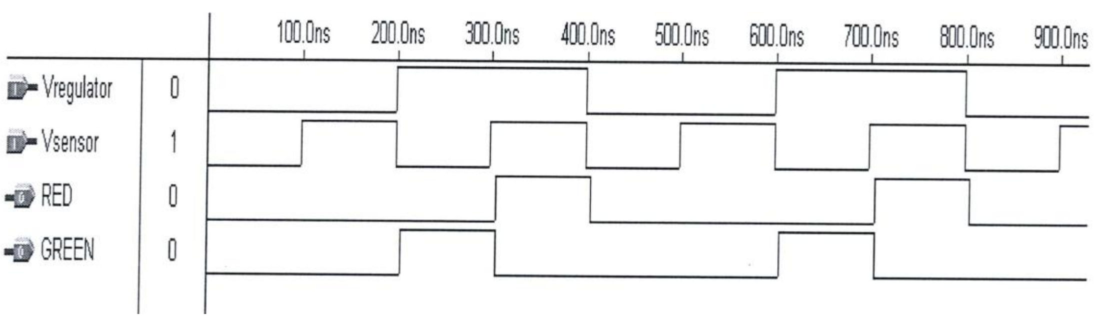


**Figure 10:** Output Waveform of Microcontroller On-Board System.

IN the presence of CO, gas sensor NAP-11A will sense the gas and send the signal to microcontroller. At critical voltage of 1.2V, green LED will immediately turns off and the red LED with the buzzer will operate simultaneously. The buzzer from the logic detector circuit will also operate as well. Voltage across resistor(as output) will increase from initial value 0.02V to approach the value of critical voltage and then finally remains constant at 5.10V for duration of approximately of 1 minute. Both devices (red LED and buzzer) operate continuously. The readings of various part of the circuit can be seen as shown in Table 3.

The process to clean up CO gas in the sensor is done during the heat cleaning operation. At this reset state, the value of the voltage at the gas sensor circuit from 0.07V will be varied to 5.50V for duration of approximately of 1 minute.

**Table 2:** Normal Operation.

| **During Normal Operation** (Voltage Supply=6.0V) | |
|---|---|
| **Descriptions** | **Voltage(V)** |
| **PIC16F84A**<br>Voltage at input of PIC16F84A | 4.95V |
| **Sensor Circuit**<br>Voltage at Sensor of common terminal base of 1 and 3 | 6.0V |
| Voltage at Sensor of common terminal base of 5 and 7 | 0.02V~<br>(Approximate at 0V) |
| Voltage at Sensor of terminal base of 2<br>Voltage at Sensor of terminal base of 6<br>Voltage across the 100KΩ | Negative Terminal<br>0.07V<br>0.02V~<br>(Approximate at 0V) |
| **Alarm System**<br>Voltage across green LED<br>Voltage across red LED<br>Voltage across Buzzer | 2.21V<br>0.00V<br>0.00V |

**Table 3:** Presence of Carbon Monoxide Gas.

| **During Presence of Carbon Monoxide Gas** (Voltage Supply=6.0V) | |
|---|---|
| **Descriptions** | **Voltage(V)** |
| **PIC16F84A**<br>Voltage at input of PIC16F84A | 4.30V |
| **Sensor Circuit**<br>Voltage at Sensor of common terminal base of 1 and 3 | 6.00V |
| Voltage at Sensor of common terminal base of 5 and 7 | 0.02V<br>Increase gradually up to maximum and constant value of 5.10V, duration of 1 minute. |
| Voltage at Sensor of terminal base of 2<br>Voltage at Sensor of terminal base of 6<br>Voltage across the 100KΩ | Negative Terminal<br>0.07V<br>0.02V<br>Increase gradually up to maximum and constant value of 5.10V, duration of 1 minute. |
| Voltage Critical | 1.20V |
| **Alarm System**<br>Voltage across green LED<br>Voltage across red LED<br>Voltage across Buzzer<br>**Voltage Critical**<br>Voltage across green LED<br>Voltage across red LED<br>Voltage across Buzzer | 0.00V<br>2.62V<br>4.22V<br>0.05V<br>1.50V<br>3.45V |

**Table 4:** Heat Cleaning Process.

| **During Heat Cleaning Process** (Voltage Supply=6.0V) | |
|---|---|
| **Descriptions** | **Voltage(V)** |
| **PIC16F84A:** Voltage at input of PIC16F84A | 4.30V |
| **Sensor Circuit**<br>Voltage at Sensor of common terminal base of 1 and 3 | <br>6.00V |
| Voltage at Sensor of common terminal base of 5 and 7 | 0.02V~ (approximate at 0V) |
| Voltage at Sensor of terminal base of 2<br>Voltage at Sensor of terminal base of 6<br>Voltage across the 100KΩ | Negative Terminal<br>5.50V<br>Voltage of 5.10V decrease gradually and slowly to 0.02~ approaches 0V, duration of 1 minute. |
| Voltage Critical | 1.20V |
| **Alarm System**<br>Voltage across green LED<br>Voltage across red LED<br>Voltage across Buzzer<br>**Voltage Critical**<br>Voltage across green LED<br>Voltage across red LED<br>Voltage across Buzzer | <br>0.00V<br>2.62V<br>4.22V<br><br>0.85V<br>0.09V<br>0.08V |

The red LED and buzzers (from microcontroller and logic detector circuit) still operate continuously. Then, the voltage of 5.50V will vary back again to 0.07V approximation after 1 minute. Whenever this happen, there will be a voltage drop across the 100KΩ resistor. Voltage 5.10V will decrease gradually to final value 0.02~approximately at 0.0V. At critical voltage of 1.20V, the red LED will off and buzzers will stop. The green LED turns on. At this state, the gas sensor circuit is completely under normal operation again and ready to sense CO gas. The readings of various part of the circuit can be seen as shown in Table 4.

## CONCLUSION

The implementation of a vehicle gas leakage detector corresponds to increased cases of death caused by gas leakage in cars. These devastating events could be avoided if CO detection systems were installed. Therefore, the main idea of this research is to create a simple and easy system that has high sensitivity and can sense the presence of CO gas in a vehicle's cabin. From the experimental results, the system described here is working as expected with simulated and implemented data on record.

The system has then been interfaced to the microcontroller on-board system. The microcontroller has been programmed to send a signal to the logic detector circuit then to the alarm system. The development of software was then tested to ensure it worked properly with the hardware. The communication test between hardware and software was successful. The hardware responded correctly to the command sent to it. This result shows that, the system has been implemented and tested successfully. This system has been designed to produce greater flexibility, ease of implementation and lower cost because the system PIC16F84A microcontroller which is a Flash based microcontroller can be programmed and erased several times.

## REFERENCES


1. New Straits Times. 2008. "Couple Died Due to Carbon Monoxide Gas". 2/1/2000 .Retrieved August 1, 2008 from http://www.nst.com.my

2. Arkib. 2000 (Sept 10). "Izzayu meninggal selepas tiga hari tidak sedarkan diri". Utusan Malaysia

(Malay Language). Retrieved August1, 2008. http://www.utusan.com.my.

3. Sinyang, A. 2007. “Pegawai polis, wanita ditemui mati dalam BMW”. Utusan Malaysia (Malay Language). Retrieved August 1, 2008. http://www.utusan.com.my

4. Arkib. 2008 (April 1). “Demi cinta, pasangan mati bersama”. Utusan Malaysia (Malay Language). Retrieved August 1, 2008. http://www.utusan.com.my

5. Arkib. 2007 (Jun 30). “Lelaki mati dijumpai dalam kereta”. Utusan Malaysia (Malay Language). Retrieved August 1, 2008. http://www.utusan.com.my

6. Arkib. 2007 (April 30). “Disyaki Kecil Hati Ibu Tidak Masak: Peniaga Mati Hidu Gas”. Utusan Malaysia (Malay Language). Retrieved August 1, 2008. http://www.utusan.com.my

7. Arkib. 2000 (Sept 8). “Pendingin kereta boleh sebabkan kematian”. Utusan Malaysia (Malay Language). Retrieved August 20, 2008. http://www.utusan.com.my

8. Arkib. 2000 (Sept 9). “Perodua diminta periksa Kancil-Ekoran kematian tiga beradik dipercayai terhidu karbon monoksida”. Utusan Malaysia (Malay Language). Retrieved August 20, 2008. http://www.utusan.com.my

9. Robert, F. and Thomas, T. 2006. “A High-Precision NDIR CO2 Gas Sensor for Automotive Applications”. *IEEE Sensors*. 6(6):1697-1705.

10. Dae-Sik, L., Duk-Dong, L., Sang-Woo, B., Minho, L., and Youn, T.K. 2002. “$SnO_2$ Gas Sensing Array for Combustible and Explosive Gas Leakage Recognition”. *IEEE Sensors*. 2(3): 140 -149.

11. Jose, K.A., Biju, P., Ashwin, W., Vijay, K.V. and Channa, R. 2004. “A Compact Wireless Gas Sensor using a Carbon Nanotube/PMMA Thin Film Chemiresistor”. *Ins of Physics Publishing, Smart Materials and Structures*. 13:1045–1049 PII: S0964-1726(04)82882-9.

12. NEMOTO CO. 1996. *Gas Sensor, User’s Manual*. NEMOTO & CO.LTD.

13. Azura, C.S, Samsul Bahari, M.N., Rahman, W., Nasri, S., and Roslina, M.S. 2002. “Traffic Light Fault Detection System”. *Proc of World Engineering Congress 2002*. Kuching Sarawak, Malaysia.

14. Azura, C.S, Samsul Bahari, M.N., Rahman, W., Nasri, S., and Roslina, M.S. 2002. “Failure Monitoring System of a Traffic Light”. *Proc of World Engineering Congress 2002*. Kuching Sarawak, Malaysia.

15. Azura, C.S. and Samsul Bahari, M.N., 2004. “Automatic Fault Detection System for Traffic Light”. *Engineering Transactions*. Mahanakorn University of Technology, Thailand. 7(2):17:90-100.

16. Tocci and Widmer. 1998. *Digital System, Principles and Application. 7th Edition*. Prentice Hall: Englewood, NJ.

## ABOUT THE AUTHORS

**A. Che Soh** received her B.Eng. degree in Electronic/Computer and her M.Sc. degree in Electrical and Electronics Engineering from the Universiti Putra Malaysia (UPM), Malaysia in 1998 and 2002, respectively. Her research interest includes artificial intelligence, process control, control systems, robotics, and automation. Presently she is a Lecturer at Universiti Putra Malaysia (UPM), Malaysia. She is currently pursuing her Ph.D. degree in intelligent urban traffic light controls at Universiti Teknologi Malaysia (UTM), Malaysia.

**M.K. Hassan** graduated from the University of Portsmouth, UK in Electrical and Electronic Engineering in 1998. He received his M.Eng. Electrical in 2001 from University of Technology Malaysia, Malaysia in 2001. Currently, he is a Senior Lecturer in the Department of Electrical and Electronic Engineering at the Universiti Putra Malaysia and working on his Ph.D. in automotive control, specifically in engine management system. His areas of interest include; natural gas combustion, renewal energy, automotive electronics and engine calibration, model based calibration and control system.

**A.J. Ishak** obtained her Bachelors degree in Electrical-Mechatronic Engineering from the University Technology Malaysia and her M.Sc. in Control Automation System Engineering from the University Putra Malaysia. She is a tutor with the Department of Electrical & Electronic Engineering University Putra Malaysia. Currently, she is a Ph.D. student with the Vision & Robotics Research Group (VIROB), Department of Electrical, Electronics & System Engineering, Universiti Kebangsaan Malaysia. Her current research interests are machine vision systems, pattern recognition, and computational intelligence.

**SUGGESTED CITATION**

Soh, A.C., M.K. Hassan, and A.J. Ishak. 2010. "Vehicle Gas Leakage Detector". *Pacific Journal of Science and Technology*. 11(2):66-76.

[Pacific Journal of Science and Technology]