

A Device to Remove High Levels of Carbon Monoxide

Jen-Yu Shieh, Bai-Hao Chang, Yu-Ting Liu, Guo-Jyun Liao

Department of Electro-Optics Engineering, National Formosa University, Yunlin County, 632, Taiwan

Abstract — This paper adopted a Holtek HT66F50, featured with Flash Memory A/D type 8-bit microcontroller (MCU), and connected with a MQ7 gas sensor and ventilation fans on the ceiling to input the level of carbon monoxide (CO) into the MCU for calculating. As the level of CO in the air reaches 100 ppm, the fans will be activated to exhaust CO out to the space; besides, if the level of CO in the air is over 200 ppm, the buzzer will sound indicating “Alarm”. Carbon monoxide detectors on the market can only buzz during alarm and chirp if a trouble is found, and the prices are high; thus, the study focused on designing a low-cost and multi-functional carbon monoxide detector.

Index Term— carbon dioxide detector, emergency lighting, microcontroller, uninterruptable power supply (UPS)

I. INTRODUCTION

With GDP growth, people’s living conditions have been improved. They also put emphasis on having a sound body; therefore, developing new products for disease prevention and disaster prevention has been the main goal, such as fire alarms, fire sprinklers, and carbon monoxide detectors. However, people normally neglect those invisible, untouchable, and unheard things. Carbon monoxide poisoning frequently happened in cold weather since the incomplete combustion of gaseous fuel in a confined space which can produce carbon monoxide (CO); if a person inhales CO unconsciously, s/he may feel dizziness; if inhales too much, s/he may even die.

The detector is far different from those on the market due to its uninterruptable power system (UPS) which can continuously run the device during power failure and provide an emergency lighting and be a USB charger. Nowadays, people have relied on 3C products; therefore, the detector has become practical, especially during power failure. The most important feature is that it can monitor the level of carbon dioxide indoor and prevent people from suffering carbon dioxide poisoning.

A. Purposes of the Study

The current carbon monoxide detectors found on the market only emit a warning alarm to alert that level of CO is too high but unable to make improvement under such condition. As the majority of detectors are plug-in or battery operated types, they would lose their effectiveness in the event of power failure or dead batteries, and so likely to cause unexpected tragedies. Therefore, the purpose of the study is to propose a carbon monoxide detector built in with a UPS that is capable of functioning properly even if power is shut off. It is also very practical to use during power outrages for being able to provide emergency lighting and has a USB charger to charge mobile phones or other 3C products. Unlike standard features found in conventional products, it will turn on the ventilation fans automatically to draw CO away from the space when the level of CO reaches 100 ppm, and sound a warning alarm when the level of CO continues to rise and reaches up to 200 ppm.

B. Literature Review

The quality of most carbon monoxide detectors found on the market today is mature and stable. Recalling the early ancestor of measuring carbon monoxide, it can be retrieved to the earliest 1913 when Franklin Institute conducted an experiment to detect carbon monoxide content in the air [1,2].

The development has become more mature after 1990, and in 1996, the first carbon monoxide detector released was able to sound a warning alarm to alert that the level of CO in the environment was harmful to human beings [3]. It has become a role model of carbon monoxide detector. Nowadays, many methods and applications have been used to detect CO, such as the use of infrared fiber optic sensor to detect CO [4], the use of rapid spectrophotometry to detect CO in the air [5], the use of pyrotannic acid method to detect CO in the bloodstream, the use in emergency rooms to take care of patients [6–8], the use to detect CO and carbon dioxide (CO2) simultaneously [9], and the use of multi-mode absorption spectroscopy to measure the emissions of engines [10].

Being capable of measuring in the air [11], carbon monoxide also comes in many other applications, such as measuring the level of CO exhaled from the human mouths to simulate CO2 in the environment [12], using an osmotic device to measure the average level of CO in the atmosphere [13], providing early warning of fire by detecting CO [14], and detecting chemical fires [15].

As the current carbon monoxide detectors found on the market only emit a warning alarm but unable to remove high levels of CO; thus, the researcher compared the advantages and disadvantages of the current carbon monoxide detectors shown in Table 1.4, discussed the issues of power supply, and provided solutions when the level of CO increases.
CO is a colorless, odorless and an inorganic compound gas that is highly toxic. It is also known as a silent killer [16], being slightly lighter than air and constituted only a small amount in the atmosphere. Even the metabolism of animals will also generate a small amount of carbon monoxide [17]. Carbon monoxide poisoning is governed under the U.S. National Fire Protection Association (NFPA) specifications [18]. In this study, the warning value settings were made in accordance with Table II.1[19].

### Table I

<table>
<thead>
<tr>
<th>Model</th>
<th>Power Supply</th>
<th>Digital Display</th>
<th>Extra Functions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kidde KN-LCB-A</td>
<td>Plug-in (a backup battery)</td>
<td>N</td>
<td>N</td>
</tr>
<tr>
<td>Kidde COPP-B</td>
<td>Battery-powered</td>
<td>Y</td>
<td>N</td>
</tr>
<tr>
<td>MK350</td>
<td>Plug-in</td>
<td>N</td>
<td>N</td>
</tr>
<tr>
<td>The study (UPS)</td>
<td>Plug-in</td>
<td>-Emergency lighting -Lowering levels of CO - USB charger</td>
<td></td>
</tr>
</tbody>
</table>

### II. RELEVANT PRINCIPLES

#### A. Carbon Monoxide

CO is a colorless, odorless and an inorganic compound gas that is highly toxic. It is also known as a silent killer [16], being slightly lighter than air and constituted only a small amount in the atmosphere. Even the metabolism of animals will also generate a small amount of carbon monoxide [17].

Carbon monoxide poisoning is governed under the U.S. National Fire Protection Association (NFPA) specifications [18]. In this study, the warning value settings were made in accordance with Table II.1[19].

### Table II

<table>
<thead>
<tr>
<th>CO Level (ppm)</th>
<th>Condition and Health Effects</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td>Slight headache in 6-8 hours</td>
</tr>
<tr>
<td>200</td>
<td>Slight headache after 2-3 hours of exposure</td>
</tr>
<tr>
<td>400</td>
<td>Headache and nausea after 1-2 hours of exposure / Life threatening in 3 hours</td>
</tr>
<tr>
<td>800</td>
<td>Headache, nausea, and cramp after 45 minutes of exposure</td>
</tr>
<tr>
<td>1600</td>
<td>Headache and dizziness after 20 minutes of exposure / Death within 2 hours</td>
</tr>
<tr>
<td>3200</td>
<td>Headache and nausea after 5-10 minutes of exposure / Death within 30 minutes</td>
</tr>
<tr>
<td>6400</td>
<td>Dizziness after 1-2 minutes of exposure / Death within 10-15 minutes</td>
</tr>
<tr>
<td>12800</td>
<td>Death within 1-3 minutes</td>
</tr>
</tbody>
</table>

#### B. The Infrared Measuring Method

The level of CO can be detected through the use of absorption characteristic of carbon monoxide. If the light source comes in the non-dispersion infrared version, it is called the non-dispersion infrared method. If the light source illuminating path is installed with a gas filter assembly, it is known as the gas filter correlation infrared method.

![Infrared Absorption Spectrum of CO and CO2](image)

#### C. The Gas Detector Measuring Method

It is a method that converts the level of CO in the air into electrical signal (voltage, current, resistance) to ease monitoring purpose. Among the common types are:

1. **Semiconductor gas detectors**
   - It is mainly composed of N-type semiconductor of SnO2 and a heater, featuring rapid heat conduction and gas explosion prevention effects. If it is generally heated up to 200 ~ 300 °C, it will cause the resistance of semiconductor to increase after absorbing CO in the air. The value of the level of CO can then be extracted from the output voltage.
2. **Electrochemical gas detectors**
   - The electrochemical activity existed in some flammable and toxic gases can be electrochemically reduced or oxidized; thus, identifying the gas components and detecting the gas concentrations can be distinguished by the reactions.
3. **Catalytic combustion type gas detectors**
   - It involves burning electric wire in gas to generate heat, allowing its resistance value to change and then obtaining the gas concentration. However, this type of the detector is not sensitive in non-combustion gases.

#### D. Uninterruptible Power Supply

Also known as a UPS, it works as a backup power source to provide a constant circuit under the abnormal electrical power supply to maintain the normal operation of electrical appliances [20].

Early in the era before batteries were being used, flywheels and internal combustion engines were once being employed by a UPS to provide electrical power. The UPS was called a flywheel UPS or a rotary UPS. As the use of internal combustion engine to provide power [21,22] has a large body size and would generate loud noise, so it is currently being used in emergency cases and some harsh natural occasions.
Now, the battery backup consists of batteries, a control circuit and an AC/DC converter. On the normal power supplying, a UPS will charge itself and supply electricity from the stored batteries in the event of power anomalies. According to working principles, it can be classified into on-line, off-line, and line-interactive types [23].

E. Performance Comparison of Different Types of UPSs

Off-line UPS system was adopted in the study due to its low cost and high efficiency. Although there is a transition time during power conversion, but it will not cause serious problems.

<table>
<thead>
<tr>
<th>TABLE III</th>
<th>COMPARISON OF UPS FUNCTIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>On-line</td>
</tr>
<tr>
<td>Battery Protection</td>
<td>Excellent</td>
</tr>
<tr>
<td>Transition Time</td>
<td>Excellent</td>
</tr>
<tr>
<td>Efficiency</td>
<td>Low</td>
</tr>
<tr>
<td>Cost</td>
<td>High</td>
</tr>
</tbody>
</table>

III. THE STRUCTURE OF THE DEVICE

The device is a system consisting of a carbon dioxide detector, ventilation fans, a buzzer, a LED light strip, and a UPS installed on the ceiling. Fig. 3 and Fig. 4 are the experimental simulation designs comprising of three 3×3 cm ventilation fans, a 2×10 cm LED light strip, a USB charging port and a 32,000 mAh UPS battery. For simple installation, the device can be directly embedded on the ceiling which is different from other products that need to do DIY work.

IV. EXPERIMENTAL MEASUREMENTS

A. Restart Efficiency

The MQ-7 detector was turned off 30 minutes, 1 hour, 6 hours, 1 day and 3 days, respectively and then re-started. From Fig. 5, it is evident that the MQ-7 detector needs to take a certain of preheat time to warm up before it can get correct values steadily. The longer the power outage is, the longer the preheat time needs. Thus, the detector does not work well as a portable product as it needs to be supplied with power constantly before it can measure the level of CO steadily.

B. Levels of CO Measurements

(1) Confined space measurements:

The MQ-7 detector and a conventional carbon monoxide detector were placed in a 20x20x20 cm confined container to carry out measurements, as shown in Fig. 6. Incenses were initially burnt for 20 seconds to fill the container with CO, and the average values of the levels of CO were noted to be compared, shown in Fig. 7.
(2) Measurements at one-meter range
The MQ-7 detector was measured one meter away from the combustion point as shown in Fig. 8. With the incenses burning, the levels of CO were noted at every 10-minute till they were extinguished after one hour, followed by noted the levels of CO continuously after extinguishing the incenses, shown in Fig. 9.

(3) Measurements at three-meter range
The MQ-7 detector was measured three meters away from the combustion point as shown in Fig. 10. With the incenses burning, the levels of CO were noted at every 10-minute till they were extinguished after one hour, followed by noted the levels of CO continuously after extinguishing the incenses, shown in Fig. 11.

C. The Experimental Measuring System of CO
The MQ-7 detector was placed in a 20x20x20 cm confined container to perform measurements as shown in Fig. 12. Incenses were initially burnt for 20 seconds to fill the container with CO, and the levels of CO were noted. When the level reached to 100 ppm, the ventilation fans would switch on to draw CO out. Fig. 13 is a data comparison chart showing the general carbon monoxide detector and the simulated effect done by the study.
D. Analysis of the Experiment

The result of the experiment shows that the level of CO is very high at the very beginning, and it needs a certain time to preheat and to be stable. It usually takes about two to three hours to obtain the right data. If it is not used for a long time, it is suggested to power up for over one day. Thus, the system proposed by the study will not be suitable to produce as a portable product.

Those CO detectors on the markets can measure the levels of CO immediately; however, the sensor MQ-7 adopted by the study needs a certain time to preheat in order to run the function perfectly. This is the only weakness, but if it starts to run with UPS, there is no need to worry about power off and the preheat time.

V. CONCLUSION

The CO detector proposed by the study can measure levels of CO between 20 to 2000 ppm. Generally, levels of CO between 100 to 400 pm may be harmful to human beings. Thus, the levels of CO between 100 to 200 ppm set up by the researcher would be reasonable. Besides, promptly turning on ventilation fans and a buzzer would play a crucial role, especially in a confined space. If the system could be installed onto the ceiling, it would save space, reduce levels of CO automatically, and provide emergency lighting and USB charger, which is far difference from those CO detectors on the market.

REFERENCES


Authors’Information

Jen-Yu Shieh received the B.S. degree in electrical engineering from Feng-Chia University, Taichung, Taiwan, in 1984 and the M.E. degree in computer engineering and Ph.D. degree in electrical engineering from Florida Atlantic University, Boca Raton, in 1989 and 1992, respectively. While completing graduate degrees at FAU, he was an associate professor of Department of Electro-Optics Engineering at National Formosa University, Huwei, Taiwan. Since February 2010, he has been an professor. His current research interests include innovation and consumer products. He also has 47 patents and 4 consumer products.

Bai-Hao Chang was born in Changhua, Taiwan, on June 4, 1990. He received the degree in Optical-Electro from the National Formosa University, in 2012. He is a student of graduate institute of Electro-Optical and Materials Science, National Formosa University of Huwei, Yun Lin, Taiwan.
Yu-Ting Liu was born in Taipei, Taiwan, on May 8, 1991. He graduated from Department of Electro-Optical Engineering of National Formosa University, in 2013. He studies in graduate institute of Electro-Optical and Materials Science, National Formosa University of Huwei, Yun Lin, Taiwan.

Guo-Jyun Liao was born in Yunlin, Taiwan, on July 16, 1991. He received the degree in Department of Electronic Engineering from the I-Shou University of Taiwan, in 2013. He is a student of graduate institute of Electro-Optical and Materials Science, National Formosa University of Huwei, Yun Lin, Taiwan.