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To Monitor Real-time Temperature and Gas in an Underground Mine Wireless on an Android Mobile

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ABSTRACT

In an underground mine there are temperature variations as well as toxic gases are released which cause potential hazards for mine workers. Hence it is necessary to monitor and assess these parameters well in advance for the safety of mine workers. This research paper discusses the concept of real-time monitoring and assessing temperature and toxic gases which are released from underground mines. Methane (CH_4) and Carbon Monoxide (CO) are the most prominent gases released in a typical underground mine. For precise detection of temperature variations and ppm values of gases; sensors can be used. This research work is an effort to develop an instrumentation system built around PIC Microcontroller using Quartz Sensor / Crystal, for precise detection of temperature variations as well as Gas sensors for precise detection of Methane (CH_4) and Carbon Monoxide (CO). Individual gas sensors are used to detect these gases, their corresponding ppm values are also measured. The temperature value being measured as well as the ppm values of these toxic gases are then transmitted wireless through an WIFI module and displayed on an Android mobile.

Keywords: Mines, Quartz Sensor, Gas Sensor, Instrumentation System, PIC Microcontroller, WIFI Module, Android mobile

INTRODUCTION

A lot of research work for the detection of temperature and gas in an underground mine has been carried out for the safety of the mine workers using various sensors (Raj *et. al*., 2018; Jha & Tikkaraja., 2020; Nie *et. al*., 2014; Mohd Anas *et. al*. 2017; Jegan *et. al*., 2018, Venkata & Gopal, 2019). In order to detect the change in temperature more precisely as well as for better sensitivity a Quartz Sensor has been chosen in this research work. Also, in today's world many people have their personal mobile. The real time temperature values in degree centigrade as well as the gas values in ppm can thus be displayed on their personal android mobile/s.

An instrumentation system is built around PIC Microcontroller using Piezoelectric Quartz crystal and Gas sensors to monitor real-time underground mine temperature as well as to detect prominent toxic gases released during a mining activity. These variations in underground temperature as well the variations in toxic gases can be hazardous for mine workers, hence these variations need to be precisely monitored.

To monitor temperature variations precisely, Quartz Sensors (Crystals) can be used. To monitor the gas variations precisely gas sensors can be used. The most prominent and harmful gases released during a mining activity are Methane (CH_4) and Carbon Monoxide (CO). In this research work two gas sensors MQ-2 and MQ-7 are used; to detect Methane (CH_4) and Carbon Monoxide (CO) respectively (Hanwei Electronics Co.,Ltd mq-2; Technical data MQ-7 gas sensor). Hence, an instrumentation system based on sensors (Sonde, 1979; Helfrick. & Cooper, 1996; Kalsi, 2010) (Temperature Quartz Sensor Crystal HTS-206, MQ-2 and MQ-7 Gas sensors) and PIC Microcontroller 16F877 is developed for the same.

INSTRUMENTATION SYSTEM - BLOCK DIAGRAM

The block diagram of the Instrumentation System developed around sensors (Temperature Quartz Sensor Crystal HTS-206, MQ-2, MQ-7 gas sensors) and PIC Microcontroller 16F877 is shown in Figure 1.

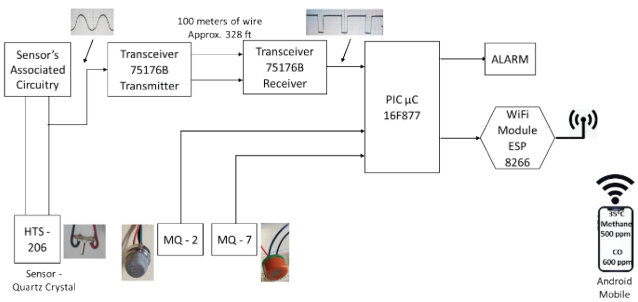
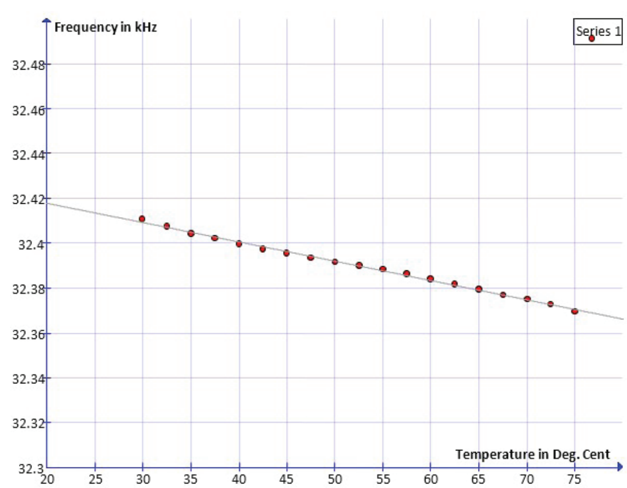


Figure 1: Instrumentation System

1. For Temperature Detection and Measurement

For precise detection of temperature variations, a temperature dependent Quartz Crystal HTS-206 is used as a sensor (www.datasheetq.com). It is interfaced to an associated circuitry to form an oscillator, which generates sine wave. The frequency of the sine wave generated at 30°C is 32.410 kHz, which is the natural frequency of HTS-206. This value of the frequency varies as the temperature around the crystal is varied. The frequency of the crystal decreases as the temperature increases. The frequency variations of the quartz sensor HTS-206 with the change in temperature are shown in Graph1.



Graph 1: Frequency variations with temperature

It is observed that for every rise in 1^0C the frequency decreases by ***1.48Hz.*** The Quartz Crystal HTS-206 is placed at the site area (mine). The frequency of HTS-206 varies as the temperature varies. These frequency variations are then transmitted around 100 meters from the site area to the ground surface through wires with the help of a pair of Driver Differential Transceivers 75176B (SN75176B datasheet). The Receiver Driver Differential Transceiver 75176B which is on the ground surface receives this frequency variations and outputs it in the form of a square wave. This square wave (frequency variations) is then given as input to TIMER1 (T1) of PIC Microcontroller 16F877 for calculating these frequency variations. The Timer is made to count the number of pulses generated in 1sec. Hence after 1 sec the 16-bit value stored in the TIMER1 registers; will be the frequency of the input signal.

The further part of this research project is to transmit the calculated value of frequency(data) on the mobile; viz, to transmit the calculated value of the frequency (data) wireless from PIC Microcontroller 16F877 onto the Android mobile.

2. For Gas Detection and Measurement

In this research work, two gas sensors are used; MQ-2 and MQ-7 for the detection Methane (CH_4) gas and Carbon Monoxide (CO) gas respectively. The MQ series Gas sensors are available in a module type or just as a sensor alone. In this research work the value of ppm of each gas is required to be measured hence both the gas sensors are used without modules. Figure 2a show the basic circuit of MQ-XX gas sensing unit.

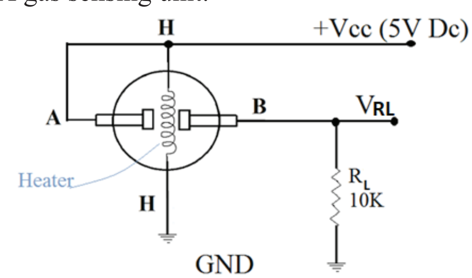
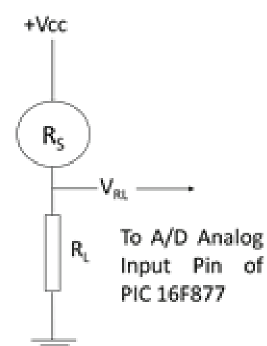


Figure 2a. Basic circuit of MQ-XX Gas Sensor Figure



2b. Simplified circuit of MQ-XX Gas Sensor

Calibrating the Gas Sensors

Referring to Figure 2a, 'H' is the heating element. The resistance between A and B is called as the internal resistance of the gas sensor whose value is inversely proportional to the concentration of the gas. The circuit can be represented can be represented as shown in Figure 2b where R_S represents the internal resistance of the gas sensor. The value of the internal resistance R_S can be calculated by using the following equation:

$$R_S\left(\frac{V_{CC}}{V_{RL}}-1\right)R_L = \ldots\ldots \text{ (1)}$$

where V_{RL} is the voltage measured across the load resistance R_L. This voltage is given as input to one of the analog input pins of the built-in A-to-D Convertor of the PIC microcontroller 16F877 (*Microchip)*. In order to measure the PPM values of the gas, the (Rs/Ro) v/s PPM graph mentioned in the datasheet of the gas sensors is referred. Hence accordingly the two gas sensors MQ-2 and MQ-7 are calibrated for ppm values in terms of voltage, individually.

The voltage across R_L of each gas sensor is given as analog inputs to Channel 0 (AN0) and Channel 1 (AN1) respectively which are the analog input pins of the built-in A-to-D converter of the PIC microcontroller 16F877. Initially, the individual calibrated ppm values in terms of voltages of each gas sensors are converted into its hex equivalent values and stored in the data memory of 16F877 in the form of a look-up tables. Hence two look-up tables are stored: one for MQ-2 and the other for MQ-7 gas sensors. The 16F877 is programmed (Predko, 2007; Peatman, 2007) in such a manner that initially the A-to-D converter will read analog voltage at Channel 0 (AN0), convert it into digital (hex) and then compared with the values in the look-up Table 1. The equivalent value from the look-up Table 1 is found out and then sent for transmitting onto the android mobile though the WIFI module. Similarly, the program will next read the analog voltage at Channel 1 (AN1), convert it into digital (hex), compared with the values mentioned in the look-up Table 2 and then send the equivalent value for transmitting on the android mobile through the WIFI module. The whole process of reading the analog inputs is repeated continuously and hence their ppm values are displayed on the android mobile continuously one by one. The PIC microcontroller is also programmed in such a manner that if any of the gas concentration (ppm values) is about to reach a value (reference set by the user) which will be harmful for miners, an alarm which is connected to one of the PORT pins of the PIC microcontroller 16877 goes "ON".

The further part of this research project is to transmit the corresponding values of the gas in ppm on the mobile; viz, to transmit the corresponding ppm values of the gas sensors wireless from PIC µC 16F877 onto the Android mobile.

3. To transmit Temperature data (Frequency value) and PPM values of Gases wireless from PIC µC 16F877 onto the Android mobile

A WIFI module ESP 8266 is interfaced to the PIC Microcontroller 16F877 to transmit the data from PIC Microcontroller 16F877 onto the Android mobile. Generally, at most of the mine sites, internet networks are not available, hence a WIFI module such as ESP 8266 can thus be useful. This module is configured as a WIFI Server (Router) (*ESP8266*. ESP8266 Wi-Fi MCU I Espressif Systems) whereas the Android mobile is made to act as a client to the WIFI module. Using Java Programming an android app is developed and installed in the mobile (Cohen & Wang, 2014; Horton, 2015). The PIC Microcontroller 16F877 is programmed in assembly language. The program first sends the Temperature data (Frequency value) to the WIFI module. Then it sends the two ppm gas values one by one onto the WIFI module. The WIFI module communicates these values to the android application. When the android app receives the Temperature data (Frequency value) it converts the received frequency value into corresponding/equivalent temperature values in ^{0}C. Similarly, when the app receives the hex ppm gas values individually it converts the corresponding/equivalent gas concentration values of each gas sensor in ppm.

Thus, the real time underground temperature as well as gas concentration of Methane (CH_4) and Carbon Monoxide (CO) released in a mine can be displayed and monitored continuously on the mobile.

OBSERVATIONS

1. Temperature detection:

The following table shows the TIMER1 output for various temperature readings:

Temperature	TIMER1 values (Hexadecimal)
25°C	1C1E
30°C	1D1F
35°C	1E11
40°C	1F1F
45°C	201C
50°C	201D
55°C	2117
60°C	2119
65°C	2237
70°C	2345
75°C	2478
80°C	2589
85°C	2656
90°C	2778
95°C	2899

2. For Gas detection:

For the detection methane gas, a methanol solution was prepared. Seven different methanol solutions of concentrations (ppm) 500, 1000, 1500, 2000, 2500, 5000 and 10000 were prepared.

The following observation table shows the output voltage measured at the output of the MQ-2 gas sensor for different concentration of methanol solutions

Methanol solutions concentration (ppm)	Rs/Ro	Rs (ohms)	V_{RL} (mV)
500	3.90	12.987	714.43
1000	3.80	12.654	731.44
1500	3.75	12.487	742.12
2000	3.70	12.321	751.28
2500	3.65	12.154	771.15
5000	3.40	11.322	808.71
10000	3.10	10.323	882.30

For the detection of Carbon Monoxide, charcoal of different quantities were burnt. When charcoal is burnt Carbon monoxide gas is also released along with other gases. The different quantities of charcoal used were 10 grams, 25 grams, 50 grams, 75 grams, 100 grams and 150 grams.

The following observation table shows the output voltage measured at the output of the MQ-7 gas sensor when different quantities of charcoal were burnt.

Amount of charcoal burnt (grams)	Rs/Ro	Rs (ohms)	V_{RL} (mV)
10	2.85	9.405	517.27
25	2.70	8.91	505.15
50	2.60	8.58	497.12
75	2.45	8.08	488.38
100	2.35	7.75	475.70
150	2.25	7.425	460.50

RESULT AND DISCUSSION:

In this research work, the real time underground temperature as well as gas concentration of Methane (CH_4) and Carbon Monoxide (CO) released are displayed and monitored continuously on the mobile. The system also gives a warning alarm if the gas concentrations are about reach the danger level. In most of the research work carried out by in this field, the result is displayed on the panel in the control room. In this research work carried out the result is displayed on the personal mobile/s. For temperature detection the Quartz sensor used has a resolution of 1.48Hz for every change of 1^0C. Hence the instrumentation system developed in this research work can even sense a change in one degree centigrade of temperature.

CONCLUSION:

An instrumentation-based warning system using sensors is developed for real time monitoring of temperature and the concentration of gases of an underground mine as well as the information from the instrumentation system is transmitted wireless on the mobile through WIFI, so that proper safety measures can be implemented for the mine workers well in advance.

CONFLICTS OF INTEREST:

There are no conflicts of interest.

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Declaration: *We also declare that all ethical guidelines have been followed during this work and there is no conflict of interest among authors.*

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