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Molecule sensing in air

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In this work, a sensor has been constructed to detect molecules such as vapor, CO_2 stream and smoke (tobacco) in the air by using an optical device with two pair led-photodiode. The working principle of the optical device is based on blocked beams.

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1. Introduction

Recently developed infrared light emitting diodes (LEDs) with sharp wavelengths have been widely used to describe molecules as moisture, CO_2, SO_2 in the air. The working principle of these optical devices with leds is based on infrared absorption. Most of the gases and liquids have strong absorption lines in infrared spectral range. Table 1 shows the absorption lines of some gases in mid infrared range.

Table 1 List of absorption lines in MIR range[1].

CH_4	3.2-3.45 μm	HC1	3.3-3.7 μm
C_2H_2	2.9-3.19 μm	HOC1	2.6-2.9 μm
C_2H_4	3.1-3.4 μm	HBr	3.7-4.0 μm
C_2H_6	3.3 μm	HI	2.2-2.3 μm
CH_3Cl	3.2-3.3 μm	H_2S	3.7-4.4 μm
OCS	3.45; 4.87 μm	HCN	2.94-3.1 μm
H_2O	2.5-2.8 μm	N_2	4.0-4.54 μm
CO_2	4.2-4.3 μm	NH_3	2.27; 2.94 μm
OH^{-}	2.38-2.63 μm	NO^{+}	4.0 -4.44 μm
H_2CO	3.3-3.7 μm	HNO_3	5.74-5.98 μm
CO	4.4-4.8 μm	NO_2	3.4 μm
HO_2	2.73-3.1 μm	SO_2	4.0 μm

According to the literature scanning, there are two methods used of designing of the optical devices. Firstly, lights falling on or passing through the medium are converted to the photo signals to perform measurements about the properties of the medium or an object, e.g. amount of CO_2, humidity, absorption coefficient, optical density, etc. Amplitudes of photo signals are determined and compared generally by taking the ratio of these voltages. Since optical densities vary in a wide range, amplitudes of photo signals also vary in a wide range. Therefore, the photo signal amplifier used in the circuit must also operate in a wide range.

Secondly, if periodical light pulses are used, the pulsed signals obtained must be converted to dc voltages before the comparison. The following steps are taken respectively. The medium is illuminated by lights with suitable wavelengths (single wave and double wave), lights passing through the medium are converted to photo signals, the pulsed photo signals are converted to dc voltages, the obtained analogue signals are compared and mathematical operations are performed (the reference and the measurement voltages are compared and the ratio, the difference, the sum or the logarithm is taken), the analogue value can be converted to a digital signal with an ADC if it is required [1–4].

The particles found in the air can be described by known methods with leds are also used. In these methods, the light transmission as detected by the photo detector facing the beam is constant if there are no particles present. Each time a particle traverses the beam, some part of the incident beam is lost, or blocked either due to the light scattered out of or absorbed by the particle. The light flux detected by the photo detector is then reduced and a negative signal pulse is produced. The amplitude of the pulse is directly related to the particle size [5].

In this work, the first method has been used. From the absorption spectroscopy, the intensity of light passing through the medium can be expressed according to the Beer–Lambert law:

$$I = I_0 e^{-\alpha_E L} \qquad (1)$$

where L is the length of the light path and α_E is the sum of air plus particulate scattering and absorption [6]. Calculations have been made by using Matlab Version 7.0.1.24704 (R14) Service Pack 1.

2. Optoelectronic design

The circuit schemas of the optical device are given in Figs.1, 2 and 3. They are simply consisting of transmitter and receiver. Two commercial leds used in the transmitter section to produce a beams at the 650 nm (red) and 940 nm (infrared) wavelengths. The same leds may use as optical detector because of compatible wavelengths. Here, two other leds are also used as receiver photo detector.

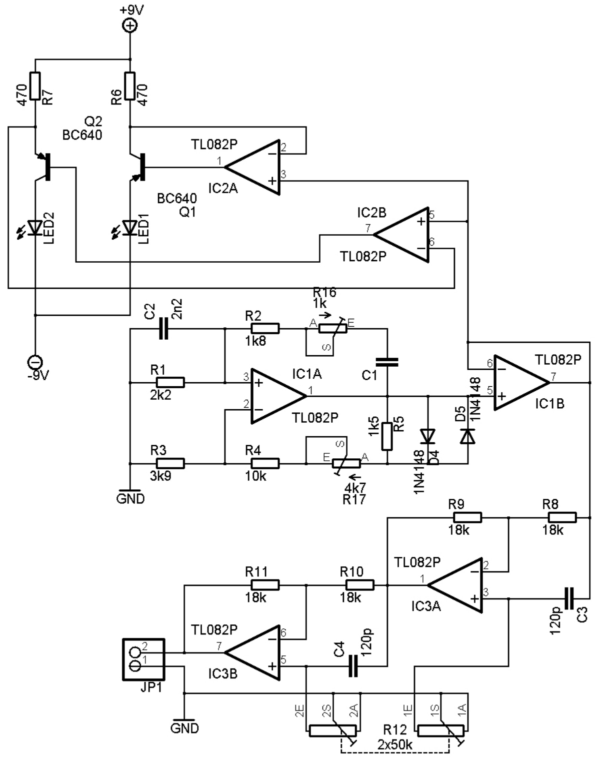

Fig.1. Led drivers and phase shifter.

In order to protect external effects the led-photodiode pairs have been placed into the metal case in the x-y plane mutually. In the experiment, the stream is given from bottom the box. Trace of the particles in the stream have been detected either of the pairs (Fig.4).

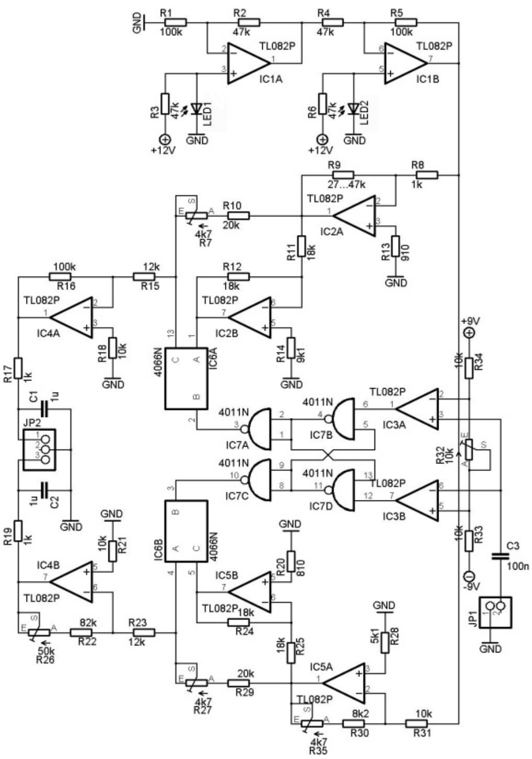

Fig.2 Phase sensitive detector.

The Wien-Bridge type low frequency sine generator produces a voltage at frequency 70 kHz. IC2A and IC2B converts this voltage to current to drive the infrared led's (see Fig.1). This generator has also been feeding phase shifter with the signal. Phase shifter included IC3A ve IC3B operational amplifiers which is necessary for phase sensitive detector at the receiver part of the device [7– 9].

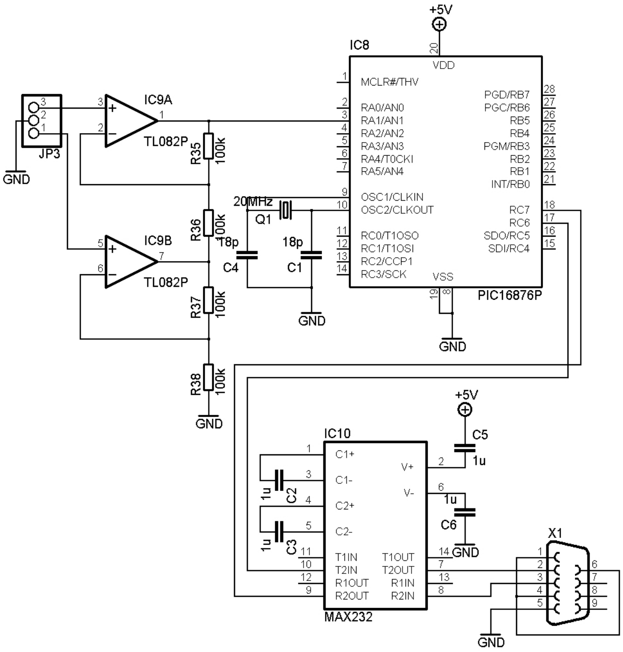

Fig. 3. ADC and RS232C.

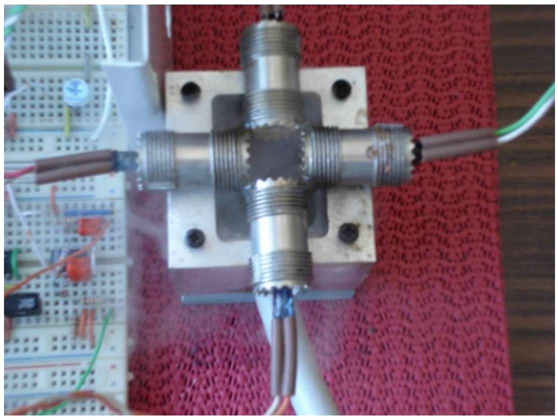

Fig.4 The led-photodiode pairs.

Phase sensitive detector compares phases of the two signals which were produced by photodiodes in the receiver part and the reference signal coming from the transmitter. Thus a noiseless signal which carries knowledge of reciprocal influence between particle-beam is obtained. This knowledge is send to PIC16F876 which has a 10 bit ADC for digitization [10]. The ADC worked at the clock frequency 20 MHz communicates with PC by means of IC MAX232. This integrated circuit is required to provide serial communications RS232C standard [11]. Fig.5 shows the entire experimental setup.

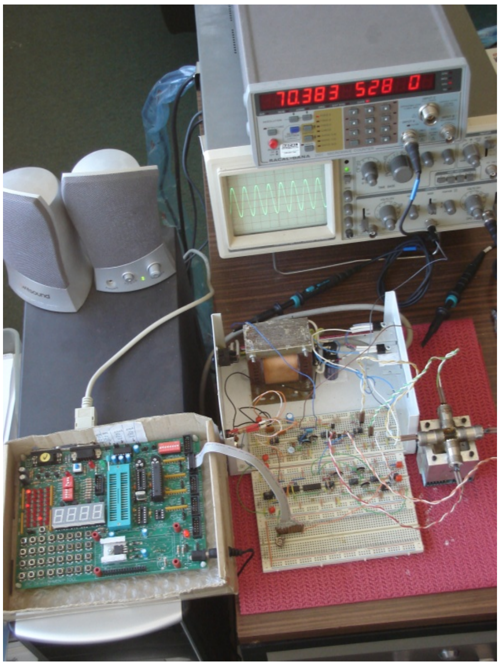

Fig. 5. Photograph of the experimental setup.

3. Measurements and results

Data have been taken for free air, vapor, CO_2 stream and tobacco respectively for 60 s time interval. Every single data taken is stored and converted as data arrays for Matlab in a PC. Fig. 6 shows the graph of the processed arrays in Matlab environment.

At Fig.7, horizontal axis is path of the medium and the vertical axis is transmittance values which were found according to Beer–Lambert law as:

$$\alpha_{Ei} = -\frac{1}{L_i}\ln\left(\frac{I_i}{I_0}\right) \qquad (2)$$

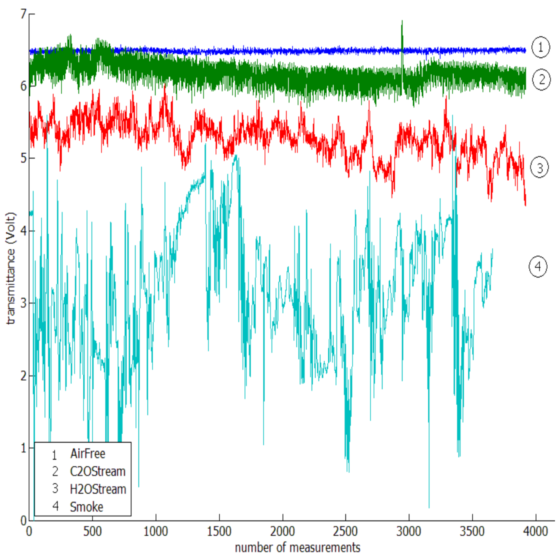

Fig.6 Experimental measurements of the I(α_E) values at L=5 cm for all streams.

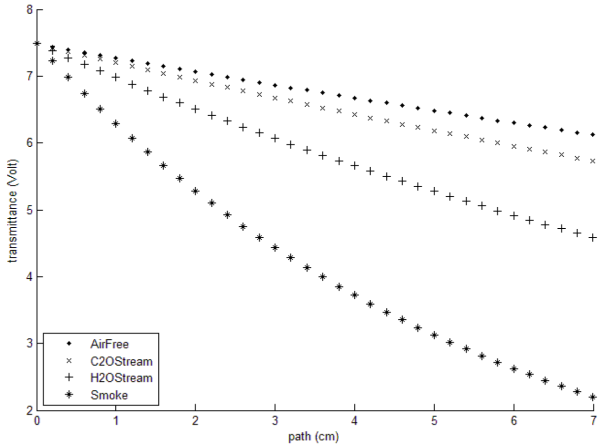

Fig.7. The exponential variation of the transmittance versus L for all streams

Table 2 shows the experimental results of transmittance values for i^{th} extinction coefficients. Here L=5 cm and I_0 is 7.483 V for L=0.

Table 2. Experimental results of the measurements.

Sample	I	Ln (I)	α_E
Air Free	6.4835	1.8693	0.0287
CO_2 Stream	6.1844	1.8220	0.0381
H_2O Stream	5.2725	1.6625	0.0700
Smoke (tobacco)	3.1257	1.1397	0.1746

4. Conclusions

This work shows that, the molecular identification is possible by using their extinction coefficients. The designed device here is compact, robust and has a very good response. Our design can also be used for various molecular gasses with a calibration.

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