Design And Development Of Prototype System For Resistive Gas Sensors

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Abstract—*This research paper reports the design and its implementation for the prototype system of resistive gas sensor having resistance of the order of few hundreds of MΩ at room temperature. The prototype consists of the half bridge,its signal conditioning circuit using instrumentation operational amplifier AD620 and V-I converter using IC LM358. The prototype gives output in the form of 4-20mA as per the industrial standards defined by the ISA (International society of automation)*

There are many gas sensors based on metal oxide semicon- ductors available in the market, for example,MQ - series gas sensors. The cost of these sensors and its prototype system is more than 1500/- rupees. The designed prototype fulfills the cost effectiveness. It ranges between 500-600 /- rupees. It gives accuracy nearby ± 1 percent at room temperature. The offset voltage and bias current generated by the prototype are in μ volts and milliampere respectively which are very less than available prototype. Portability and small size is also adds to the effective use of the prototype system. The industrial standard output (4-20 mA) given by the prototype can be used for further industrial processes like controlling, manipulating, storage purpose, etc. The power consumption of the prototype is less than the existing systems by 10-12 Watt. Major available gas prototype systems in the market are dedicated to the particular gas sensor. The present prototype can be used for any resistive type of gas sensor by simple adjusting the variable resistance on the half bridge circuit provided in the prototype. The major application areas where the prototype may be used effectively are oil and gas industries,cylinder gas filling industries,mines,dairy and food industries and also in household uses.

Keywords: Humidity sensor (resistive type), IC AD620 (voltage amplifier), IC LM358 (voltage to current converter), normal temperature (25 - 30 degree C), operating temperature range (10 to 50 degree C). ESD(electrostatic discharge)

I.INTRODUCTION

In last few decades humidity control is one of the noticeable factor for human comfort as well as the industrial operat- ing conditions. From the evolution of the more use of the electronic specially digitized control of industrial operations, the humidity is one of the considerable factor in the industrial operating conditions along with temperature and other factors. The effect of change in humidity on industrial operations has been reported in literature[2].

The commonly available gas detectors in the market are costlier with starting range of 1500Rs. These market detectors are having low life span as well as use and through type. Power requirement of these prototype is also more (15-20 watt). These market prototypes cannot be used in noisy environment. Also the temperature of the circuit have to be maintained at particular temperature using heater in available prototype for proper working of sensors. this raised temperature may cause thermal noise in the remaining circuit. The major drawback of the market prototype is that generally they are dedicated to the particular gas sensor.

Hence to overcome these drawbacks of market prototype,we have designed a resistive gas sensor prototype which are having characteristics like low cost, small size,low power consumption (8-10watt), long life with replaceability facility of failed components and standby in the noisy environment. Also we have to add the simple arrangement so that a single prototype can be used for all the resistive type gas sensors. These are the needs kept in front during component selection and design of the prototype.Also the the special precaution have been taken during PCB designing using noise reduction technics. The designed resistive humidity sensor detects per- cent RH humidity content and accordingly gives output in the form of resistance.Sensor is made up of SnO_2 layer which is sensitive to humidity or water vapour content in air because of adsorption and desorption processes on sensitive layers.The resistance of sensitive material depends on the number of SnO_2 layers.The important feature of this humidity sensor is its good recovery response.

During testing of the humidity sensor we have used a half bridge method excited with +15Vdc supply for conversion of resistance to voltage signal. Because of high resistance (250MΩ)of the sensor at room temperature, we have to provide +15V dc excitation voltage to half bridge. This output of half bridge is in the range of millivolts is proportional to percent RH.This millivolt signal is fed to opamp for amplification in the range of Volts. Now this voltage converted in to 4-20 mA signal by using LM358 V-I converter.Following are some examples where humidity detection is an important aspect.

In case of paper and pulp industry the width and quality of paper are dependable factors on humidity.Now a days heating, ventilation and air conditioning system (HVAC) is commonly used in hospitals, offices, data centers, control rooms, etc. In HVAC system humidity control and poisonous gas delectation are important aspects used for survival and human comfort applications. Special efforts taken by many industries for HVAC controlling in building automation solution. With the help of these HVAC technique, the productivity issues of the workers were improved with positive results from last few decades. The effects of humidity content on the human comfort has been reported in literature[4]. Hence, humidity can affect the industrial operations as well as human comfort. The various humidity detection system are available , one of them has been reported in literature[5].

The use of the designed prototype may reduce the cost and power consumption considerably in above mentioned examples. The major application areas where the prototype may be used effectively are oil and gas industries,cylinder gas filling industries,mines,dairy and food industries and also in household uses. A Block diagram of system

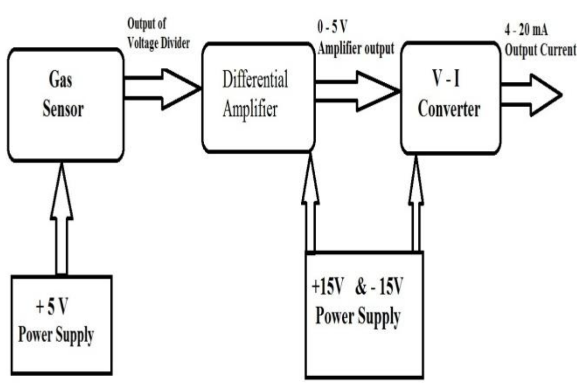

Fig. 1. Block Diagram

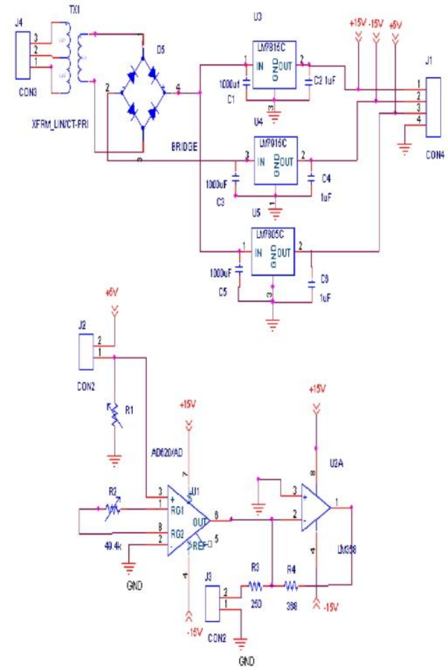

Fig. 2. Circuit diagram

II. EXPERIMENTAL TECHNIQUES

A. System Design

The functionality of developed prototype is divided into three parts. These are sensor connected in half bridge circuit, signal amplification and voltage to current conversion. The system consist of power supply, humidity sensor, half bridge, voltage amplification IC AD 620,V to I convertor IC LM358 and ammeter as shown in fig.2. The dc power supply provides the output of + 15V , - 15V, +5V and 1 A current specification. The voltage consist of humidity sensor, excitation voltage of +15V dc and other grounded resistor. This half bridge gives output in millivolts. Humidity contents in air changes at room temperature, the resistance of sensor get changed which ultimately varies the output of half bridge is interfaced with the IC AD 620 amplifier. A Block diagram of system software as shown in fig 3.

The second step is amplification IC AD620 is provided with supply voltage of +15V dc and fed as input from output of half bridge. The variable gain resistor of 100M Ω is attached between pin no. 1 and 8 of IC AD620 for adjustment of gain of opamp. The value of resistance for particular gain value was as per specified in the data sheet. This IC AD620 amplifies voltage signal from millivolt range to volt range. The third step is to convert the voltage signal into industrial standard current signal using IC LM 358 with same supply voltage (+15Vdc). With the connection of proper feedback resister (mostly 250Ω for 1-5V), and grounded ammeter we got the current signal in the range of

(4-20 mA) as per the industrial standard. This current signal can be fed to the controller for humidity controlling for the purpose of industrial operations or human comfort.

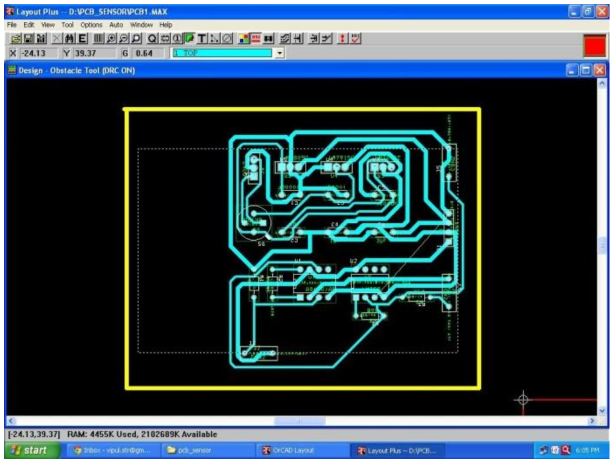

Fig. 3. PCB designing

B. Hardware design

The hardware consist of power supply, humidity sensor, half bridge circuit, opamp IC AD 620, V-I converter IC LM358, connectors, ammeter, voltmeter and passive component like resistors and capacitors. Sensor connected Through 10 meter coaxial cable. The schematic designed using ORCAD 9.1. The component selection is an important step in this prototype design because all the characteristics mentioned in the Introduction part like less power consumption, low cost, noise reduction etc are depends upon the component selection step. In the power supply circuit,we have selected 18-0-18,1A transformer for the requirement of ±15V,0.7-0.8A output by considering the internal current and thermal losses. The commonly available rectifier bridge which consumes 0.1A of current for rectification of voltage signal from transformer. This rectified voltage is fed to the ICs 7815 and 7915 voltage regulators. The heat loss is compensated using the heat sink to the voltage regulator ICs. The capacitors are connected parallel to the voltage regulator for pure dc voltage.

We have selected half bridge technic which is simple and less power required for high resistive sensors. Also the the components required in half bridge are less than the other resistive to current conversion technics like Whiston bridge. The half bridge is excited with positive 15 volt because of high resistance of the sensor. The ground resistance across which output is measured is connected to the sensor is of value 2MΩ. Because this is the maximum available variable resistance in the market. The output range of prototype in 4-20mA can be adjusted using this variable resister.

The op-amp AD620 is selected as amplifier to convert millivolt output of half bridge to few volts. some special characteristics like high input resistance in few GΩ, low output resistance in few ohm, low offset in µV, low biasing current in mA, high gain adjustment capacity ranging from 1-1000,low power consumption (2-3 watt) output linearity add the effectiveness of the prototype.External variable resister of value 100KΩ is selected for output voltage gain adjustmenta as per value given in data sheet of IC AD620.

The IC LM358 is used as V-I convertor which is commonly available, low cost(10RS),less power consuming(nearby 2watt),highly linear.The resister with calculated value of 250Ω is selected for conversion of 0-5V into 0-20mA range. The special precautions like separate grounding, power line thickness,distance between adjacent line and component placement on PCB are taken for redusing noise related problems.

III. RESULTS AND DISCUSSION

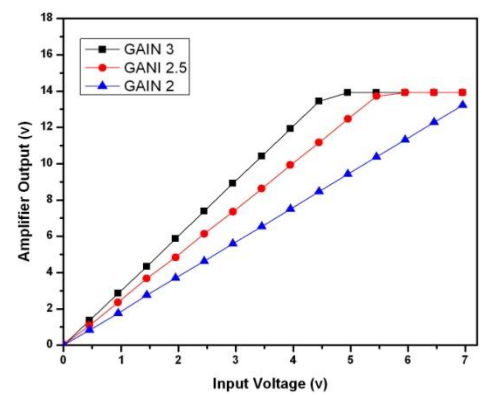

Fig. 4. Graph of output voltage of opamp with various gain values

The designed prototype is tested using an experimental setup as shown in fig.6 .The sensor is placed inside the sealed glassware which is saturated with water vapours using the boiled water in a beaker. Before start calibration, the percent RH will reach up to 90-95 percent in side the glassware. Now,the powder of P_2O_5 is placed in a glass plate inside the glassware which absorbs the moisture content. According to that percent RH meter shows the present percent RH value and temperature on its indicator. The output current of the prototype is measured using the multi meter as shown in fig.6. The opamp AD620 is tested by varying the input voltage between 0-7 volts with variable gain values(2, 2.5 and 3 resp.). The graph 5 shows the linear behaviour of opamp with accuracy of nearby ± 0.1 percent for all three gain values.

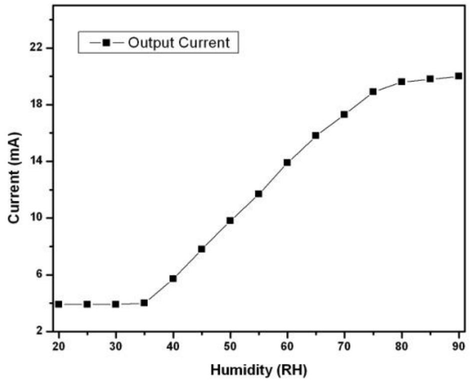

Fig. 5. Graph of output current of prototype Vs percent humidity

Also, this graph shows that, as the gain of opamp increases, it will saturate the output voltage earlier than the lower gain values.

The fig.4 shows the output current of the designed prototype with the percent RH value tasted with resistive humidity sensor. The graph shows that, the prototype is in active region varying its output current value in the range of 4-20mA from 35 percent to 85 percent of the RH value. After 85 percent RH, it will shows saturation 20mA current output value. The region from 0 percent RH to 35 percent RH shows live zero band of the prototype system.

In the mentioned active region, the prototype shows linear characteristics with $\pm$ 0.1 accuracy.The recovery time of the prototype is in few milliseconds at room temperature.

figure 6 . experimental setup

IV. CONCLUSION

A small size,handy,with lower power consumption and economic prototype is designed using signal conditioning circuitry for detection of leaked gas or change in humidity at room temperature. Detection range is from 10 - 90 percent of percentage RH with output range of prototype in 4- 20 mA for resistive humidity sensor. The prototype is useful for gas and humidity detection in industries like Oils and gas industries,cylinder gas filling industries, mines,dairy and food-stuff,paper and pulp industry as well as building automation solution(BAS)efficiently.

V. ACKNOWLEDGEM ENT

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