Development of a Non-Contact Temperature Indicator for Hazardous Process-Control Applications

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ABSTRACT

The paper presents design and development of a non-contact temperature indicator based on LM335 for temperature sensing and monitoring of hazardous process-control applications. The simulation results as well as the experimental results observed, show a linear relation between the voltage and the respective change in temperature. After testing, it was fabricated on a PCB followed by component assembly. After characterization and successful demonstration, such an alarm system was tried at an in-house process-control instrument wherein fluid is to be monitored and maintained at a controlled temperature.

KEYWORDS: *Non-contact, Control circuit, Simulation, Temperature sensor, Process-control*

I. INTRODUCTION

Temperature sensors are finding wide applications in circuit-control as well as in household products [1-5]. The sensors are also active at the industrial sector, such as, in controlling and regulating the temperature of chemical reactors. Further, these can also be employed for food preservation, cold storage and bacteria culture, as a contact based sensor in thermocouples, thermometers and non-contact sensor in pyrometers. These sensors are also effective in providing the necessary activation energy for a chemical reaction to take place [6-8].

A temperature sensor circuit typically detects temperature change in the surrounding environment and converts it into a quantifiable electrical signal (such as resistance, voltage etc.). Temperature sensors are also effective in realizing applications in industrial and research platforms. Temperature sensor circuits form a very important part of the setup along with temperature controllers, since almost every scientific process and experiment today is temperature controlled, for maximum efficiency and successful execution.

II. DESIGN AND SIMULATION

The circuit is simulated as shown in Figure 1. The temperature sensor circuit involves the following components: a precision 3 pin temperature sensor LM335/LM315 or equivalent, 14 pin quad operational amplifier LM324 or equivalent, resistors: 1 kΩ, 3.55 kΩ, 5.55 kΩ, a buzzer or alarm and 9 V battery or DC power supply. The LM335/LM315 series sensors are precise and can easily be calibrated. The LM335 temperature sensor, used for the above mentioned purpose, is fundamentally a zener diode that has its reverse breakdown voltage proportional to the absolute temperature and an accuracy of ±3 °C. Considering self-heating tendency of the zener diode as a noteworthy factor, the diode (i.e. LM335 sensor) is biased at 2 mA, which is possible with a resistance of 1 kΩ. This selection of bias current is in accordance with the specification chart. Furthermore, the LM324 operational amplifier is essentially a comparator that compares the voltage between its inverting and non-inverting terminals. The sensor usage method is represented by the encircled portion in Figure 1.

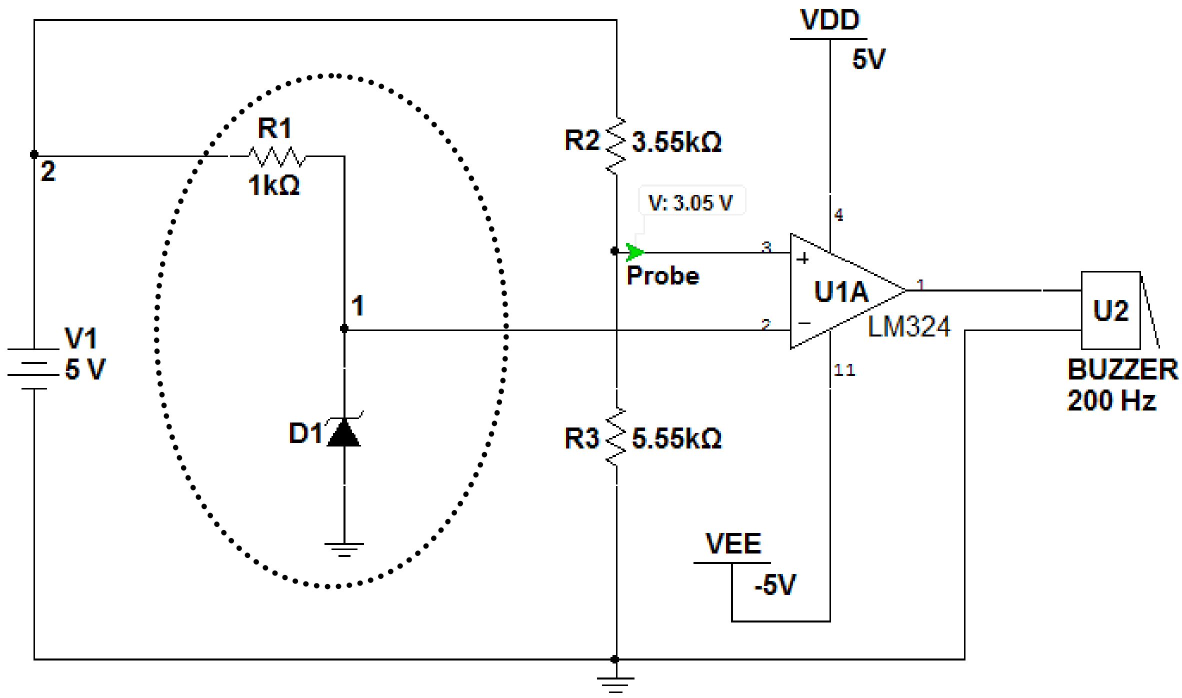

Figure 1. Simulated circuit diagram

The essential connections which need to be pointed out are - pin no. 1 of LM335 which is connected to the inverting terminal (pin no. 2) of LM324. Pin no. 2 of the same sensor is connected to the voltage supply. The voltage through LM335 varies whenever the sensor is exposed to varying temperature. The pin nos. 4 and 11 of LM324 are connected to the positive (VDD) and negative (VEE) terminal of the power supply while the output pin (i.e. pin no. 1) of LM324 is connected to a buzzer. The voltage at the inverting terminal of LM324 is adjusted at 2.98 V which is tuned in accordance with a temperature of 25 °C. Also, the voltage at the non-inverting terminal (pin no. 3) of LM324 is kept constant with the use of two resistors – 3.55 kΩ and 5.55 kΩ.

The circuit starts to function whenever the power supply is switched 'ON', which results in the development of a corresponding voltage across the LM335 sensor. The voltage reading at the non-inverting terminal of LM324 is given by the formula V=5.55 x 5/ (5.55 + 3.55)) ≈ 3.05 V, with the use of values of resistors and voltage supply, as mentioned above. This 3.05 V is the reference voltage applied for temperature measurement, which is depicted in Figure 1 by a probe at the non-inverting terminal of LM324. The reference voltage (i.e. 3.05 V) can be calibrated by changing the resistor values, which is generally constant for a given set of resistor values at a constant power supply. The voltage values at the inverting terminal of LM324 and at the positive terminal of LM335 are alike and are dependent upon temperature. An output in the form of a buzz is observed at the output pin (i.e. pin no. 1) of LM324 whenever a difference in voltage at the non-inverting and the inverting terminal of the comparator is produced. The circuit diagram for the above mentioned mechanism is shown in Figure 1. The above circuit is fabricated on a PCB followed by component assembly. The complete circuit is shown in Figure 2.

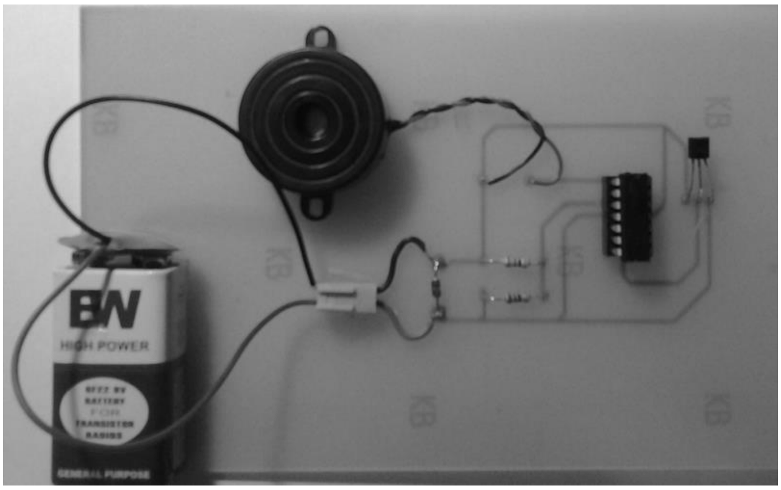

Figure 2. Complete circuit fabricated on a PCB

III. RESULTS

Even a small change in temperature will cause a change in the voltage resulting in an alarm (Table 1). Figure 3 represents the Voltage vs. Temperature characteristics for the circuit that is fabricated and tested on a PCB (shown in Figure 2).

Table 1. Temperature vs. Voltage characteristics of the sensor

Temperature (in deg. Celsius)	Voltage (in Volts)
25.24	3.02
26.15	3.15
27.13	3.29
28.18	3.44
29.16	3.58
30.21	3.73
31.19	3.87
31.96	3.98

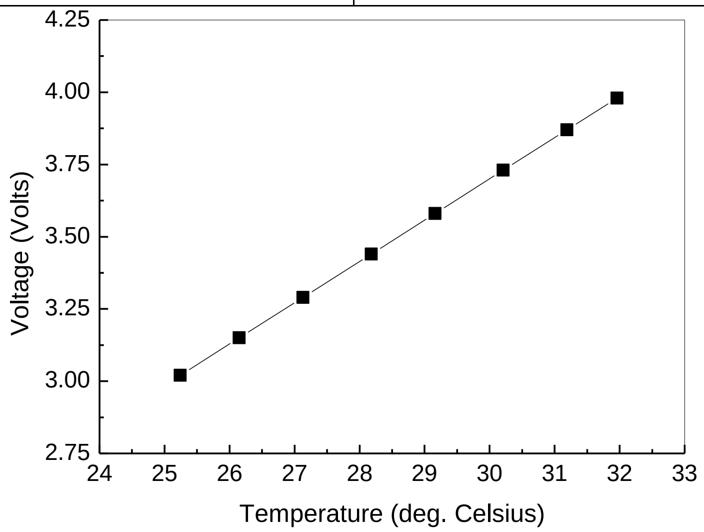

Figure 3. Temperature vs. voltage characteristics of the sensor

The schematic diagram of the off-contact measurement technique for hazardous fluids is depicted in Fig. 4. The sensor is in contact with the fluidic channel through which the fluid is flowing so that there is no contact between the hazardous fluid and the sensor. The actual temperature of the fluid and the temperature measurement using the sensor varies by a fixed amount. This temperature difference should be added to the actual measured value to obtain the exact temperature of the fluid.

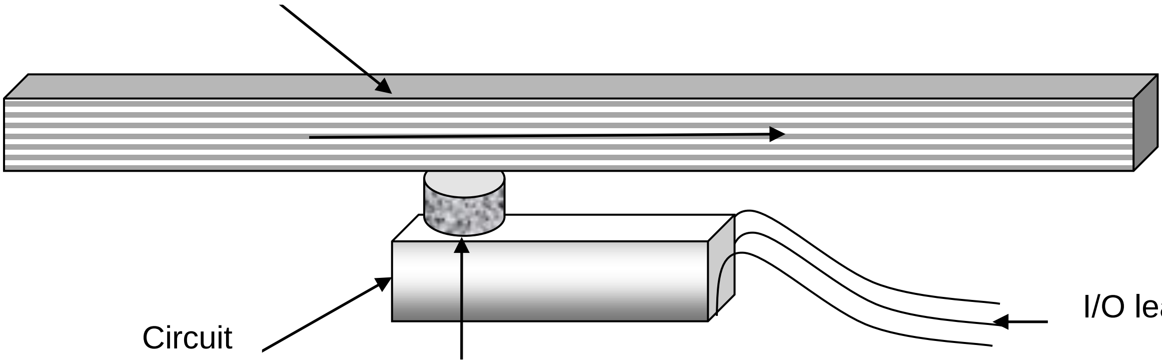

Figure 4. Schematic of the off-contact measurement techniques for hazardous fluids

IV. CONCLUSIONS

The circuit is designed, conceptualized and simulated using Multisim/ Ultiboard software and after realization on a breadboard, it was fabricated on a PCB.

This alarm system was tried at an in-house process-control instrument wherein fluid is to be monitored and maintained at a controlled temperature. Work on further control of temperature and its monitoring is in process. This development will provide a precise control in temperature to exceed the lifetime of the fluid used in the process, its quality; which in turn improves the process and thus saves resources and reduces the effective cost.

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