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Application of a Schottky Diode as a Temperature Sensor

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ABSTRACT

A simple technique is proposed for low range temperature measurement using a Schottky barrier diode. A square root circuit is applied to regulate the thermionic current of the diode into a linear relationship with ambient temperature variation. The experimental data observed from the work using a Schottky diode IN5822 shows a notable temperature sensitivity of 6.2mV/K over a temperature range 300K to 400K.

***Keywords**:* Temperature sensor, Schottky diode, Square root circuit

1. Introduction

The metal-semiconductor junction diodes find a wide spread applications in electronic devices and circuits especially in high frequency and microwave applications. In electronic devices the metal-semiconductor junction is generally used to provide the ohmic metal contact to the connecting wires [1]. In circuit applications Schottky contacts are often used in high frequency circuits [2], low noise amplification, microwave and optical signal detection. Besides the above applications, a metal-semiconductor contact can also be used as a sensing probe for in temperature measurement. A number of works have been carried out earlier to study the performance of a metal-semiconductor diode in temperature sensing [3-5]. G.Brezeanu et al have described that the forward voltage of a Schottky diode over a temperature range varies almost linearly with temperature [3] at a fixed current value. They have designed a temperature probe which can sense temperature from 20^0C to 400^0C having sensitivity from 1.3mV/K to 2.8mV/K, whereas Andrews, Jr. et al have developed a sensing circuit using two Schottky diode connected in series [4]. An another arrangement was proposed by Khadikikar et al where an adjustable constant current source is connected to a reverse biased Schottky diode and output is taken from the voltage drop across the junction which is a direct function of temperature [5]. All these above arrangements use the variations of voltage drop accross the diode with temperature for sensing application . In this work we have proposed a simple technique using a metal-semiconductor diode and a square root circuit which can effectively sense and measure the low range ambient temperature. In section 2 the details of the experimental process have been discussed and in section 3 the results are analyzed and explained.

2. Experimental process

A simple and low cost technique to apply a metal-semiconductor diode in temperature sensing is presented here with the help of a square root circuit. The forward current of a metal semiconductor junction is generally dominated by thermionic current model given by [6]

$$J = A^{*}T^{2}e^{\frac{-q\phi_{bn}}{KT}}\left(e^{\frac{qV}{KT}} - 1\right) \tag{1}$$

where A* is the effective Richardson constant for thermionic emission, ϕ_{bn} is the barrier height at the metal semiconductor junction and V is the applied forward bias voltage across the junction. The term ‘1’ in equation (1) can be neglected for elevated value of ‘V’. Thus the forward current density at the metal semiconductor junction is proportional to T^2 when barrier height is equal to the applied forward bias. In addition a linear temperature dependent current density can be found if the current density of equation (1) at a condition of ϕ_{bn} =V, is passed through a square root circuit. The schematic diagram of the experimental set up is presented in figure 1.

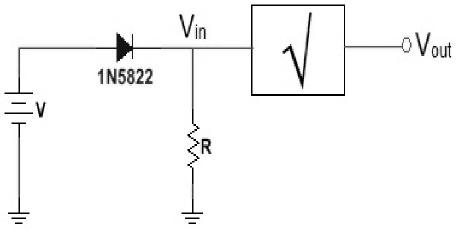

Figure 1: *Schematic representation of our work*

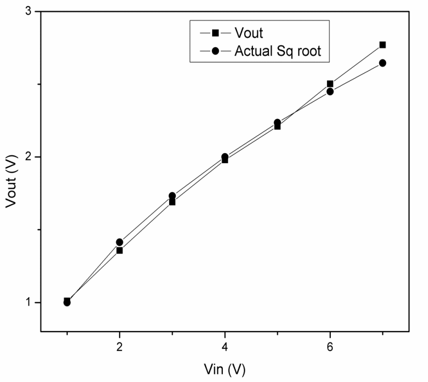

Figure 3: *characteristic of the square root circuit*

The square root circuit is made of one logarithmic amplifier, inverting amplifier of gain 0.5 and anti-logarithmic amplifier presented in figure 2. The performance of the square root circuit is compared with the simulated results in figure 3. We have used IN5822 Schottky diode in our work and using activation energy measurement method we have determined its barrier height equal to 0.4 volt. To study the temperature dependence, the diode is placed inside the oven of a PID temperature controller. The voltage drop V_{in} across the resistance R is proportional to the thermionic current of the diode. The value of R is chosen to be very small (10Ω) to avoid the loading effect with the square root circuit. The voltage V_{in} is applied to a square root circuit as input voltage and V_{out} is measured from the output of the square root circuit.

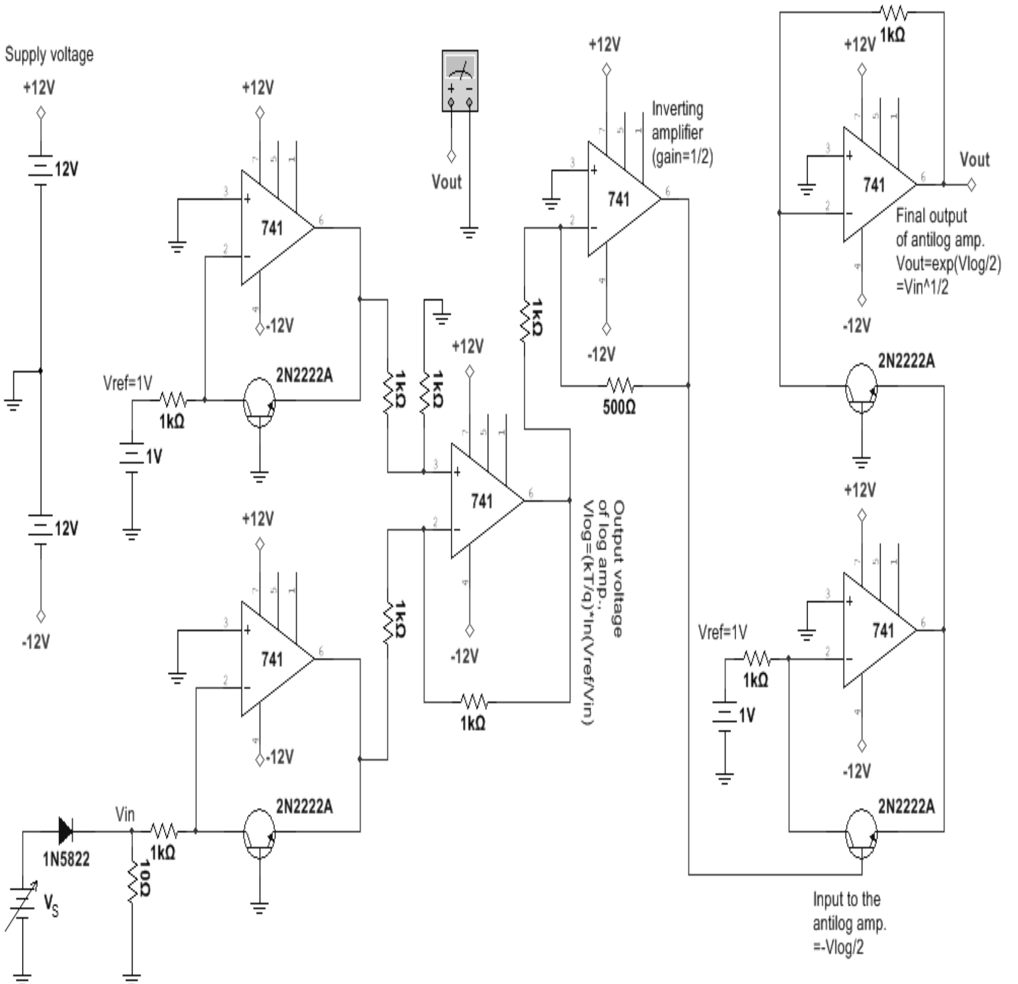

Figure 2: Square root circuit

3. Results and discussions

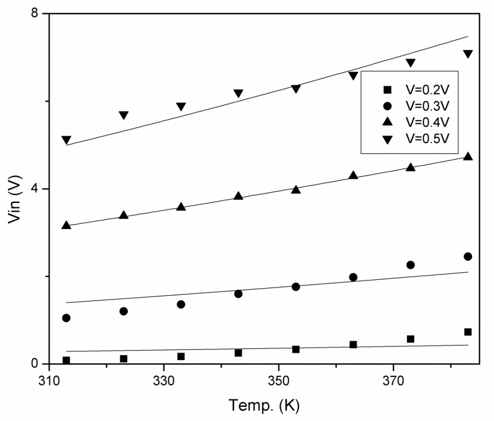

Figure 4: Variation of V_{in} with temperature

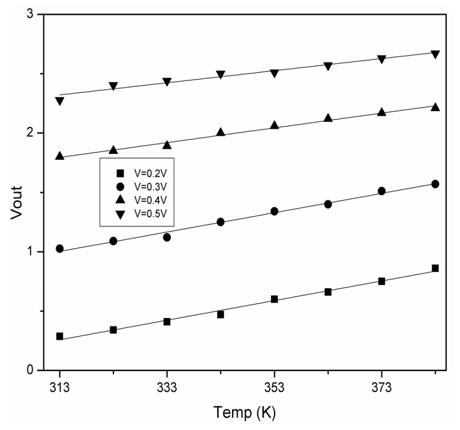

Figure 5: Variation of V_{out} with temperature

The output voltage V_{out} is measured for different temperatures from 310 K to 380K. In this analysis, the variation of barrier height with temperature is neglected as the measurements are performed for low temperature ranges [6]. Figure 4 shows the variation of V_{in} with ambient temperature for different applied diode voltages ranging from V = 0.2V to 0.5V. The measured data at various temperatures is fitted with non-linear equation having T^2 dependence for each diode bias. It is observed that the fitting error is found to be minimum for V = 0.4V, which is equal to the barrier height of the metal semiconductor junction. It signifies that that the diode current shows a better T^2 dependence if junction voltage is equal to the barrier height of the junction. In figure 5 the variation of V_{out} with ambient temperature is presented. It is also observed from the figure that V_{out} depends on temperature almost linearly and the linear fitting error is minimum for junction voltage equal to 0.4V. The variation of output voltages with ambient temperatures are observed to be a linear relation from the figure and the applicability of the entire system becomes more feasible in temperature sensing at the condition when $\phi_{bn} = V$. From figure 1 it is also noted that the voltage drop across the diode (V_D) is given by, $V_D = V - I(T)R$, where $I(T)$ is the temperature dependent diode current. For a particular applied voltage V the diode voltage changes with temperature and consequently diode current changes. As a result with the increase of temperature the diode voltage decreases. Thus it is very difficult to maintain a fixed junction voltage across the diode which is required to be equal with the barrier height of the diode for its application as a temperature sensor. This problem can be minimized choosing a low value of resistance R, so that diode voltage cannot changes much with the change of diode current. We have also calculated the temperature sensitivity and fitting error for a temperature range from 310K to 380K for different applied voltages and it is presented in table 1. This table shows the temperature sensitivity decreases with junction voltage whereas the linear fitting error is minimum when diode voltage is equal to the barrier height of the metal-semiconductor contact.

V	Sensitivity	Error
0.2	8.26mV/K	3.52551E-4
0.3	8.15mV/K	3.56564E-4
0.4	6.21mV/K	2.92576E-4
0.5	5.10mV/K	4.07955E-4

Table 1: Temperature sensitivity and fitting error for different junction voltage

4. Conclusion

In conclusion, a simple laboratory technique has been developed to measure low range temperature using a Schottky barrier diode (IN5822). The sensing arrangement shows a good temperature sensitivity of 6.21mV/K for an approximate temperature range 300K to 400K, though for high temperature sensing the application of this system becomes limited.

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