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INVESTIGATE THE PERFORMANCE OF NONLINEAR BIPOLAR TRANSISTOR AT HIGH TEMPERATURE

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Abstract: An increase in the board temperature can have an effect on the basic characteristics of electronic elements which may influence the performance of the circuit. The objective of this paper is to investigate the influence of thermal rise on some characteristics of Bipolar junction transistor. Some static and dynamic characteristics have been experimentally measured and analyzed of a transistor type 2SC2120 at high temperatures. The obtained results indicate that with an increase in temperature over the range 30-90 °C, a collector current will increase by about 0.04 A, whereas the current will be around 0.12 A. The applied threshold voltage has been droped from 0.63 V to 0.45 V. The obtained results also illustrate that the reverse breakdown of emitter-to-base transition capacitance has been increased from 41 pF to 47 pF.

Keywords: BJT; Temperature; Performance; Static and dynamic characteristics

1 INTRODUCTION

The global demand for high stability integrated circuits with environmental sensors was increased in modern electronic devices in a wide range of applications. From the first transistors to the modern complicated integrated circuits, semiconductor parts play an essential role in such diverse fields as for information technology, electronic communications, medical and energy [1].

Major changes in the design of electronic components starting in the 1970s have resulted in the design and fabrication of highly complex, integrated, high-powered devices [2]. Much effort has been made by the researchers to develop new building alloys to enhance the lifetime of semiconductor components [3]. Since the majority of semiconductor components operate together in an electronic circuit, there is excessive heat generated. Such heat or retained heat can cause damage or decrease the capacity of the system [4]. However, thermal heat is at all times represent a hazard to semiconductors. Often, coolers and blowers were very often the first defense used against extreme heat and humidity [5]. A lot of industries require an electrical utility that can hold up well to challenging conditions and temperatures. Professionals typically propose devices to measure temperature, investigate motor temperature variations, and to ensure that the system is operating properly while keeping its performance unchanged [6].

Although many of our electronic equipment can withstand high temperatures, the operating systems are unable to withstand impacts and vibrations. The amount of heat treatment time is defined by the heat treatment processing unit [7]. All the products have to be stable to be dependable. However, their design is limited and cannot withstand high temperatures [8].

In the present time, in which nuclear technology, space technology and satellite industry play an essential role, the need for the use of high-temperature solid-state components has considerably increased. A lot of studies have been conducted to solve this important necessity. Bipolar junction transistors (BJT) have proved to be suitable candidates for such applications thanks to their utility in a variety of circuits [9]. As the NPN transistor is a component of modern electronics, a particular attention has been given to the analyzing the emitter-base connection of the silicon NPN transistor [10]. It is essential to fully understand the silicon-based BJT parameters under thermal conditions [11].

The performance of BJT at higher temperatures has been closely studied in a lot of literatures, it is obvious that the researchers are focusing on the material properties analysis under overloading and under electrostatic charging. Others are to optimize, design optimization, dynamic and steady-state behavior, and non-linear behavior.

Kozmic et al. [13] have proposed a new HEMT electrical thermal characterization method. By combining this method with an interferometry mapping (TIM) approach, a baseline understanding of the temperature distribution over time in HEMTs is obtained. Following pulse initiation, the heating time is held constant at 200 ns and the heat resistance of the AlGaN/GaN/Si HEMT is 70 K/W for 400 ns [14].

Gutierrez et al [15], investigated the influence of thermal looping on the electrical breakdown. By using high ambient temperature to manage the heating performance of the electrical equipment. characterizing and analyzing thermal data for failure modes and damage mechanisms of the electrical systems [16]. The characteristics of tunnel field-effect transistor (TFET) under high voltage and discharge current were studied and analyzed by using numerical simulation. The influence of surrounding temperature, variation of rising and falling times, and the power system conditions on the operational and non-operational voltages were considered. The simulation results indicate that TFET perform better than the isolated diodes in the protection of the complete chip circuit [17].

The physical properties of the semiconductor materials can be changed by the temperature. The thermal characteristics of the transistors must be taking into account during the design process for a particular application. The present paper investigates the BJT performance under temperature degree fluctuations.

2 METHOD

In the present study, electric performance of 2SC2120 (BJT) at different temperatures (30, 45, 75 and 90 °C) have been tested. This investigation was conducted in the electrical lab using Tektronix 370A line monitor and RCL Fluke PM6306 for precise measurements on variety of products. Figure 1 presents the schematic of bipolar junction transistor [18]. Table 1 presents the main characteristics of 2SC2120 transistor.

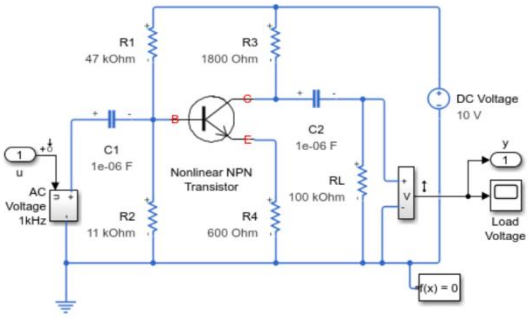

Figure 1 Nonlinear BJT circuit [18]

Table 1 The basic parameters of the 2SC2120 transistor being tested [20-23]

Parameter	Value
Power Dissipation of collector	0.60 Watt
Collector-Base Voltage	30.4 Volt
Voltage of Collector-Emitter	32 Volt
Voltage of Emitter-Base	5.4 Volt
Junction Temp.	153 °C
Current Transfer Ratio (h_{FE})	11

3 RESULTS AND DISCUSSION

The obtained results are listed in Tables 2 and 3 and the graphical representation is shown in figures 2-8. The measurements of collector current depending on the collector voltage V_{CE} and emitter supply voltage for transistor under testing for various temperatures with I_B baseline value being 1 mA is shown in Table 2. A graph of the results is presented in Figure 2.

Table 2 Collector current at testing temperature

	Collector current, Ic(A)			
VCE (V)	30 OC	45 OC	75 OC	90 OC
1	0.135	0.45	0.62	0.84
2	0.136	0.46	0.63	0.85
4	0.141	0.48	0.66	0.91
6	0.143	0.49	0.75	0.99
8	0.150	0.51	0.78	1.03

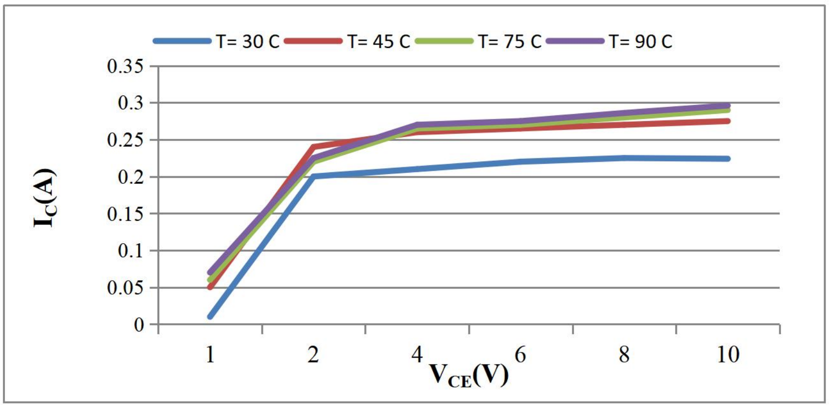

Figure 2 Collector current at rising temperature degrees.

It can be seen from Figure 2 that there is a rise in IC with increasing temperature. At $V_{CE} = 2$ V (measured at 90 °C), the value is 1.0 A compared to 0.18 A (measured at 30 °C).

The bipolar junction transistor currents under different temperatures may be calculated as follows [2].

$$R_{out} = \frac{\Delta V_{CE}}{\Delta I_C} \tag{1}$$

ΔV_{CE}: change of collector-emitter voltage, ΔIC indicates change of collector current. The changes in the transition resistance value is illustrated in Figure 3.

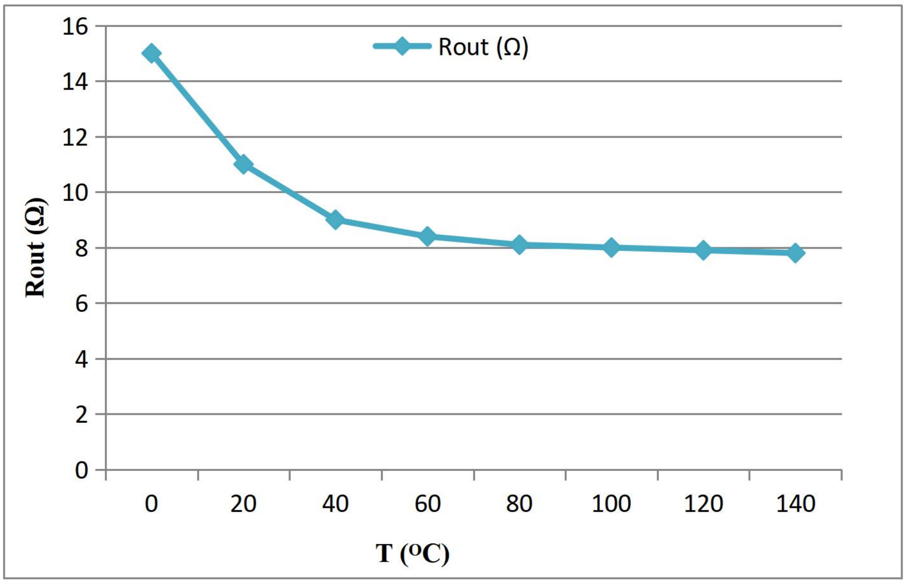

Figure 3 Transition output resistance values under temperature degrees fluctuations

However, Figure 3 demonstrates the capacitance value dropping from 15Ω at 30 °C to 8.54Ω at 90 °C. This indicates that an increasing in temperature will affect the transistor output resistance of the tested transistor.

The DC gain of h_{FE} can be calculated using equation (2) The plot shows the increment of DC gain of H_{FE} versus temperature [24].

$$h_{FE} = \frac{\Delta I_C}{\Delta I_B} \tag{2}$$

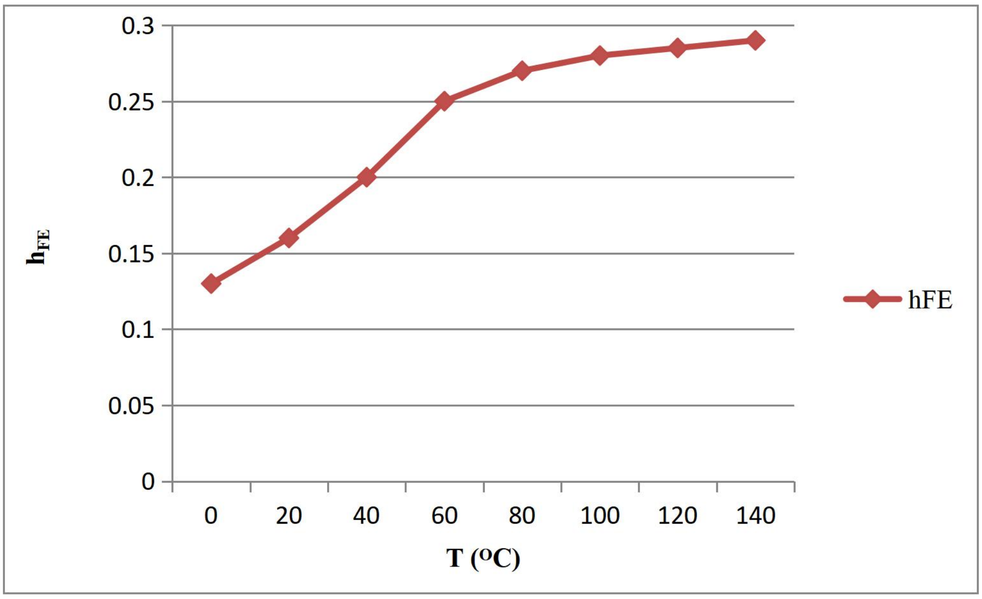

Figure 4 Current gain h_{FE} value due to temperature degrees fluctuations

Figure 4 gives an indication of the increase in h_{FE} going from 0.13 (at 20 °C) to 0.23 (at 125 °C). This indicates that when the supply current increases as a consequence of temperature, then the h_{FE} value also increases.

The taken at room temperature can be obtained by the following formula [26]:

$$V_{Th}(T) = V_{Th}(0) - AT \tag{3}$$

$V_{Th}(T)$ and $V_{Th}(0)$ are the initial voltages recorded at room temperature, respectively. Figure 5 illustrates the change of threshold voltage V_{Th} as a functions of the temperature.

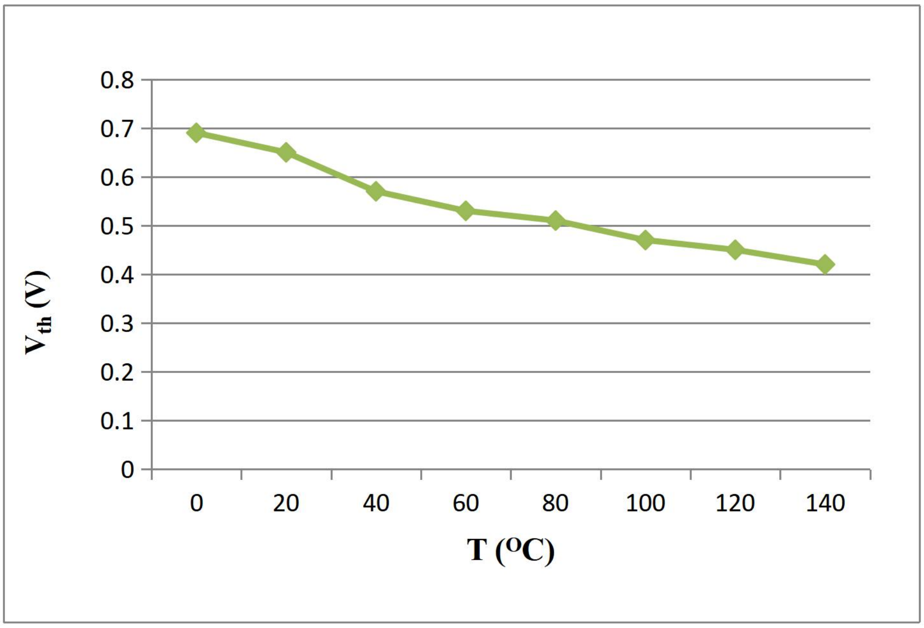

Figure 5 The threshold voltage drop with temperature rising

From Figure 5, it can be noted that the magnitude of V_{Th} drops from 0.66 V to 0.41 V with temperature increase. This causes the electrons within the valence band to be excited and migrate to the conduction band, resulting in a larger current.

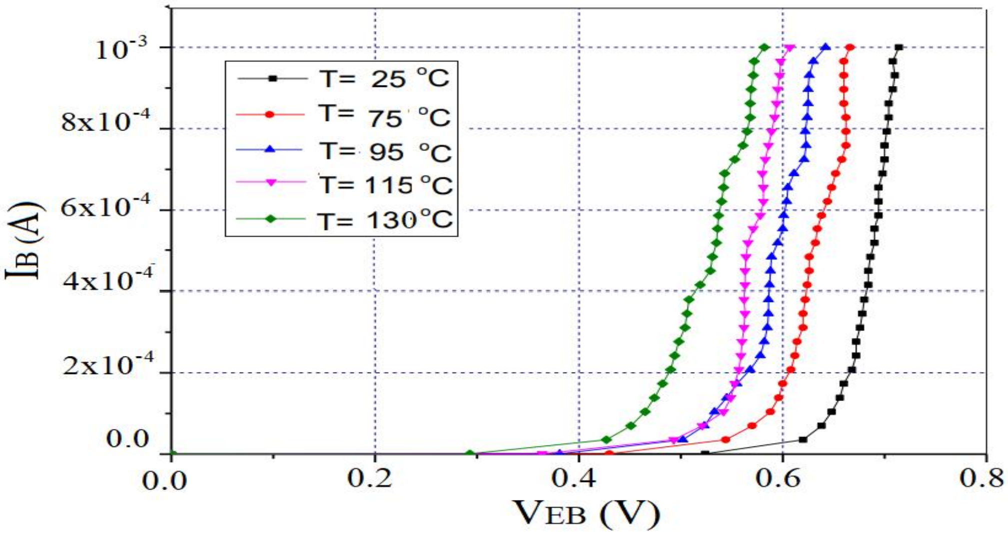

Figure 6 I_B-V_{BE} value changing at temperature rising

Figure 6 indicates that as V_{EB} is greater than 0.5 V, current of the base will increase with increasing temperature. This suggests that the current through the base is influenced by the temperature rise.

Table 3 provides a representation of the C_T and C_d Capacitors values. Changes of C_T as a function of the temperature rises (25 °C) is shown in Figure 7, the C_T change is given in Figure 8.

Table 3 C_T and C_d Capacitors changing values

Capacitance (nF)	Collector - base				Emitter - base			
Temp. (°C)	30	45	75	90	30	45	75	90
C_T (nF)	178	35	49	54	61	12	3	8
C_d (nF)	24	34	44	57	68	16	10	7

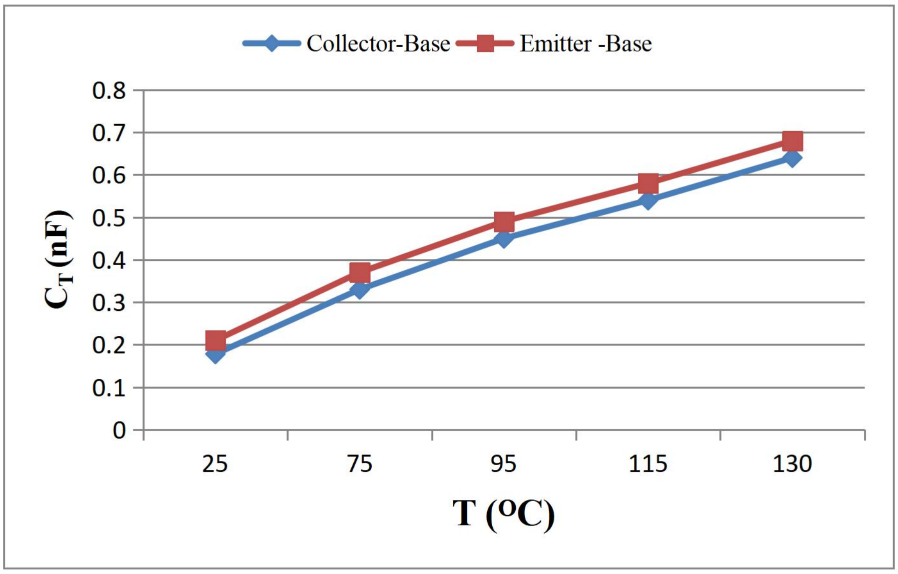

Figure 7 The (C_T) values as a function of the temperature change

Figure 7 illustrates that C_T gradually rises from 0.22 nF to 0.68 nF and Cd from 0.179 nF to 0.69 nF. This means that the C_d value is influenced by the increasing of temperature.

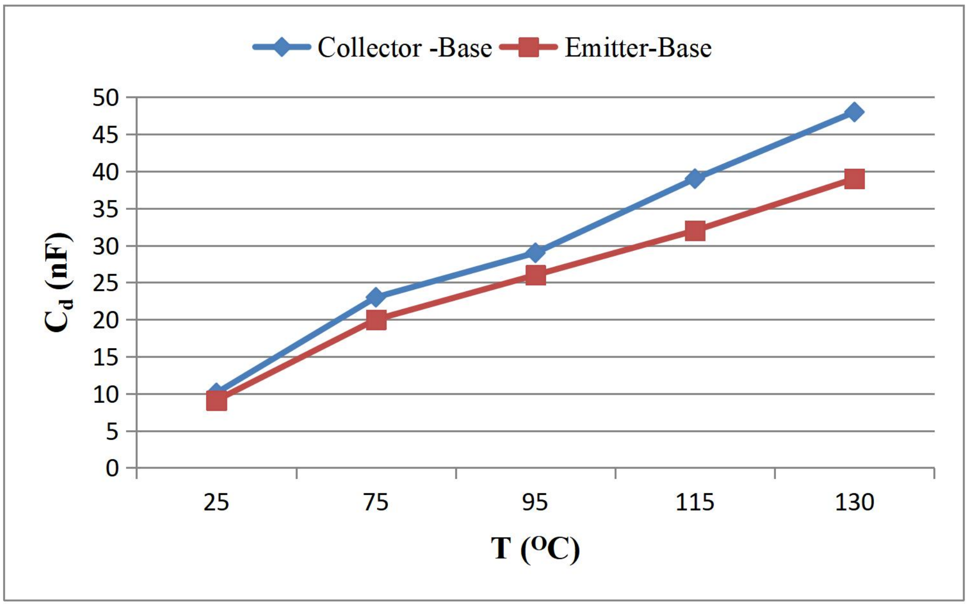

Figure 8 C_d value as a result of temperature rising.

4 CONCLUSION

The high development of the electronics industry nowadays has resulted in the emergence of a higher number of high temperature and high cool electronic products, such as facilities for heat monitoring or controlling many associated processes. Such devices may involve high-temperature facilities as well as nuclear power reactors used to produce nuclear energy. These application and facilities requires steady operation under high temperatures, need air conditioning for temperature reduction, and add to size and cost. One solution to these challenges is through the use of silicon carbide electronic devices. In this paper, the influence of the high temperature on the BJT- 2SC2120 performance has been experimentally investigated and analyzed. on some parameters of a bipolar junction transistor type 2SC2120 at high temperatures. The experimental results indicate that in case of an increase in temperature over the range 30-90 °C, a collector current has been increased by about 0.045 A, whereas the current raised for 0.122 A. The applied threshold voltage has been decreased from 0.65 V to 0.47 V. The obtained results also illustrate that the reverse breakdown of emitter-to-base transition capacitance has been increased from 40 pF to 46 pF. From the obtained results, it can be conclude that the rising of temperature will results in some changes in the transistor parameters such as output current, output voltage and output resistance.

COMPETING INTERESTS

The authors have no relevant financial or non-financial interests to disclose.

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