FORM - 2

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COMPLETE SPECIFICATION

(Section 10; rule 13)

The Impact of Temperatures on the Functioning of A Group of Semiconductor Components

Dr.K. Prathap, Professor / Department of H&S, **Malla Reddy Institute of Engineering & Technology.**	**Malla Reddy Institute of Engineering & Technology, Maisammaguda, Secunderabad, Hyderabad, Telangana-500100.**
Dr.R.Balaji, Associate Professor / Department of Physics, **Vignan Institute of Technology and Science.**	**Vignan Institute of Technology and Science, Deshmuki Village, Yadadri, Bhuvanagiri, Telangana-508284.**
Dr.Nagaveni Sangisetti, Associate Professor in Physics / Department of H&S, **Guru Nanak Institute of Technology (Autonomous).**	**Guru Nanak Institute of Technology (Autonomous), Ibrahimpatnam, R. R. Dist, Telangana-501506.**
Grandhe.Radhika, Assistant Professor in Physics / Department of H&S, **Malla Reddy College of Engineering.**	**Malla Reddy College of Engineering, Maisammaguda, Dhulapally, Hyderabad, Telangana-500100.**
Dr.Ch.Kanchana Latha, Associate Professor in Physics / Department of Physics, **Government Degree College for Women (A).**	**Government Degree College for Women (A), Begumpet, Hyderabad, Telangana-500016.**
K.Vamshi Babu, Assistant Professor in Physics / Department of H&S, **Guru Nanak Institute of Technology (Autonomous).**	**Guru Nanak Institute of Technology (Autonomous), Ibrahimpatnam, R. R. Dist, Telangana-501506.**
Kesava Vamsi Krishna Vajjala, Associate Professor in Physics**, Malla Reddy Engineering College.**	**Malla Reddy Engineering College, Maisammaguda, Secunderabad, Hyderabad, Telangana-500100.**
Dr.Rekharani Maddula, Assistant Professor in Physics, **Gokaraju Lailavathi Womens Engineering College.**	**Gokaraju Lailavathi Womens Engineering College, Bachupally, Kukatpally, Hyderabad, Telangana-500090.**

The following specification particularly describes the invention and the way it is to be performed:

The Impact of Temperatures on the Functioning of A Group of Semiconductor Components

Field and Background of the Invention

A wide variety of semiconductor devices, such as diodes, bipolar semiconductors, and even unipolar transistors, are used in electronic channels. As a result of thermal processes including self-heating as well as mutual thermal connections, the internal temperature Tj among these electronics rises as a consequence of the electrical energy expended within them during operation. For the sake of this discussion, the temperature Tj refers to the operating point of a semiconductor device. The geographic locations of their optimal functioning points shift as Tj rises. The experimental and theoretical findings demonstrate how thermal processes affect the characteristics of certain transistors and electronic networks with these transistors. The researchers' small electro-thermal models written specifically for the SPICE programme are used for the computations. This study states and discusses the impact of temperature conditions on the non-isothermal DC properties of power BJTs, and IGBTs, including power components. The unusual (not as depicted in the catalogue) nature of such properties and the potential for destruction of such devices while they are operating within the safe working area are discussed. The non-isothermal DC or even dynamic features of some electrical networks are calculated just using the same models. We looked into transistor switching, differential amplifiers, and parallel circuits between two transistor networks. The effect of transistor self-heating including thermal couplings among devices is explored and discussed. Many scenarios where semiconductor devices in these networks could be damaged are presented and analyzed. In addition, it is demonstrated that reciprocal thermal couplings could serve as a form of network defence in certain circumstances. However, it is demonstrated that with extensive use of the networks under consideration, the operational point might shift significantly. It is proposed that these networks be shielded and that thermal couplings be used to maintain a constant temperature at their nodes to ensure their reliability.

It wasn't until the early 1970s that the first tiny electro-thermal models of semiconductor devices appeared in print. The models were written in the form of a set of equations that described, among other things:

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- how much electricity is lost as heat inside the gadget

Summary of the Invention

The non-isothermal DC properties of certain types of these transistors have been determined using the miniature electro thermal BJTs as well as IGBT models reported in this work. Comparisons between the calculated and measured outcomes are shown in the accompanying figures. Employing an APPA 210 digital multi-meter and the traditional indirect measurement technique, we determined the current and voltage readings at the locations with non-isothermal features. When a stable temperature was reached, the measurements were recorded. There was a single measurement taken of everything. So, from now on, we will employ only type B evaluations of uncertainty. Following the manufacturer's specifications, the measured values have a relative error of less than 0.2% for current flow and less than 0.06% for voltages. After that, a Keighley 2617A source metre was used to take pulse measurements of isothermal properties. Our measurements showed a precision of less than 0.06% for current flow and 0.03% for voltage. This figure shows the resulting parameters of a 2N3055 capacity BJT at various amounts of base voltage iB and a constant resistance temperature detector T_a = 32 C. In this diagram, the dots represent data from measurements, the straight lines represent electro thermal studies, and the dashed lines represent isothermal calculations. The standard error for voltage measurements is less than 0.25 V, and the standard error for current measurements is less than 18 mA. The error bars are not visible because the standard uncertainties are so small. The devices in the investigated networks' electro-thermal simulations were used for the electro thermal studies, while the isothermal models were used for the isothermal analysis. The electro thermal studies corroborate the experimental findings. There is no mathematical function that can be applied to the non-isothermal features. They clearly show where the electro-thermal disintegration occurs. As the power dissipated by the other parts of the module rises, the voltage VCE1, over which the electro thermal breakdown occurs, drops. As the power dissipated by the rest of the module rises, the amount of the series resistance of the transistor under study also rises as a function of time and temperature processes. It's also important to note that the same amount of power dissipated in transistor T2 has a larger effect on the behaviour of semiconductor T1's characteristic IC1 than it does in diode D2. It is also demonstrated that significant changes in component temperature correspond with changes in the shape of feature IC1. Because of the thermal interactions between its constituent parts, the temperature of the entire module can increase by as much as 100 °C.

Brief description of the system

It's interesting to note that the VCE waveform stabilizes two hours after the transistor gate voltage is turned on. This is when the ambient temperature of the probed transistor goes from 23 to 110 degrees Celsius. The threshold potential of the transistor drops as its temperature rises, leading to a higher collector current value. Finally, the voltage VCE drops. After 6 seconds of the power being on, the transistor turns on when the resistance RC is 11.3 and the casing temperature is over 150 C in stable condition. The time required to reach a steady state grows linearly with the resistance RC, reaching 7500 s for very high RC values. As the amount of power wasted in the IGBT decreases, the load line's slope also decreases, leading to this improvement. In contrast, if the VCC voltage is significantly higher than the electro thermal breakdown voltage, the semiconductor would reach a steady state within around 10 minutes of being powered on. After roughly 6700 seconds from the time the power is turned on, both the collector voltage of the IC and the circuit temperature begin to fluctuate significantly. This increase in collector current is due to thermal inertia in the BJT, which reaches a steady state at the specified period. Using the load line in Figure 8b and the ambient temperature Ta = 30 C, we can see that the BJT exhibits DC non-isothermal output characteristics with vBE = 0.63 V (blue solid line). In the absence of a thermally steady state at the electro-thermal failure point, the functioning point shifts to point B in the lower collector-emitter voltage zone, and this phenomenon is known as the electro thermal break. The dotted lines represent the non-isothermal DC behaviour between $Ta_1 = 25^0C$ and $Ta_2 = 35^0C$. As can be observed, an increase in the average temperature has the same impact. It is significant to note that the heat dissipation at location A is roughly 50 °C. However, the junction temperature at this point, among other things, determines whether this switching effect causes functional or catastrophic failure. It is assumed that at equilibrium temperature, the connection surface temperature T_j is 84^0C. The difference between the observed and calculated values of this transistor after powering it on is as large as 10% due to the disparity between the tested and computed electrical characterization of the BJT inside the range of extreme values of IC voltage.

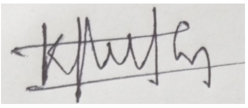
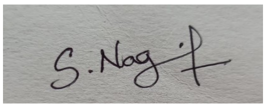
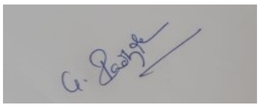
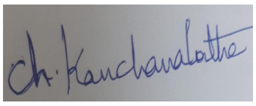
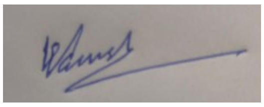
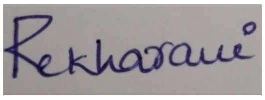
The problems of delayed switching on the semiconductor transition owing to heat phenomena have been illustrated by the instances that have been presented up until this point. The following subsection of this Section discusses the issue of heat phenomena and the electrical persistence of the BJT affecting the off operation of such a switching. In our modelling tests, we used the following criteria for the network parameters shown in Figure: A continuous pulse of 5 V from the supply voltage V_{gg} has a period of t_D = 30 s and a value of V_{gg} = 20 V, having V_{CC} = 50 and R_C = 10 k. For the sake of brevity, it was assumed that the transistor thermal concept has a single thermal constant value, t_{he} = 10 s. Analyses were carried out with a variety of R_{th} thermal equivalent resistances. It has been demonstrated that if Rth is less than 140 K/W, the BJT is defective. Longer times off-state are required for higher R_{TH} values. For higher R_{TH} levels, the junction temperature increases to the point where the device fails before turning off. The junction temperature of the BJT has reached an unacceptable level at R_{th} = 200 K/W, indicating that the BJT has reached a thermally stable state. The numbers point to two factors that are responsible for this conundrum. To begin, the current from the backwards-biased collector junction can be used to create a forward bias at the transmitter junction. As long as the value of resistance RB is significant enough, the temperature-dependent reverse current can enable the emission voltage drop to be large enough to allow the BJT to operate in the forward positive cycle. Second, even after the input pulse has stopped, the current must continue to flow through the transistor junctions due to the voltage drop across them. The risk of malfunctioning, which in the investigated circuit stands for just a transistor remaining on, is only visible in the electro thermal concept where elements modelling electrical inertia (C > 0) are present. This indicates that the time required for the instrument's internal temperature to rise to a point where the current flowing from the base of the transistor is strong enough to polarise the base-emitter junction from the forward mode can be prolonged employing electromagnetic capacitances. To maximize current efficiency, many power systems connect semiconductors in parallel. This subsection examines the issue of thermal phenomena' impact on the functioning of such a system with BJTs as its main components. This is a picture of the system that was studied. The source voltage throughout this network is 25 V, while the values for R_C and R_B are 100 and 5 k, respectively. It can be seen that, when operating at room temperature, the collector currents from both transistors are equal, and their nonlinearities on voltage V_{CE} are steadily increasing over time. However, it is apparent that the voltage V_{CE} rises, and the disparity here between the collector current flows of the two transistors (i_{C1} and i_{C2}) also rises, indicating that imperfect cooling and the lack of reciprocal thermal couplings are to blame. As the collection voltage VCE rises, the collector current through the higher thermal resistance transistor T_1 grows, while the collector current through the other transistor diminishes. At a voltage V_{CE} = 8 V, when the current i_{C2} is nearly zero, the self-heating threshold of transistor T_1 is reached. Even when considering the mutual thermal connections between transistors, the variation in collector currents cannot exceed 80%. In this scenario, both transistors have a similar $i_{C\ (VCE)}$ connection shape.

We Claim

1. A variation in the output slope of the considered transistors is indicative of an electro thermal breakdown, as shown by these features. The breakdown voltage indicated by the manufacturer is often significantly higher than the transistor output voltage at which this phenomenon is observable.
2. However, in IGBTs, this phenomenon is already detected at a core temperature of approximately 60^0 C, whereas in BJTs working with the management of constant current, it happens at an internal temperature above the value that the manufacturer has specified (about 180^0C -200 ^{0}C).
3. The self-heating effect of a signal generator causes its output voltage to have a peak-to-peak frequency. By increasing transistor thermal resistance, its output voltage's form deviates more sharply from the input voltage's curve. Whenever the thermal interactions between transistors in this circuit are considered, we can say that perhaps the output voltage follows the same pattern as the input voltage.
4. The analyses found in this research show that heat events can have a major impact on the properties of the semiconductor devices and electronic networks under consideration. In particular, it has been demonstrated that the operational frequency of the transistors in considered circuits may vary as a result of self-heating, causing damage to the transistors.
5. It is also demonstrated that continuous thermal couplings, which permit the minimization of temperature differences within these transistors, seem to be crucial for the proper operation of the examined circuits involving two transistors. If certain couplings are not guaranteed, the networks will not function as intended. Analog and switching design engineers may find the offered inquiry results and conclusions useful.

Abstract

The research outlines the results of an investigation into the effect of thermal phenomena, including self-heating throughout semiconductor materials and mutual thermal connectors between them, on the performance characteristics of certain electronic networks that make use of bipolar transistors (BJTs). To determine the non-isothermal DC as well as the dynamic properties of the transistors and specified networks utilizing transistors. The researchers utilized tiny electro-thermal models that have been developed independently. The measurement findings are compared to those chosen to define them. The current waveforms inside the investigated networks are determined after considering thermal phenomena. Discrepancies between the calculated and measured values, as well as the calculated results obtained without thermal phenomena, are highlighted. In particular, we focus on cooling situations when the considered networks are vulnerable to thermal phenomena and need to be protected.

			
Dr.K. Prathap	**Dr.R.Balaji**	**Dr.Nagaveni Sangisetti**	**Grandhe.Radhika**
			
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