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Power Dissipation Analysis of UBCT Cascode Amplifier Circuit

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Abstract - The Unipolar-Bipolar Composite Transistor (UBCT) cascode amplifier circuit is designed to combine the advantages of UBCT common-source amplifier and BJT common-base amplifier to maintain high voltage gain in higher range of frequencies by minimizing the input miller capacitance. For satisfactory operation of the UBCT cascode amplifier circuit, a particular range of supply voltage is taken into consideration for experimental observations with the optimized circuit components. As the supply voltage is increased, the corresponding total power dissipation in the circuit also increases due to rise in power dissipation in individual circuit components. In this paper, the power dissipation in the circuit components of UBCT cascode amplifier and the variation in voltage gain with corresponding total power dissipation are precisely analyzed on the basis of experimental observations.

Keywords – UBCT, UBCT Amplifier, UBCT Cascode Amplifier, Wideband Amplifier, High Gain Amplifier

I. INTRODUCTION

The Unipolar-Bipolar Composite Transistor (UBCT) is a circuit combination of unipolar transistor JFET and bipolar transistor BJT, which offers high input resistance and linear transfer characteristics [1]. An experimental circuit of a typical UBCT is designed with n-channel JFET (BFW10), npn BJT (CL100) and source-emitter resistor pair (R_S-R_E) (100Ω-10Ω), which exhibits improved static and dynamic characteristics in comparison with JFET [2]. Due to these characteristic enhancements, the UBCT is found suitable in designing amplifier circuits [3]. On the basis of experimental analysis, the best performance is achieved by a typical UBCT having JFET (BFW10), BJT (CL100) and source-emitter resistor pair (R_S-R_E) (100Ω-10Ω) as common-source amplifier at the supply voltage of 18V [4] with maximum voltage gain to power ratio of 0.066dB/mW [5]. The UBCT amplifier achieves mid-band voltage gain of 13.77dB with frequency bandwidth of 1MHz [6]. For obtaining much wider frequency bandwidth, the UBCT cascode amplifier circuit is designed with a UBCT common-source (CS) amplifier directly coupled to a BJT common-base (CB) amplifier. The circuit components of UBCT cascode amplifier are optimized on the basis of experimental observations to achieve maximum voltage gain with negative feedback [7]. The UBCT cascode amplifier having optimized circuit components offers frequency bandwidth of 3.3MHz along with mid-band voltage gain with negative feedback of 14.04dB [8] and gain roll-off rate of -26dB/decade [9] for the supply voltage of 18V.

For satisfactory operation of the UBCT cascode amplifier circuit, a particular range of supply voltage is taken into consideration for experimental observations with the optimized circuit components. As the supply voltage is increased, the corresponding total power dissipation in the circuit also increases due to rise in power dissipation in individual circuit components. In this paper, the power dissipation in the circuit components of UBCT cascode amplifier (e.g. load resistor, BJT, UBCT, source feedback resistor, BJT biasing resistor pair and gate resistor) and the variation in voltage gain with corresponding total power dissipation in the circuit are precisely analyzed on the basis of experimental observations.

II. UBCT CASCODE AMPLIFIER CIRCUIT

The UBCT cascode amplifier is a two-stage amplifier circuit in which a UBCT CS amplifier at input stage is directly coupled to a BJT CB amplifier at output stage. The UBCT CS amplifier circuit is connected in self-biased topology and the BJT CB amplifier circuit in voltage-divider biased topology to provide better stability [10]. In the UBCT cascode amplifier circuit, the UBCT CS input stage offers low voltage gain to reduce the input miller capacitance. As a result, the operating frequency bandwidth is expanded into higher frequency region by minimizing the input miller capacitance. Also, the overall voltage gain of UBCT cascode amplifier remains high because the BJT CB output stage offers high voltage gain [11]. Therefore, the UBCT cascode amplifier circuit is designed to combine the advantages of UBCT CS amplifier and BJT CB amplifier to

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achieve wide frequency bandwidth along with high voltage gain [12].

As depicted in fig.1, the circuit of UBCT cascode amplifier is designed with optimized value of circuit components using UBCT [having JFET (BFW10), BJT (CL100) & source-emitter resistor pair (R_S-R_E) (100Ω-10Ω)], an additional BJT (CL100), load resistor R_L=1kΩ, source feedback resistor R_{SF}=100Ω, gate resistor R_G=1MΩ, BJT biasing resistor pair (R_1-R_2) (4.7kΩ-10kΩ), input & output coupling capacitors C_{IC}=C_{OC}=10µF, base bypass capacitor C_{BB}=10µF and source bypass capacitor in no-connection mode (C_{SB}=N/C) to obtain voltage gain with negative feedback [13]. The optimized performance of the UBCT cascode amplifier circuit is achieved for supply voltage in the range of 18V to 21V with corresponding small variation in voltage gain with negative feedback from 14.07dB to 14.80dB [14].

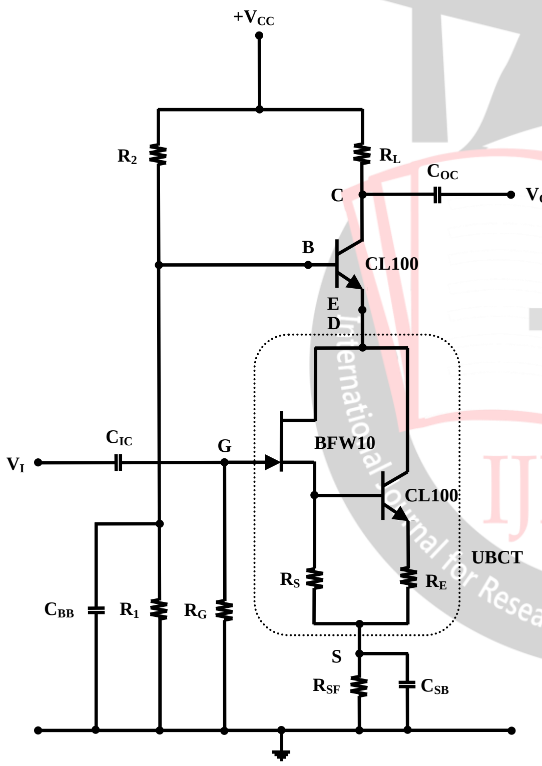

Fig.1. Circuit Diagram of UBCT Cascode Amplifier

III. POWER DISSIPATION ANALYSIS

In the power dissipation analysis of UBCT cascode amplifier circuit, the experimental observations are obtained by measuring DC voltage across individual circuit component and the corresponding DC current to obtain DC power dissipation for the supply voltage ranging from 9V to 21V. An input signal ac voltage (sine wave) of 100mV(p-p) having a frequency of 1kHz is applied to the UBCT cascode amplifier circuit and the corresponding ac output voltage is measured to obtain voltage gain for the normal operating temperature range of 30°C to 33°C.

The fig.2 depicts the total power dissipation in the UBCT cascode amplifier circuit for a particular range of supply voltage. For increase in supply voltage from 9V to 21V, the power dissipation increases almost linearly from 52.67mW to 260.90mW.

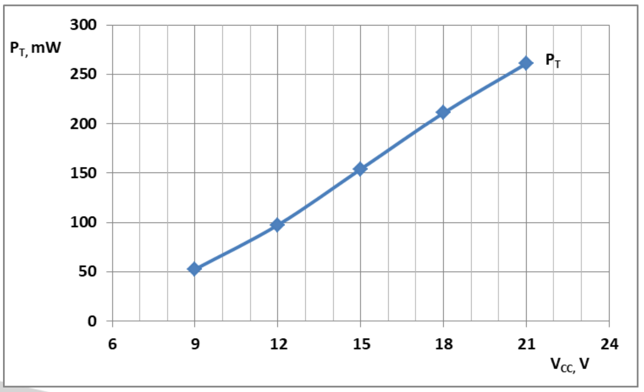

Fig.2. Total Power Dissipation (P_T) in the UBCT Cascode Amplifier Circuit versus Supply Voltage (V_{CC})

The fig.3 depicts the power dissipation in the load resistor and source feedback resistor of the UBCT cascode amplifier circuit for total power dissipation ranging from 52.67mW to 260.90mW. In this particular range of total power dissipation in the circuit, the power dissipation in the load resistor increases from 27.25mW to 120.12mW in which linear property is shown up to about 200mW and then it tends to saturate for higher power dissipation level. Approximately the similar curve nature is obtained for the power dissipation in the source feedback resistor, which increases from 2.92mW to 12.54mW.

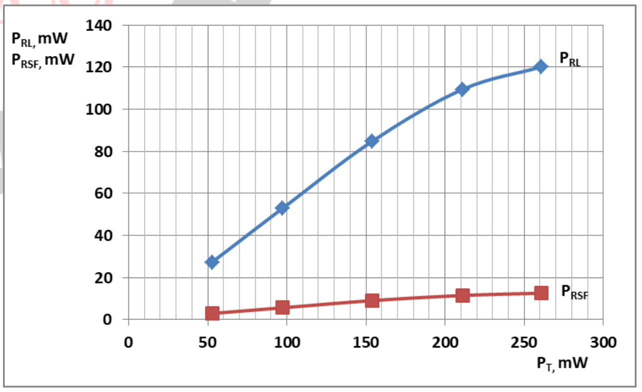

Fig.3. Power Dissipation in Resistor R_L and R_{SF} (P_{RL} and P_{RSF}) versus Total Power Dissipation (P_T) in the UBCT Cascode Amplifier Circuit

As depicted in fig.4, for variation in the total power dissipation from 52.67mW to 260.90mW, the power dissipation in the UBCT increases from 8.11mW to 51.19mW and the corresponding power dissipation in BJT increases from 8.87mW to 47.02mW. In this particular experimental range, the power dissipation curve for UBCT is approximately linear, whereas the corresponding power dissipation curve for BJT is non-linear in nature.

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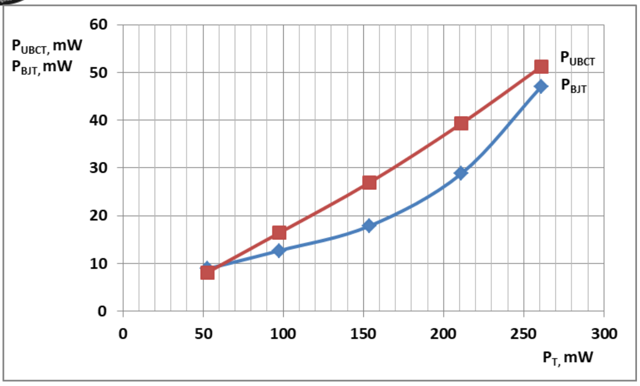

Fig.4. Power Dissipation in UBCT and BJT (P_{UBCT} and P_{BJT}) versus Total Power Dissipation (P_T) in the UBCT Cascode Amplifier Circuit

In the fig. 5, it is shown that by increasing total power dissipation in the range of 52.67mW to 260.90mW, an increment in power dissipation in BJT biasing resistor R_2 ranging from 3.94mW to 21.29mW is observed along with corresponding increment in power dissipation in resistor R_1 ranging from 1.57mW to 8.74mW. The power dissipation curves for both resistors R_2 and R_1 exhibit similar nature.

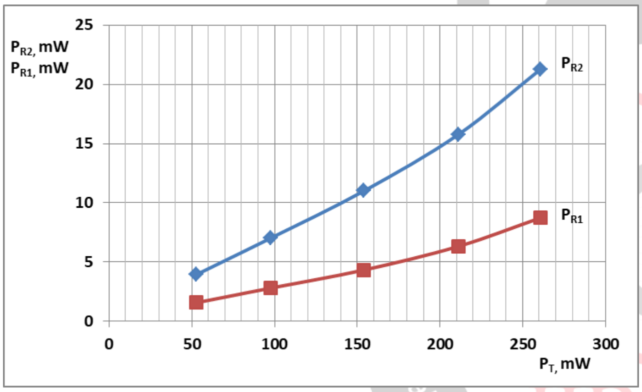

Fig.5. Power Dissipation in BJT Biasing Resistor R_2 and R_1 (P_{R2} and P_{R1}) versus Total Power Dissipation (P_T) in the UBCT Cascode Amplifier Circuit

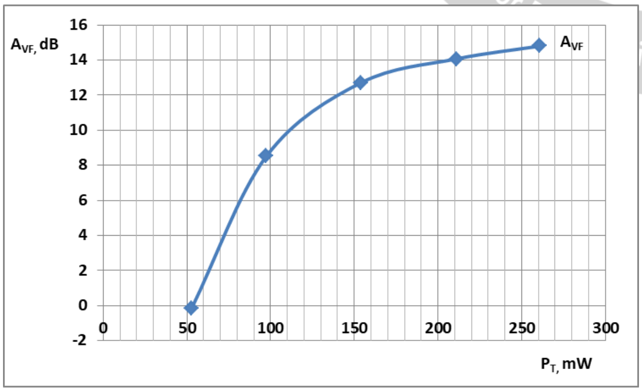

Fig.6. Voltage Gain with Negative Feedback (A_{VF}) versus Total Power Dissipation (P_T) in the UBCT Cascode Amplifier Circuit

As depicted in fig.6, for variation in the total power dissipation from 52.67mW to 260.90mW, the voltage gain with negative feedback of the UBCT cascode amplifier increases from -0.18dB to 14.80dB. The voltage gain with negative feedback is increased sharply from -0.18dB to 12.71dB by increasing total power dissipation from 52.67mW to 154.02mW. For larger value of total power dissipation ranging from 210.96mW to 260.90mW, the corresponding voltage gain with negative feedback increases gradually with a little variation from 14.07dB to 14.80dB.

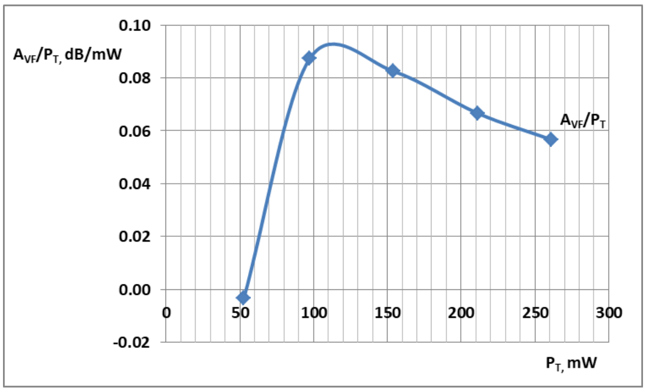

Fig.7. Voltage Gain with Negative Feedback to Total Power Dissipation Ratio (A_{VF} / P_T) versus Total Power Dissipation (P_T) in the UBCT Cascode Amplifier Circuit

The fig.7 shows that for variation in the total power dissipation in the circuit from 52.67mW to 97.48mW, the voltage gain to power dissipation ratio initially increases sharply from -0.003dB/mW to 0.087dB/mW and then decreases up to 0.057dB/mW for further increment in total power dissipation of 260.90mW. It is observed that the voltage gain with negative feedback to total power dissipation ratio attains its optimized value of 0.087dB/mW and 0.083dB/mW for corresponding total power dissipation of 97.48mW and 154.02mW respectively.

The power dissipation in the gate resistor (P_{RG}) is often assumed to be zero because the gate terminal is in the virtual ground condition (having approximately zero voltage) due to very high input resistance of UBCT associated with the corresponding very small gate current. Also, because of large value consideration for gate resistor R_G, the corresponding gate resistor current becomes almost zero. Thus the power dissipation in the gate resistor is found negligible in comparison with other circuit components of the UBCT cascode amplifier.

IV. CONCLUSION

In the power dissipation analysis of UBCT cascode amplifier circuit, for variation in supply voltage from 9V to 21V, the total power dissipation increases from 52.67mW to 260.90mW in association with different curve of increment for individual circuit components. In this particular range of total power dissipation, the voltage gain with negative feedback is varied from -0.18dB to 14.80dB. For total power dissipation of 210.96mW and 260.90mW, the UBCT cascode amplifier provides satisfactory voltage gain with negative feedback of 14.07dB and 14.80dB respectively. As far as the voltage gain with negative feedback to total power

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dissipation ratio is concerned, the elevated value of 0.087dB/mW and 0.083dB/mW are achieved for corresponding total power dissipation of 97.48mW and 154.02mW respectively.

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