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Operating-Point Based Performance Analysis of Optimized Circuit for UBCT Cascode Amplifier

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Abstract: **The circuit design of Unipolar-Bipolar Composite Transistor (UBCT) Cascode Amplifier is enriched with the aids of UBCT common-source amplifier and BJT common-base amplifier to preserve high voltage gain even in a limited high frequency range. The experimental analysis based on the optimization of supply voltage reveals that the voltage gain (with negative feedback) of the UBCT cascode amplifier circuit is mostly affected by the performance exhibited by the constituent components of both the UBCT common-source amplifier and BJT common-base amplifier. To elaborate these facts, the present correspondence is devoted to the analysis of the supply voltage and corresponding voltage distribution among various components of UBCT cascode amplifier circuit and these observations have been experimentally analysed for a particular range of supply voltage to obtain the acceptable voltage gain along with the requirements of satisfactory amplification based on the performance related to operating-point of the amplifier circuit.**

Keywords – ***Unipolar-Bipolar Composite Transistor, UBCT Amplifier, UBCT Cascode Amplifier, Operating-Point Analysis, Power Amplifier, Class-A Amplifier***

I. INTRODUCTION

The Unipolar-Bipolar Composite Transistor (UBCT) symbolizes the composite circuit design having a unipolar transistor JFET, a bipolar transistor BJT and a pair of resistors; therefore, it offers high input resistance along with 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, 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 higher 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 the related frequency response is associated with the gain roll-off rate of -26dB/decade for the supply voltage of 18V [9].

II. UBCT CASCODE AMPLIFIER CIRCUIT

The UBCT cascode amplifier circuit is a combination of two amplifier stages in which a UBCT CS transconductance amplifier at input stage is followed by a BJT CB unity gain current 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 in to 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. Therefore, the UBCT cascode amplifier circuit is designed to combine the advantages of UBCT CS amplifier and BJT CB amplifier to achieve wide frequency bandwidth along with satisfactory voltage gain [11].

III. OPTIMIZED CIRCUIT DESIGN

The fig.1 depicts that the circuit of UBCT cascode amplifier is designed with optimized value of circuit components

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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) [12]. The optimized performance of the UBCT cascode amplifier circuit is achieved for the supply voltage of 18V and 21V with corresponding voltage gain (with negative feedback) of 14.07dB and 14.80dB respectively [13], [14], [15]. In power dissipation analysis, it is observed that, for increase in supply voltage from 9V to 21V, the power dissipation increases almost linearly from 52.67mW to 260.90mW and the voltage gain (with negative feedback) of 14.07dB and 14.80dB which are associated with the power dissipation levels of 210.96mW and 260.90mW respectively [16], [17]. Also as far as the voltage gain (with negative feedback) to total power dissipation ratio is concerned, the elevated value of 0.087dB/mW and 0.083dB/mW are achieved at corresponding total power dissipation of 97.48mW and 154.02mW respectively [18].

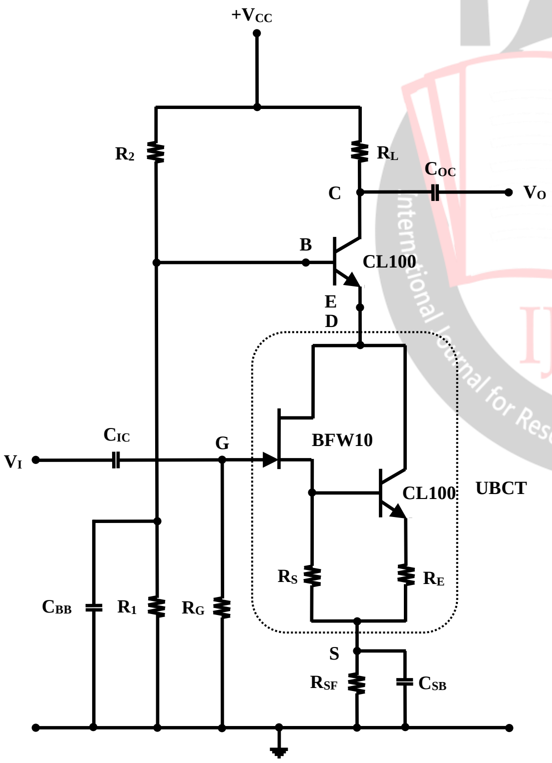

Fig.1. Circuit Diagram of UBCT Cascode Amplifier

IV. EXPERIMENTAL METHODOLOGY

For operating-point based performance analysis 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 voltage distribution among the circuit components also tends to increase. In the present correspondence, the supply voltage and corresponding voltage distribution among various components have been experimentally analysed for a particular range of supply voltage to obtain the acceptable voltage gain along with the requirements of satisfactory amplification based on the operating-point of the amplifier circuit.

In the analysis of UBCT cascode amplifier circuit, the experimental observations are obtained by measuring DC voltage using Multimeter across individual various circuit components for the supply voltage ranging from 9V to 21V being applied by the Power Supply Unit. An input signal ac voltage (sine wave) of 100 mV(p-p) having a frequency of 1kHz (as provided by the Function Generator and observed by the Oscilloscope) is applied to the UBCT cascode amplifier circuit and the corresponding ac output voltage is measured to obtain voltage gain for the operating temperature range of 30°C to 33°C as recorded by the digital thermometer during the period of experiments.

Also at the optimized operating-point conditions, the input signal is increased gradually from 1V(p-p) to about 18V(p-p) ac voltage (sine wave) of having a frequency of 1kHz and then the amplification performance is carefully examined till any distortion in either cycles is being occurred. Therefore, the amplifier operation is precisely limited up to the threshold of occurrence of distorted output signals as observed by the Oscilloscope.

V. PERFORMANCE ANALYSIS

The fig.2 depicts the voltage distribution among load resistor, collector-to-emitter terminal of BJT, drain-to-source terminal of UBCT and source feedback resistor along with voltage gain (with negative feedback) for variation of supply voltage ranging from 9V to 21V. In this range of supply voltage the voltage gain (with negative feedback) increases from -0.18dB to 14.80dB, voltage across load resistor increases from 5.22V to 10.96V and voltage across source feedback resistor increases from 0.54V to 1.12V. Also with increase in supply voltage from 9V to 21V results the increment in collector-to-emitter voltage of BJT from 1.70V to 4.29V and corresponding increase in drain-to-source voltage of UBCT from 1.54V to 4.63V. Therefore, at supply voltage of 18V and 21V, the UBCT cascode amplifier provides satisfactory voltage gain of 14.07dB and 14.80dB respectively.

In the fig. 3, it is shown that for variation in supply voltage from 9V to 18V, the voltage gain and voltage across load resistor increases vastly from -0.18dB to 14.07dB and 5.22V to 10.46V respectively but in between 18V to 21V, the increment in both the parameters are obtained and it is appeared to be nearly saturated. Also, the voltage across

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source feedback resistor shows slow increment in this range of supply voltage.

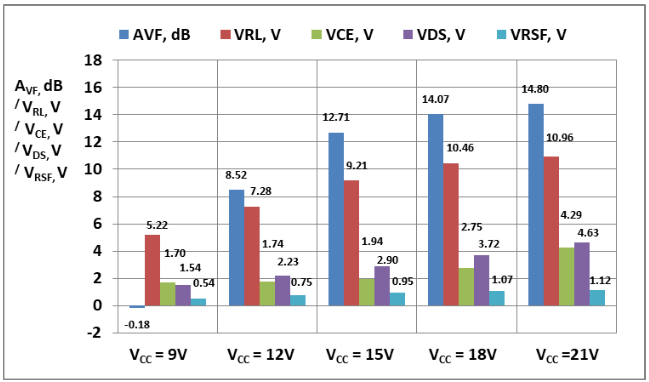

Fig.2. Voltage distribution among various circuit components and Voltage gain (with negative feedback) versus Supply Voltage

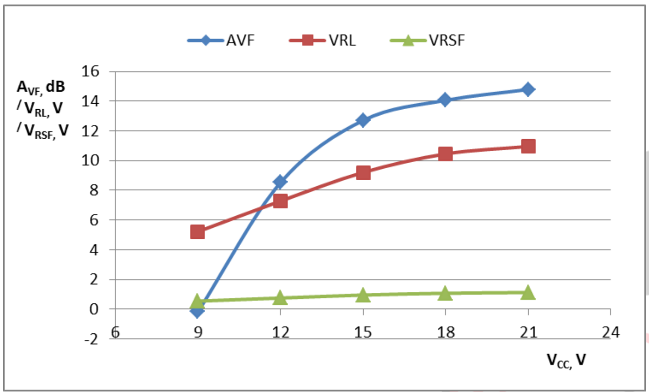

Fig.3. Voltage across Load Resistor, Source Feedback Resistor and Voltage gain (with negative feedback) versus Supply Voltage

The Fig. 4 shows that as the supply voltage increses from 9V to 21V, the collector-to-emitter voltage of BJT and drain-to-source voltage of UBCT both exhibit slow increment from 1.70V to 4.29V and 1.54V to 4.63V respectively, whereas, corresponding voltage gain of the UBCT cascode amplifier circuit shows a large variation in the particular voltage range.

Fig. 5 exhibits the voltage distribution among various circuit components in the relative percentage of supply voltage along with the corresponding voltage gain (with negative feedback) for a paricular range of supply voltage. For increment in supply voltage from 9V to 21V the load resistor voltage holds a large part of 58% to 52% of the total supply voltage, whereas, the source feedback resistor voltage contains a small part of 6% to 5%. The corresponding variation in voltage percentage of collector-to-emitter voltage of BJT and drain-to-source voltage of UBCT are 19% to 21% and 17% to 22% respectively. The range of supply voltage from 9V to 15V is not taken into further consideration because the UBCT cascode amplifier circuit offers low voltage gain in that particular voltage range. Also, it provides good voltage gain (with negative feedback) of 14.07dB and 14.80dB for supply voltage of 18V and 21V respectively.

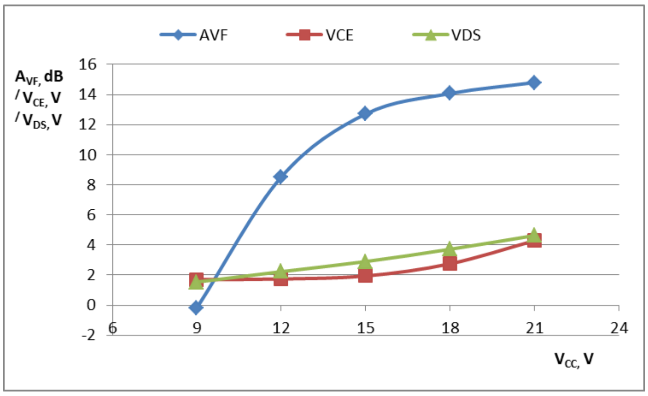

Fig.4. Collector-to-Emitter Voltage of BJT, Drain-to-Source Voltage of UBCT and Voltage gain (with negative feedback) versus Supply Voltage

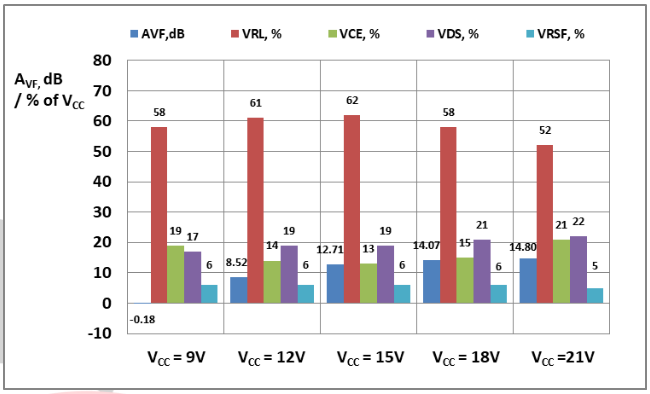

Fig.5. Voltage distribution percentage among various circuit components and Voltage gain (with negative feedback) versus Supply Voltage

In fig. 6, it is shown that at supply voltage of 18V, the voltage distribution of 58% is availed by the load resistor voltage itself and the rest 42% is disributed among the collector-to-emitter voltage of BJT, drain-to-source voltage of UBCT and source feedback resistor voltage with a satisfactory voltage gain of 14.07dB. It also exhibits that the location of the operating-point of the UBCT cascode amplifier circuit is at the 42% of the supply voltage which is near to 50% as defined for an ideal class-A power amplifier circuits.

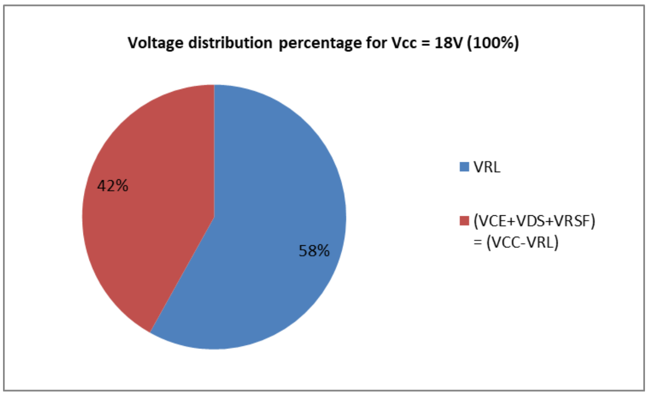

Fig.6. Voltage distribution percentage for Supply Voltage of 18V (as 100%) with Voltage gain (with negative feedback) of 14.07dB

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Fig. 7. shows that for supply voltage of 21V, the voltage distribution of 52% is contained by the load resistor voltage and its counter part of 48% is distributed among the collector-to-emitter voltage of BJT, drain-to-source voltage of UBCT and source feedback resistor voltage with a better voltage gain (with negative feedback) of 14.80dB. It reveals that the location of the operating-point of the UBCT cascode amplifier circuit goes more high at 48% as compared to 42% at supply voltage of 18V. Therefore, at the supply voltage of 21V, the operating-point of amplifier circuit goes very close to the ideal location of 50% and then achieving a potential to become a good class-A power amplifier.

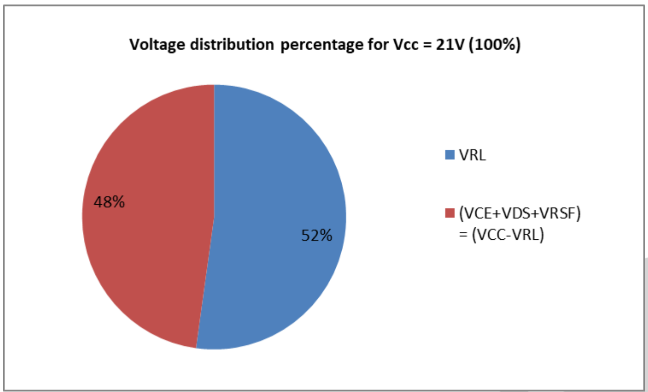

Fig.7. Voltage distribution percentage for Supply Voltage of 21V (as 100%) with Voltage gain (with negative feedback) of 14.80dB

VI. CONCLUSION

In operating-point based performance analysis of the UBCT Cascode Amplifier circuit, for variation in supply voltage from 9V to 21V, the voltage gain (with negative feedback) varies from -0.18dB to 14.80dB. At supply voltage of 18V and 21V, it provides satisfactory voltage gain (with negative feedback) of 14.07dB and 14.80dB respectively. In this particular range of supply voltage, the location of operating-point of amplifier circuit is usually observed at 42% and 48% (of the supply voltage) at 18V and 21V respectively. The operating-point location of 48% at 21V is nearly close to 50% (of the supply voltage), which is an ideal condition to operate in class-A mode of power amplifier circuit. Therefore, the optimized circuit provides satisfactory amplification for both the polarity of signals as provided by class-A power amplifier and able to handle large output signal of approximately 9V(peak). On the basis of these experimental observations, the UBCT Cascode Amplifier may also find expectations for its application in designing the power amplifier circuits.

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