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Comparative Performance Analysis of UBCT Cascode Amplifier

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Abstract - The Unipolar-Bipolar Composite Transistor (UBCT) cascode amplifier circuit consists of a UBCT common-source amplifier stage followed by a BJT common-base amplifier stage. The resultant mid-band voltage gain of UBCT cascode amplifier is almost identical to that of individually designed UBCT amplifier under the similar circuit specifications with an advantage of comparatively wider frequency bandwidth. Thus the primary benefit of using cascode amplifier circuit is the expansion of frequency bandwidth in higher frequency region without sacrificing the voltage gain. In this paper, on the basis of experimental observations, the comparative performance concerning to mid-band voltage gain, frequency bandwidth and gain roll-off rate are analyzed for UBCT cascode amplifier with respect to UBCT amplifier.

Keywords - UBCT, JFET-BJT Composite Transistor, UBCT Amplifier, UBCT Cascode Amplifier, Wideband UBCT Amplifier

I. INTRODUCTION

In JFET-BJT composite transistor circuit, JFET and BJT are combined together to achieve better performance that can be obtained with either device alone [1]. This type of composite transistor is classified as Unipolar-Bipolar Composite Transistor (UBCT), which comprises unipolar transistor JFET and bipolar transistor BJT to attain high input resistance and linear transfer characteristics. A typical UBCT is designed with n-channel JFET (BFW10), npn BJT (CL100) and source-emitter resistor pair (R_S-R_E) (100Ω-10Ω) and therefore, it is labelled as a three terminal composite transistor equivalent to JFET [2]. The circuit components of UBCT are optimized for the best performance [3] and it also shows transfer curve linearity and high input resistance [4]. The drain resistance and transconductance are appeared constant over a wide range of drain-to-source voltage and gate-to-source voltage respectively up to the pinch-off voltage [5]. Due to enhanced dynamic performance of UBCT, it is found more suitable in designing the amplifier circuits [6]. 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 [7] and it provides maximum efficiency of 0.066dB/mW [8]. The UBCT amplifier achieves mid-band voltage gain of 13.77dB with frequency bandwidth of 1.0MHz [9]. For further expansion of frequency bandwidth, the UBCT cascode 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 to achieve maximum voltage gain for a particular supply voltage [10]. In the frequency response of UBCT cascode amplifier circuit, the frequency bandwidth of 3.3MHz is obtained with mid-band voltage gain with negative feedback of 14.04dB for optimized supply voltage of 18V [11]. In the present paper, on the basis of experimental observations, the frequency response based performance of UBCT cascode amplifier is investigated in comparison with UBCT amplifier and therefore, the comparative analysis of mid-band voltage gain, frequency bandwidth and gain roll-off rate are precisely explored.

II. UBCT AMPLIFIER CIRCUIT

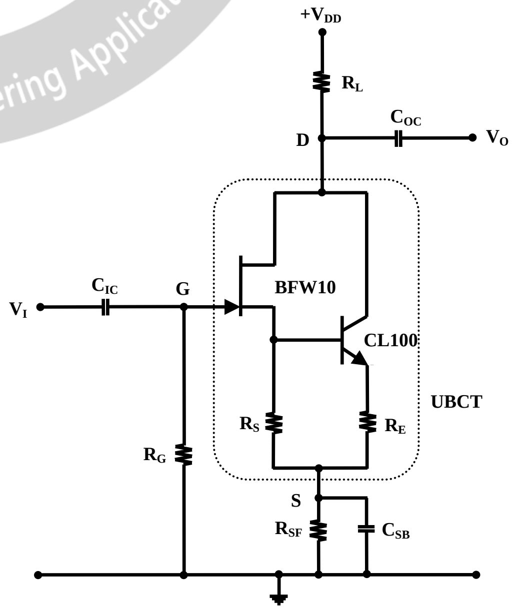

Fig.1. Circuit Design of UBCT Amplifier

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As depicted in fig.1, the UBCT amplifier circuit is designed in common-source mode with self-biased arrangement to provide circuit stabilization against change in transistor parameters and temperature. The experimental circuit of UBCT amplifier consists of UBCT having JFET (BFW10), BJT (CL100) and source-emitter resistor pair (R_S-R_E) (100Ω-10Ω) with optimized value of circuit components as load resistor R_L=1kΩ, gate resistor R_G=1MΩ, source feedback resistor R_{SF}=100Ω and input & output coupling capacitors C_{IC}=C_{OC}=10µF [12]. The source bypass capacitor is kept in No-Connection mode (C_{SB}=N/C) to obtain voltage gain with negative feedback.

The properly designed UBCT amplifier having the above circuit specifications offers frequency bandwidth of 1.0MHz with the mid-band voltage gain with negative feedback of 13.77dB and 15.11dB for optimized supply voltage of 18V and 21V respectively [13].

III. UBCT CASCODE AMPLIFIER CIRCUIT

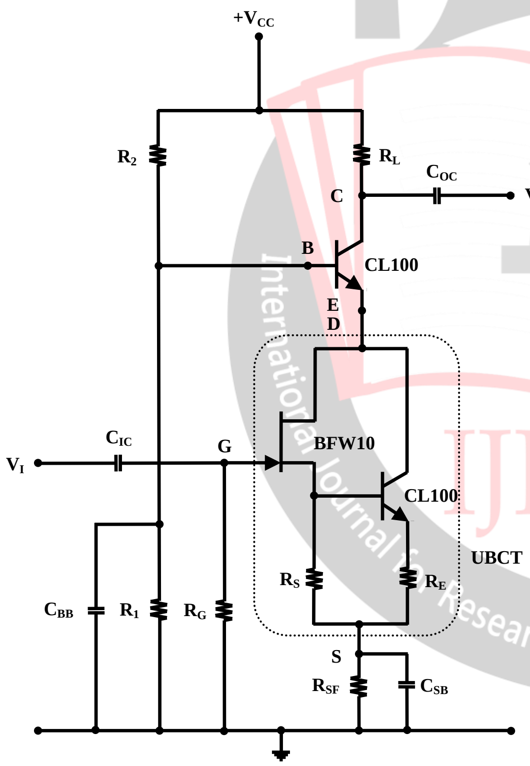

Fig.2. Circuit Design of UBCT Cascode Amplifier

As depicted in fig.2, the UBCT cascode amplifier circuit comprises two amplifier stages in which a UBCT CS input amplifier stage is followed by a BJT CB output amplifier stage. The UBCT CS amplifier circuit is designed with self-biased arrangement and BJT CB amplifier circuit with voltage-divider biased arrangement to offer better circuit stability. In the UBCT cascode amplifier circuit, the UBCT CS input stage provides low voltage gain due to low load resistance offered by the BJT CB stage. Thus the input miller capacitance and voltage gain product also becomes low, which ultimately causes the expansion of frequency bandwidth. The overall voltage gain delivered by UBCT cascode amplifier is basically the voltage gain provided by the BJT CB output amplifier stage [14]. Therefore, the UBCT cascode amplifier circuit is designed to combine the advantages of both amplifier stages to achieve wide frequency bandwidth and high voltage gain. The resultant voltage gain of the UBCT cascode amplifier is almost identical to that of individually designed UBCT amplifier having the same load resistance as does the BJT CB stage with an advantage of comparatively wider frequency bandwidth [15]. Thus the primary benefit of using cascode amplifier circuit is the expansion of frequency bandwidth in higher frequency region without sacrificing the voltage gain.

The experimental circuit of UBCT cascode amplifier is designed with optimized value of circuit components of UBCT amplifier having JFET (BFW10), BJT (CL100) and source-emitter resistor pair (R_S-R_E) (100Ω-10Ω) with gate resistor R_G=1MΩ, load resistor R_L=1kΩ, source feedback resistor R_{SF}=100Ω, input & output coupling capacitors C_{IC}=C_{OC}=10µF and source bypass capacitor in No-Connection mode C_{SB}=N/C (for obtaining voltage gain with negative feedback) along with optimized value of circuit components of BJT amplifier having an additional BJT (CL100) with BJT biasing resistor pair (R_1-R_2) (4.7kΩ-10kΩ) and base bypass capacitor C_{BB}=10µF [16].

The UBCT cascode amplifier provides frequency bandwidth of 3.3MHz with the mid-band voltage gain with negative feedback of 14.04dB and 14.78dB for optimized supply voltage of 18V and 21V respectively [17].

IV. COMPARATIVE PERFORMANCE ANALYSIS

Both the amplifier circuits as depicted in fig. 1 and fig. 2 are designed and operated at the optimized value of DC supply voltage ranging from 18V to 21V for analyzing comparative performance concerning to mid-band voltage gain, frequency bandwidth and gain roll-off rate of UBCT cascode amplifier with respect to UBCT amplifier. For experimental observations regarding frequency response, an input signal ac voltage (sine wave) of 100mV(p-p) having variable frequency ranging from 10Hz to 10MHz is applied to the amplifier circuit and corresponding output voltage is measured within the operating temperature range of 31°C to 35°C.

As depicted in fig.3, the UBCT cascode amplifier and UBCT amplifier provide mid-band voltage gain with negative feedback of 14.04dB and 13.77dB respectively for the supply voltage of 18V. Both values for voltage gain are very close and appear almost similar. As far as the higher cut-off frequency (f_H) and gain roll-off (GRO) rate are concerned, the considerable differences are observed. The UBCT cascode amplifier offers higher cut-off frequency of

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3.3MHz with gain roll-off rate of -26dB/decade, whereas the UBCT amplifier attains higher cut-off frequency of 1.0MHz with gain roll-off rate of -18dB/decade.

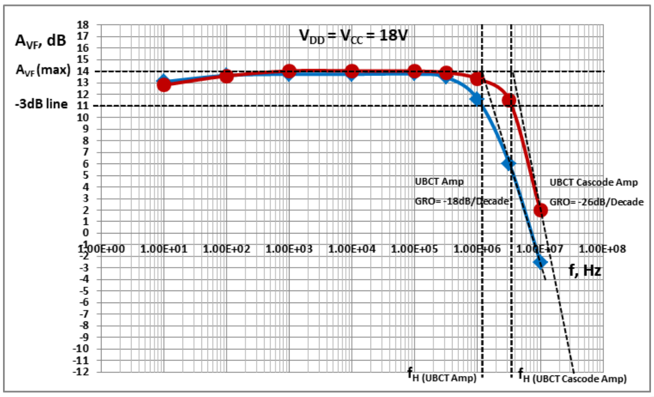

Fig.3. Comparative Frequency Response of UBCT Cascode Amplifier and UBCT Amplifier at Supply Voltage of 18V

As depicted in fig.4, the UBCT cascode amplifier and UBCT amplifier achieve the mid-band voltage gain with negative feedback of 14.78dB and 15.11dB respectively at the supply voltage of 21V. It is observed once again that the UBCT cascode amplifier provides higher cut-off frequency of 3.3MHz with gain roll-off rate of -26dB/decade, while the UBCT amplifier offers higher cut-off frequency of 1.0MHz with gain roll-off rate of -18dB/decade.

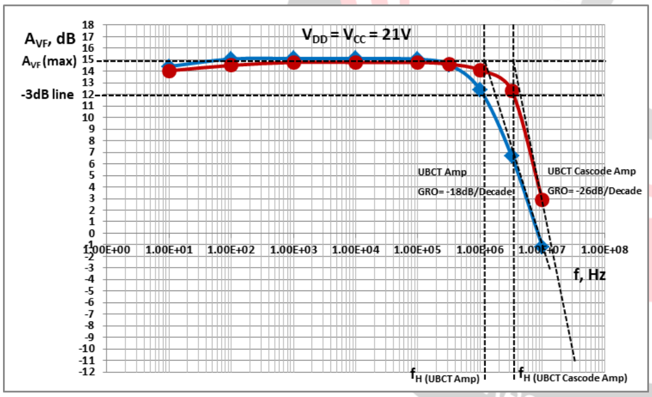

Fig.4. Comparative Frequency Response of UBCT Cascode Amplifier and UBCT Amplifier at Supply Voltage of 21V

Thus the UBCT cascode amplifier achieves mid-band voltage gain with negative feedback of 14.04dB and 14.78dB for supply voltage of 18V and 21V respectively with higher cut-off frequency (f_H) of 3.3MHz having gain roll-off rate of -26dB/decade, whereas the UBCT amplifier provides mid-band voltage gain with negative feedback of 13.77dB and 15.11dB for supply voltage of 18V and 21V respectively with higher cut-off frequency (f_H) of 1.0MHz having gain roll-off rate of -18dB/decade. For both amplifier circuits, the lower cut-off frequency (f_L) appears to be less than 10Hz and therefore, due to very low value of lower cut-off frequency, the resultant frequency bandwidth ($BW=f_H-f_L$) is almost equal to the higher cut-off frequency.

V. Conclusion

In the comparative analysis, UBCT cascode amplifier and UBCT amplifier both provide approximately same mid-band voltage gain for a particular supply voltage. The average values calculated for mid-band voltage gain with negative feedback are 13.905dB and 14.945dB for optimized supply voltage of 18V and 21V respectively. However, the frequency bandwidth of UBCT cascode amplifier is adequately extended up to 3.3MHz with gain roll-off rate of -26dB/decade in comparison with the UBCT amplifier having frequency bandwidth of 1.0MHz with gain roll-off rate of -18dB/decade. Therefore, the UBCT cascode amplifier offers almost same mid-band voltage gain, wider frequency bandwidth and steeper gain roll-off rate than that of UBCT amplifier under the similar circuit specifications.

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