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Frequency Response of UBCT Cascode Amplifier Circuit

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Abstract: The Unipolar-Bipolar Composite Transistor (UBCT) cascode amplifier is a two-stage amplifier circuit, which consists of a UBCT common-source amplifier at input stage and a BJT common-base amplifier at output stage. The UBCT input stage provides lower voltage gain to minimize the input Miller capacitance-gain multiplication effect and thus achieves high frequency performance, whereas the BJT output stage delivers high voltage gain. Therefore, the UBCT cascode amplifier circuit offers wide frequency bandwidth along with high voltage gain. In the present paper, the experimental observations regarding frequency response of the UBCT cascode amplifier are analyzed to obtain mid-band voltage gain and frequency bandwidth.

Index Terms: Unipolar-Bipolar Composite Transistor, UBCT, UBCT Amplifier, Wideband UBCT Amplifier, UBCT Cascode Amplifier

1. INTRODUCTION

The Unipolar-Bipolar Composite Transistor (UBCT) is a composite circuit design, which comprises unipolar transistor, bipolar transistor and resistors. A typical experimental circuit of UBCT is designed with n-channel JFET, npn BJT and source-emitter resistor pair (R_S-R_E) and therefore, it is treated as a composite transistor having three terminals equivalent to JFET [1]. The UBCT shows improved static and dynamic characteristics as compared to that of JFET. The circuit components of UBCT are optimized for the best feasible performance [2]. The UBCT offers wide range linearity in transfer curve along with high input resistance [3]. The drain resistance and transconductance of UBCT also exhibit linear performance over a wide range of voltage [4]. These features of UBCT offer its application as an efficient amplifier in common-source mode [5]. In the experimental analysis of the variants of UBCT amplifier, the best result is offered by a typical UBCT having JFET (BFW10), BJT (CL100) and source-emitter resistor pair (R_S-R_E) (100Ω-10Ω) [6]. The power budget estimation of this typical UBCT common-source amplifier explores that the peak of the voltage gain to total power dissipation ratio is found at the supply voltage of 18V with an efficiency of 0.066dB/mW at the operating frequency of 1kHz [7]. It also provides frequency bandwidth of 1MHz with mid-band voltage gain with negative feedback of 13.77dB for the supply voltage of 18V [8]. For extension of frequency bandwidth into higher frequency region, the UBCT cascode circuit arrangement 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 the maximum voltage gain with negative feedback of 14.07dB at the supply voltage of 18V [9]. In the present paper, frequency response of UBCT cascode amplifier circuit is analyzed to obtain mid-band voltage gain and frequency bandwidth.

2. CIRCUIT DESIGN OF UBCT CASCODE AMPLIFIER

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 quiescent-point stability. In the UBCT cascode amplifier circuit, the UBCT CS input stage delivers low voltage gain to ensure the reduction in input Miller capacitance. Thus the operating frequency bandwidth is expanded into higher frequency region due to minimization of input Miller capacitance-gain multiplication effect. Also, because of high voltage gain provided by the BJT CB output stage, the overall voltage gain of UBCT cascode amplifier becomes high [10]. Therefore, the UBCT cascode amplifier circuit is designed to combine the advantages of both stages to achieve wide frequency bandwidth along with high voltage gain.

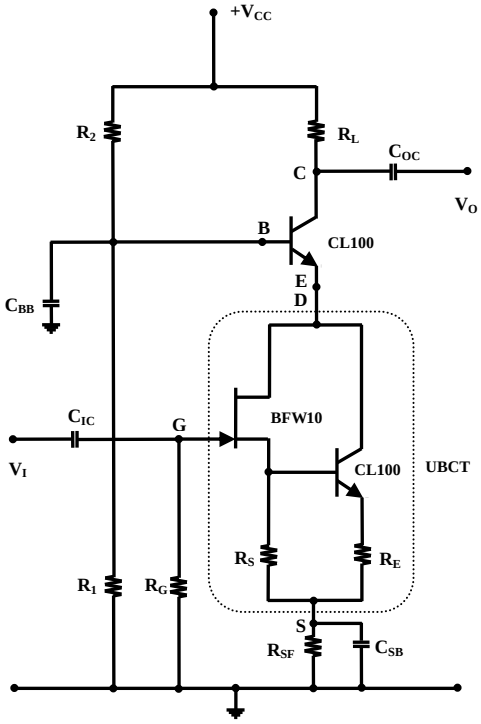

Fig.1. Circuit Design of UBCT Cascode Amplifier

3. FREQUENCY RESPONSE OF UBCT CASCODE AMPLIFIER

To obtain the frequency response of the UBCT cascode amplifier, the experimental circuit is designed as depicted in fig.1 by using UBCT having JFET (BFW10), BJT (CL100) with source-emitter resistor pair (R_S-R_E) (100Ω-10Ω), an additional BJT (CL100) and the optimized value of circuit components having BJT biasing resistor pair (R_1-R_2) (4.7kΩ-10kΩ), 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, base bypass capacitor C_{BB}=10μF, source bypass capacitor C_{SB}=N/C (to achieve voltage gain with negative feedback) for a particular range of supply voltage (V_{CC}) within the operating temperature range of 30°C-33°C. For input signal, ac voltage (sine wave) of 100mV(peak-to-peak) having variable frequency ranging from 10Hz to 10MHz is applied to the circuit.

To realize the optimum supply voltage for experimental investigation of frequency response of UBCT cascode amplifier, a quick reference experiment is conducted in which the input signal voltage (sine wave) of 100mV(peak-to-peak) having a frequency of 1kHz is applied to the circuit and the corresponding output voltage is measured for different supply voltage ranging from 9V to 21V.

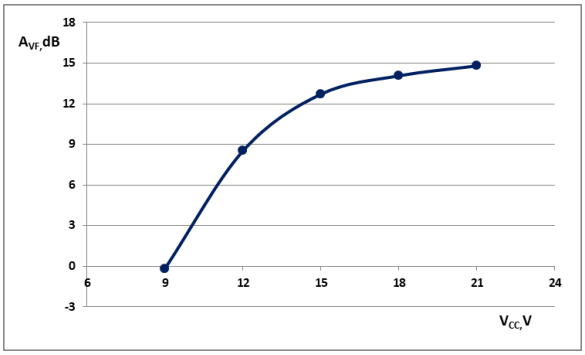

Fig.2. Voltage Gain with Negative Feedback versus Supply Voltage for UBCT Cascode Amplifier

[Circuit specifications: UBCT [JFET BFW10, BJT CL100 and (R_S-R_E) resistor pair (100Ω-10Ω)], BJT CL100, (R_1-R_2) resistor pair (4.7kΩ-10kΩ), R_G=1MΩ, R_L=1kΩ, R_{SF}=100Ω, C_{IC}=C_{OC}=10μF, C_{BB}=10μF, C_{SB}=N/C, V_I=100mV_{P-P}, f=1kHz, T=30°C-31°C].

As depicted in fig.2, the voltage gain with negative feedback (A_{VF}) of UBCT cascode amplifier varies from -0.18dB to 14.80dB with the variation in supply voltage from 9V to 21V. For supply voltage of 12V, 15V and 18V, the amplifier provides voltage gain with negative feedback of 8.52dB, 12.71dB and 14.07dB respectively. With increase in supply voltage from 9V to 15V, the voltage gain increases sharply and after that starts to be approximately saturated at 18V. For further increase in the supply voltage from 18V to 21V, a little increment in the voltage gain is observed. Therefore, the UBCT cascode amplifier delivers higher voltage gain for optimized supply voltage in the range of 18V to 21V.

As depicted in fig.3, the frequency response of UBCT cascode amplifier is obtained for optimized supply voltage of 18V and 21V with the variation in input signal frequency from 10Hz to 10MHz. The UBCT cascode amplifier provides mid-band voltage gain with negative feedback of 14.04dB and 14.78dB for supply voltage of 18V and 21V respectively. For both supply voltages, the higher cut-off frequency (f_H) is found to be about 3.3MHz whereas, the lower cut-off frequency (f_L) appears to be approximately less than 10Hz. Due to very low value of lower cut-off frequency, the resultant frequency bandwidth

(BW=f_H–f_L) is equal to the higher cut-off frequency and therefore, the UBCT cascode amplifier exhibits wide frequency bandwidth of about 3.3MHz.

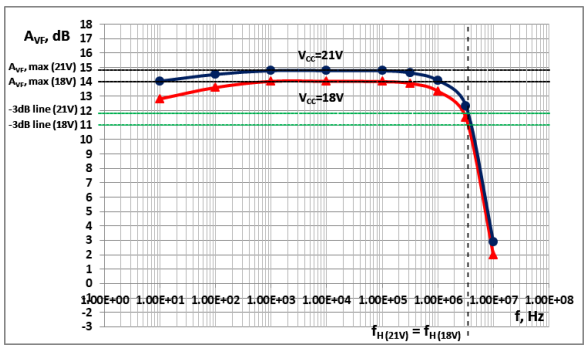

Fig.3. Frequency Response of UBCT Cascode Amplifier

[Circuit specifications: UBCT [JFET BFW10, BJT CL100 and (R_S-R_E) resistor pair (100Ω-10Ω)], BJT CL100, (R_1-R_2) resistor pair (4.7kΩ-10kΩ), R_G=1MΩ, R_L=1kΩ, R_{SF}=100Ω, C_{IC}=C_{OC}=10μF, C_{BB}=10μF, C_{SB}=N/C, V_I=100mV_{P-P}, f=10Hz-10MHz, T=31°C-33°C].

4. CONCLUSION

In the present paper, the experimental observations regarding frequency response of UBCT cascode amplifier circuit explore that frequency bandwidth of about 3.3MHz is achieved with mid-band voltage gain with negative feedback of 14.04dB and 14.78dB for optimized supply voltage of 18V and 21V respectively. Therefore, the proposed UBCT cascode amplifier circuit provides wide frequency bandwidth along with high voltage gain.

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