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Frequency Response of the Circuit Variants of UBCT Amplifier

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Abstract - The Unipolar-Bipolar Composite Transistor (UBCT) is incorporated with add-on features of unipolar transistor JFET and bipolar transistor BJT. By optimizing the circuit components, the UBCT exhibits better static and dynamic performance to that of JFET. Therefore, UBCT is adeptly used in designing amplifier circuits. In the present correspondence, the experimental observations regarding the frequency response of the circuit variants of UBCT amplifier have been analyzed. These observations reveal that the UBCT amplifier circuit is unified with moderate voltage gain and wide frequency bandwidth.

Keywords: Composite Transistor, Unipolar-Bipolar Composite Transistor, UBCT, JFET-BJT Composite Transistor, M-FET, UBCT Amplifier.

I. INTRODUCTION

The Unipolar-Bipolar Composite Transistor (UBCT) is designed with unipolar transistor JFET and bipolar transistor BJT along with resistors to achieve better performance that can be obtained individually with either JFET or BJT. The resultant JFET-BJT composite transistor circuit is boosted with high input resistance of JFET in association with linear transfer characteristics of BJT and it is also designated as UBCT having three equivalent terminals specifically Drain, Source & Gate.

As reported earlier, the JFET-BJT composite transistor circuit consists of n-channel JFET and pnp BJT along with three resistors has been designed, which offers high input resistance with an added advantage of widespread linear transfer characteristics [1]. Also, the JFET-BJT composite transistor is further thermally improved by comprising of an n-channel JFET, four npn BJTs, a pnp BJT and three resistors [2]. Due to its improved FET like characteristics, it is designated as "Modified Field Effect Transistor (M-FET)". The M-FET has marked improvement in the transfer curve linearity associated with good thermal stability [3]. Since it exhibits superior performances to that of JFET, hence this JFET-BJT composite transistor may finds better application in linear instrumentation system and also in designing amplifiers and oscillators [4] by maintaining the optimized value of circuit components [5].

II. CIRCUIT DESIGN OF UBCT AMPLIFIER

The circuit of UBCT has been designed with n-channel JFET (BFW10), npn BJT (CL100) and a pair of source and emitter resistors (R_S-R_E) and it is represented as a three terminal equivalent circuit of UBCT as depicted in fig.1.

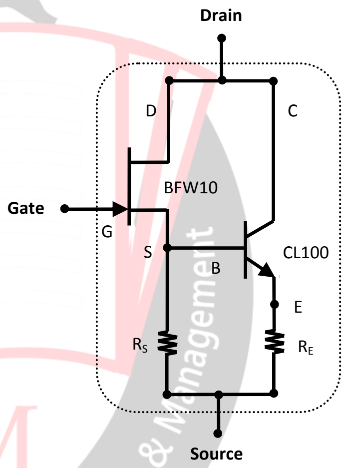

Fig.1. Three terminal equivalent circuit of UBCT

This circuit of UBCT is specifically considered as a simplified circuit design of earlier reported JFET-BJT composite transistors [6]. The circuit components of UBCT (JFET-BJT composite transistor) have been optimized for its best performance [7]. It also offers wide range linearity in transfer curve and very high input resistance [8]. The drain resistance and transconductance curves also exhibit linear performance over wide range of drain-to-source voltage and gate-to-source voltage respectively up to the pinch-off value of the UBCT [9]. Therefore, the dynamic performance of UBCT circuit promotes its application as an efficient amplifier [10]. The experimental analysis of the variants of UBCT amplifier reflects that the best voltage gain is offered by a typical UBCT having JFET (BFW10), BJT (CL100) and source-emitter resistor pair (R_S-R_E) (100Ω-10Ω) [11]. The power budget analysis of this typical UBCT amplifier also describes that peak of the voltage gain to total power dissipation ratio appears at the supply voltage of 18V with an efficiency of 0.066dB/mW [12].

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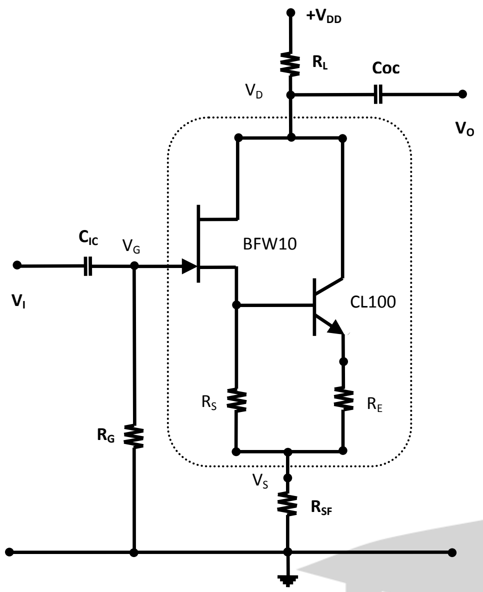

Fig.2. Circuit design of UBCT Amplifier

Fig.2 depicts that the UBCT is used as an active component in a common source amplifier circuit biased under the source self-biasing topology of JFET amplifier, which provides Q-point stabilization against change in transistor parameters and the variation in temperature. The passive circuit components used in UBCT amplifier e.g. the resistors and capacitors have been optimized for the best performance of the circuit. The optimized values for circuit components are 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 [13].

III. Frequency Response Of The Variants Of UBCT Amplifier

The four variants of UBCT are designed by changing the values of source-emitter resistor pair (R_S-R_E). The experimental values for source-emitter resistor pair (R_S-R_E) are (100Ω-10Ω), (100Ω-100Ω), (1kΩ-100Ω) and (10kΩ-1kΩ). To obtain the frequency response, the experimental observations have been taken for UBCT amplifier circuit having JFET (BFW10), BJT (CL100) and different sets of source-emitter resistor pair (R_S-R_E) with optimized values for amplifier 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 for the DC supply voltage ranging from 15V to 21V within the operating temperature range of 32°C to 35°C. For input signal, ac voltage (sine wave) of 100mV(peak-to-peak) having frequency range (10Hz-10MHz) is applied to the UBCT amplifier circuit.

The fig.3 depicts the voltage gain with negative feedback in decibel (A_{VF}, dB) versus frequency range of 10Hz to 10MHz for the variants of UBCT amplifier having different source-emitter resistor pairs (R_S-R_E) at constant supply voltage V_{DD}=18V, which is an optimized value for supply voltage provided to the UBCT amplifier circuit.

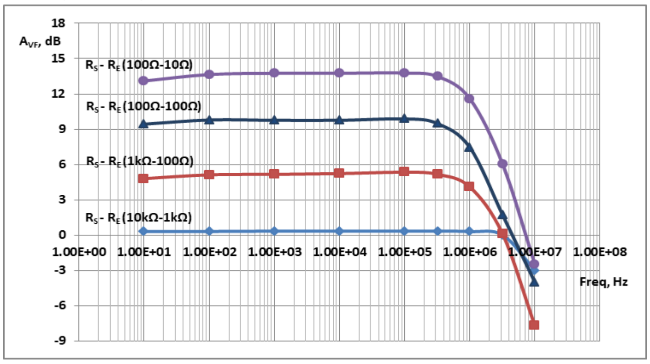

Fig.3. Frequency response of the variants of UBCT Amplifier

[Circuit specifications: UBCT having JFET BFW10, BJT CL100 with (R_S-R_E) pair (100Ω-10Ω), (100Ω-100Ω), (1kΩ-100Ω) & (10kΩ-1kΩ) and Amplifier circuit components having R_G=1MΩ, R_L=1kΩ, R_{SF}=100Ω, C_{IC}=C_{OC}=10µF, T=32-35°C, V_{DD}=18V]

The fig. 4 depicts the voltage gain with negative feedback in decibel (A_{VF}, dB) versus frequency range of 10Hz to 10MHz for a typical variant of UBCT amplifier having source-emitter resistor pair (R_S-R_E) (100Ω-10Ω) for three different supply voltages V_{DD} of 15V, 18V and 21V.

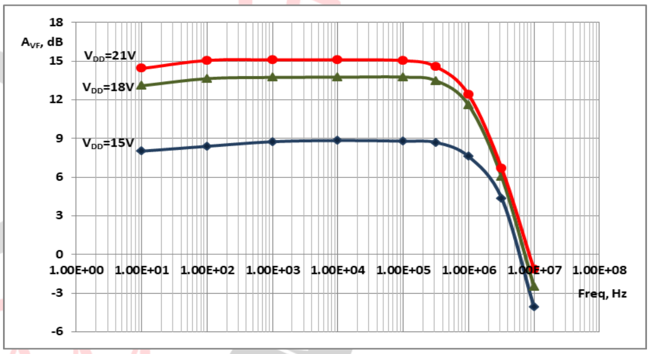

Fig.4. Frequency response of a typical variant of UBCT Amplifier

[Circuit specifications: UBCT having JFET BFW10, BJT CL100 with (R_S-R_E) pair (100Ω-10Ω) and Amplifier circuit components having R_G=1MΩ, R_L=1kΩ, R_{SF}=100Ω, C_{IC}=C_{OC}=10µF, T=32-35°C, V_{DD} =15V to 21V]

IV. Performance Analysis

The performance based on two different frequency responses of the variants of UBCT amplifier circuit as depicted in fig.3 and fig.4 is precisely analyzed. The observations regarding the frequency response at constant supply voltage of 18V for the variants of UBCT amplifier having different resistor pairs (R_S-R_E) as depicted in fig.3, show that the maximum voltage gain A_{VF} of 13.77dB is achieved for resistor pairs (R_S-R_E) (100Ω-10Ω) at supply voltage V_{DD}=18V. As the value of resistor pairs (R_S-R_E) is increased the substantial reduction in voltage gain is observed. For resistor pairs (R_S-R_E) (100Ω-100Ω) and (1kΩ-100Ω), the maximum voltage gains are 9.88dB and 5.35dB respectively. For resistor pair (R_S-R_E) (10kΩ-1kΩ), there is no amplification of signal is observed and hence

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this variant of UBCT amplifier is kept out of consideration. The lower cut-off frequencies for all the considerable variants of UBCT amplifier are below 10Hz and the higher cut-off frequencies or the associated frequency bandwidths for these variants of UBCT amplifiers having resistor pairs (R_S-R_E) (100Ω-10Ω) and (100Ω-100Ω) are about 1MHz, whereas for resistor pair (R_S-R_E) (1kΩ-100Ω) the frequency bandwidth is about 2MHz at the supply voltage of 18V.

Among all the variants of UBCT, a typical variant having resistor pair (R_S-R_E) (100Ω-10Ω) gives the best result as the maximum voltage gain of 13.77dB is achieved for the supply voltage of 18V. Hence for further optimization of circuit regarding frequency response of the UBCT amplifier having resistor pair (R_S-R_E) (100Ω-10Ω), the effect of change in supply voltage on the resultant frequency response is presented in fig.4. The observations regarding the frequency response for different supply voltages, show that the maximum voltage gain A_{VF} of 8.85dB is achieved for supply voltage V_{DD}=15V. As the supply voltage is increased the voltage gain also increases. For supply voltage V_{DD}=18V, the maximum voltage gain A_{VF} is 13.77dB, which increases up to a value of 15.11dB for V_{DD}=21V. Thus, with increase in supply voltage from 18V to 21V, a small increment in voltage gain of 1.34dB is observed. The frequency bandwidth of about 1MHz is achieved for supply voltage of 21V and 18V with maximum voltage gain of 15.11dB and 13.77dB respectively, whereas for supply voltage of 15V the wider frequency bandwidth of about 2MHz is achieved with reduced voltage gain of 8.85dB. The lower cut-off frequencies for all three supply voltages are below 10Hz. Therefore, the supply voltage in the range of 18V to 21V provides better performance for a typical variant of UBCT amplifier having source-emitter resistor pair (R_S-R_E) (100Ω-10Ω).

V. CONCLUSION

On the basis of experimental observations regarding the frequency response of the variants of UBCT amplifier circuit, the best performance is achieved by a typical variant of UBCT having source-emitter resistor pair (R_S-R_E) (100Ω-10Ω) as it attains the frequency bandwidth of about 1MHz with the maximum voltage gain of 15.11dB and 13.77dB at the supply voltage of 21V and 18V respectively. It also offers wider frequency bandwidth of about 2MHz with reduced voltage gain of 8.85dB at the supply voltage of 15V. Therefore, these observations exhibit that the UBCT amplifier circuit is incorporated with moderate voltage gain and wide frequency bandwidth.

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