

Power Budget Estimation of a Common Source UBCT Amplifier

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Abstract: The Unipolar-Bipolar Composite Transistor (UBCT) consists of circuit combination of Unipolar (JFET) and Bipolar (BJT) active components along with a resistor pair. The UBCT exhibits superior performance to that of JFET and therefore, this composite transistor is found suitable for designing the amplifier circuits. In the present correspondence, UBCT is used as an active component in a common source small signal amplifier circuit biased under the self-biasing topology of JFET amplifier. The experimental observations regarding the power budget estimation of circuit components of the UBCT amplifier have been analyzed for optimization of the circuit to improve voltage gain to power efficiency. Therefore, the UBCT amplifier circuit may be competently applicable to analog circuit design.

Index Terms:

Composite Transistor, Unipolar-Bipolar Composite Transistor, UBCT, JFET-BJT Composite Transistor, M-FET, Common Source UBCT Amplifier

1. INTRODUCTION

The Unipolar-Bipolar Composite Transistor (UBCT) utilizes the advantages of high input resistance of JFET along with linear transfer characteristics of BJT. Since the resultant circuit is designed with unipolar transistor JFET and bipolar transistor BJT and it can also be fabricated as a three terminal composite transistor, hence it is classified as Unipolar-Bipolar Composite Transistor. In this composite transistor circuit, JFET and BJT are combined together to achieve better performance that can be obtained with either active device alone [1]. The JFET-BJT composite transistor structure is coined by Mylroie [2] and also in monolithic integrated circuit, BJT is fabricated along with thin ion implanted JFET on the same chip to create BIFET structure [3].

The JFET-BJT composite transistor circuit consists of n-channel JFET and pnp BJT along with three resistors, which has been reported earlier and offers high input resistance with an add-on advantage of widespread linear transfer characteristics [4]. 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 [5]. 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 [6]. 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 [7] by maintaining the optimized value of circuit components [8].

2. CIRCUIT DESIGN OF COMMON SOURCE UBCT AMPLIFIER

A typical 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) (100Ω - 10Ω) and it is considered as a three terminal composite transistor device as depicted in fig.1.

This circuit of UBCT is specifically considered as a simplified circuit design of earlier reported JFET-BJT composite transistors [9]. The circuit components of UBCT (JFET-BJT composite transistor) have been optimized for its best performance [10]. It also offers wide range linearity in transfer curve and very high input resistance [11]. 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 [12]. Therefore, the dynamic performance of UBCT circuit promotes its application as an efficient amplifier [13]. The

experimental analysis of the variants of UBCT also reflects that the best result is offered by a variant of UBCT having JFET (BFW10), BJT (CL100) and resistor pair (R_S - R_E) (100 Ω -10 Ω) [14].

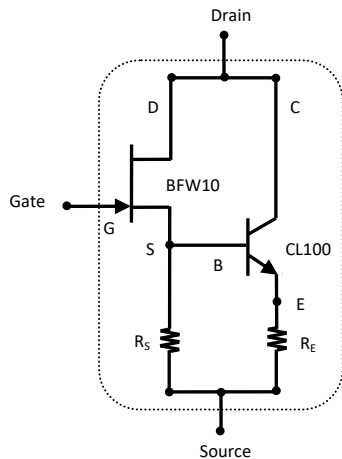


Fig.1. Three terminal equivalent circuit diagram of UBCT [JFET (BFW10), BJT (CL100), Resistor pair (R_S - R_E) (100 Ω -10 Ω)]

This UBCT is used as an active component in a common source amplifier circuit biased under the source self-biasing topology of JFET amplifier as depicted in fig.2. The source self-biasing is a current series feedback circuit, which provides Q-point stabilization against change in transistor parameters as well as 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, load resistor $R_L=1k\Omega$, gate resistor $R_G=1M\Omega$, source feedback resistor $R_{SF}=100\Omega$ and input & output coupling capacitors $C_{IC}=C_{OC}=10\mu F$ for the supply voltage V_{DD} ranges from 12V to 24V within the operating temperature range of 32 $^{\circ}C$ to 35 $^{\circ}C$.

3. POWER BUDGET ESTIMATION OF UBCT AMPLIFIER

For Power Budget Estimation of the UBCT amplifier circuit, the sequential experiments have been performed in which the power dissipation level of each of the components of the amplifier circuit have been analyzed on the basis of voltage gain of the amplifier in accordance with the variation in supply voltage.

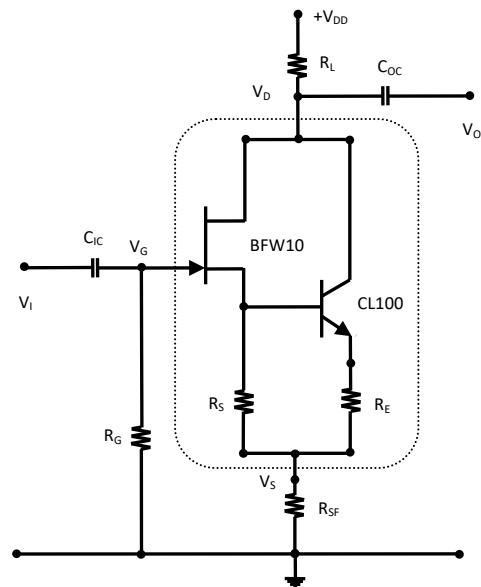


Fig.2. Circuit diagram of Common Source UBCT Amplifier providing voltage gain with negative feedback [$R_L=1k\Omega$, $R_G=1M\Omega$, $R_{SF}=100\Omega$, $C_{IC}=C_{OC}=10\mu F$, $V_{DD}=12V$ to $24V$]

The experimental observations have been taken for a typical UBCT amplifier circuit having JFET (BFW10), BJT (CL100) and a resistor pairs (R_S - R_E) (100 Ω -10 Ω) with the supply voltage ranging from 12V to 24V DC with a small input ac voltage of 100mV (peak-to-peak) of constant frequency of 1kHz (sine wave). The power dissipation level of any circuit component is determined by measuring the voltage drop across that particular component and the corresponding current passing through it.

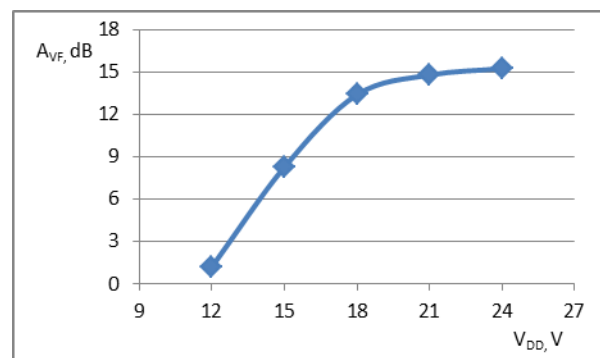


Fig.3. Voltage gain with negative feedback of the UBCT amplifier for different supply voltage.

As depicted in fig. 3, the curve shows that the voltage gain increases sharply from 1.21dB at 12V to 13.39dB at 18V and thereafter a small variation in voltage gain is observed, which ranges from 13.39dB to 15.24dB with the variation in supply voltage from 18V to 24V.

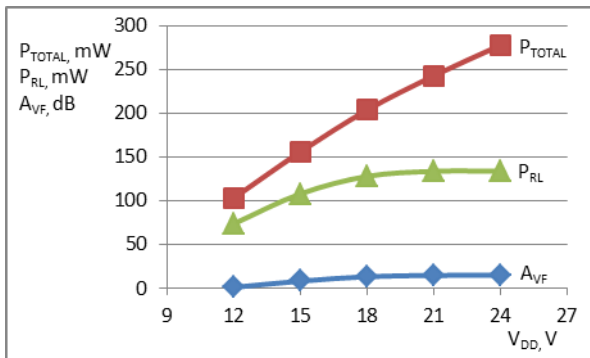


Fig.4. Total power dissipation level of the UBCT amplifier circuit, power dissipation level of the load resistor and voltage gain of the amplifier circuit for different supply voltage.

As depicted in the fig.4, the total power dissipation level increases from 102.96mW to 277.68mW by changing the supply voltage from 12V to 24V respectively. The load resistor power dissipation level is initially at 73.62mW for 12V, while in the range of 18V to 24V it is almost saturated with a small variation from 127.92mW to 133.86mW. The condition for saturation in load resistor power dissipation level in the range of 18V to 24V directly limits the voltage gain of the UBCT amplifier in the range of 13.39dB to 15.24dB.

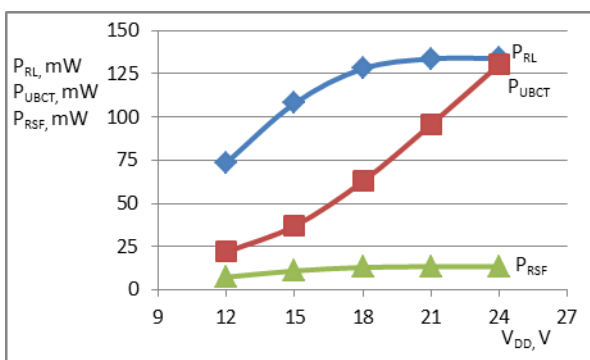


Fig.5. Distribution of power dissipation levels among the three main components of the UBCT amplifier circuit which consists of Load resistor, UBCT and Source feedback resistor for different supply voltage.

As depicted in fig.5, and also described in the previous fig.4, the power dissipation level of the load resistor is 73.62mW at 12V and gets saturated from 127.92mW to 133.86mW for supply voltage ranging from 18V to 24V. The power dissipation level of the source feedback resistor also follows the similar curve pattern as that of load resistor. Since the source feedback resistor ($R_{SF}=100\Omega$) have $1/10^{\text{th}}$ value of the load resistor ($R_L=1k\Omega$) and the drain current is almost equal to that of source current for the UBCT hence the power dissipation level of source feedback resistor should also have $1/10^{\text{th}}$ value to that of load resistor. This fact reflects in the value of the power dissipation level of the source feedback resistor, which ranges from 7.40mW to 13.46mW with variation in the supply voltage from 12V to 24 V respectively. The power dissipation level of the UBCT increases from 21.96mW to 130.39mW with the increase in supply voltage from 12V to 24V respectively and it actually follow the trend of total power dissipation level curve of the UBCT amplifier.

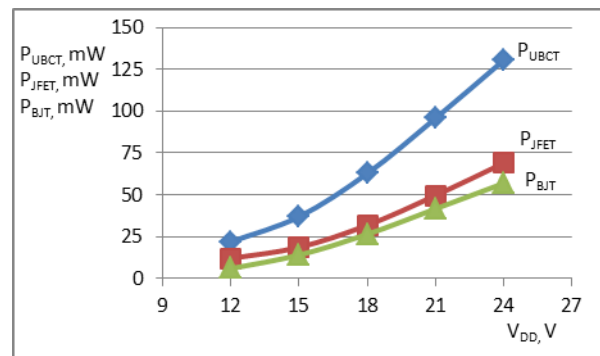


Fig.6. Distribution of power dissipation level of UBCT between its active components JFET and BJT for different supply voltage.

As depicted in fig. 6, the power dissipation level of UBCT increases with the supply voltage and the JFET and BJT power dissipation levels also follow the similar curve pattern. The JFET power dissipation level varies from 12.03mW to 69.03mW and the corresponding BJT power dissipation level from 6.05mW to 56.89mW with variation in supply voltage from 12V to 24V.

The curve depicted in fig.7 discloses remarkable fact that the voltage gain to total power dissipation ratio increases sharply from 0.012dB/mW to 0.066dB/mW with increase in the supply voltage from 12V to 18V and thereafter the ratio tends to decrease up to

0.055dB/mW as supply voltage increases up to 24V. Thus the peak of the voltage gain to total power dissipation ratio appears at 18V with an efficiency of 0.066dB/mW.

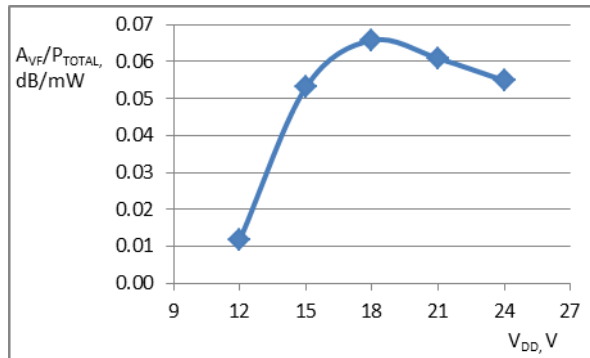


Fig.7. Voltage gain to total power dissipation ratio of UBCT amplifier for different supply voltage.

4. CONCLUSION

The present paper represents power budget estimation of a typical variant of UBCT having JFET (BFW10), BJT (CL100) and source-emitter resistor pair (R_S - R_E) (100 Ω -10 Ω) used as active component in common source UBCT amplifier biased under self-biased topology. The UBCT amplifier is designed by using optimized value of passive components as load resistor $R_L=1k\Omega$, gate resistor $R_G=1M\Omega$, source feedback resistor $R_{SF}=100\Omega$ and input & output coupling capacitors $C_{IC}=C_{OC}=10\mu F$. The experimental observations have been obtained for a small input ac voltage (sine wave) of 100mV(p-p) of 1kHz frequency with DC supply voltage ranging from 12V to 24V within the operating temperature range of 32°C to 35°C.

The variation in supply voltage in the range of 12V to 24V results as increase in total power dissipation level of the UBCT amplifier circuit from 102.96mW to 277.68mW along with increase in UBCT, JFET and BJT power dissipation levels from 21.96mW to 130.39mW, 12.03mW to 69.03mW and 6.05mW to 56.89mW respectively. Since the power dissipation levels of load resistor along with the source feedback resistor are increased sharply from 73.62mW to 127.92mW and 7.40mW to 13.00mW respectively for the supply voltage ranging from of 12V to 18V. For further increase in supply voltage from 18V to 24V, power dissipation levels of load resistor and source feedback resistor are saturated which tend the voltage

gain with negative feedback of the amplifier to follow the similar curve trend and start to be saturated for supply voltage of 18V and above. Thus for the supply voltage of 18V, voltage gain of 13.39dB and total power dissipation level of 203.58mW determine the voltage gain to total power dissipation ratio of 0.066dB/mW, which is estimated as the maximum voltage gain to power efficiency of the common source UBCT amplifier for a specific circuit design. Therefore, the UBCT amplifier circuit may be competently applicable to analog circuit design.

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