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The Simulation Study of Small-Signal BJT and FET Amplifiers through Pspice

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Abstract: Small signal Common Source FET RC coupled amplifier and Common Emitter BJT amplifier are considered as basic building block for the electronic circuits. In this paper these two important amplifier circuits compared in various parameters like frequency response, bandwidth etc. We have also compared these two amplifier circuits on various parameter e.g. maximum voltage gain, current gain, power dissipation, operating voltage and input-output impedance etc. In this communication simulation study of bandwidth variation with respect to load resistance and bandwidth variation with respect to Vcc has been carried out.

Keywords: Small Signal Amplifiers, Basic Electronics Circuits, BJT Amplifier, FET Amplifier

1. INTRODUCTION

Continuous research in automation area has enabled human tasks replaced by computers and machines. Various industrial applications use transducers which convert energy from one form to another. Transducers and sensors produce signal in milli and micro volts range which need amplification by amplifiers for further processing[1]. Sensors used in emerging areas like image processing, ultrasound imaging, healthcare, banking, satellite communication, wireless communication etc, generate low magnitude of signals in order of milli and micro volts which need amplification by amplifiers [2,3,4]. Most popular amplifier CE BJT amplifier and CS FET amplifier when operated in linear region can be used to amplify signals. Determination of amplifier performance is done through parameters like bandwidth, frequency response, voltage gain, power gain, input-output impedance and power dissipation etc. The active and passive component used to bias the BJT and FET amplifiers play vital role in amplifier.

The three BJT amplifiers configurations are common emitter (CE), common base (CB) and common collector (CC) configurations. Each of these configurations exhibits certain characteristics which are useful in a specific circuit application. There are three basic FET amplifiers configurations. They are common source (CS), common gate (CG) and common drain (CD) configurations. Each of these configurations exhibits certain characteristics which are useful in a specific circuit application. Study of BJT using cascade topology has provided 22% improvement in bandwidth[5]. FET has high input impedance, high current gain, and low output impedance are some of the important advantages of FET amplifiers [6,7]. FET common source amplifier is used mostly in industry among the FET amplifiers due to its wide and popular range of applications in electronics. Multistage fractional order BJT amplifier study revealed that its performance is better than conventional order BJT amplifiers [8]. Amplifier performance is determined with amplifier parameters like voltage gain, frequency response, bandwidth, current gain and input –output impedance etc.

There are continuous research studies to improve the performance of the FET amplifiers in terms of frequency response, bandwidth, gain, etc. Water-gated field effect transistor (WG-FET) common source amplifier study revealed that at 5 Hz frequency increased the gain from 1.65 dB to 8.05 dB and the unity-gain frequency from 10 Hz to 1 kHz [9]. A Common Source FET amplifier provides medium range voltage gain with added feature of high input impedance and inverted amplified signal [10,11]. More than one decade improvement in the output noise level in the low noise performance is achieved by the integrated JEFT without compromising on JFET amplifier performance greatly benefits analog applications [12]. Simulation study has been carried out using Pspice simulation software student version 9.5.2 [13,14].

2. EXPERIMENTAL SETUP

Two different amplifier configurations CE BJT and CS FET were selected for present studies, and exhaustively studied their frequency response, voltage, bandwidth, power dissipation and input-output impedance with respect to different passive and active components. The common emitter RC coupled transistor amplifier is shown in figure-1 while common

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source RC coupled FET amplifier shown in figure-2. The basic parameters of both proposed amplifiers circuits (Figure - 1 and Figure-2) were compared.

N channel J2N3819 JFET active component which is commercially available was selected for study while R_{SR}=500Ω, R_S=5KΩ, R_D=10KΩ, R_L=10KΩ, R_1=600KΩ, R_2=110KΩ, C_1=1μF, C_2=1μF and C_S=10μF are used as passive biasing elements. NPN transistor Q2N2222 (β=255.9) was selected as active element for the present studies is a while R_S=500Ω, R_C=10KΩ, R_E=2KΩ R_1=47KΩ, R_2=5KΩ, R_L=10KΩ, C_1=1μF, C_2=1μF and C_E=10μF as passive biasing elements.

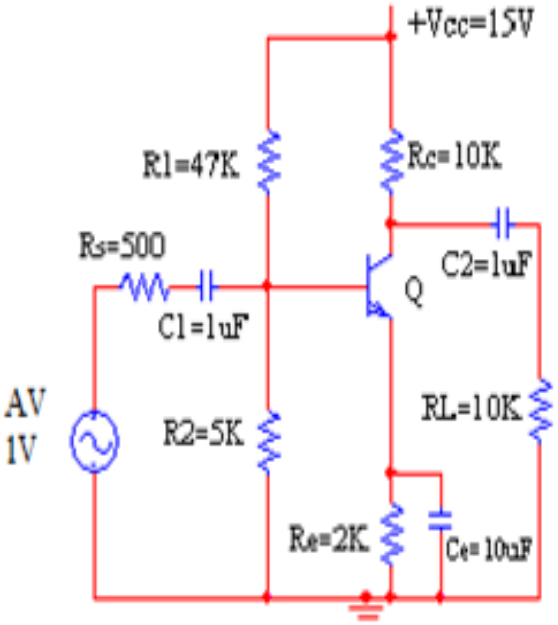

Figure-1:Common Emitter RC Coupled Transistir Amplifier

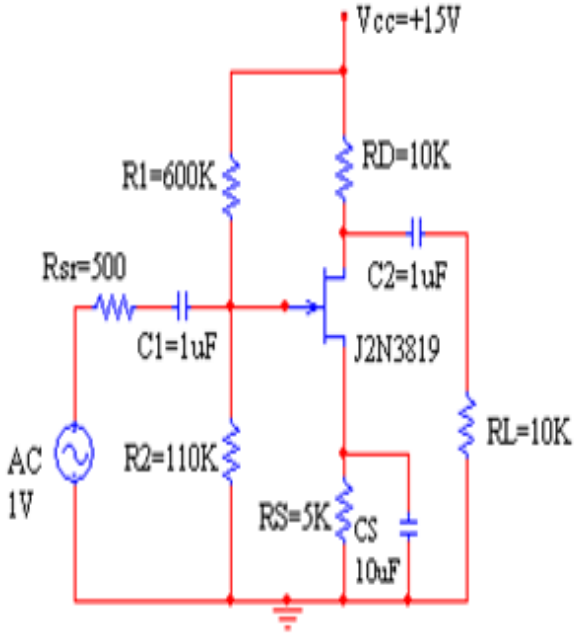

Figure-2:Common Sourse RC Coupled FET Amplifier

Supply voltage V_{CC} +15V used to bias the amplifiers circuits. 1V AC signal source at 1 KHz frequency used and the observations are made with PSpice simulation software[13,14]. Both active component NPN transistor Q2N2222 and N channel J2N3819 JFET is selected from Pspice model editor. By using the software write the simulation program for figure-1 and figure-2 then running the simulation file viewing output and simulation results.

3. RESULTS AND DISCUSSION

The bandwidth study of both circuits found 1199 KHz for figure-1 and 15425 KHz for figure-2 which is CS FET bandwidth is 1186.48% more than CE BJT amplifier. The maximum voltage gain for the CE BJT amplifier is found 65.55 while for CS FET amplifier is 10.65.

Variation of bandwidth with different load resistance R_L values are plotted in figure-3. We observed that bandwidth value for BJT amplifier decreases from $3.98x10^6$Hz to $6.69x10^5$Hz when R_L value varies from 1 KΩ to 500 KΩ which is 83.19% decrease in bandwidth. In case of FET amplifier bandwidth decreases drastically from $5.92\ x10^7$Hz to $8.90\ x10^6$Hz when R_L changes from 1 KΩ to 100 KΩ which is 84.19% decrease in bandwidth. While R_L ranges from 100 KΩ to 500 KΩ not much change is observed in bandwidth which is $8.90\ x10^6$Hz to $8.30\ x10^6$Hz which is 6.7% decrease in bandwidth.

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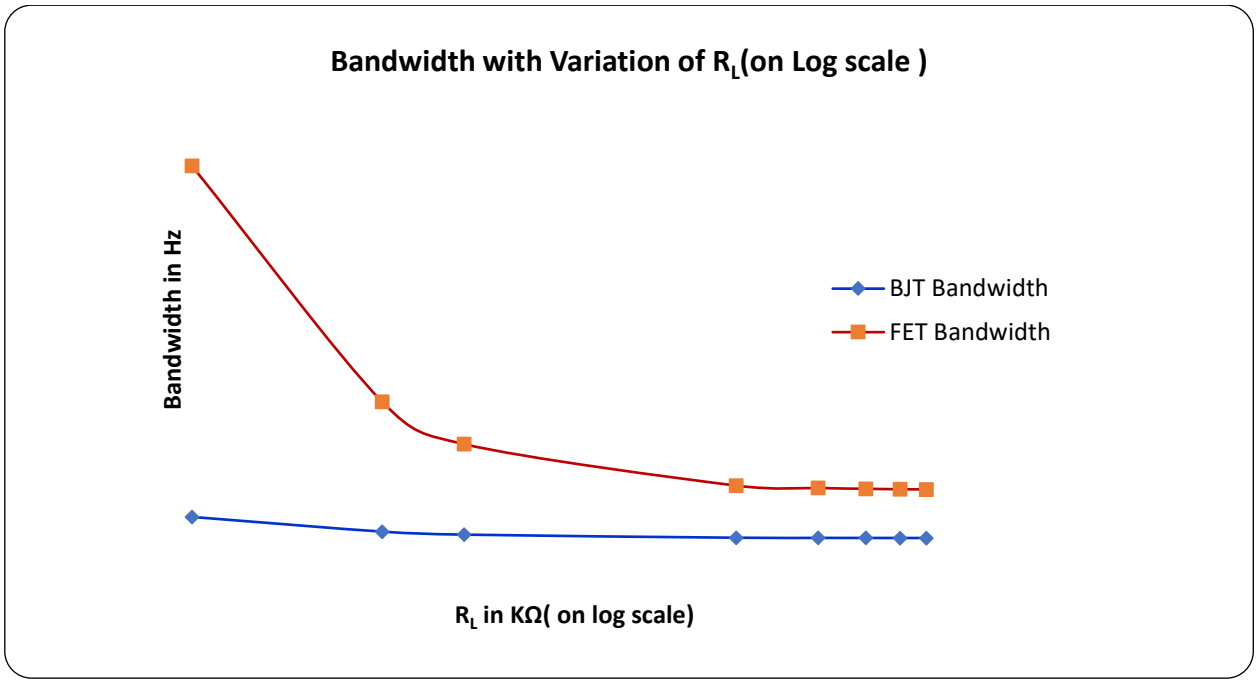

Fig. 3. Bandwidth at Various R_L values

Table-1 shows the various values of bandwidth with respect to variation in R_L values. Same values has been taken to draw graph in Figure-3

Table.1. Bandwidth with different values of R_L

R_L (KΩ)	BJT Bandwidth (Hz)	FET Bandwidth (Hz)
1	$3.98x10^6$	$5.92x10^7$
5	$1.67x10^6$	$2.21x10^7$
10	$1.20x10^6$	$1.54x10^7$
100	$7.15x10^5$	$8.90x10^6$
200	$6.86x10^5$	$8.53x10^6$
300	$6.77x10^5$	$8.40x10^6$
400	$6.72x10^5$	$8.34x10^6$
500	$6.69x10^5$	$8.30x10^6$

Variation of bandwidth with different supply voltage values of V_{CC} is plotted in figure-4. The bandwidth value for BJT amplifier decreases from $1.20x10^6$Hz to $5.30x10^5$Hz when V_{CC} value varies from 15V to 40V which is 55.83% decrease in bandwidth. FET amplifier bandwidth increases from $1.54x10^7$Hz to $2.11x10^7$Hz when V_{CC} varies from 15V to 40V which is 37% increase in bandwidth.

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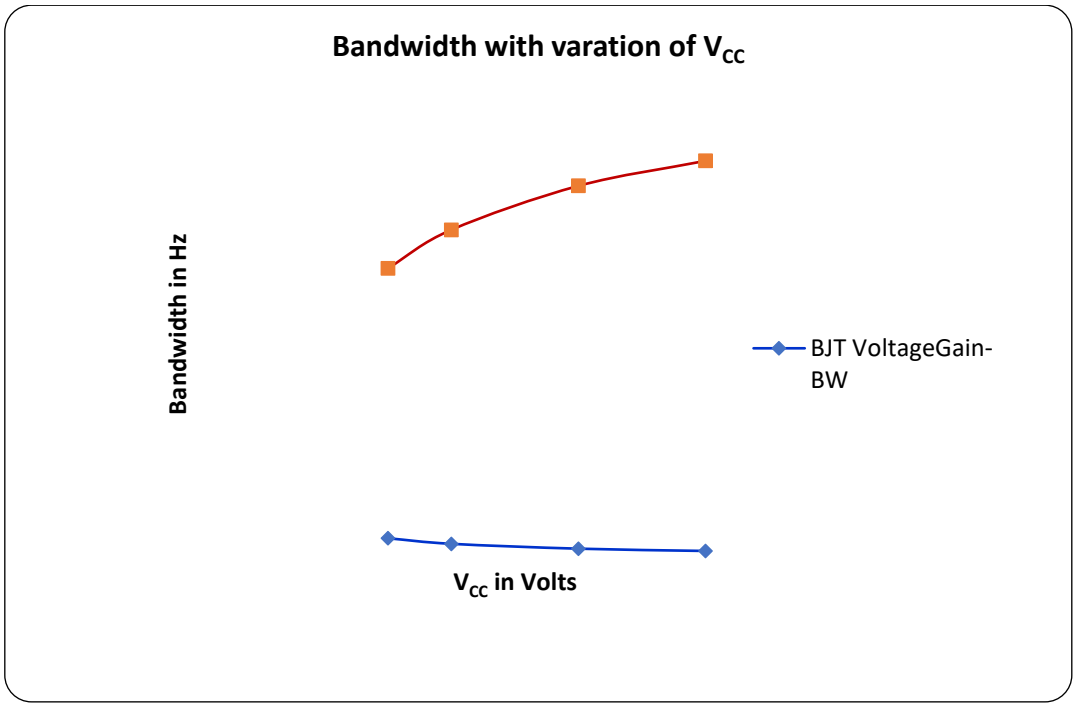

Fig. 4. Bandwidth at Various V_{CC} values

Table-2 shows the Pspice simulation results from figure-1 and figure-2 circuits. The various values of bandwidth with respect to variation in V_{CC} values. It has been observed that BJT bandwidth decreases with increase in V_{CC} while the FET bandwidth increases when V_{CC} increases from 15V to 40V.

Table.2. Bandwidth with different values of V_{CC}

V_{CC} (Volts)	BJT Bandwidth (Hz)	FET Bandwidth (Hz)
15	$1.20x10^6$	$1.54x10^7$
20	$9.05x10^5$	$1.75x10^7$
30	$6.49x10^5$	$1.98x10^7$
40	$5.30x10^5$	$2.11x10^7$

CONCLUSION

Simulation study of various parameters of Common Emitter BJT amplifier and Common Source FET amplifiers were carried out. Amplifiers performance parameters like bandwidth, voltage gain etc could possibly change by varying the values of some of the passive components. Study of bandwidth of both the BJT and FET amplifiers carried out, the bandwidth value for BJT amplifier decreases from $3.98x10^6$Hz to $6.69x10^5$Hz when R_L value varies from 1 KΩ to 500 KΩ. In case of FET amplifier bandwidth decreases from 5.92 $x10^7$Hz to 8.30 $x10^6$Hz when R_L value varies from 1 KΩ to 500 KΩ. The BJT amplifier bandwidth value decreases from $1.20x10^6$Hz to $5.30x10^5$Hz when V_{CC} value varies from 15V to 40V. The bandwidth value of FET amplifier increases from $1.54x10^7$Hz to $2.11x10^7$Hz when V_{CC} varies from 15V to 40V.

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