International Journal of Scientific Research and Engineering Development-– Volume 3 Issue 2, Mar-Apr 2020

Available at www.ijsred.com

RESEARCH ARTICLE OPEN ACCESS

Error Analysis of Calculation of Voltage Divider Biased BJT Amplifier

San Thiri Aung*,Khaing Myat Nwe**, Aye Aye Mar***

[1,2,3]Faculty of Computer Systems and Technologies, University of Computer Studies (Mandalay),Myanmar

santhiriaung465@gmail.com,khaingmyatnwe.mdy@gmail.com, mmoesan.84@gmail.com

--************************----------------------------------

Abstract:

The goal of the BJT amplifier is to create a Q-point on which current and voltage variations will occur in response to an AC input sign.The Q-point principle is used when transistor acts as an amplifier and is therefore worked in the active input output region. To operate the BJT at a point it is necessary to provide voltages and currents through external sources. The Common Emitter amplifier is calculation for voltage divider rule and Thevenin theorem equation. The main purpose of this paper is to associate voltage divider traditional methods with the equivalent of Thevenin and to obtain the difference between the two methods. Thevenin's Theorem is especially useful in the circuit analysis of power amplifier and other interconnected resistive circuits.Voltage divider biasing typical emitter amplifier is one of the core content of the analog circuit curriculum and almost all conventional textbooks use approximate method of calculation to estimate all characteristic parameters. The calculation shows that the voltage divider traditional method can produce an error of about 10 Percent, and even extreme with a higher Q- point for small signal amplifier.The equations derived from equations show 10% errors in the voltage divider traditional and Thevenin's theorem.

Keywords **—**Common-Emitter Amplifier, Quiescent Point, Thevenin Equivalent Circuit, Small Signal Amplifier

--************************----------------------------------

I. INTRODUCTION

An amplifier is one of the most important contents of electronic circuit systems. The main reason is that almost all the analog signals from the sensors are very weak and could not drive loads directly. The main function of the amplifiers is amplifying the weak signals so that the signal can become strong enough for practical applications.We can classify the research into two different fields. The voltage divider traditional rule always assumes that the output resistor is not loaded; the equation is not valid when the output resistor is loaded by a parallel component. Fortunately, most circuits following a voltage divider are input circuits, and input circuits are usually high resistance circuits. When a fixed load is in parallel with the output resistor, the equivalent parallel value comprised of the output resistor and loading resistor can be used in the voltage divider calculations with no error. Many people ignore the load resistor if it is ten times greater than the output resistor value, but this calculation can lead to a 10% error.

II. OVERVIEW OF THE SYSTEM

To analyse a voltage-divider biased transistor circuit for base current loading effects, we will apply Thevenin’s theorem to evaluate the circuit [2].We then replace the remaining circuit with a simple series equivalent circuit, thus Thevenin's theorem simplifies the analysis. Voltage divider biasing common-emitter amplifier based on the voltage divider is most prevalent in conventional textbooks and practical applications.As we know, we can design or evaluate the circuit from a quiescent point to a small-signal AC situation, thus splitting the problem into two phases. In the first step, that is, we can deal with the circuit in two most commonly different ways during the Q- point determination. The first option is to use a rough approach.In the method, we disregard the base current called $I_B$because in almost all cases the base current is very small compared to the biased current through the two biased resistors.The second method is based on the same principles as Thevenin.We do not neglect the base current in this method and we can obtain correct values of several voltages and currents [7]. As we all know, no matter what approach is used, we can evaluate the working region of the bipolar junction transistor after we get the values of currents and voltages of quiescent level.By using the figure 1, the difference will calculate between the base current, emitter current, collector current, base voltage, collector voltage, emitter voltage, collector to emitter voltage and voltage gain values in two ways.

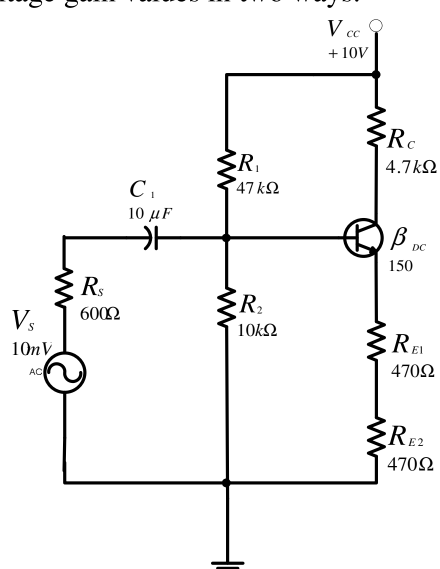

Figure.1Voltage divider biasing common emitter amplifier

A. *Common Emitter Amplifier*

Amplifier is the generic term used to describe a circuit which produces and increased version of its input signal. However, not all amplifier circuits are the same as they are classified according to their circuit configurations and modes of operation.The single stage common emitter amplifier circuit shown above uses what is commonly called Voltage Divider Biasing.This type of biasing arrangement uses two resistors as a potential divider network across the supply with their canter point supplying the required Base bias voltage to the transistor [1,3] .

Voltage divider biasing is commonly used in the design of bipolar transistor amplifier circuits.This method of biasing the transistor greatly reduces the effects of varying Beta, (β) by holding the Base bias at a constant steady voltage level allowing for best stability. The quiescent Base voltage is determined by the potential divider network formed by the two resistors,R1, R2and the power supply voltage Vcc as shown with the current flowing through both resistors.Then the potential divider network used in the common emitter amplifier circuit divides the supply voltage in proportion to the resistance.The aim of any small signal amplifier is to amplify all of the input signal with the minimum amount of distortionpossible to the output signal, in other words, the output signal must be an exact reproduction of the input signal butonly bigger (amplified) [6, 7].

B. *DC Analysis of Voltage Divider Bias*

To analyze the amplifier in Figure 1, the DC bias values must first be determined. To do this, a DC equivalent circuit is developed by removing the coupling and bypass capacitors because they appear open as far as the DC bias is concerned [5]. This also removes the load resistor and signal source. The DCequivalent circuit is shown in figure2.

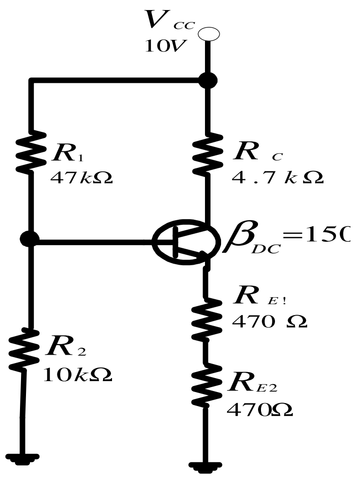

Figure.2 DC equivalent circuit for Voltage divider biasing common emitter amplifier

C. ***Voltage Divider Rule***

A DC bias voltage at the base of the transistor can be developed by a resistive voltage divider that consists of R_1 and R_2, as shown in figure 2. V_{CC} is the dc collector supply voltage. Two current paths are between point *A* and ground: one through R_2, and the other through the base-emitter junction of the transistor and R_E [4, 5, 6].

To analyze a voltage-divider circuit in which I_B is a small compared to I_2, first calculate the voltage on the base using the unloaded voltage-divider rule;

$$V_B \cong \left(\frac{R_2}{R_1 + R_2}\right) V_{CC} \qquad (1)$$

The quiescent point currents and voltages, Base voltage, Base current, Collector voltage and Collector current can be evaluated as shown in equation.

$$I_C \cong I_E = \left(\frac{V_B - V_{BE}}{R_E}\right) \qquad (2)$$

The quiescent point voltage can be calculated as shown in equation 3.

$$V_C = V_{CC} - I_C R_C \qquad (3)$$

Base current can be evaluated as in equation 4.

$$I_B = \left(\frac{V_B - V_{BE}}{R_E(1 + \beta)}\right) \qquad (4)$$

It is possible to test the emitter voltage as in equation 5.

$$V_E = V_B - V_{BE} \qquad (5)$$

The voltage between collector and emitter can be calculated as shown in equation 6.

$$V_{CE} = V_C - V_E \qquad (6)$$

If we can decide that the transistor is biased in the active forward region, we can use hybrid equivalent circuit to continue designing or analysing the dynamic situation.

III. THEVENIN EQUIVALENT METHODS

Thevenin's theorem states that it is possible to simply any linear circuit, no matter how complex, to an equivalent circuit with just a single voltage source and series resistance connected to a load. There are occasions when isolating a portion of the circuit is useful to simplify the study of the circuit's isolated part [2].

The qualification of linear is identical to that found in the superposition theorem, where all the underlying equations must be linear. If we do not ignore the base current I_B, we can use Thevenin equivalent methods to find Q-point and currents and voltages. The basic equivalent circuit is shown in figure3.Equivalent voltage source V_{TH} can be calculated according to equation 7.

$$V_{TH} = \left(\frac{R_2}{R_1 + R_2}\right) V_{CC} \qquad (7)$$

Then solving emitter current I_E,by usingequation 8.

$$I_{EQ} = \frac{V_{TH} + V_{BE}}{R_E + {R_{TH}}/{\beta_{DC}}} \qquad (8)$$

The base current can be acquired from equation 9.

$$I_{BQ} = \frac{V_{TH} - V_{BE}}{R_{TH} + (1 + \beta_{DC})R_E} \quad (9)$$

Equivalent resistance R_{TH} can be evaluated as shown in equation 10.

$$R_{TH} = R_1 // R_2 \quad (10)$$

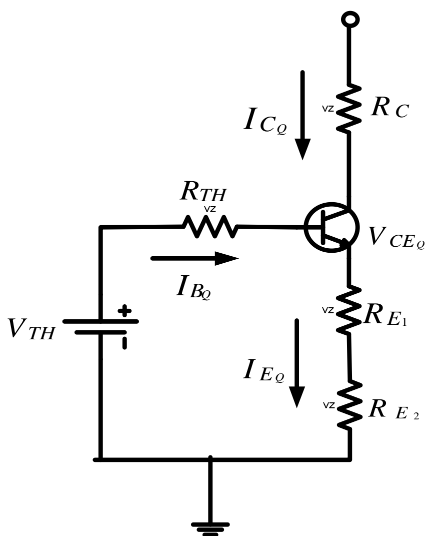

Figure.3 Thevenin equivalent circuit of Voltage divider biasing common emitter amplifier

IV. COMPARISON OF THE TWO APPROACHES

Comparing the current I_B andI_{BQ}, according to equations 4 and 9, the absolute error $I_{BQ-Error}$can be obtained due to the estimated approximation as shown in equation 11.

$$I_{B-Error} = I_B - I_{BQ} \quad (11)$$

So from the first approach as shown in equation 10 we can get the relative error of quiescent point currentI_B.

$$\text{Error} = \frac{I_{B-Error}}{I_B} \quad (12)$$

D. ***Calculation Resultsof Error For Two Methods***

For Method 1,

$$I_B = \left(\frac{V_B - V_{BE}}{R_E(1+\beta)}\right)$$

$$= \left(\frac{1.75 - 0.7}{(470+470)(1\ +150)}\right) = 7.397\mu A$$

For Method 2,

$$I_{BQ} = \frac{V_{TH} - V_{BE}}{R_{TH} + (1 + \beta_{DC})R_E}$$

$$= \frac{1.75 - 0.7}{8.25k + (1+150)(470+470)} = 6.99\mu A$$

$$I_{B-Error} = I_B - I_{BQ}$$

$$= 7.397\mu A\ - 6.99\mu A$$

$$= 0.407\mu A$$

$$\text{Error} = \frac{I_{B-Error}}{I_B}$$

$$= \frac{0.407\mu A}{6.99\mu A} = 5.8\%$$

Two different equations are calculated and the error is calculated in figure 1. If should be noted that the error is not small. The residual values will be calculated using equation12.The equations derived from the equations show 10% errors in the methods voltage divider and the theorem of Thevenin.From the above evaluations we are able to see the difference between the results achieved from the method 1 and the method 2. The results are described in table 1 and table 2.

TABLE1.

QUIESCENT POINT CURRENTS PARAMETERS ACQUIRED BY THE TWO METHODS

	$I_B(\mu A)$	$I_{B-Error}$ (μA)	$I_C(\mu A)$	$I_{C-Error}(\mu A)$
1	7.397	0.407	1.117	0.057
2	6.99	**5.8%**	1.06	**5.4%**

TABLE2.

QUIESCENT POINT VOLTAGE PARAMETERS ACQUIRED BY THE TWO METHODS

Method	V_{CE}	$V_{CE-Error}$
1	3.686V	0.334V
2	4.02V	**8.3%**

From the results as shown in the above two examples and equation 12, we need a lower resistance ratio between R_{TH} and (1+β)R_E if we want the relative IB error to be lower. In other words, there should be less biased resistance. Less biasing resistance, as we all know, means higher biasing current, which causes higher consumption of DC power. It can also decrease the resistance of the input and thus decrease the amplification factor of the source voltage.This means that the first method's relative error may not be very high; the value is often higher than 10%.

V. CONCLUSION

In this paper, we compared the two common-used approaches to the common-emitter amplifier solution, giving the formula of the quiescent point base current difference.We will learn from the formula and some simulation tests that the higher quiescent point means more significant error of quiescent base current.The contribution of this paper will boost the understanding of this principle and avoid major errors in evaluating the quiescence of bipolar junction transistor amplifiers and, moreover, allow designers to characterize the characteristics of AC amplifiers.For the two approaches discussed in this paper, we will explore some more complicated circuits in the future in order to prevent errors in the design process.

REFERENCES

[1] Assaad, R.S. and Silva-Martinez, J. (2009) A Graphical Approach to Teaching Amplifier Design at the Undergraduate Level. IEEE Transactions on Education, 52,39-45. https://doi.org/10.1109/TE.2008.917190

[2] Bandyopadhyay, Anup Kumar, Thevenin's theorem: An easy proof suitable for undergraduate teaching, Lat. Am. J. Phys. Educ. 9, 2015, 2502-1

[3] Diffenderfer, Robert. Electronic devices: systems and applications. Cengage Learning, 2005

[4] Kang, H. (2001) Analog Part in Fundamental of Electronic Technology, 4th Edition, High Education Publishing House, Beijing

[5] Leonard S. Bobrow, Fundamentals of Electrical Engineering, Second Edition

[6] Yang, Z., Nath, D.N., Zhang, Y.J., Khurgin, B. and Rajan, S. (2015) Common Emitter Current and Voltage Gain in III-Nitride Tunneling Hot Electron Transistors. IEEE Electron Device Letters, 36, 436-438. https://doi.org/10.1109/LED.2015.2413934.

[7] https://en.wikipedia.org/wiki/Bipolar_transistor_biasing

