A NEW APPROACH TO MINIMIZE STABILITY FACTOR OF AN AMPLIFIER

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Abstract

In this paper, a method is proposed for minimizing stability factor and removing the negative feedback from Self Bias Configuration of an Amplifier. Stability is an important concern in the designing of Amplifier. For stabilization of an Amplifier different biasing techniques are used. Among all biasing techniques Self Bias technique is best but the major drawback is the introduction of negative feedback by Emitter resistance R_e. Due to the introduction of negative feedback the gain of an amplifier decreases. An ideal Ammeter has infinite internal resistance so to remove the negative feedback an ideal Ammeter is used instead of Emitter resistance R_e. With the application of proposed method the Stability factor is minimized and coming out to be equal to Unity and the problem of negative feedback is also removed. In this paper the analysis of proposed Self Bias Circuit is done with the help of Thevenin Theorem.

Keywords: *Negative Feedback, Stability Factor, Self-Bias Circuit, Amplifier*

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1. INTRODUCTION

Transistors are used as amplifiers, oscillators, switching circuits etc. However, the principal use of transistor is as an amplifier [1]. An amplifier increases the magnitude of a given signal applied to its input. Most of the transistor amplifiers are required to work as linear amplifier. An amplifier is said to be linear if its output voltage is a linear function of its input voltage. Such a linear operation is ensured when zero signal operating point is selected properly, desirably in the middle of the active region and the operation is restricted in the linear region of the characteristic curves, thereby avoiding the distortion of the signal waveform [2]. Thus selection of zero signal operating point is of great importance and may be done by using suitable biasing arrangement i.e. by applying proper dc voltages to emitter-to-base junction and collector-to-base junction. The biasing circuit used in transistor should be such as:

i. To establish conveniently the operating point in the middle of the active region of the characteristics.
ii. To make the operating point independent of transistor parameters
iii. To stabilize the collector current against temperature variations.

2. MATERIALS AND METHODS

2.1 Stability Factor

Stability Factor S indicates the variation in collector current I_c due to variation in reverse saturation current I_{co} because of variation in Temperature. Smaller the value of S, better will be the thermal stability. In Ideal case the minimum value of S=1 and in Practical case, the minimum value of S=1.3. If S is less than 1+β then the amplifier is stable otherwise unstable [3

$$S = \frac{\partial I_c}{\partial I_{co}} \qquad (1)$$

Where V_{BE} and β are constant.

General equation of Stability Factor S

$$I_c = \beta I_b + (1+\beta) I_{co} \qquad (2)$$

Differentiating both side with respect to I_c

$$1 = \beta \frac{\partial I_b}{\partial I_c} + (1+\beta)\frac{\partial I_{co}}{\partial I_c} \qquad (3)$$

Using Equation (1) in equation (3), we get

$$1 = \beta \frac{\partial I_b}{\partial I_c} + (1+\beta)\frac{1}{S} \qquad (4)$$

On simplifying Equation (4), we get

$$S = \frac{1+\beta}{1-\beta\frac{\partial I_b}{\partial I_c}} \qquad (5)$$

2.2 Algorithm to Find Stability Factor S

Step 1: apply KVL to the input Mesh to obtain input Equation.
Step 2: Substitute $I_e = I_c + I_b$ in input equation and simplify.
Step 3: differentiate the equation obtained above with respect to I_c keeping V_{BE} and β as constant.
Step 4: simplify the obtained equation to get $\frac{\partial I_b}{\partial I_c}$.

Step 5: substitute the value of $\frac{\partial I_b}{\partial I_c}$ in general equation of S.

2.3 Biasing Circuits

There are three basic Biasing Circuits

2.3.1 Fixed Bias Circuit

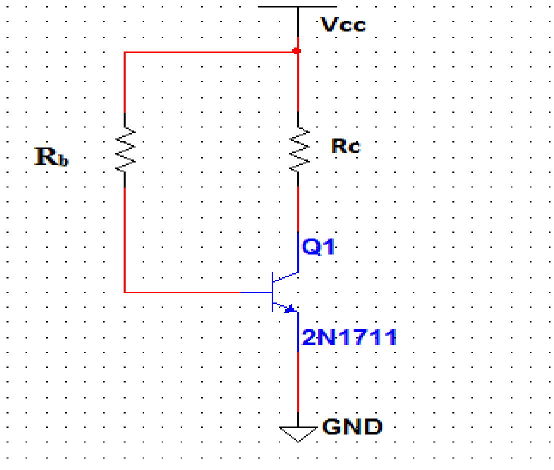

Fig -1: Fixed Bias Circuit

In fixed bias circuit the stability factor

$$S=1+\beta$$

S is very high that is poor thermal stability.

2.3.2 Collector to Base Bias Circuit

In collector to Base bias circuit Stability factor

$$S = \frac{1+\beta}{1+\beta\frac{R_C}{R_C+R_b}} \qquad (6)$$

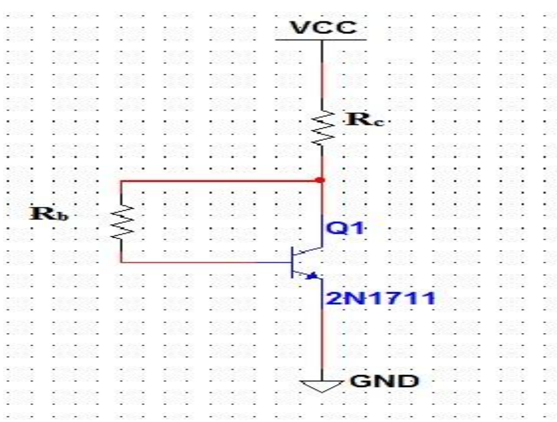

Fig -2: Collector to Base Bias Circuit

S is small that is the circuit is having good thermal stability. The function of base resistance R_b is to provide a base current to the transistor and since it is connected between collector and base it will introduce the unwanted negative feedback and reduces the voltage gain of the amplifier. This biasing circuit is also practically rejected.

2.3.3 Self Bias Circuit

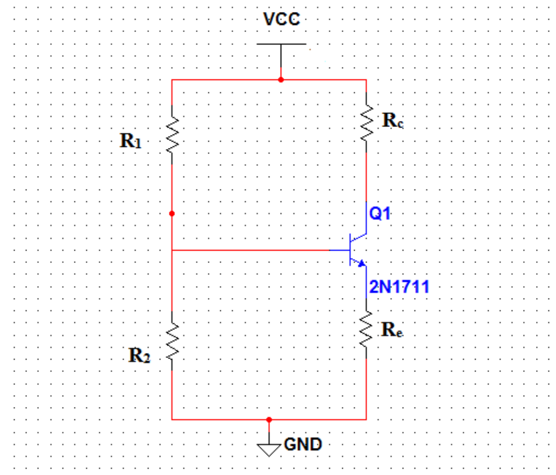

Fig -3: Self Bias Circuit

Self-bias circuit is also called potential divider or emitter bias circuit. This is the popularly used biasing circuit. The BJT is in CE mode with emitter resistance R_e and will introduce 180^0 phase shift for the input signal. R_1 and R_2 are biasing resistors and they are used to provide a base current into the transistor ($R_1 \geq 10R_2$). Simplified Self-bias Circuit using Thevenin Theorem.

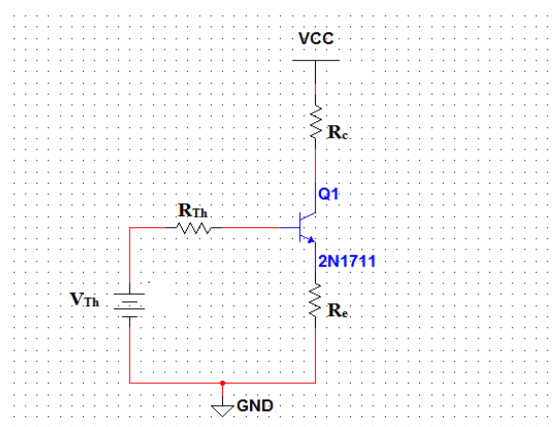

Fig -4: Thevenin Equivalent of Self Bias Circuit

Thevenin open circuit voltage

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

And Thevenin Internal resistance

$$R_{Th} = R_1 \parallel R_2 \qquad (8)$$

On applying KVL in input Mesh

$$V_{Th} = I_b R_{Th} + V_{BE} + I_e R_e$$

$$\text{Substitute } I_e = I_c + I_b$$

and on simplifying, we get

$$V_{Th} = I_b R_{Th} + V_{BE} + I_c R_e + I_b R_e$$

On differentiating with respect to I_c we get

$$0 = (R_{Th} + R_e)\frac{\partial I_b}{\partial I_c} + R_e$$

On simplifying,

$$\frac{\partial I_b}{\partial I_c} = \frac{-R_e}{R_{Th} + R_e}$$

On substituting the above equation in equation (1)

$$S = \frac{1+\beta}{1+\beta\frac{R_e}{R_{Th}+R_e}} \qquad (9)$$

S is very small and that is self- bias circuit is having excellent thermal stability.

Self- bias circuit with emitter resistance R_e=0 is unstable and stability factor becomes

$$S = 1+\beta$$

That is R_e is mainly responsible for providing the thermal stability or Q-point stability in the circuit hence R_e is called the Stabilization Resistance. The major disadvantage of using emitter resistance R_e is that negative feedback is introduced in the circuit due to which gain decreases.

2.4 Proposed Biasing Circuit

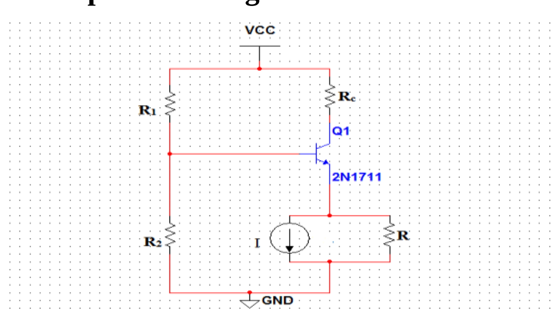

Fig -5: Proposed Biasing Circuit

To eliminate the problem of negative feedback across R_e, a practical current source is connected in place of emitter resistance so that the internal resistance of current source which is very large will be working as an emitter resistance in the circuit. By this the problem of negative feedback in the circuit is eliminated.

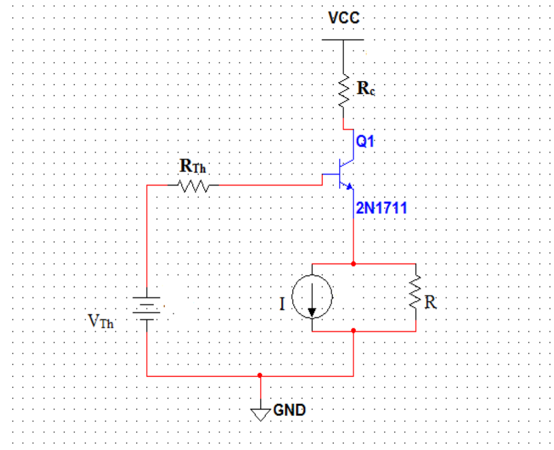

Fig -6: Thevenin Equivalent of Proposed Biasing Circuit

On applying KVL in input Mesh

$$V_{Th} = I_b R_{Th} + V_{BE} + R\, I_R$$

$$\text{Substitute } I_R = I_e - I_A$$

and on simplifying, we get

$$V_{Th} = I_b R_{Th} + V_{BE} + I_e R - I_A R$$

On differentiating with respect to I_c we get

$$0 = (R_{Th} + R)\frac{\partial I_b}{\partial I_c} + R$$

On simplifying,

$$\frac{\partial I_b}{\partial I_c} = \frac{-R}{R_{Th} + R}$$

On substituting the above equation in equation (1),

$$S = \frac{1+\beta}{1+\beta\frac{R}{R_{Th}+R}}$$

$$S = \frac{(1+\beta)\,(R+R_{Th})}{(1+\beta)R + R_{Th}} \qquad (10)$$

As R is the internal Resistance of Ideal current source therefore R is very high ($R \to \infty$).

On applying this condition on Equation (10), we get

$$S = \lim_{R\to\infty} \frac{(1+\beta)\,(R+R_{Th})}{(1+\beta)R + R_{Th}} \qquad (11)$$

On solving, we get
S=1.

3. CONCLUSIONS

In this paper, we have proposed a method to stabilize the amplifier with the help of an ideal Ammeter so that the problem of negative feedback is also removed. An interesting by-product of this work is that the minimum stability factor i.e. S=1 is achieved.

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BIOGRAPHIES

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