A Solution to Improve the Quality of BJT Amplifiers

Anh Dang Thi Ngoc

Abstract—**A advantagae of BJT amplifier is wide bandwidth. However, when designing a amplifier has two disadvantages. The first, by given gain, the designing depends on many parameters (ex working area, value of resistors..) so it is dificult to meet with the application having changeable amplification. Secondly, the input resistance of them is small so the gain is not high if the source has a large internal resistance. To overcome the above disadvantages, the author proposed a amplifier designing using combination operational amplifier (OA) and BJT. The results on multisim simulation software also show that the amplifier has better frequency response.**

Index Terms— BJT amplifier, Operational amplifier, multisim

I. INTRODUCTION

When using transistor for an amplifier, it has the advantage of a large amplification and good response with high frequencies, but has a major drawback of difficult amplifier changing and small input resistance. How to design a transistor amplifier has been presented in many documents [2], [3], [4]. But the design of a amplifier with easily variable gain has not been addressed.

Amplifiers using OA have the advantage of being able to easily change the amplification factor, but the main drawback is the limitation of output power.

The paper gives the idea of designing an amplifier that combines OA and BJT transistors to create amplifiers that can amplify at high frequencies and can easily change the gain.

The paper is organized follow, introduction is presented in section I, basic configuration BJT, OA amplifier as well as some problems given are done in section II and III. Propose structure and simulations in multisim software are presented in section IV and conclution is in the end.

II. DESIGN BJT AMPLIFIER

When designing BJT amplifier, there are three basic configurations: Common emiter (CE), Common base (CB) and Common collector (CC). In which, CE configuration (Figure 1) is often used. In this, the change of resistor values, capacitors, it will change the working mode, input/output resistance, gain ... of the circuit.

The calculation of amplifier parameters with small signal is based on the position of the working point in the active mode working and the replacement of the circuit diagram with equivalent replacement. We have CE amplifier in Figure 1 and its equivalent circuit shown in Figure 2.

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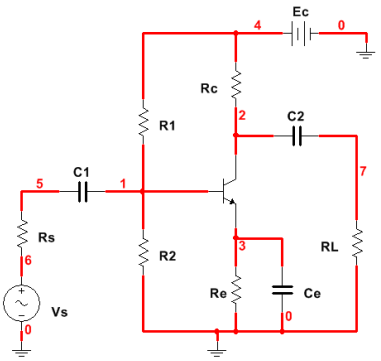

Fig 1: CE amplifier configuration

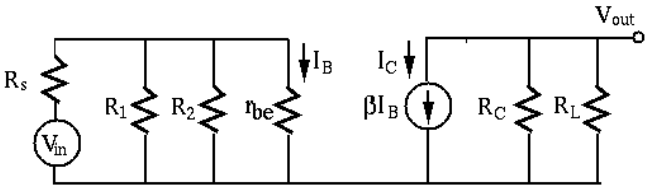

Fig 2: Equivalent circuit of CE amplifier

Some isues need to discuss:

- Input resistance $R_{in} = R1//R2//r_{be}$, where r_{be} is junction resistance between base and emiter, r_{be} is small so R_{in} small, too.
- The voltage gain of circuit:

$$G = -\frac{R_{in}}{Rs + R_{in}}.g_m(R_c // R_L // r_o) \quad (1)$$

In which: $g_m = I_C / V_T$ (2)

The gain *G* depends on the working point, and the collector resistance *Rc*. If we want to change this gain, we have to change these factors. With the requirement changing a wide range, the formulas (1), (2) will not be exact if the selection of Q point falls into saturation or cutoff area. Therefore, in order to ensure the quality of the amplifier, changing the amplification factor requires very complicated calculations, so we need to be taken to reduce the calculation steps. It is also important to note that the design of amplifiers using BJTs with large resistances (about kΩ) and large gain is difficult, in some cases, it is not possible.

- Bandwidth of BJT is high, so it is convinent for input signal in term of frequency.

III. DESIGN AMPLIFIER USING OA

It is easily to change voltage gain when designing an amplifier using OA. However, we have an inverse relationship between this factor and the signal frequency. One of the parameters of OA that affects the bandwidth of amplifier is slew-rate parameter (*SR*). Because of SR, OA has power bandwidth that determines the maximum frequency at which output is still sinusoidal signal without causing too slew rate.

In common, invert configuration is used. Figure 3 is that circuit:

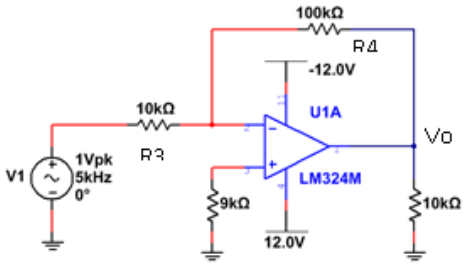

Fig 3: EC amplifier configuration

Some isues mentioned:

- Input resistance of circuit is R_3, so if you want to increase this parameter, it means that R_3 should be increased.
- Gain $G = -R4/R3$, therefore, if G is increase, R_3 is decreased.
- Ouput current of OA is small, so if the load need high power, this is limited.
- When working in high frequency, power bandwidth makes us pay attention in gain and frequency.

IV. DESIGN AMPLIFIER USING OA AND BJT

From these analysics above, if using BJT in designing amplifier, changing gain is quite difficult due to more calculation by rechoising Q point. But BJT has high bandwidth. For OA, the adjustment of gain is very easy, in turn at high frequency, signal is easily distorted.

Combining OA and BJT will take advantage of two components. The first stage using OA will increase the input impedance, and to change the amplification factor. The second stage uses BJT that specified gain and deliver power to the load.

Now, we show the result in simulation software to confirm. Consider signal input has $V_p = 100\ mV$, frequency $f = 5kHz$, inner resistor $R_s = 10K\Omega$,

If we use OA to amplify, here LM324 is used, SR = 0.3V/µs. Circuit is in Fig 3, maximum frequency of input signal is:

$$f_{\max} = \frac{SR}{2\pi.V_P} = 4.78kHz$$

In this case, the frequency of input signal is higher than $f_{\max}$, so output signal will be distorted. Its spectrum is shown in fig 4:

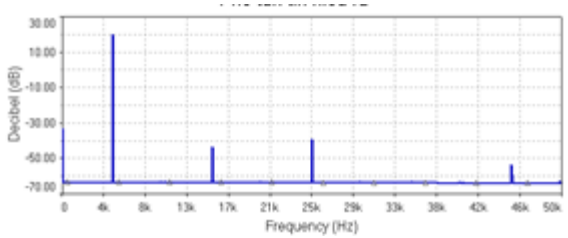

Fig 4: Output spectrum

We see that, spectrum involves high frequency signal at 15kHz, 25kHz and 45kHz.

When combining OA and BJT, we design of a amplifier whose gain is 20V/V. In which, first stage is an OA amplifier with 5V/V of gain, the second stage is a BJT amplifier with 4 V/V. Designing amplifier using BJT is done by following steps:

1. Choose BJT, here is 2SC1815
2. Calculate emitter resistor by choosing emitter voltage (generally should be 10% of supply voltage)
3. Calculate collector resistor by choosing V_{CE} (need to be half the supply voltage)
4. Determine the base voltage, and then calculate base resistor
5. Determine Emitter bypass capacitor.
6. Determine input and output capacitor value.

Circuit diagram and simulation results are shown in Figure 5:

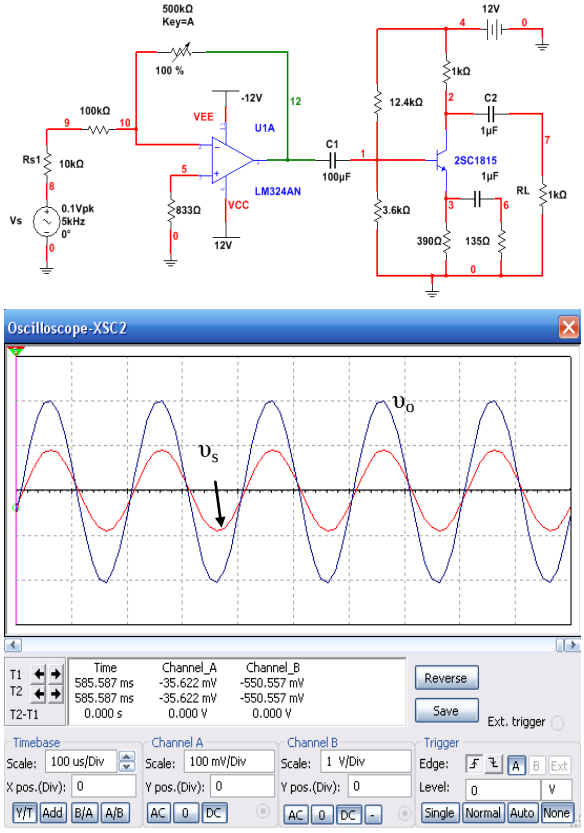

Fig 5: Amplifier using OA and BJT circuit and its result simulation

We see that, the gain is 20 V/V and the output signal is not distorted. So, with two stages amplifier, we get the amplifier having 100kΩ input resistance and the amlification can be changed from 0-20V/V by using rheostat.

Based on this structure, we can calculate the range of the gain when input frequency increases. In here, LM324 with saturation voltage is ±12V, amplitude of input signal is Vp=0.1V, table below shows the result:

Input frequency *(kHz)*	**Input resistance** (kΩ)	**Maximum of gain**
1.00	8.33	120.00
10.00	8.33	120.00
100.00	52.33	19.11
500.00	261.67	3.82
1000.00	523.33	1.91

V. CONCLUSION

The paper presents a configuraton of amplifier designing by combining operational amplifier and transistor. Amplifiers designed by this method can estimate the harmonic component that exists in the output signal. One advantage in this design is that it is possible to take advantage of the two components to create an amplifier that can change the amplification factor (based on the first stage) and increase the power amplifier of the amplifier (based on the second stage).

The next work will focus on improving the amplifier gain using compensation in high frequency to reduce harmonics and quantify the output harmonic components.

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