Bachelor of Engineering Electronic Engineering (HONS)

Headphone Amplifier Design

By

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Electronic Engineering

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Chapter 1

Simple transistor circuit

1.1 Transistor basic property

Figure 1.1 shows the basic NPN bipolar junction transistor circuit.

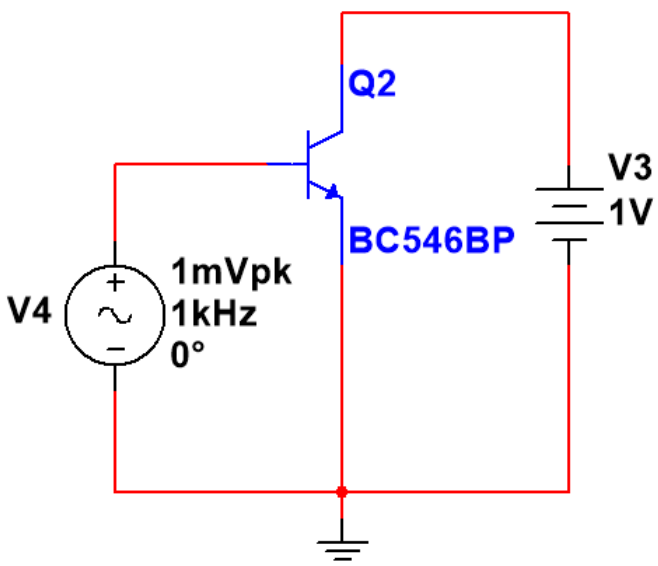


Figure 1.1: Single transistor circuit

We can get transistor operating state from simulation result as Table 1.1. It's obvious that I_C and I_E is proximately 200 times greater than I_B which is the main function of transistor.

Equation 1.1 defines β which is the most important parameter of transis-

I_B	9.09789μ
I_C	$2.02293m$
I_E	$-2.03003m$

Table 1.1: DC operating point analysis result

tor.

$$\beta = \frac{I_C}{I_B} \tag{1.1}$$

1.2 Relationship between Base voltage(V_{be}) and Collector current(I_c)

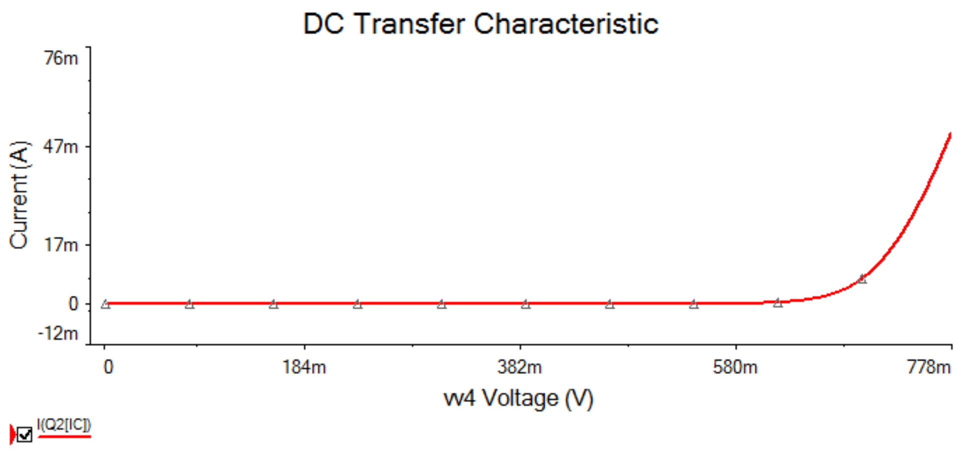


Figure 1.2: V_{be} and I_c curve

After running DC sweep command on $V4$ in circuit of Figure 1.1, We can get the curve of Figure 1.2. This illustrate that when $V_{be} < 0.65V$, I_c is very small and when $V_{be} > 0.65V$, I_c is increase significantly. Therefore, We can simply consider that when $V_{be} > 0.65V$, transistor is on.

1.3 Limit current gain

Generally, we need a method to control the current gain as we want. Figure 1.3 is a simply solution by adding transistor R_C and R_E.

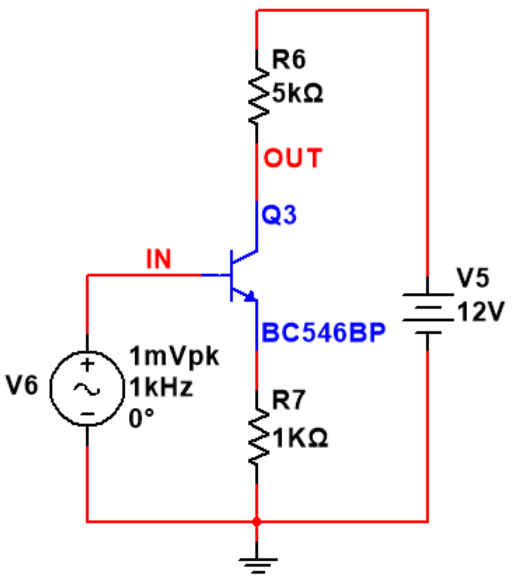


Figure 1.3: Basic transistor circuit with R_c and R_e

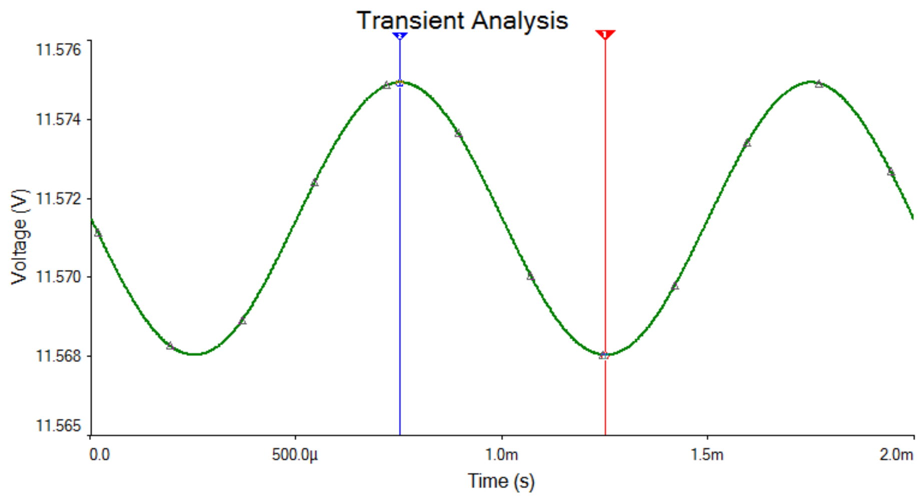
We can derive voltage gain A_V with Equation 1.2. And in circuit in Figure 1.3, A_V is approximate 5 theoretically.

$$A_V \triangleq \frac{V_{out}}{V_{in}} \approx -\frac{R_C}{R_E} \tag{1.2}$$

From simulation result in Figure 1.4, the practical $A_V = \frac{7.6486m}{2m} = 3.8243$ which is close to theoretic value.

1.4 Add voltage divider

As we know, we need make sure $V_{be} > 0.65V$ for transistor operating correctly. But in practical application, it's hard to keep input signal always meeting this requirement. So we can add capacitor and voltage divider solve this problem like Figure 1.5. In which, capacitor block the original DC voltage of input signal and voltage divider add the DC voltage which we require to signal. Finally, we use another capacitor for outputting pure AC signal form our circuit.



	V(in)	V(out)
x1	1.2508m	1.2508m
y1	658.7000m	11.5676
x2	749.1749µ	749.1749µ
y2	656.7000m	11.5752
dx	-501.6502µ	-501.6502µ
dy	-1.9999m	7.6486m
dy/dx	3.9867	-15.2469
1/dx	-1.9934k	-1.9934k

Figure 1.4: Output of the circuit in Figure 1.3

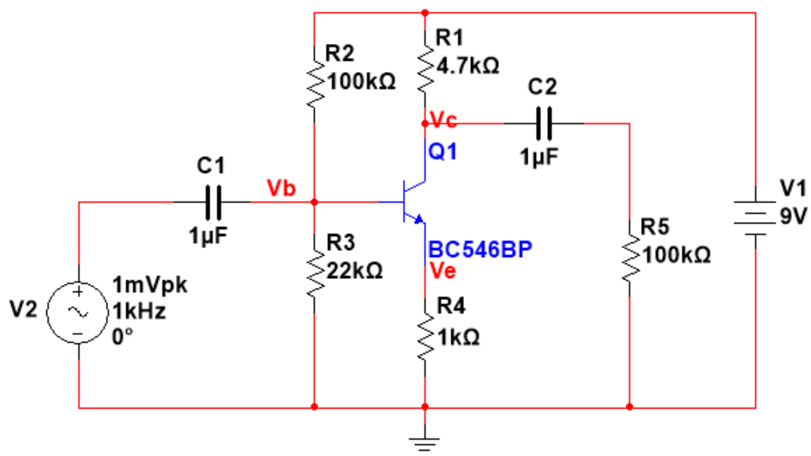


Figure 1.5: Add voltage divider and capacitors

Chapter 2

Negative Feedback

2.1 Simple Negative Feedback system

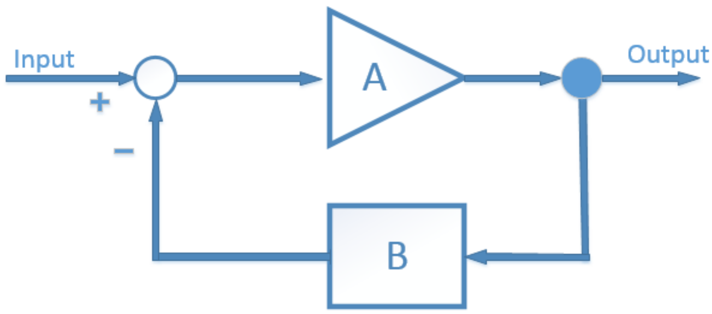


Figure 2.1: simple negative feedback system

Figure 2.1 show a simple negative feedback system in which A is ideal amplifier and B is feedback network.

$$\frac{V_{out}}{V_{in}} = B$$

2.2 Implement With Op-amp

In Figure 2.2, an Op-amp 741 is used to implement the negative feedback circuit in Figure 2.1.

741 is part A while R1 and R2 form feedback network.

$$\frac{V_{out}}{V_{in}} = B = \frac{R1 + R2}{R2} = \frac{10K + 1K}{1K} = 11$$

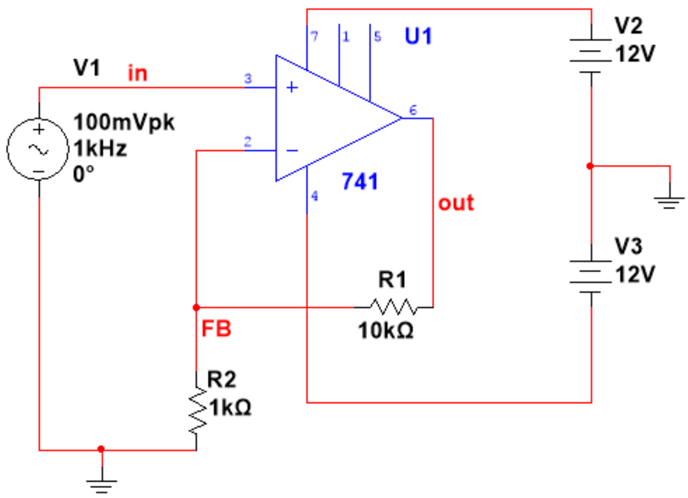
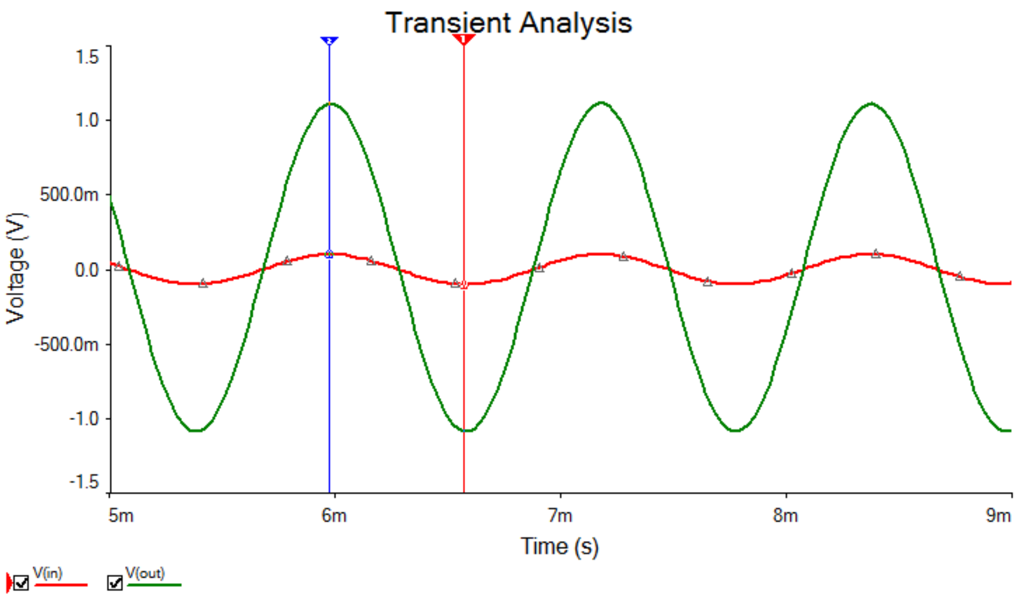


Figure 2.2: Implement negative feedback circuit with Op-amp

From simulation result in Figure 2.3,

$$B = \frac{\Delta V_{out}}{\Delta V_{in}} = \frac{2.1972}{199.8674m} = 10.99328$$

Obviously, the simulation result is very close to our estimation.



	V(in)	V(out)
x1	6.7433m	6.7433m
y1	-99.9112m	-1.0862
x2	6.2453m	6.2453m
y2	99.9562m	1.1110
dx	-498.0000µ	-498.0000µ
dy	199.8674m	2.1972
dy/dx	-401.3402	-4.4121k
1/dx	-2.0080k	-2.0080k

Figure 2.3: Op-amp feedback simulation result curve