EE210: Microelectronics-I

Lecture-12 :BJT Amplifier-part-1

https://youtu.be/fdJsixN-YKU

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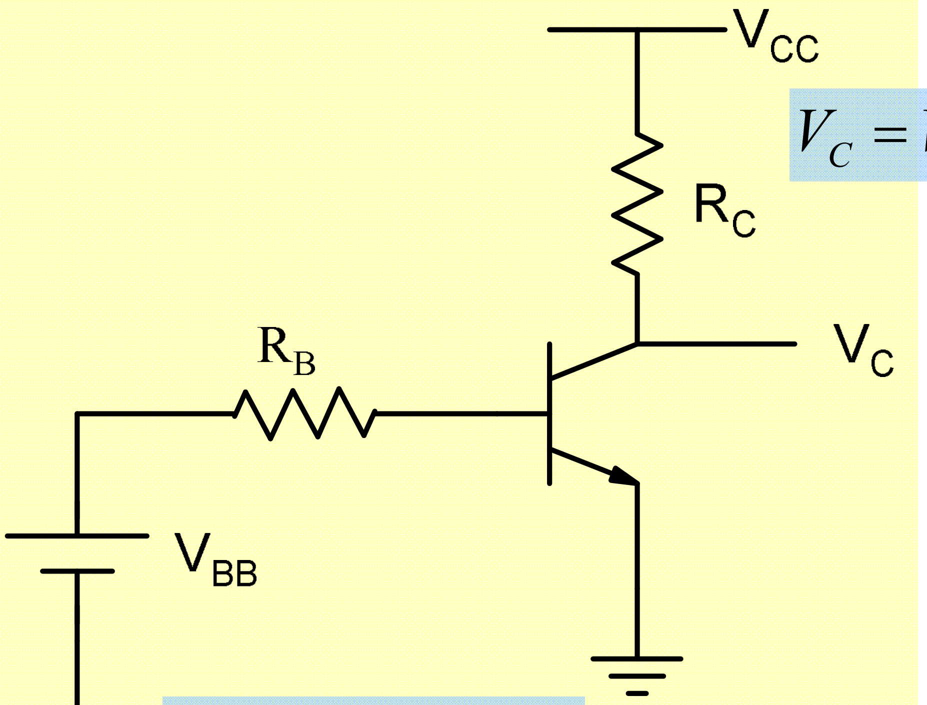
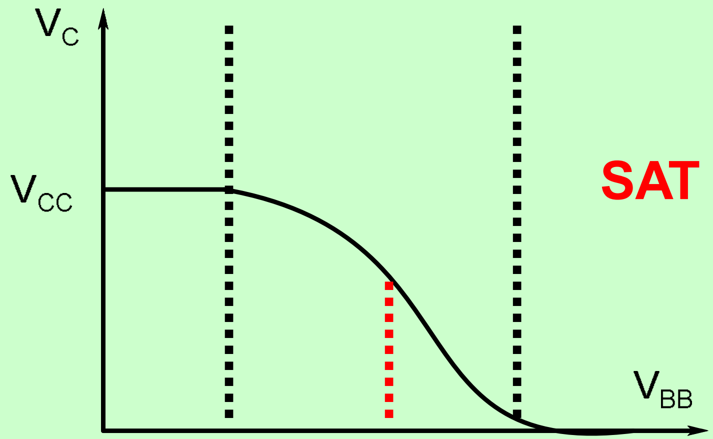
Amplifier: Basic Concept



$$V_C = V_{CC} - I_C R_C$$

$$\Delta V_C = -\Delta I_C \times R_C$$

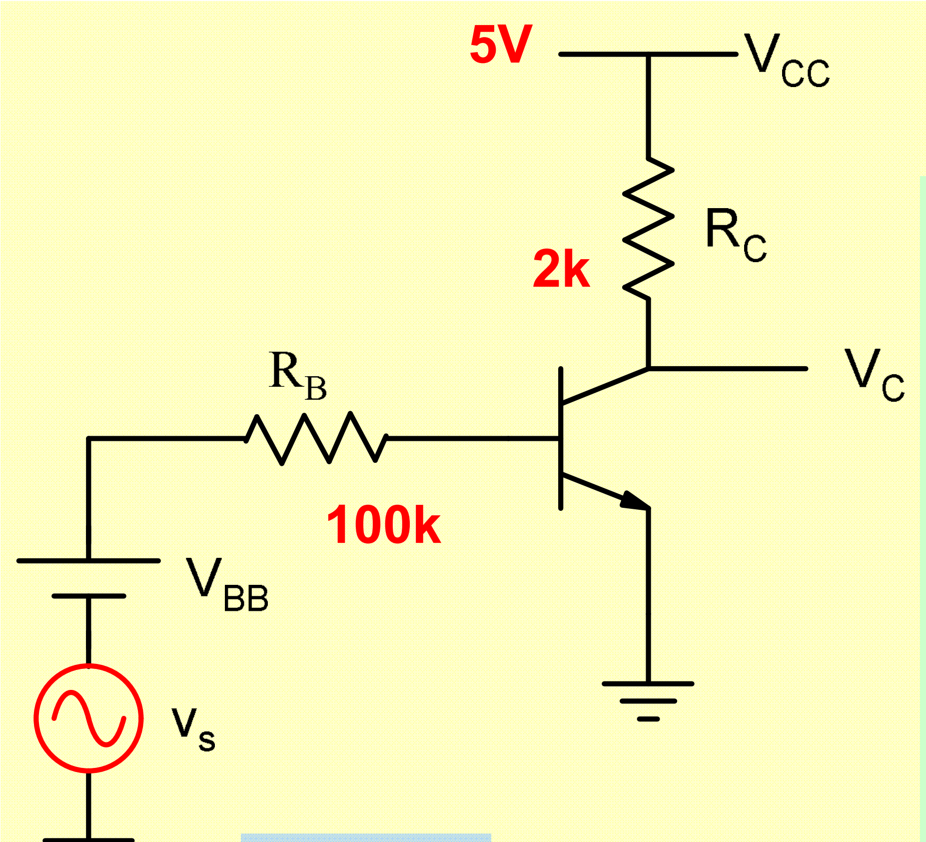
$$V_{BB} = I_B R_B + V_{BE}$$



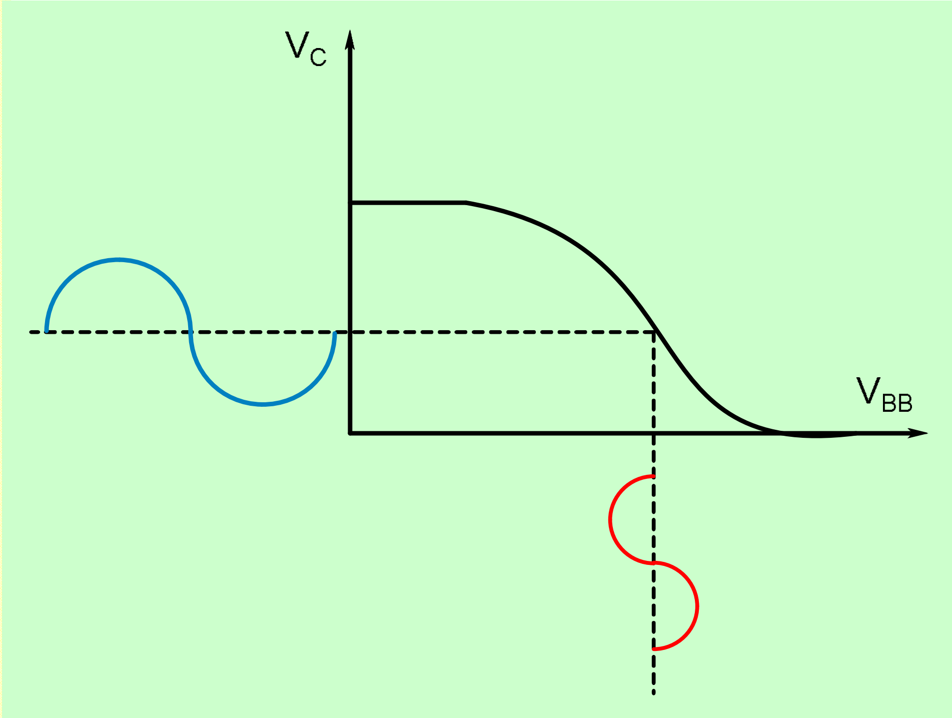
$$\Delta V_{BB} = \Delta I_B \times R_B + \Delta V_{BE}$$
$$= \Delta I_B \times \left(R_B + r_\pi\right)$$

$$\frac{\Delta V_C}{\Delta V_B} = -\left(\frac{\Delta I_C}{\Delta I_B}\right) \times \left(\frac{R_C}{R_B + r_\pi}\right) = -\beta \times \frac{R_C}{R_B + r_\pi}$$

$$\frac{\Delta V_{BE}}{\Delta I_B} = r_\pi = \frac{V_T}{I_B}$$



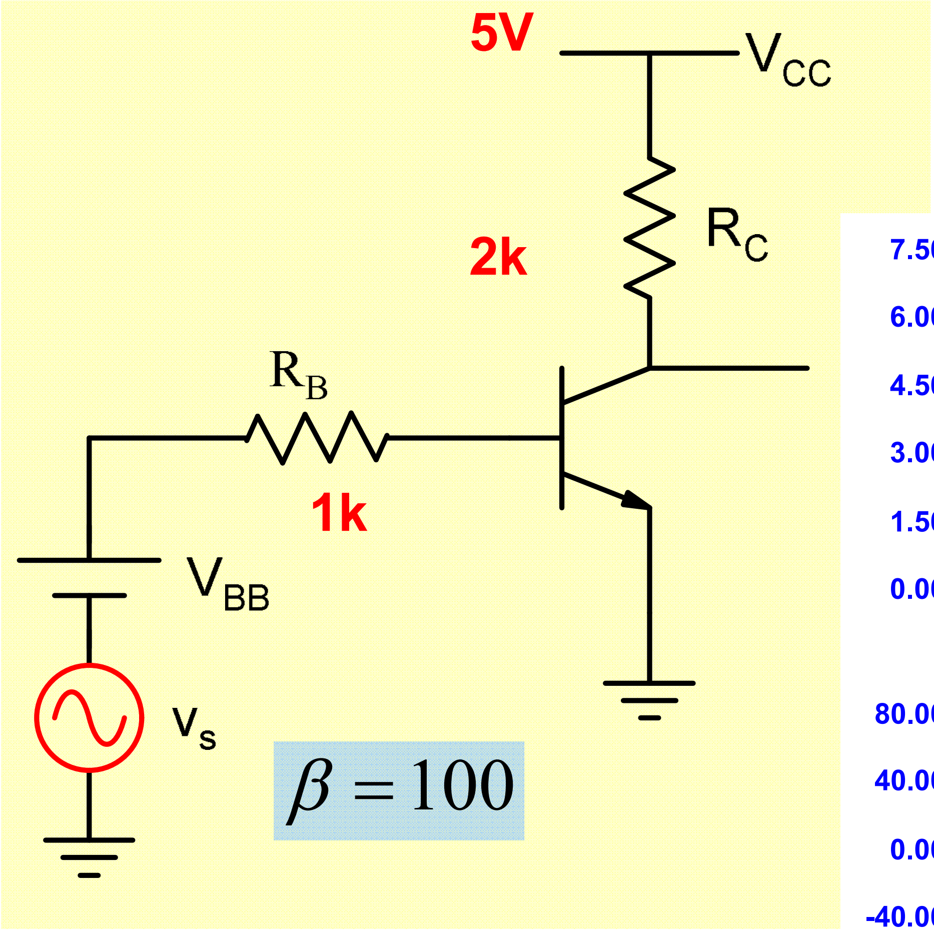
$$\beta = 100$$

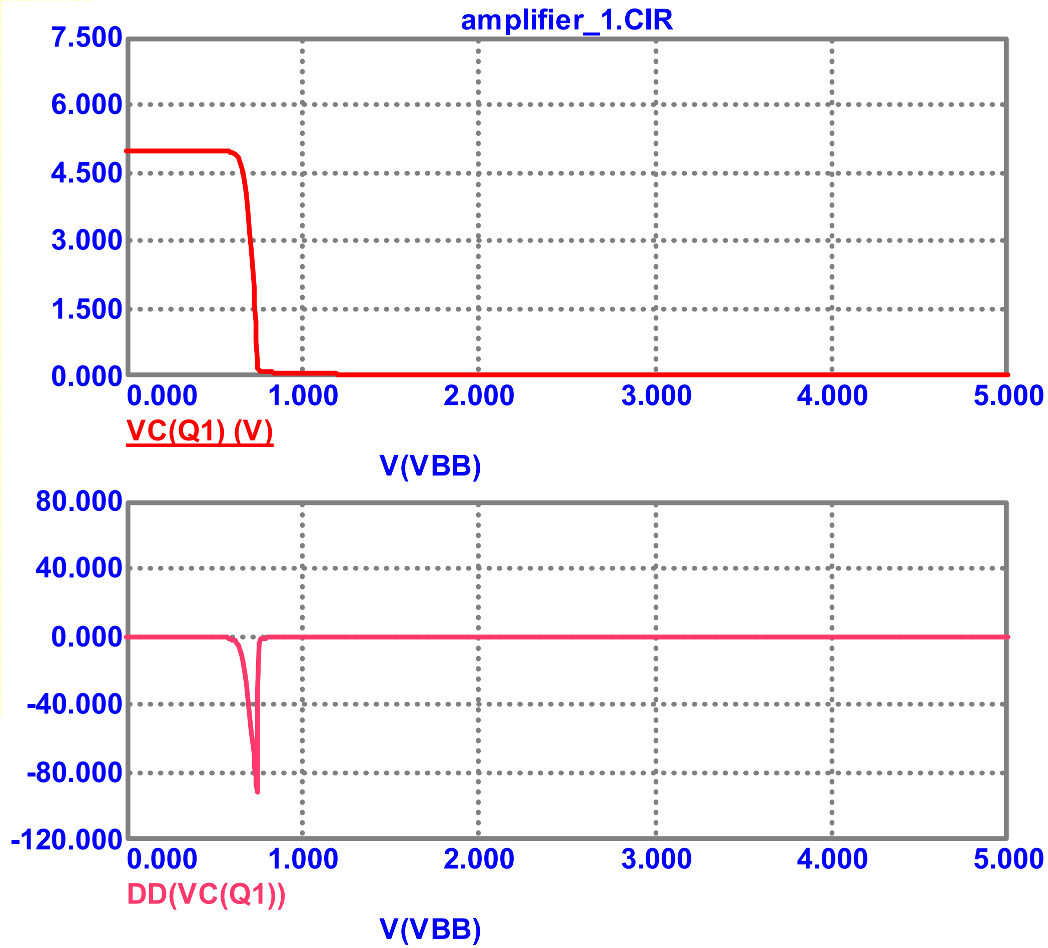


$$A_V = \frac{\Delta V_C}{\Delta V_B} = -\beta \times \frac{R_C}{R_B + r_\pi}$$

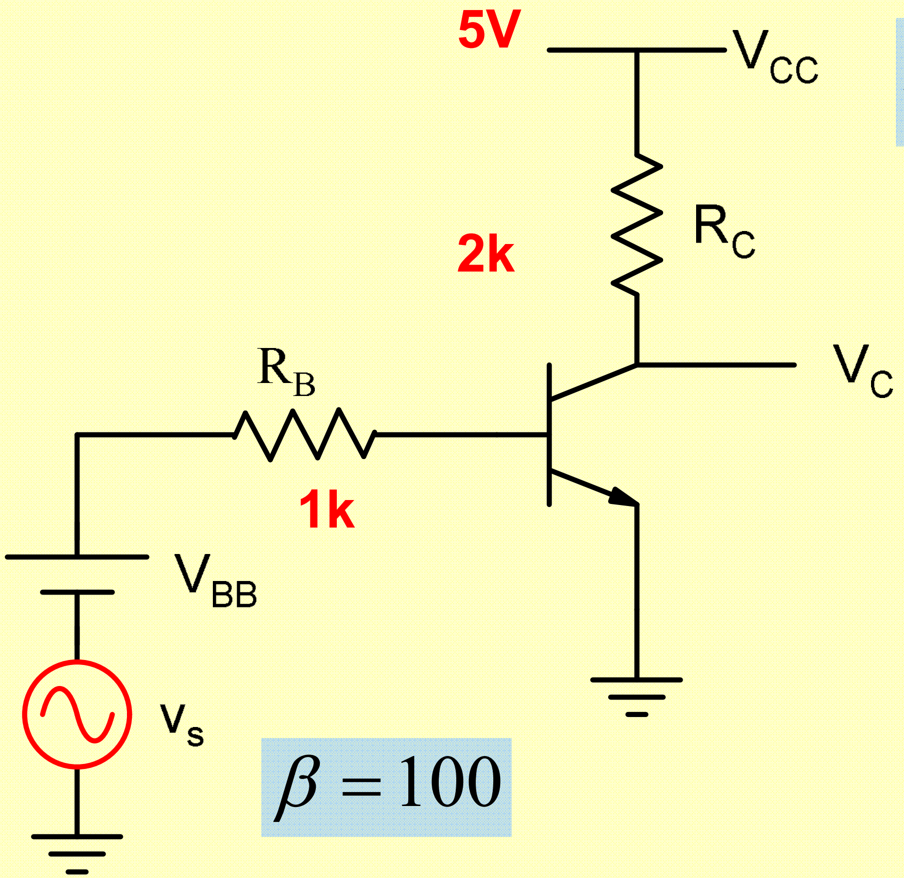
Very low

Simulation Results





$$A_V = -\beta \times \frac{R_C}{R_B + r_\pi}$$

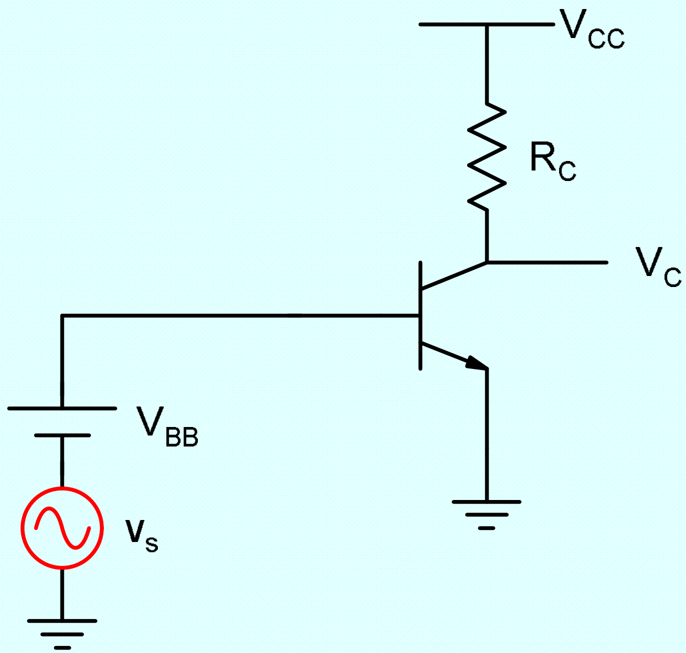


$$\beta = 100$$

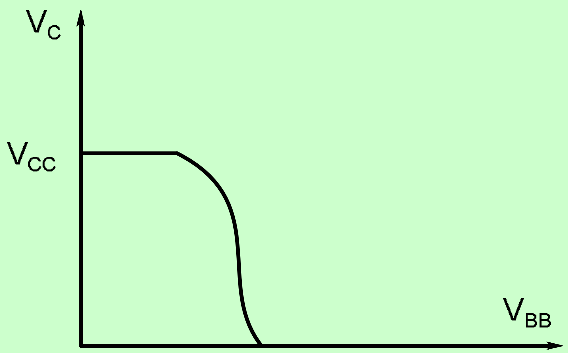
$$I_{C\max} \sim \frac{V_{CC}}{R_C} = 2.5mA$$

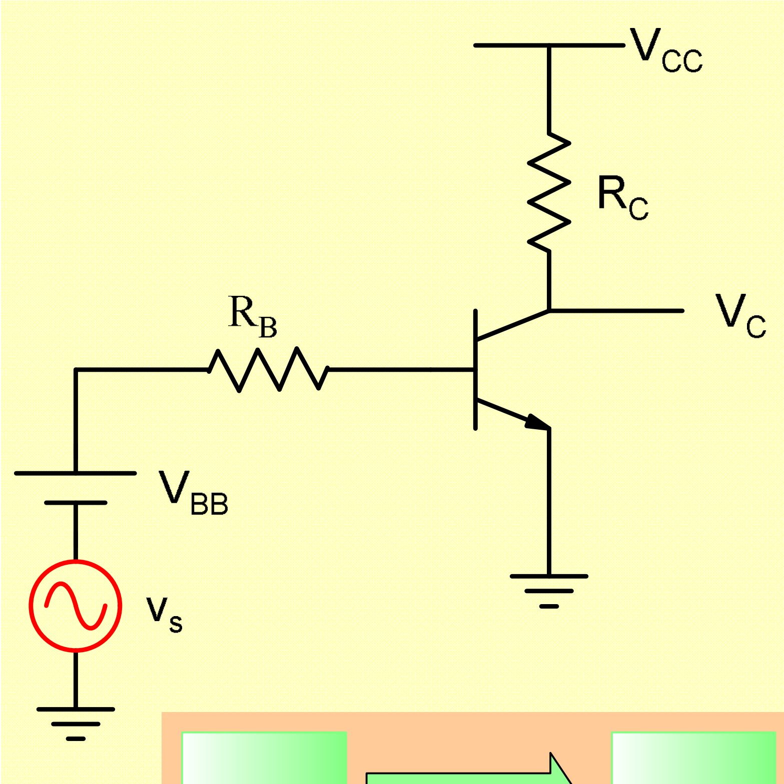
$$I_{B\max} \sim \frac{I_{C\max}}{\beta} = 25\mu A$$

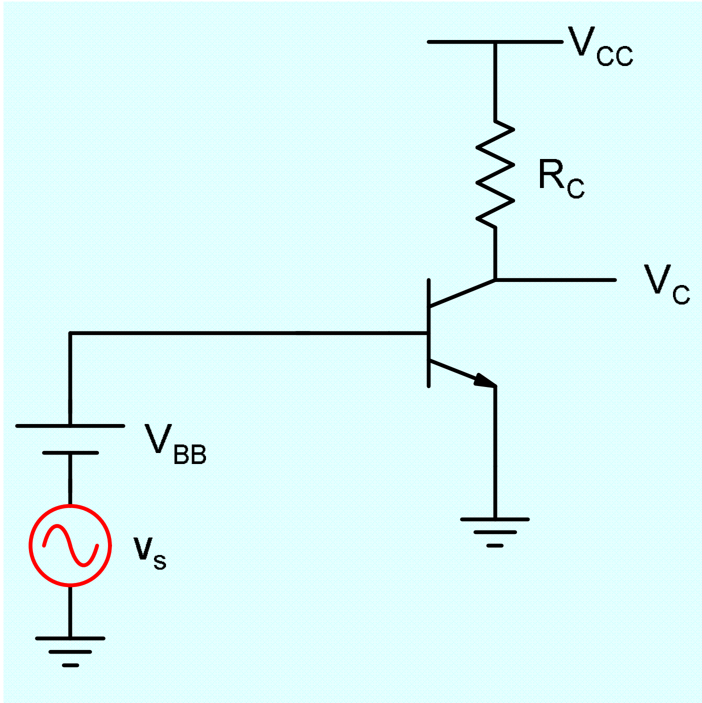
$$I_{B\max} \times R_B \sim 25mV$$

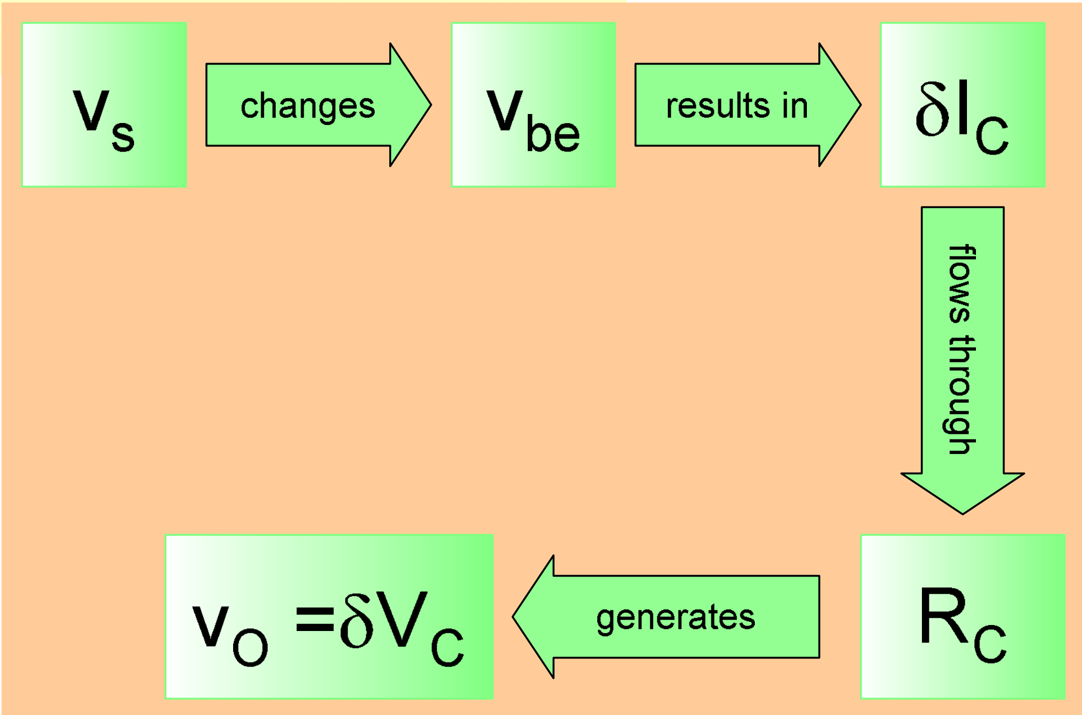


$$A_V = -\beta \times \frac{R_C}{R_B + r_\pi}$$

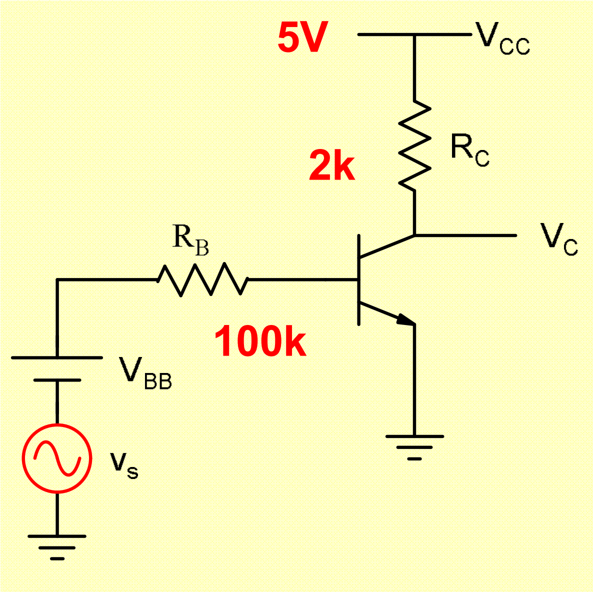


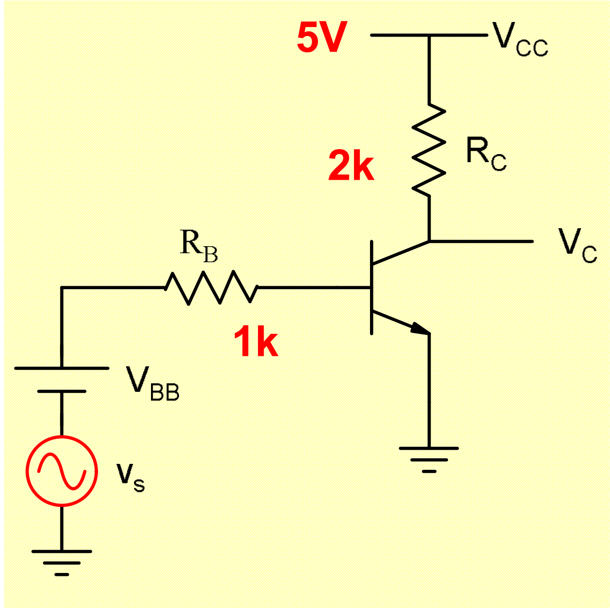


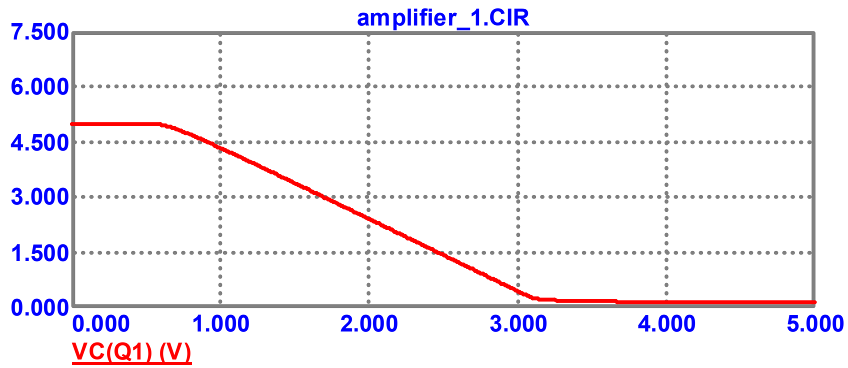


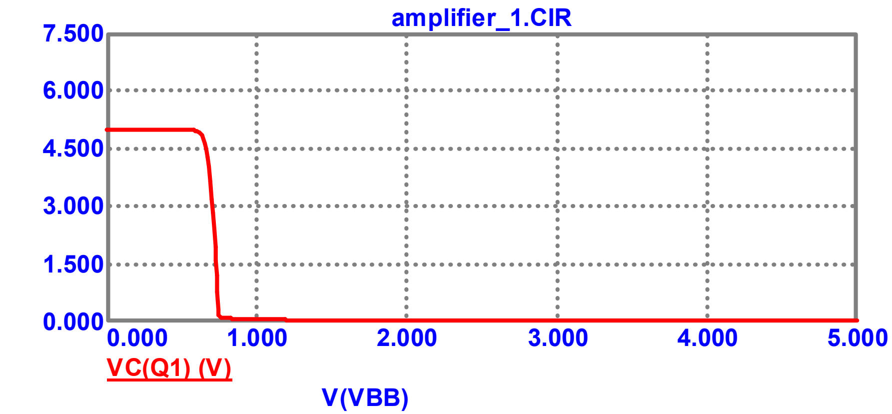


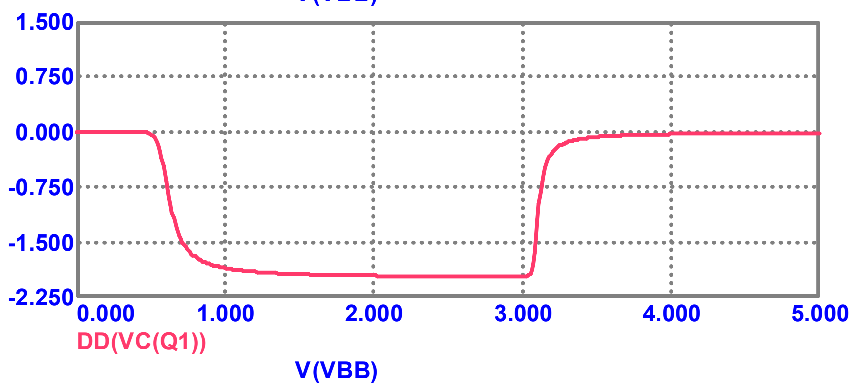
$$I_c = I_S\left(\exp\left(\frac{V_{be}}{V_T}\right) - 1\right)$$

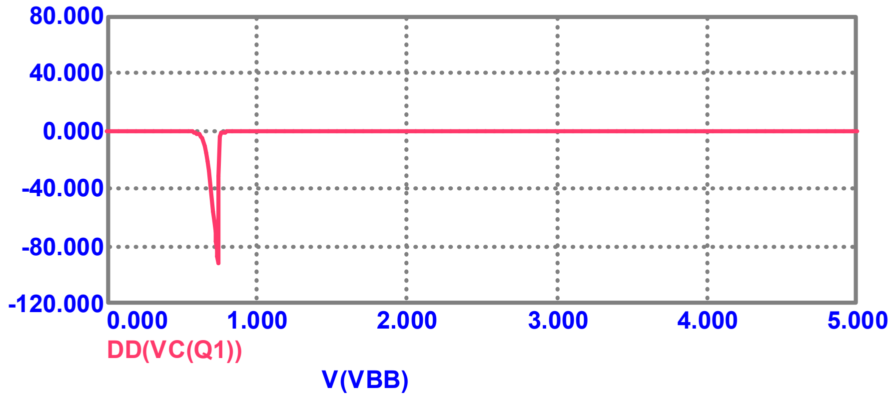

5V
V_{CC}
2k
R_C
V_C
R_B
100k
V_{BB}
v_s

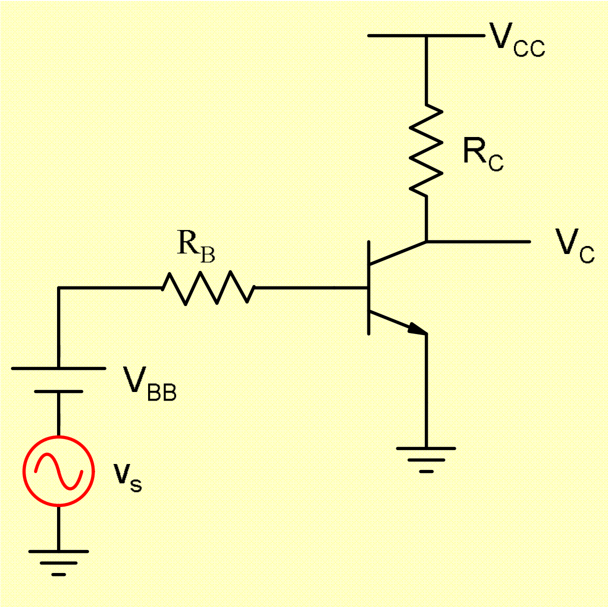

5V
V_{CC}
2k
R_C
V_C
R_B
1k
V_{BB}
v_s


amplifier_1.CIR
7.500
6.000
4.500
3.000
1.500
0.000
0.000
1.000
2.000
3.000
4.000
5.000
VC(Q1) (V)
V(VBB)

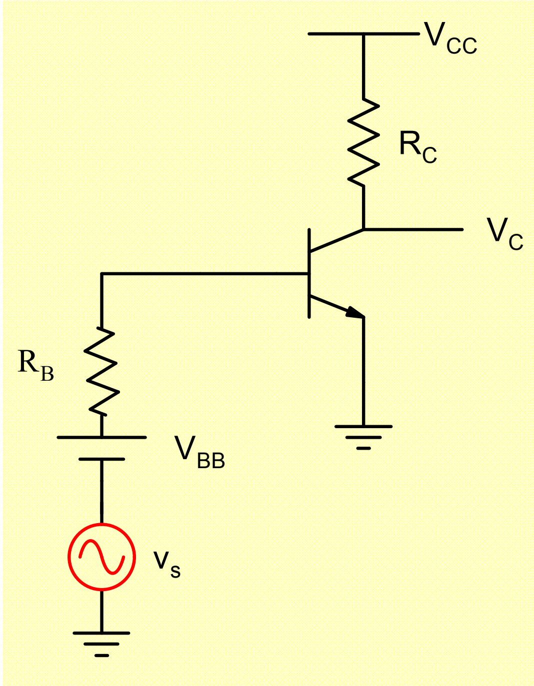

amplifier_1.CIR
7.500
6.000
4.500
3.000
1.500
0.000
0.000
1.000
2.000
3.000
4.000
5.000
VC(Q1) (V)
V(VBB)


1.500
0.750
0.000
-0.750
-1.500
-2.250
0.000
1.000
2.000
3.000
4.000
5.000
DD(VC(Q1))
V(VBB)

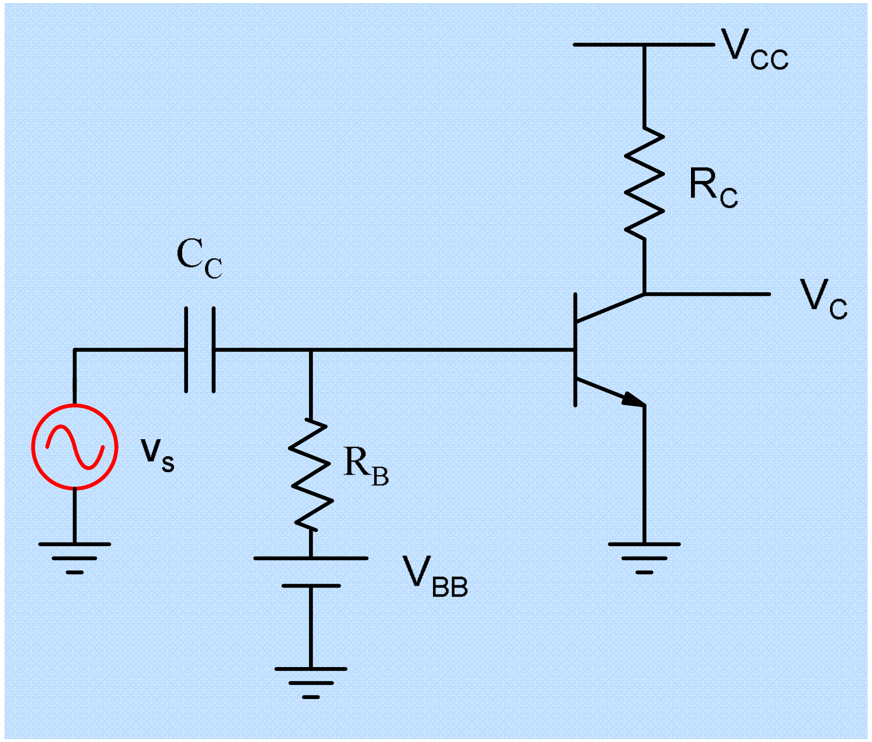

80.000
40.000
0.000
-40.000
-80.000
-120.000
0.000
1.000
2.000
3.000
4.000
5.000
DD(VC(Q1))
V(VBB)



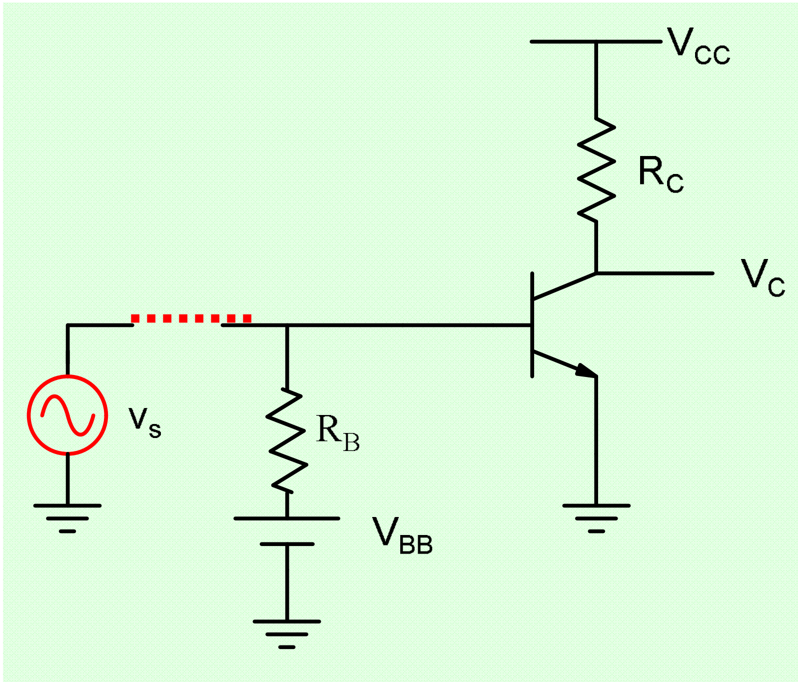
VCC
RC
RB
VC
VBB
vs



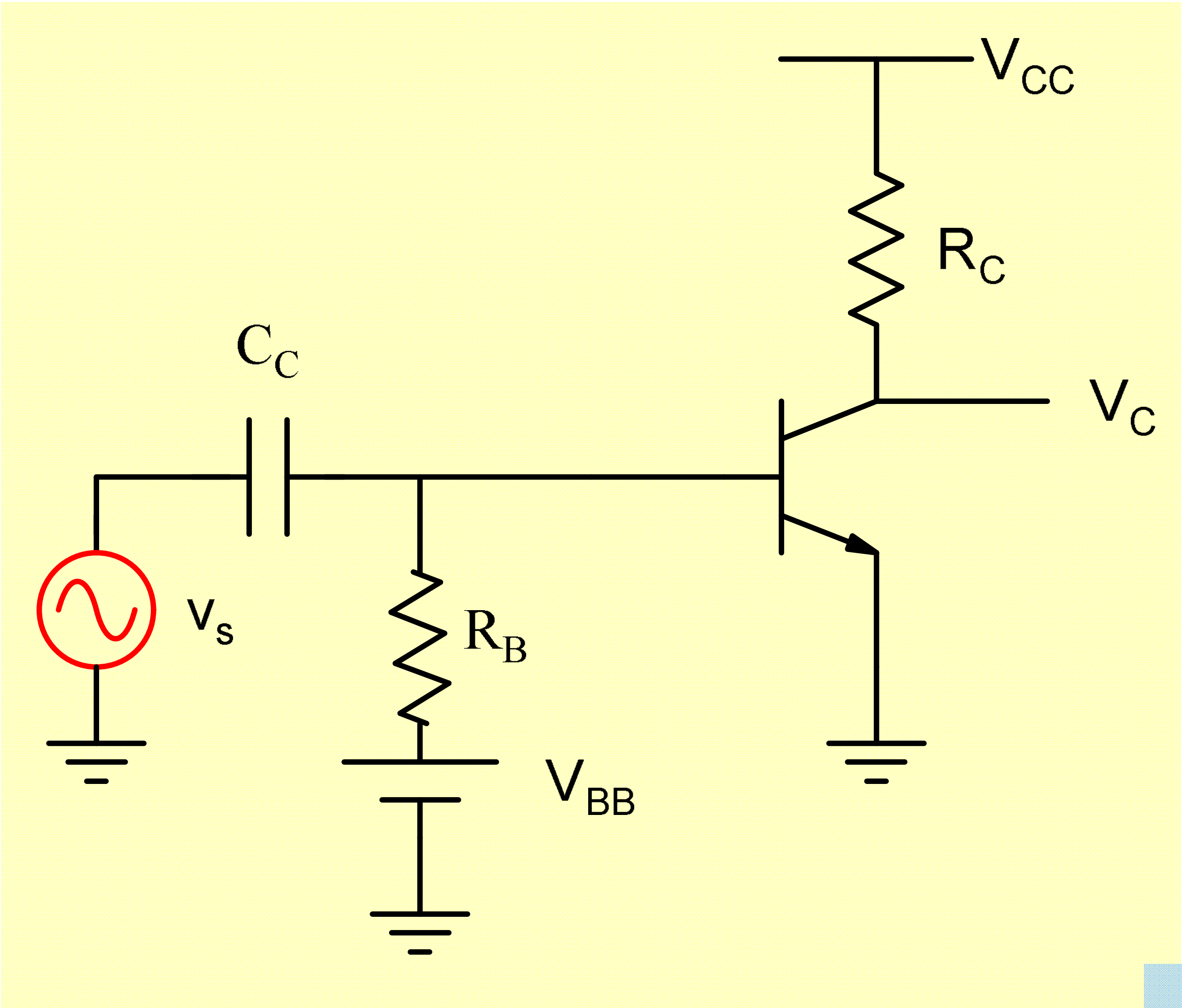
VCC
RC
VC
RB
VBB
vs



VCC
RC
CC
VC
vs
RB
VBB



VCC
RC
VC
vs
RB
VBB



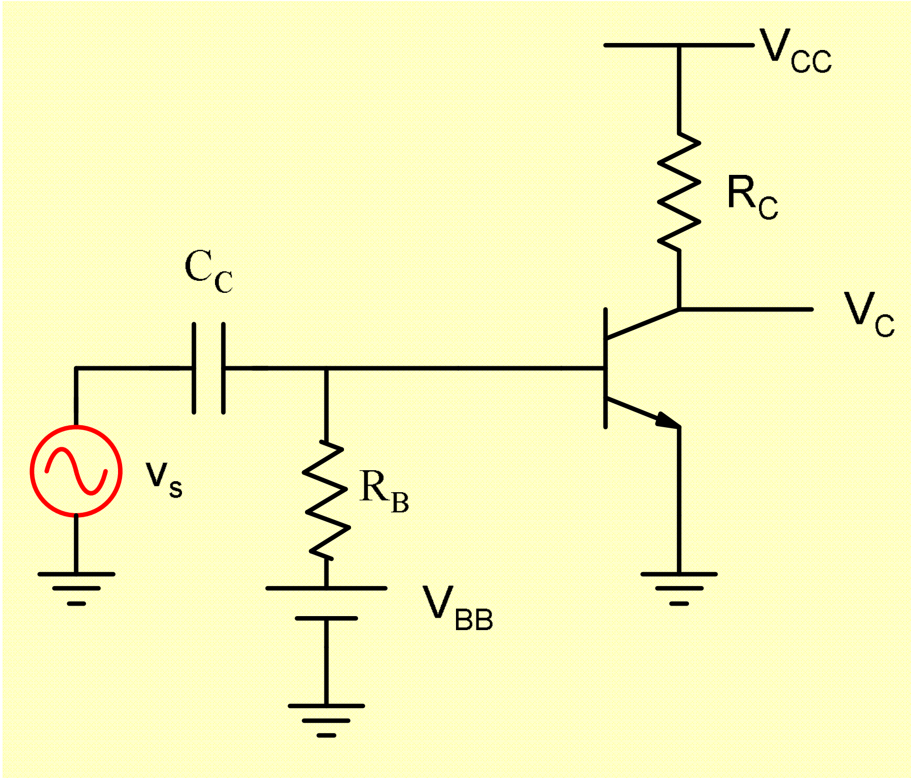
$$v_S = \Delta V_{BE} = \Delta I_B \times r_\pi$$

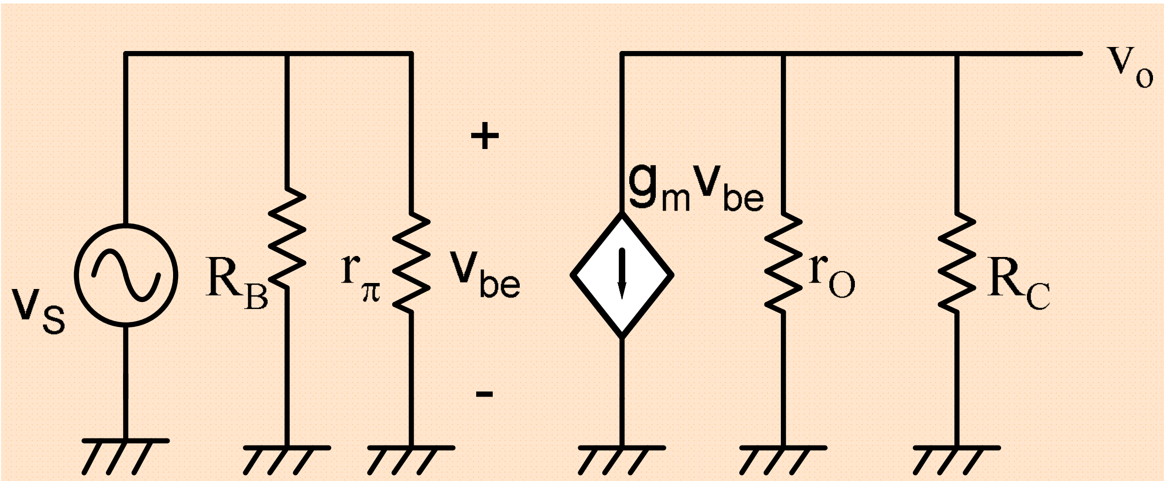
$$\Delta V_C = -\Delta I_C \times R_C$$

$$\frac{\Delta V_C}{v_s} = -\beta \times \frac{R_C}{r_\pi}$$

$$r_\pi = \frac{V_T}{I_C}\beta$$

$$A_V = \frac{\Delta V_C}{v_s} = -\frac{I_C \times R_C}{V_T}$$

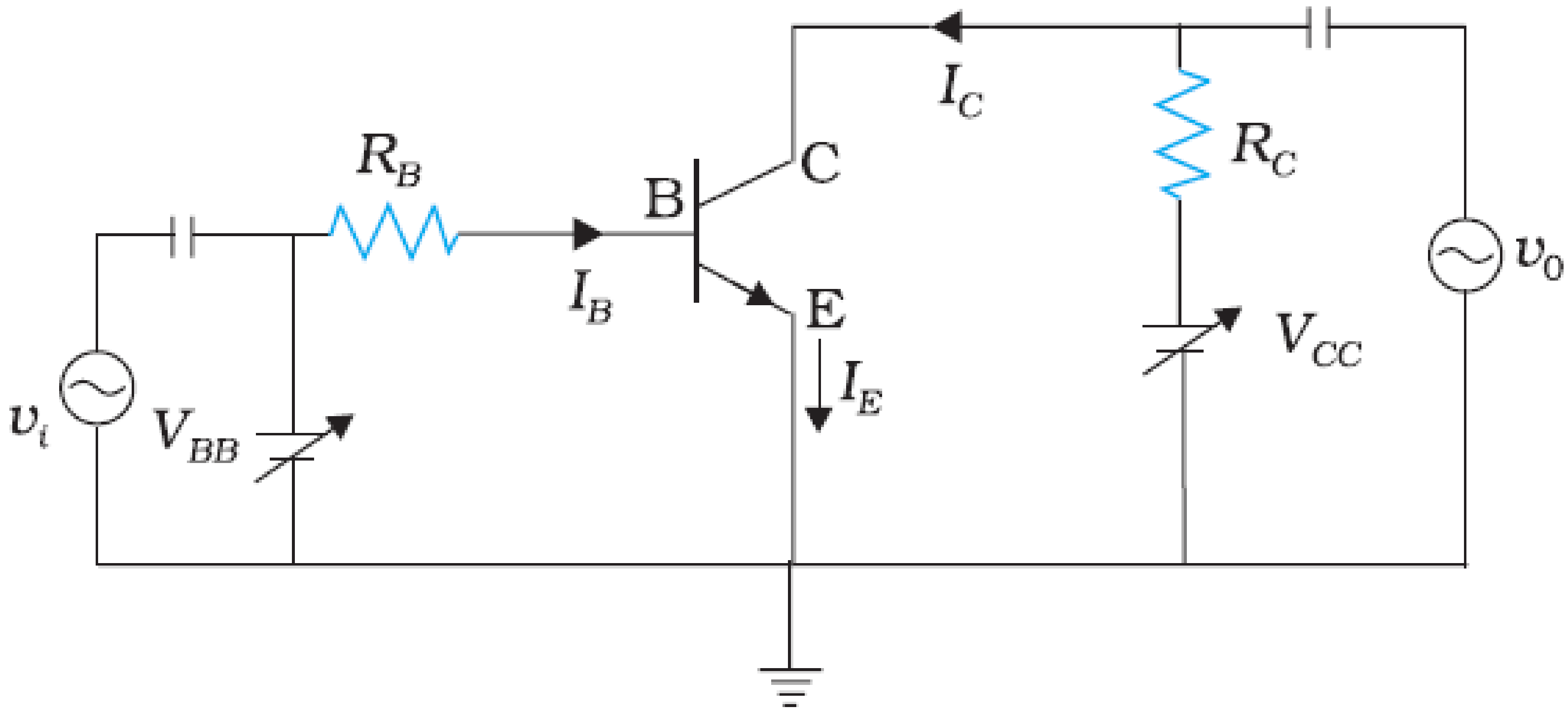




$$A_v = -g_m \times r_0 \parallel R_C$$

$$\cong -g_m \times R_C$$

$$g_m \times R_C = \frac{I_C \times R_C}{V_T}$$



Spot the errors

Chapter Fourteen

SEMICONDUCTOR ELECTRONICS: MATERIALS, DEVICES AND SIMPLE CIRCUITS

14.1 Introduction

Devices in which a controlled flow of electrons can be obtained are the basic *building blocks* of all the electronic circuits. Before the discovery of transistor in 1948, such devices were mostly vacuum tubes (also called valves) like the vacuum diode which has two electrodes, viz., anode (often called plate) and cathode; triode which has three electrodes – cathode, plate and grid; tetrode and pentode (respectively with 4 and 5 electrodes). In a vacuum tube, the electrons are supplied by a heated cathode and the controlled flow of these electrons *in vacuum* is obtained by varying the voltage between its different electrodes. Vacuum is required in the inter-electrode space; otherwise the moving electrons may lose their energy on collision with the air molecules in their path. In these devices the electrons can flow only from the cathode to the anode (i.e., only in one direction). Therefore, such devices are generally referred to as *valves*. These vacuum tube devices are bulky, consume high power, operate generally at high voltages (~100 V) and have limited life and low reliability. The seed of the development of modern *solid-state semiconductor electronics* goes back to 1930's when it was realised that some solid-state semiconductors and their junctions offer the possibility of controlling the number and the direction of flow of charge carriers through them. Simple excitations like light, heat or small applied voltage can change the number of mobile charges in a semiconductor. Note that the supply

14.9.4 Transistor as an Amplifier (CE-Configuration)

To operate the transistor as an amplifier it is necessary to fix its operating point somewhere in the middle of its active region. If we fix the value of V_{BB} corresponding to a point in the middle of the linear part of the transfer curve then the dc base current I_B would be constant and corresponding collector current I_C will also be constant. The dc voltage $V_{CE} = V_{CC} - I_C R_C$ would also remain constant. The operating values of V_{CE} and I_B determine the operating point, of the amplifier.

If a small sinusoidal voltage with amplitude v_s is superposed on the dc base bias by connecting the source of that signal in series with the V_{BB} supply, then the base current will have sinusoidal variations superimposed on the value of I_B. As a consequence the collector current also will have sinusoidal variations superimposed on the value of I_C producing in turn corresponding change in the value of V_O. We can measure the ac variations across the input and output terminals by blocking the dc voltages by large capacitors.

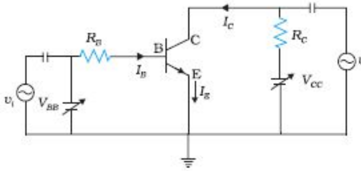


FIGURE 14.32 A simple circuit of a CE-transistor amplifier.

In the discription of the amplifier given above we have not considered any ac signal. In general, amplifiers are used to amplify alternating signals. Now let us superimpose an ac input signal v_i (to be amplified) on the bias V_{BB} (dc) as shown in Fig. 14.32. The output is taken between the collector and the ground.

The working of an amplifier can be easily understood, if we first assume that $v_i = 0$. Then applying Kirchhoff's law to the output loop, we get

$$V_{cc} = V_{CE} + I_c R_L \quad (14.15)$$

Likewise, the input loop gives

$$V_{BB} = V_{BE} + I_B R_B \quad (14.16)$$

When v_i is not zero, we get

$$V_{BE} + v_i = V_{BE} + I_B R_B + \Delta I_B (R_B + r_i)$$

The change in V_{BE} can be related to the input resistance r_i [see Eq. (14.8)] and the change in I_B. Hence

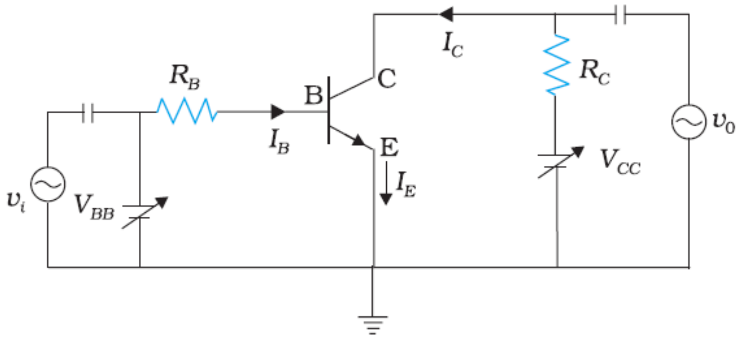
$$v_i = \Delta I_B (R_B + r_i)$$
$$= r \Delta I_B$$

The change in I_B causes a change in I_c. We define a parameter β_{ac}, which is similar to the β_{dc} defined in Eq. (14.11), as

$$\beta_{ac} = \frac{\Delta I_c}{\Delta I_B} = \frac{i_c}{i_b} \quad (14.17)$$

which is also known as the *ac current gain* A_i. Usually β_{ac} is close to β_{dc} in the linear region of the output characteristics.

The change in I_c due to a change in I_B causes a change in V_{CE} and the voltage drop across the resistor R_L because V_{CC} is fixed.



the ground.

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$V_{BB} + v_i$

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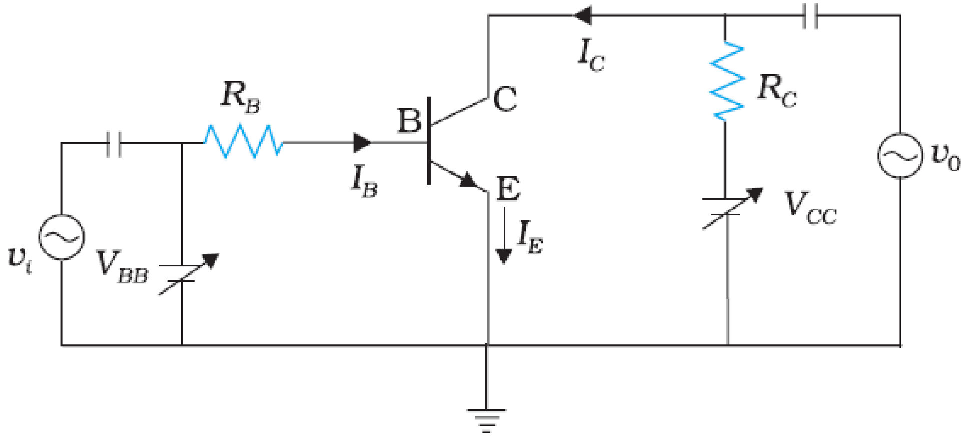
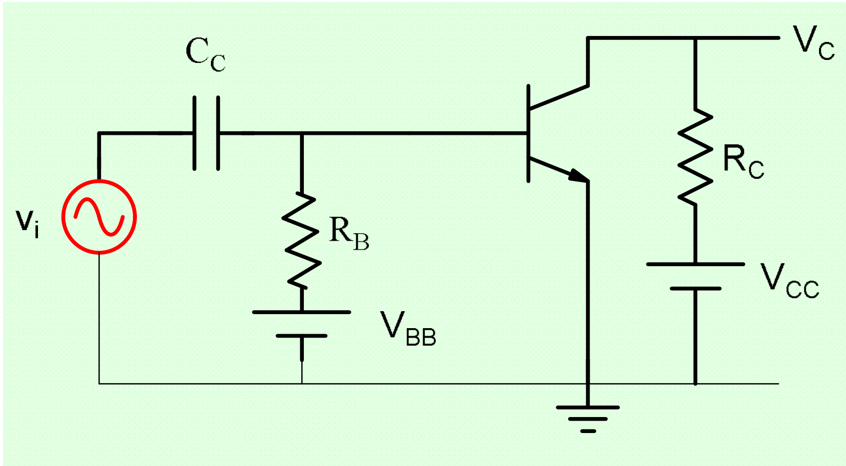
$$v_i = \Delta V_{BE} = \Delta I_B \times r_i$$





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$$= r\,\Delta I_B$$