PROBLEMS

Select R_1 and R_2 for maximum output voltage swing in the circuit shown in fig. 5.

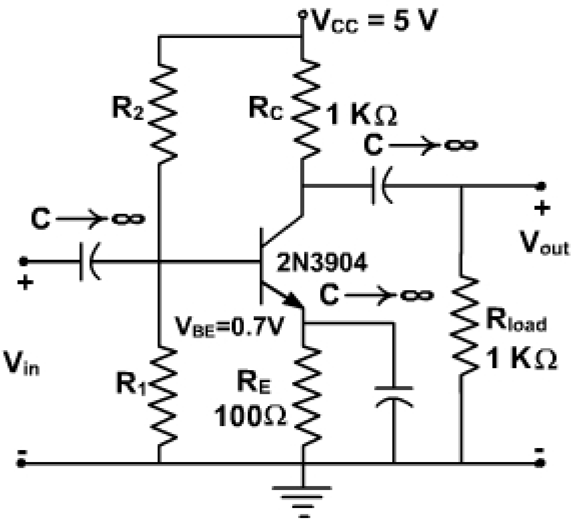

Fig. 5

Solution:

We first determine I_{CQ} for the circuit

$$R_{ac} = R_C \parallel R_{load} = 500$$
$$R_{dc} = R_E + R_C = 1100$$
$$I_{CQ} = \frac{V_{CC}}{R_{ac} + R_{dc}} = \frac{5}{500 + 1100} = 3.13 \text{ mA}$$

For maximum swing,

$V'_{CC} = 2\,V_{CEQ}$

The quiescent value for V_{CE} is the given by

V_{CEQ}= (3.13 mA) (500 W) = 1.56 V

The intersection of the ac load line on the v_{CE} axis is V'_{CC} = 3.13V. From the manufacturer's specification, β for the 2N3904 is 180. R_B is set equal to 0.1 βR_E. So,

R_B = 0.1(180)(100) = 1.8 K W

V_{BB} = (3.13 x 10-3) (1.1 x 100) + 0.7 = 1.044 V

Since we know V_{BB} and R_B, we find R_1 and R_2,

$$R_1 = \frac{R_B}{1 - V_{BB} / V_{CC}} = \frac{1800}{1 - 1.044/5} = 2.28\ K\Omega$$

$$R_2 = \frac{R_B V_{CC}}{V_{BB}} = \frac{1800 \times 5}{1.044} = 8.62\ K\Omega$$

The maximum output voltage swing, ignoring the non-linearity's at saturation and cutoff, would then be

$$\text{Max collector current swing} = 2\, I_{CQ}\, (R_C \parallel R_{load})$$
$$= 2\,(3.13\ mA)\,(500\ \Omega) = 3.13\ V$$

The load lines are shown on the characteristics of fig. 6.

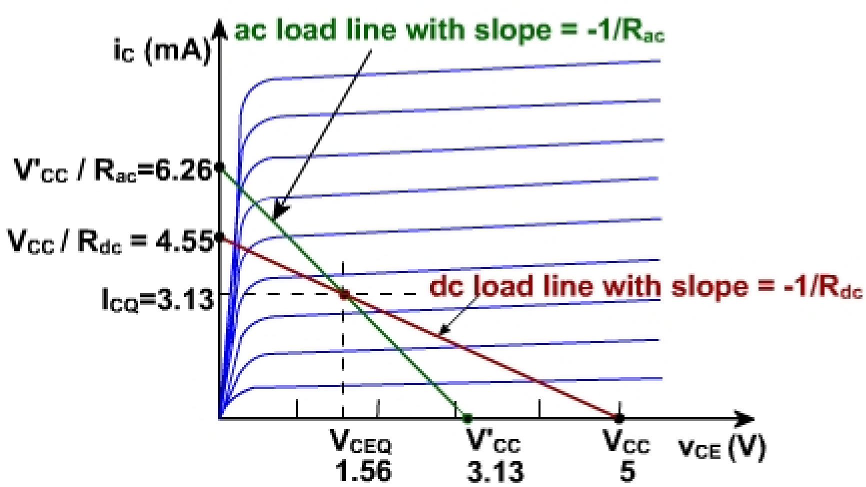

Fig. 6

The maximum power dissipated by the transistor is calculated to assure that it does not exceed the specifications. The maximum average power dissipated in the transistor is

$P_{(transistor)} = V_{CEQ}\, I_{CQ} = (1.56\ (V))\ (3.13\ mA) = 4.87\ mW$

This is well within the 350 mW maximum given on the specification sheet. The maximum conversion efficiency is

$$\eta = \frac{P_{out}(ac)}{P_{VCC}(dc)} = \frac{\left(3.13 \times 10^{-3}/2\right)^2 \times 1000/2 \times 100}{5 \times 3.13 \times 10^{-3} + 5^2/10.9 \times 10^3} = 6.84\%$$

The swamped Amplifier:

The ac resistance of the emitter diode r'_e equals $25mV / I_E$ and depends on the temperature. Any change in r'_e will change the voltage gain in CE amplifier. In some applications, a change in voltage is acceptable. But in many applications we need a stable voltage gain is required.

To make it stable, a resistance r_E is inserted in series with the emitter and therefore emitter is no longer ac grounded. fig .7.

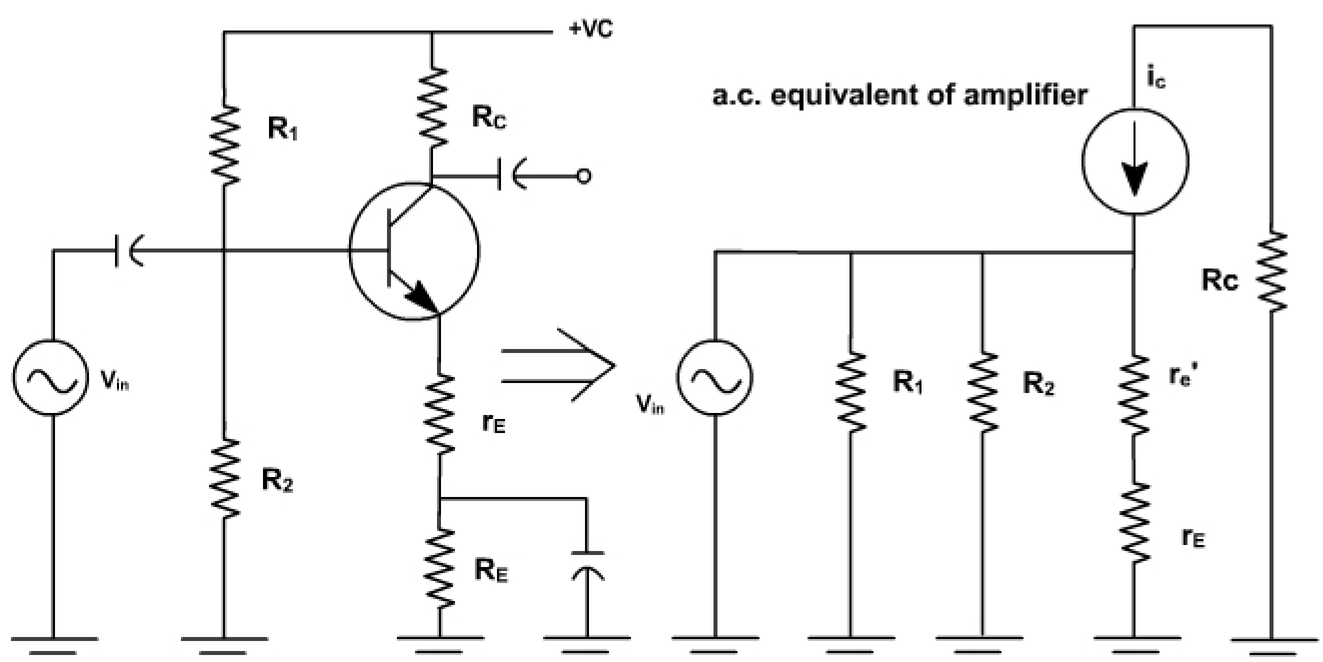

Fig. 7

Because of this the ac emitter current flows through r_E and produces an ac voltage at the emitter. If r_E is much greater than r'_e almost all of the ac input signal appears at the emitter, and the emitter is bootstrapped to the base for ac as well as for dc.

In this case, the collector circuit is given by

$$i_C = \frac{V_{in}}{r'_e + r_E}$$

and $V_{out} = -i_C R_C$

Therefore,

$$A = \frac{V_{out}}{V_{in}} = -\frac{i_C R_C}{i_C (r'_e + r_E)}$$

$$= -\frac{R_C}{(r'_e + r_E)}$$

Now r'_e has a less effect on voltage gain, swamping means $r_E >> r'_e$ If swamping is less, voltage gain varies with temperature. If swamping is heavy, then gain reduces very much.

Design a common-emitter amplifier with a transistor having a β =200 and V_{BE} = 0.7 V. Obtain an overall gain of $|A\ V| \geq 100$ and maximum output voltage swing. Use the CE configuration shown in fig. 1 with two power supplies. R_{source} is the resistance associated with the source, v_{source}. Let R_{source}= 100 Ohms. The output load is 2KΩ. Determine the resistor values of the bias circuitry, the maximum undistorted output voltage swing, and the stage voltage gain.

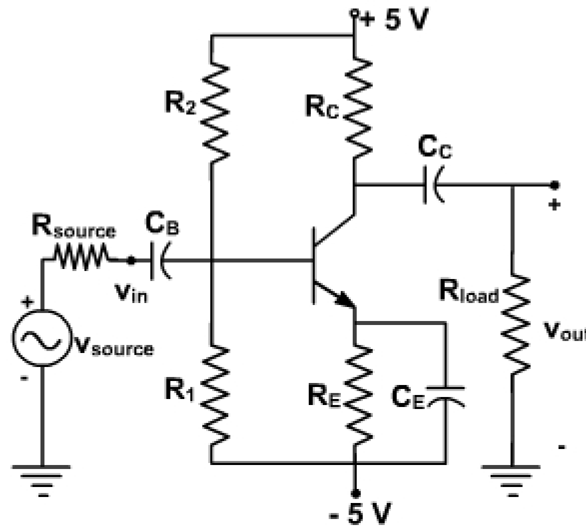

Fig. 1

Solution:

The maximum voltage across the amplifier is 10 V since the power supply can be visualized as a 10V power supply with a ground in the center. In this case, the ground has no significance to the operation of the amplifier since the input and output are isolated from the power supplies by capacitors.

We will have to select the value for R_C and we are really not given enough information to do so. Let choose $R_C = R_{load}$.

We don't have enough information to solve for R_B – we can't use the bias stability criterion since we don't have the value of R_E either. We will have to (arbitrarily) select a value of R_B or R_E. If this leads to a contradiction, or "bad" component values (e.g., unobtainable resistor values), we can come back and modify our choice. Let us select a value for R_E that is large enough to obtain a reasonable value of V_{BB}, Selecting R_E as 400Ω will not appreciably reduce the collector current yet it will help in maintaining a reasonable value of V_{BB}. Thus,

$R_B = 0.1\ \beta\ R_E = 0.1\ (200)(400) = 8\ K\ \Omega$

To insure that we have the maximum voltage swing at the output, we will use

$$I_{CQ} = \frac{V_{CC}}{R_{ac} + R_{dc}} = \frac{10}{1000 + 2400} = 2.94 \text{ mA}$$

$$V_{BB} = V_{BE} + I_{CQ}\,(R_B/\beta + R_E) = 0.7 + 2.9 \times 10^{-3}\left(\frac{8000}{200} + 400\right) = 1.99 \text{ V}$$

Note that we are carrying out our calculations to four places so that we can get accuracy to three places. The bias resistors are determined by

$$R_1 = \frac{R_B}{1 - V_{BB}/V_{CC}} = \frac{8000}{1 - 1.99/10} = 9.99 \text{ K}\Omega$$

$$R_2 = R_B \frac{V_{CC}}{V_{BB}} = 8000\left(\frac{10}{1.99}\right) = 40.2 \text{ K}\Omega$$

Since we designed the bias circuit to place the quiescent point in the middle of the ac load line, we can use

V_{out}(undistorted p-p) 1.8 (2.94×10^{-3}) (2 K Ω || 2 K Ω) =5.29 V

Now we can determine the gain of the amplifier itself.

$$|A_v| = g_m\,(R_C \,||\, R_{load}) = \frac{2.94 \times 10^{-3} \times 1000}{26 \times 10^{-3}}$$

Using voltage division, we can determine the gain of the overall circuit.

The value of Rin can be obtained as

$$R_{in} = r_\pi \,||\, R_B = 1.77\text{k}\Omega \,||\, 8\text{k}\Omega = 1.45 \text{ k}\Omega$$

Thus the overall gain of the amplifier is

$$|A_v| \text{ overall} = \left|\frac{v_{out}}{vin} = 113\right| \times \frac{R_{in}}{R_{in} + R_{source}} = 106$$

This shows that the common-emitter amplifier provides high voltage gain. However, it is very noisy, it has a low input impedance, and it does not have the stability of the emitter resistor common emitter amplifier.