blocking any DC component that would upset the biasing. Unfortunately, the use of capacitors restricts the low-frequency performance of the arrangement and produces a complicated and bulky circuit.

- An alternative method is to use direct coupling between stages. This requires fewer components and permits operation down to DC.
- Bipolar transistors are used in a wide range of applications in addition to their use as simple amplifiers. More complicated circuits, such as operational amplifiers and other integrated circuits, are often constructed using bipolar transistors.

Exercises

18.1 Why are bipolar transistors so called?

18.2 Is a bipolar transistor a voltage-controlled or a current-controlled device?

18.3 Sketch the relationship between the base current and the collector current in a bipolar transistor (when the device is in its normal operating environment).

18.4 Sketch the construction of the two polarities of bipolar transistor.

18.5 What is meant by the symbols V_{CC}, V_{CE}, V_{BE}, v_{be} and i_c?

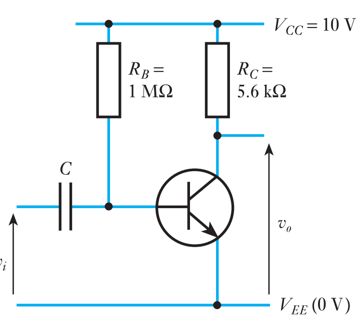
18.6 Explain what is meant by 'transistor action'.

18.7 Explain the terms h_{FE} and h_{fe} and describe their relative magnitudes.

18.8 Sketch the relationship between the base voltage and the collector current in a bipolar transistor (when the device is in its normal operating environment).

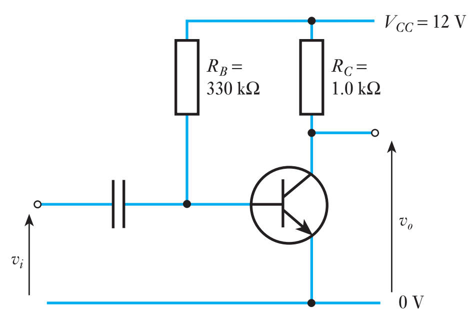
18.9 What is meant by the transconductance of a transistor? How does this quantity relate to the characteristic described in the previous exercise?

18.10 Determine the quiescent collector current and the quiescent output voltage of the following circuit, given that the h_{FE} of the transistor is 100.



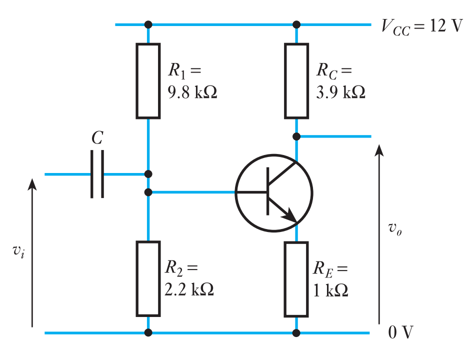
18.11 Repeat Exercise 18.10, but replace the transistor with one that has a current gain of 200. Is this circuit useful as an amplifier?

18.12 Derive a simple small-signal equivalent circuit for the following circuit, then deduce the small-signal voltage gain, input resistance and output resistance, given that $h_{FE} \approx h_{fe} = 175$ and $h_{oe} = 15$ µS. How is the small-signal voltage gain related to the quiescent voltage across R_C?



18.13 Repeat the calculations of Exercise 18.12, this time assuming that the transistor has $h_{oe} = 330$ µS.

18.14 Calculate the quiescent collector current, quiescent output voltage and small-signal voltage gain of the following circuit.



Exercises continued

18.15 For the circuit of Exercise 18.14, estimate the small-signal input and output resistance.

18.16 For the circuit of Exercise 18.14, estimate the effect on the frequency response of the circuit of using a coupling capacitor C of 1 μF.

18.17 Use simulation to confirm your answers to Exercises 18.14 and 18.16.

18.18 If the circuit of Exercise 18.14 were modified by the addition of an emitter decoupling capacitor of 10 μF, estimate the quiescent output voltage, small-signal voltage gain and low-frequency cut-off of the resulting circuit. What would be a suitable value for the decoupling capacitor if the amplifier were required for use with signals down to 100 Hz?

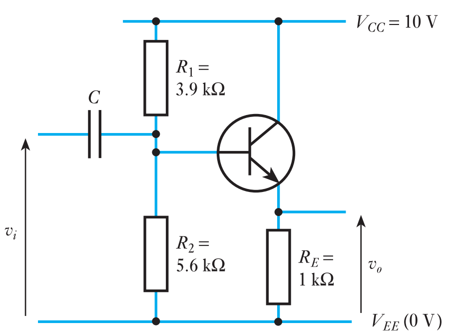
18.19 Use simulation to confirm your answers to Exercise 18.18.

18.20 Using a circuit of the form shown in Exercise 18.14, design an amplifier with a small-signal voltage gain of −3, quiescent output voltage of 7 V, supply voltage of 12 V and collector load resistance of 2.2 kΩ.

18.21 Use simulation to confirm the operation of your solution to Exercise 18.20.

18.22 For the amplifier designed in Exercise 18.20, calculate the small-signal input resistance and then determine an appropriate value for the input capacitor to allow satisfactory operation at frequencies down to 50 Hz.

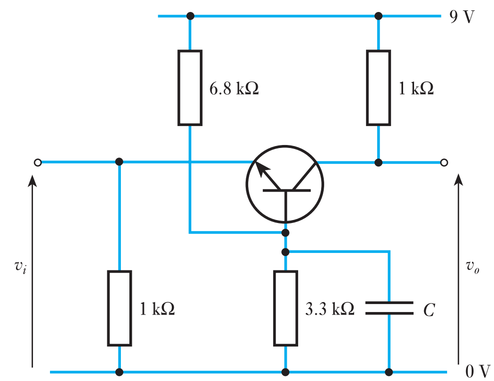
18.23 Calculate the quiescent collector current, quiescent output voltage and small-signal voltage gain of the following circuit.



18.24 Estimate the input resistance of the circuit in Exercise 18.23, then determine an appropriate value for a coupling capacitor to allow satisfactory operation down to 50 Hz.

18.25 Use simulation to confirm your answers to Exercises 18.23 and 18.24.

18.26 Determine the quiescent output voltage, voltage gain and input and output resistance of the following circuit. You may find it helpful to redraw the circuit in a more familiar form. You may assume that the capacitor C has a negligible impedance at the frequencies of interest.



18.27 Design a two-stage, direct-coupled amplifier with a voltage gain of 10. The circuit should operate from a 15 V supply and have a maximum output swing of at least 4 volts peak to peak.

18.28 Use simulation to investigate the performance of your solution to the previous exercise.

18.29 Design a long-tailed pair amplifier based on the circuit of Figure 18.38 and use simulation to determine the small-signal voltage gain of the circuit and its CMRR.