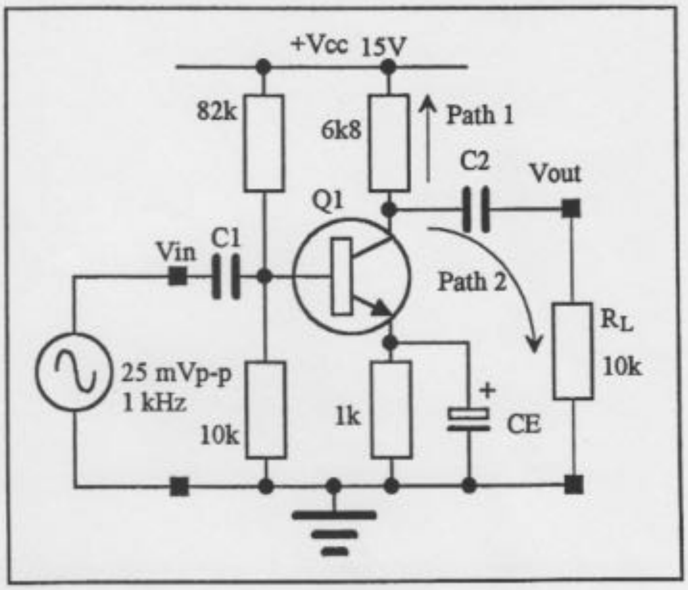
AMPLIFIER CONFIGURATIONS AND CIRCUIT VARIATIONS

Revision

The voltage divider bias circuit was previously introduced. This circuit features very good temperature stability due to the divider current (10 x I_B or greater), swamping small variations of base current and with the inclusion of an Emitter resistor (R_E), variations of collector current due to change of Beta or V_{BE} with temperature are minimised.

Amplifier Considerations

The purpose of an electronic amplifier is to increase the amplitude of a small input signal voltage and then apply the output voltage to a load. The presence of a load has the effect of reducing the gain of an amplifier and the previously given gain equation must be modified to include the value of this load. Any ac signal variations of the Collector current now has two paths to earth, one through the Collector resistor and another through the coupling capacitor C2 to the load resistor R_L.



The value of re is still dependent on the current in the Emitter circuit and is found from

$re = \frac{30mV}{I_C}$ and the gain of the stage is now found from

$A_V = \frac{R_C // R_L}{re}$ For the above circuit the results still require knowing the quiescent conditions

$V_B = \frac{10k}{82k+10k} \times 15 = 1.83V$ $\quad V_E = 1.63 - 0.6 = 1.03V$ $\quad I_C = \frac{1.03V}{1k} = 1.03mA$

$V_C = 15 - 1.03mA \times 6k8 = 8V$ $\quad re = \frac{30mV}{1.03mA} = 29\Omega$ $\quad A_V = \frac{6k8//10k}{29} = \frac{4k}{29} = 139$

$V_{out} = 25mV_{p-p} \times 139 = 3.5V_{p-p}$

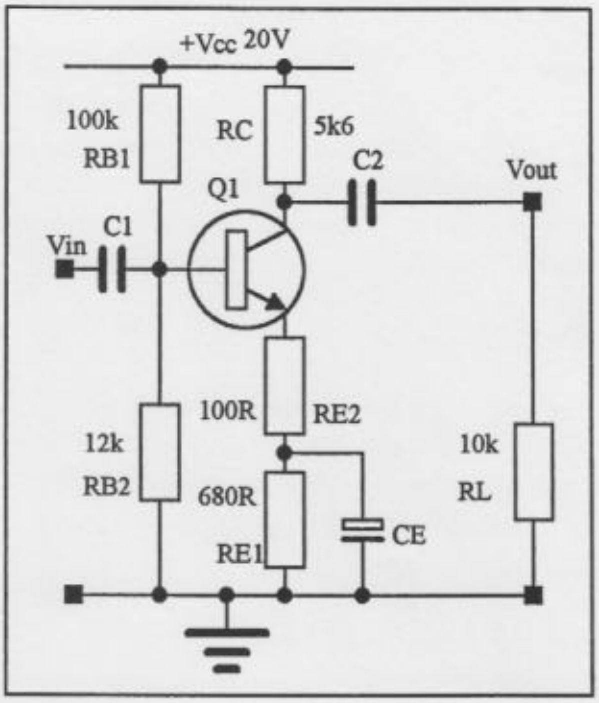
Note that the presence of the load resistor does not affect the quiescent conditions and only the ac gain is affected. With out the load resistor, gain would be calculated to around 230.

The Emitter bypass capacitor C_E stops the current variations from producing a voltage variation across the Emitter resistor (R_E). Without this resistor the gain would be further reduced since beside the internal re resistance the external RE must now be included in the gain equation.

With out C_E $A_V = \frac{R_C // R_L}{re + R_E}$ and for the above circuit $A_V = \frac{6k8//10k}{29+1k} = 3.9$

This large gain reduction shows how the basic amplifier can be further modified to give a desired gain value.

Partial Emitter Bypassing



In the circuit on the right, only a part of the total Emitter resistance is bypassed by C_E and there will be a gain reduction by R_{E2}. the unbypassed Emitter resistance. By selecting the appropriate resistors for the desired Emitter current in the correct ratio, the gain can be adjusted to any level between the fully bypassed value to the completely unbypassed condition. For the circuit on the right

$$V_B = \frac{12k}{100k+12k} \times 20 = 2.14V$$

$$V_E = 2.14 - 0.6 = 1.54V$$

$$I_C = \frac{1.54}{680+100} = 1.97mA$$

$$V_C = 20 - 1.97mA \times 5k6 = 8.96V$$

$$re = \frac{30mV}{1.97mA} = 15.23\Omega$$

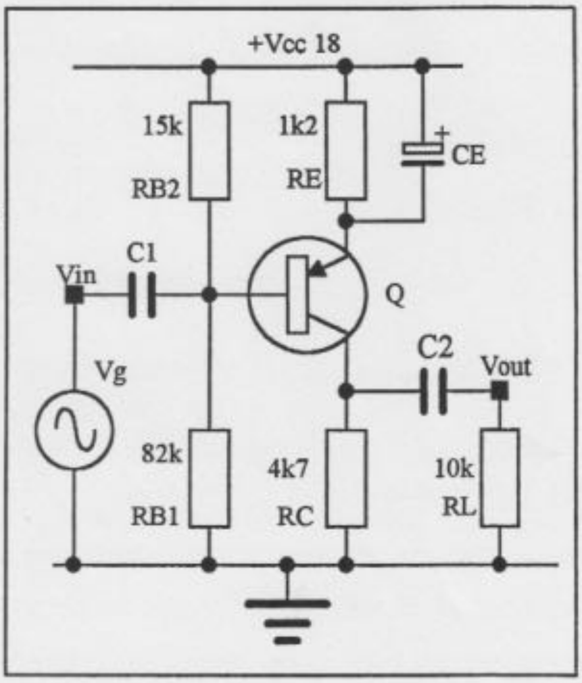
$$A_V = \frac{5k6//10k}{15.23+100} = 31.15$$

For an input signal of 15 mV_{p-p} the output across the 10k is

$$15mV_{p-p} \times 31.15 = 0.467V_{p-p}$$

If the Emitter resistors were $R_{E1} = 750\Omega$ and $R_{E2} = 30\Omega$ the gain would have increased to around 79 with out a change in the quiescent conditions.

Using a PNP Transistor with Positive Rail Voltage



By turning a PNP transistor upside down and applying the positive rail voltage to the Emitter circuit, a Common Emitter amplifier can be constructed. The dc analysis, requires some modification to the equations but the gain results will be similar to an NPN transistor.

$$V_B = \frac{R_{B1}}{R_{B1}+R_{B2}} \times V_{CC} = \frac{82k}{82k+15k} \times 18 = 15.2V$$

$$V_E = V_B + V_{BE} = 15.2 + 0.6 = 15.8V$$

To be forward biased, V_{BE} must be added to V_B.

$$I_C = \frac{V_{CC}-V_E}{R_E} = \frac{18-15.8}{1k2} = 1.83mA$$

V_{CC} - V_E is the volts drop across R_E.

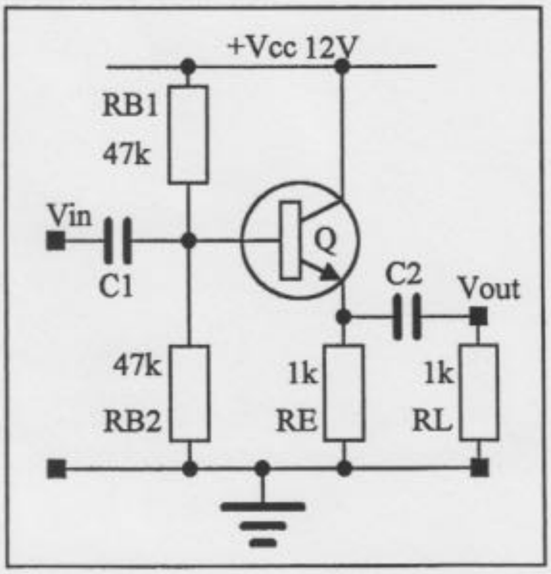
$$V_C = I_C \times R_C = 1.83mA \times 4k7 = 8.6V$$

$$re = \frac{30mV}{1.83mA} = 16.4\Omega \qquad A_V = \frac{R_C//R_L}{re} = \frac{4k7//10k}{16.4} = 195$$

(Circuit has 180° phase difference)

Common Collector Amplifiers

The loaded Common Emitter amplifier has a been shown to have a gain that is dependent on the value of the load resistor. If the load resistance is of a very low value, the resulting gain and output voltage would be restricted due to the limited output current capability from the transistor. An amplifier that has a higher signal current output is the *Common Collector Configuration* and hence can drive lower value loads. The voltage gain of this type of amplifier is slightly less than 1 but has a high current gain and as such forms a *Buffer* between any signal source and lower value loads. This circuit is also called an *Emitter Follower* because the Emitter is in the same phase relationship to the base. The voltage divider biasing circuit is used and as before, the analysis involves find the quiescent conditions first.



$$V_B = \frac{R_{B2}}{R_{B1}+R_{B2}} \times V_{CC} = \frac{47k}{47k+47k} \times 12 = 6V$$

$$V_E = V_B - V_{BE} = 6 - 0.6 = 5.4V$$

$$I_C = \frac{V_E}{R_E} = \frac{5.4}{1k} = 5.4mA$$

$$re = \frac{30mV}{I_C} = \frac{30mV}{5.4mA} = 5.5\Omega$$

The V_{CC} is of course 12V and does not vary.

The transistor sees an ac load of $R_E//R_L$ and the voltage gain can be found from

$$A_V = \frac{R_E//R_L}{re+R_E//R_L} = \frac{1k//1k}{5.5+1k//1k} = 0.989$$

Since this value is so close to 1, for practical purposes this will be used in future problems involving BJT's (this will not be true of other devices used as such amplifiers).

The quiescent current in this case is 5.4mA and hence if it is assumed that this can be driven by an input signal to 0 in the negative direction to 10.8mA in the positive direction then for the above ac load of 500Ω, the output voltage can be close to 10.8mA x 500Ω = $5.4V_{p\text{-}p}$.

The Common Collector amplifier can drive lower value loads but the available output voltage swing without distortion will be less. Note that without a load, the above circuit could have had an output near $10.8V_{p\text{-}p}$.

Since the circuit has a gain near 1, the input signal must be very close in amplitude to the output signal i.e. a $5V_{p\text{-}p}$ output voltage requires a slightly greater than a $5V_{p\text{-}p}$ input signal.

Decibel Gain Figures

Amplifiers specifications are usually quoted in terms of Decibels and a knowledge of the application of this quantity is an important characteristic of amplifiers. See the handout on Decibels for an introduction to this gain figure.

7794B - Amplifiers 2 - Introduction to dB's

Decibel's are base on the *Bel*, name in honour of Alexander Graham Bell. The Bel represents a 10 × multiple of acoustic power, which is perceived by the human ear as a doubling of loudness. The decibel (dB) is one tenth of a Bel and is the unit that is commonly used. Decibels can be used to express the relationship between voltage levels and power levels. When dB's are used to compare voltage levels, such as and amplifiers output compared to its input, the ratio V_{out}/V_{in} is placed in the equation.

$$dB = 20 \times \log(\tfrac{V_{out}}{V_{in}})$$

The voltages may be expressed as RMS. Peak or peak to peak, as long as the same units are used for both voltages.

Two commonly used ratios are doubling = 6dB and 10 × = 20dB gain. A gain of 200 would yield a dB value of 46.

Note that the dB uses a logarithmic function (log to the base 10) and this should be evaluated first before multiplying by 20.

As stated above, dB's are also used to compare power levels. Linear amplifiers used to increase power such as Hi Fi types are often rated in terms of dB gain. An amplifier that has a power gain of 10dB is able to amplify an input power level 10 times while a 20dB power gain is 100 times. The power gain in dB can be determined from

$$dB = 10 \times \log(\tfrac{P_{out}}{P_{in}})$$

Note that the value of the dB is dependent on the *power ratio* not the actual power levels. If the power levels were P_{in} = 10mW and P_{out} = 100 mW, this will yield the same dB figure if P_{in}=1W and P_{out} = 10W.

The figure of dB will yield the same value of dB for a voltage ratio as for a power ratio *if the input and output loads are identical.* If the loads are not identical (typical of a BJT Common Emitter amplifier) the dB values will be different.

A figure of 3dB is commonly used in electronics to show a power gain of 2, the corresponding voltage would be 1.414.

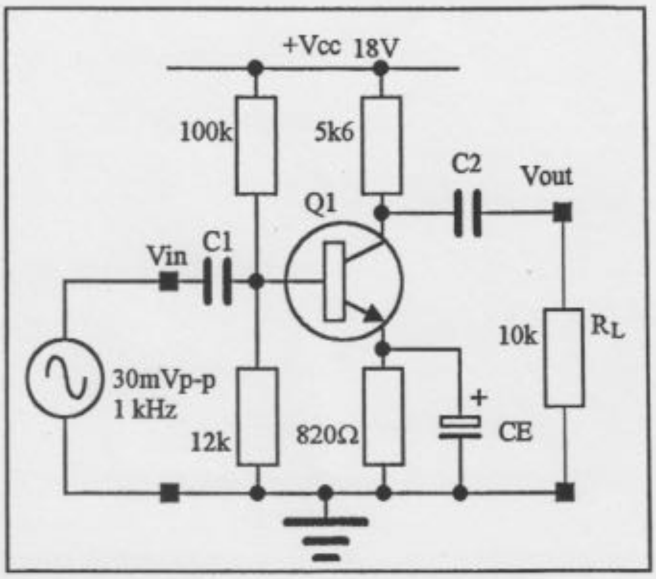
If the output is less than the input, the resulting dB value will have a minus sign in front of it (typically found in attenuator circuits).

e.g. if the output power is 3 mw and the input power is 30 mw, then

$$dB = 10 \times \log(\tfrac{3mW}{30mW}) = -10dB$$

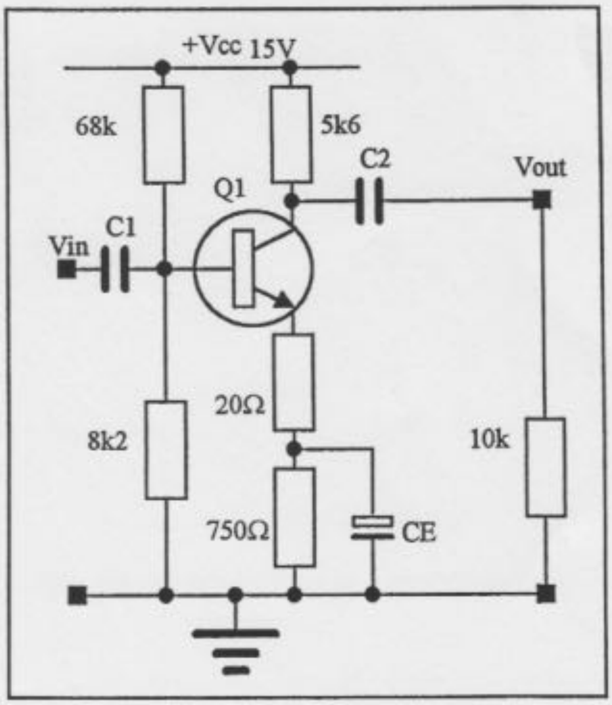
Q.1 a) For the circuit on the right, determine the quiescent conditions and hence determine the output voltage across R_L.

b) Calculate the gain in dB.



Q.2 a) For the circuit on the right, determine the quiescent conditions and find the approximate gain.

b) Calculate the gain in dB.



7794B - Amplifiers 2 - Lesson 3 - Answers to Student Problems

Q.1 a) $V_B = \frac{12k}{100k+12k} \times 18 = 1.9V$ $V_E = 1.9 - 0.6 = 1.3V$

$I_C = \frac{1.3}{820} = 1.58mA$ $V_C = 18 - 1.58mA \times 5k6 = 9.15V$

$re = \frac{30mV}{1.58mA} = 19\Omega$ $A_v = \frac{5k6//10k}{19} = 189$

$V_{out} = 189 \times 30mV = 5.67V_{p-p}$

b) $A_{V(dB)} = 20 \times \log(189) = 45.5dB$

Q.2 a) $V_B = \frac{8k2}{68k+8k2} \times 15 = 1.6V$ $V_E = 1.6 - 0.6 = 1V$

$I_C = \frac{1}{770} = 1.3mA$ $V_C = 15 - 1.3mA \times 5k6 = 7.7V$

$re = \frac{30mV}{1.3mA} = 23\Omega$ $A_V = \frac{5k6//10k}{23+20} = 83$

b) $A_{V(dB)} = 20 \times \log(83) = 38.4dB$

Q.3 a) $V_B = \frac{82k}{82k+12k} \times 12 = 10.46V$ $V_E = 10.4 + 0.6 = 11V$

$I_C = \frac{12-11}{820} = 1.2mA$ $V_C = 1.2mA \times 4k7 = 5.64V$

$re = \frac{30mV}{1.2mA} = 25\Omega$ $A_V = \frac{4k7//10k}{25} = 128$

$V_{out} = 128 \times 15mV = 1.92V_{p-p}$

b) $A_{V(dB)} = 20 \times \log(128) = 42dB$

Q.4 a) $V_B = \frac{47k}{47k+47k} \times 18 = 9V$ $V_E = 9 - 0.6 = 8.4V$

$I_C = \frac{8.4}{2k2} = 3.8mA$ $V_C = 18V$

b) $A_V \doteqdot 1 \therefore V_{out} = 4V_{p-p}$

Student Name ____

TRANSISTOR BIAS CIRCUITS

Objectives: While performing this experiment you will be able to

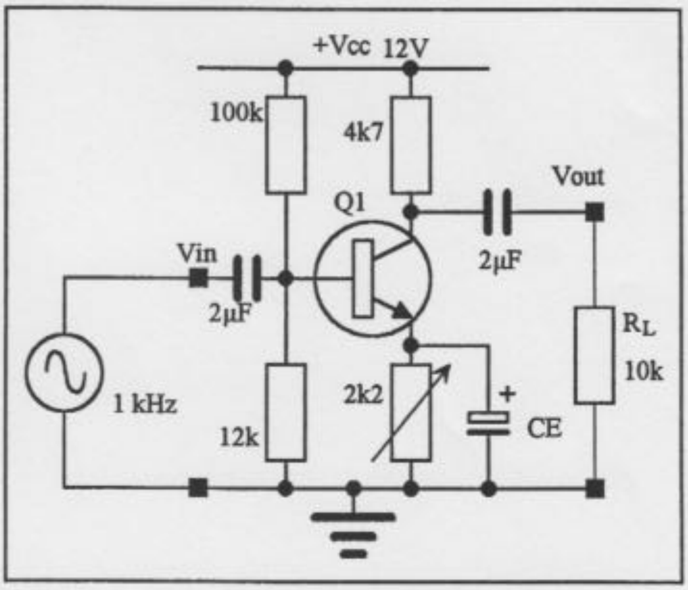
1. Measure the typical voltage values in a BJT voltage divider bias circuit.
2. Calculate the approximate quiescent values and compare with theory.
3. Compare your measured gain results with the calculated approximations.

Materials Required:

1 x DMM
1 x panel ET 5
1 x Mother board and power lead
1 x CRO
1 x Function generator
3 x BNC/4mm leads
3 x 4mm/4mm leads (short)

Procedure:

1. Plug in panel No. **ET5** and connect the circuit shown on the right.



2. Set the Vcc from the mother board to +12V and Vin from the function generator to zero.

3. Use the DMM to monitor the collector voltage V_C and adjust the 2k2 variable base resistor to achieve +6V between the collector and the earth.

4. Remove power from the mother board and temporarily remove module ET 5 from the motherboard. Be careful not to move the potentiometer knob and measure the total Emitter resistance R_E. Record this value below.

R_E = ______________________

5. Replace the ET 5 module and reapply power (Check V_{CE} is still 6V) Measure and record the value of V_E..

V_E = ______________________

6. Use the previously measured values to calculate Collector current I_C.

____

7. Use the DMM to measure the base voltage V_B. Record this value

$V_B =$ ____________________

8. Use the DMM to measure the value of V_{BE}. Record this value

$V_{BE} =$ ____________________

9. Set the input voltage from the function generator to 10 mV_{p-p} sinewave at a frequency of approximately 1 kHz. (Monitor with Y1 CRO input).

10. Measure the output voltage (Y2 CRO input). Record this value.

$V_{out} =$ ____________________ p-p

11. Remove the 10k load resistor and again measure the output voltage. Record this value.

$V_{out} =$ ____________________ p-p

12. Return all equipment to its correct stowage places. Complete the Questions and Observations section and return this practical to the teacher for marking.

Questions and Observations:

Q.1 Use the appropriate equations to determine the value of V_B and compare the results with the measured value in step 7. Suggest a reason for any differences.

____

____

Q.2 Does the value of V_{BE} measured in step 8 compare with given theory ?

____

Q.3 Use the value of V_C as an aid to determine the Collector current and compare with the value determined in step 6.

Q.4 From the measured value of step 10, determine the gain of the amplifier.

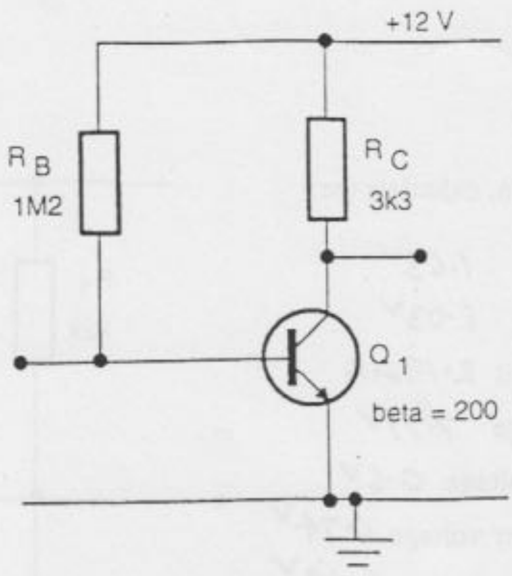
Q.5 From the measured value of step 11, determine the gain of this condition.

Q.6 Use the appropriate equations and calculate the loaded gain of the amplifier and compare with the measured result.

AMPs 2 HOMEWORK

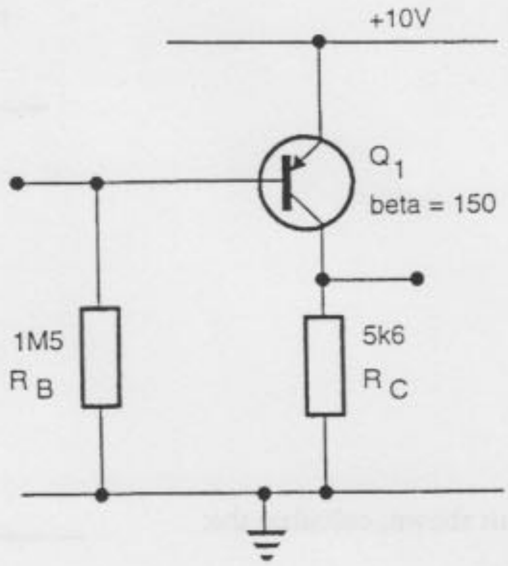
1 For the circuit shown, calculate the:

(a) base voltage 0.6V
(b) base current 9.5µA
(c) collector current 1.9mA
(d) collector voltage 5.73V



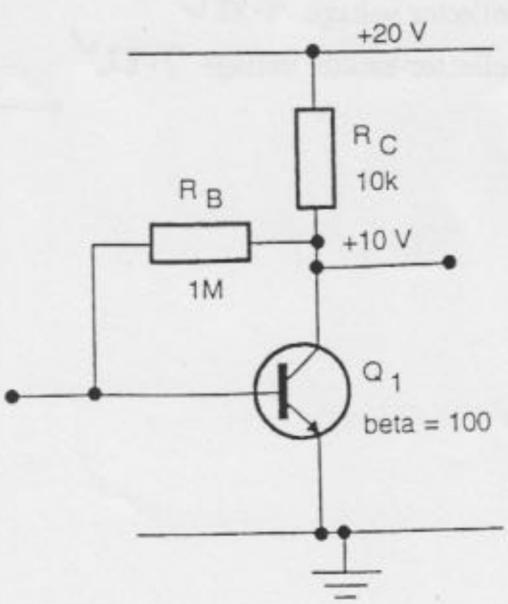
2 For the circuit shown, calculate the:

(a) base voltage 9.4
(b) base current 6.27µA
(c) collector current 941µA
(d) collector voltage 5.27V



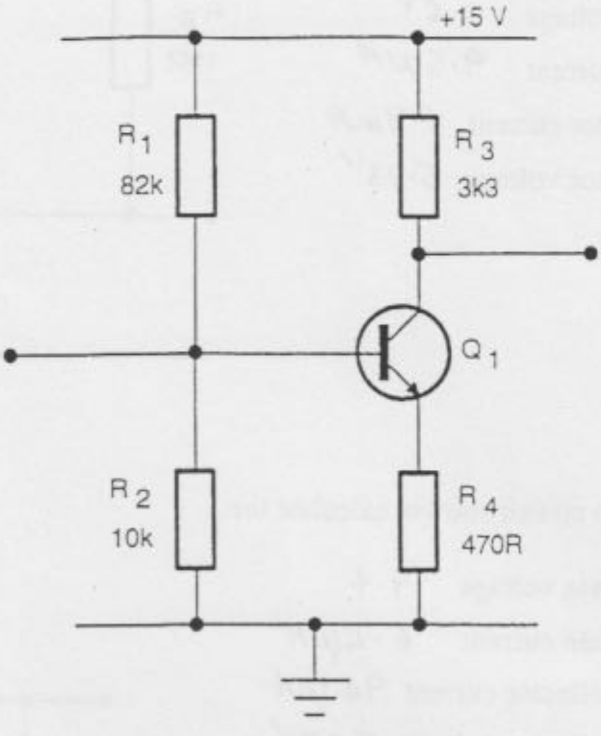
3 For the circuit shown on the right, assume the DC collector voltage is 10V and calculate the:

(a) base voltage 0.6V
(b) base current 9.4µA
(c) collector current 940µA



4 For the circuit shown, calculate the:

(a) base voltage 1·63V
(b) emitter voltage 1·03V
(c) collector current 2·19mA
(d) collector voltage 7·77V
(e) base-emitter voltage 0·6V
(f) collector-emitter voltage 6·74V
(g) collector-base voltage 6·14V



5 For the circuit shown, calculate the:

(a) base voltage 16·1
(b) emitter voltage 16·7
(c) collector current 1·08 mA
(d) collector voltage 8·88V
(e) collector-emitter voltage 7·82V