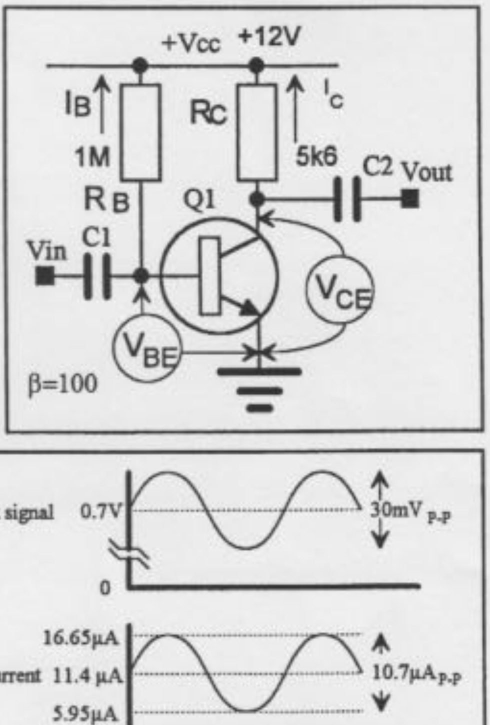
Practical Biasing Circuits

Introduction

The previously used circuit for the basic BJT amplifier is not very practical since two separate supplies are required and is inconvenient. A single supply can be utilised to produce a simple amplifier, which for battery type circuits improves the practicality.

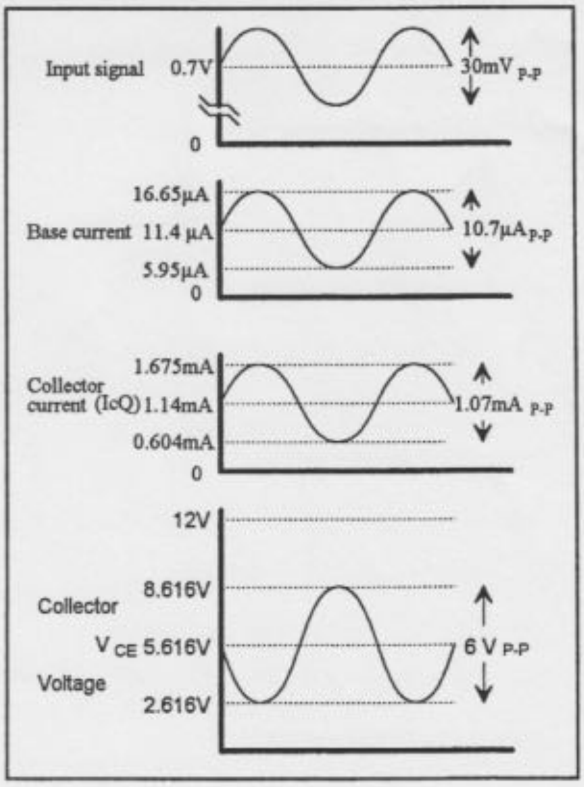
Simple Base Biasing.

For a BJT amplifier to operate correctly, both the Base and the Collector must have appropriate d.c. voltage levels with respect to the Emitter. The Base/Emitter voltage must be such as to have a voltage of between 0.6 to 0.7 V to forward bias the Base /Emitter diode. The Base must have a static base current (quiescent) about which any input signal is superimposed. To produce an output signal of minimum distortion at the collector, the Collector voltage must lie near the middle of its linear range. This voltage is conveniently arranged to be somewhere near the middle of the V_{CC} supply voltage. These quiescent values are commonly called the Q point of the amplifier. The circuit on the right shows the basic circuit. If $V_{BE} = 0.6V$ then the voltage drop across R_B must be 12V - 0.6V =11.4V and hence the Base current can be determined from



$I_B = \frac{12-0.6}{1M\Omega} = 11.4\mu A$ hence the collector current is $I_C = 100 \times 11.4\mu A = 1.14mA$ the voltage drop across the 5k6 resistor is $1.14mA \times 5k6 = 6.384V$ and this leaves a Collector /Emitter (V_{CE}) voltage of $12 - 6.384 = 5.616V$.

The coupling capacitors C_1 and C_2 are necessary to isolate the dc quiescent voltages from the input signal source and any output load that may be connected to the amplifier. The general equations for the analysis of the dc conditions for this circuit are:



$$I_B = \frac{V_{CC}-V_{BE}}{R_B} \quad I_C = \beta \times I_B$$

$$V_{CE} = V_{CC} - I_C \times R_C$$

If a signal of about 30 mV_{p-p} was applied to the input of the amplifier, the waveforms on the right illustrate the results. The waveforms are superimposed on the quiescent conditions of the amplifier and shows that the output is 180° out of phase with the input.

The basic definition of voltage gain is

$$A_v = \frac{V_{out}}{V_{in}} = \frac{6V_{p-p}}{30mV_{p-p}} = 200$$

(Typical for this type of amplifier)

Ac Voltage Gain Calculation

The previous calculation of gain would be used if a CRO was used to measure the input and output waveforms but there is a method that can be used to approximate the gain from the calculated value of Collector current I_C. In the Emitter of the transistor, there is a small resistive component through which passes the ac emitter current. This resistance is designated re and can be estimated from

$$re = \frac{30mV}{I_C}, \text{ having found this value, then } A_v = \frac{R_C}{re}$$

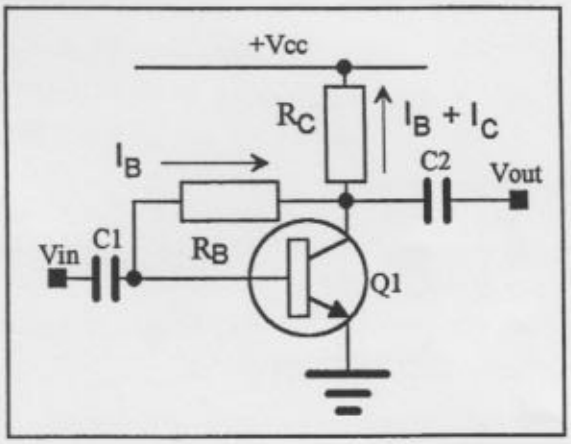
For the previous amplifier, $I_C = 1.14$ mA, hence $re = \frac{30mV}{1.14mA} = 26.3\Omega \therefore A_v = \frac{5k6}{26.3} = 212$

This is slightly higher than previously calculated and with this approximation it will always be so.

This amplifier is dependent on Beta and this transistor parameter varies greatly from transistor to transistor so a change of transistor is likely to upset the quiescent conditions. Also the value of Beta tends to vary with temperature and hence this amplifier is somewhat unstable as far as the quiescent conditions are concerned.

Collector Biased Amplifier

This amplifier will give better temperature stability compared to the previous circuit. If there is a change in Beta due to temperature, there will be a change in I_C in such a direction as to tend to oppose the original change due to temperature. If there is an increase in Beta, there will be an increase in I_C and hence a greater voltage drop across R_C. Since the base current is derived from the difference between the collector voltage and V_{BE} there will be a drop in base current that will now make the original collector change much less than if the Base bias current was derived from Vcc.



The equation for finding I_C is

$$I_C = \frac{V_{CC} - V_{BE}}{R_C + \frac{R_B}{\beta+1}} \text{ From which } V_{CE} = V_{CC} - I_C \times R_C$$

For this circuit, if $V_{CC} = 12V$, $R_C = 4k7$, $R_B = 620k$ and $\beta = 150$ then

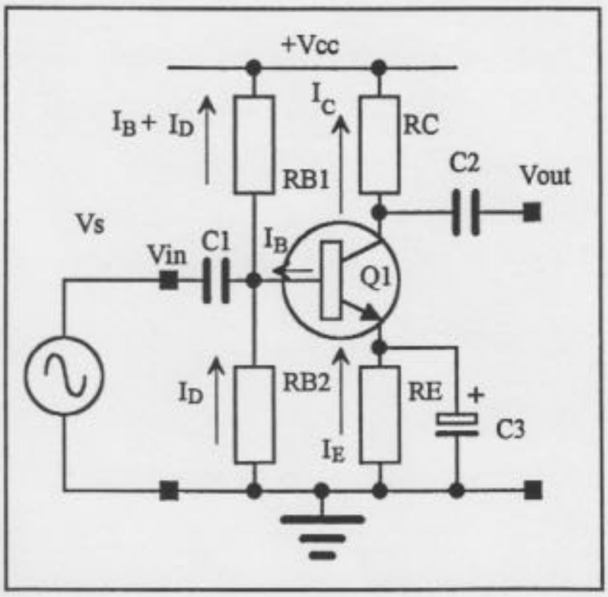
$$I_C = \frac{12-0.6}{4k7+\frac{620k}{150}} = 1.29mA \;\&\; V_{CE} = 12 - 1.29mA \times 4.k7 = 5.93V$$

The circuit is still dependent on Beta and a change of transistor will give a different set of quiescent conditions e.g. $\beta = 100$, $I_C = 1.045$ mA and $V_{CE} = 7V$ while $\beta = 200$ gives $I_C = 1.46$ mA and $V_{CE} = 5.13V$.

The use of collector to base feedback via R_B reduces the voltage gain, the calculation of which is beyond the requirements for this module. Other circuit parameters are also altered and hence this circuit is not commonly used.

Voltage Divider Biasing

A circuit that is near independent of Beta is desirable and the circuit illustrated on the right fulfills this requirement. The type of circuit is stable against temperature effects and change of transistor.



The following points apply:

1. R_{B1} and R_{B2} form a voltage divider and are selected so that the divider current (I_D) is large compared to the Base current (I_B). This has the effect of swamping any small changes in I_B.
2. An Emitter resistor R_E is added and is selected to voltage drop about 10% of V_{CC} (V_E) due to the Emitter current I_E. This has he effect of compensating for any changes of Emitter current due to temperature changes. An increase of Emitter current due to an increase in temperature will cause an increase in voltage drop across R_E and hence will reduce V_{BE} which will in turn reduce the Emitter current change and thus tending to stabilise the circuit.
3. The value of the Base voltage (V_B) must of course be 0.6 to 0.7 V above the Emitter voltage (V_E) to produce the required Base/Emitter voltage (V_{BE}) for class A operation.
4. The Collector current (I_C) is selected to produce a quiescent Collector voltage (V_C) that will be still within a volt or two of the centre of the V_{CC} range. This value of collector current can be very conveniently set by the value of R_E.
5. To still produce a high gain, it is necessary to bypass R_E with a sufficiently large capacitor (C_3) such as to be effective at the lowest audio frequency to be amplified. This capacitor is usually designated as C_E in most circuits.
6. The capacitors C_1 and C_2 give dc isolation the input and output circuits respectively.

The approximate analysis for this circuit uses some simplifying assumptions. Because of point number 1, I_B is ignored and the base voltage is determined using the voltage divider equation

$V_B = \frac{R_{b2}}{R_{B1}+R_{B2}} \times V_{CC}$ (Small error introduced here but is close enough in practice)

The Emitter must be 0.6V below this value to be biased for class A operation.

$V_E = V_B - 0.6V$ The Emitter current can be calculated from $I_E = \frac{V_E}{R_E}$

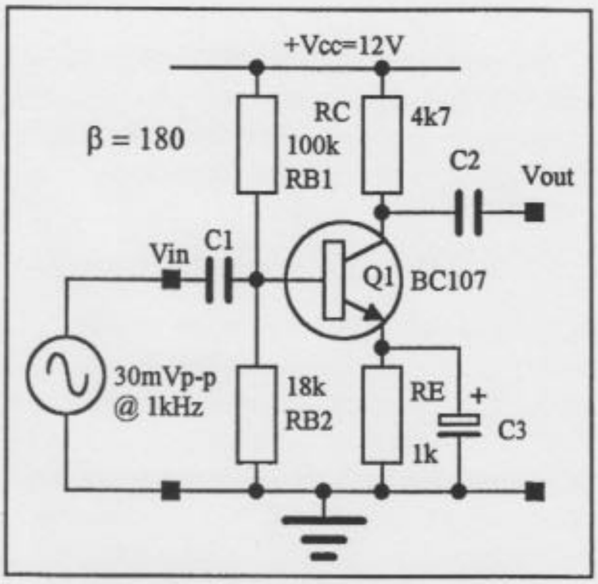
Since the Emitter current is very close to collector current this is assumed to be the same and hence $I_C \approx I_E$ and using this, the voltage from collector to common is $V_C = V_{CC} - I_C \times R_C$.

From previous $re = \frac{30mV}{I_C}$ & $A_V = \frac{R_C}{re}$

This is a very stable circuit is by far the most common biasing method that gives excellent temperature stability and a change of the transistor has very little effect. Note than in the above equations, the value of ß is not required to be known.

Example Problem

Determine the quiescent voltage and current values for circuit and hence determine the amplitude of V_{out}.



$$V_B = \frac{18k}{100k+18k} \times 12V = \underline{1.83V}$$

$$V_E = 1.83 - 0.6 = \underline{1.23V}$$

$$I_C = \frac{1.23V}{1k} = \underline{1.23mA}$$

$$V_C = 12 - 1.23mA \times 4k7 = \underline{6.2V}$$

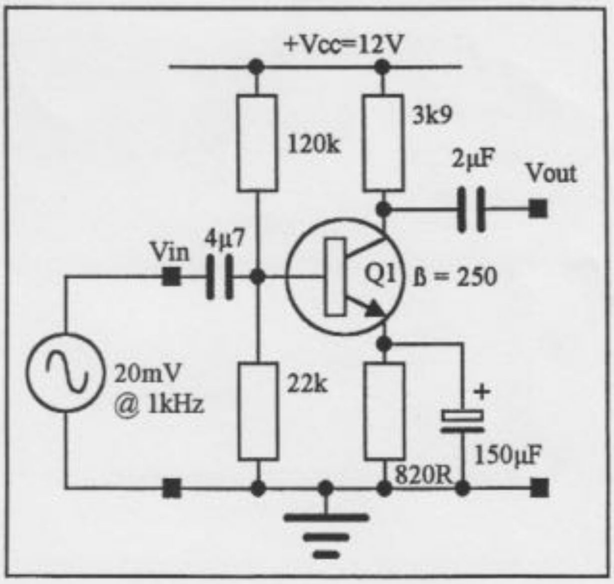
$$re = \frac{30mV}{1.23mA} = \underline{24.39\Omega}$$

$$A_v = \frac{4k7}{24.39} = \underline{192.7}$$

$$V_{out} = 30mV_{p-p} \times 192.7 = \underline{5.78V_{p-p}}$$

Student Problem

1. Determine all quiescent voltages and the approximate collector current.



2. Determine the value of V_{out}.

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Student Name ____

TRANSISTOR BIAS CIRCUITS

Objectives: While performing this experiment you will be able to

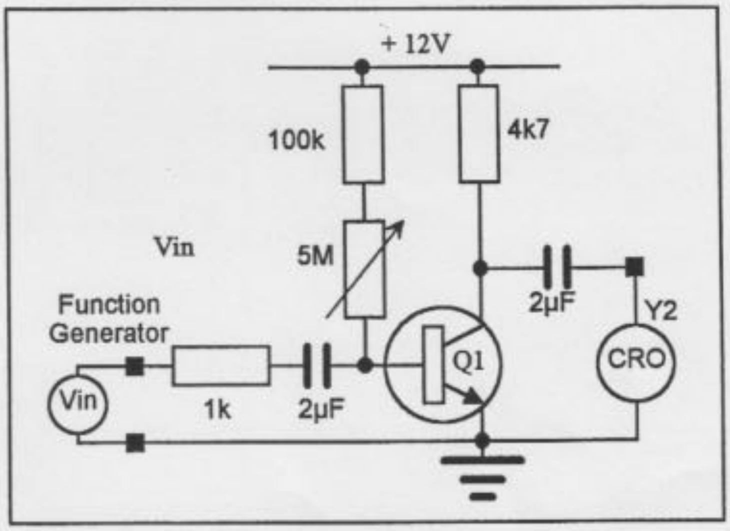
1. Measure the typical voltage values in a BJT simple base bias circuit.
2. Calculate the approximate Base and collector currents and compare with theory.
3. Compare your measured gain results with the calculated approximations.

Materials Required:

- **1 x DMM**
- **1 x panel ET 4 & 1 x DIN Plug mounted NPN transistor**
- **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. **ET4** 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 5M variable base resistor to achieve +6V between the collector and the emitter.

4. Remove power from the mother board and temporarily remove the V_{CC} from the base bias connection. Be careful not to move the potentiometer knob and measure the total base bias resistance R_B. Record this value below.

R_B = ______________________________

5. Replace base bias circuit and reapply power (Check V_{CE} is still 6V) Measure and record the value of V_{BE}..

V_{BE} = ______________________________

6. Use the previously measured values to calculate Base current I_B.

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

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8. From the above calculated results, determine the Beta of the transistor.

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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. Sketch the input and output waveforms in the space provided on the right (show the relative phase relationship).

11. From the measured results, determine the voltage gain of the amplifier

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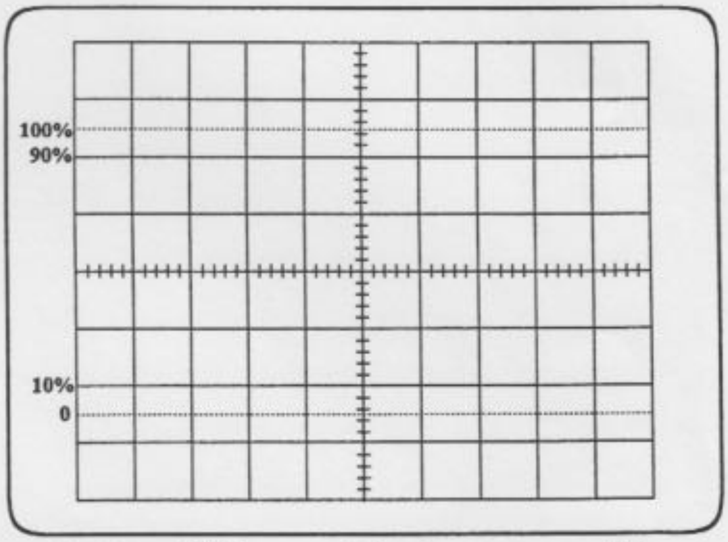

CH 1. **V/div** **Timebase.** **ms/div**

CH 2. **V/div** **Timebase multiplier.** **x1**

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 Comment on the value of V_{BE} measured compared to the suggested theoretical value.

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Q.2 Use the value of I_C determined in step 7 to arrive at a theoretical voltage gain. Comment on the result compared to the value determined in step 11.

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Q.3 What is the likely result if all components remained the same, but the transistor is changed for a new one of the same type number ?

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