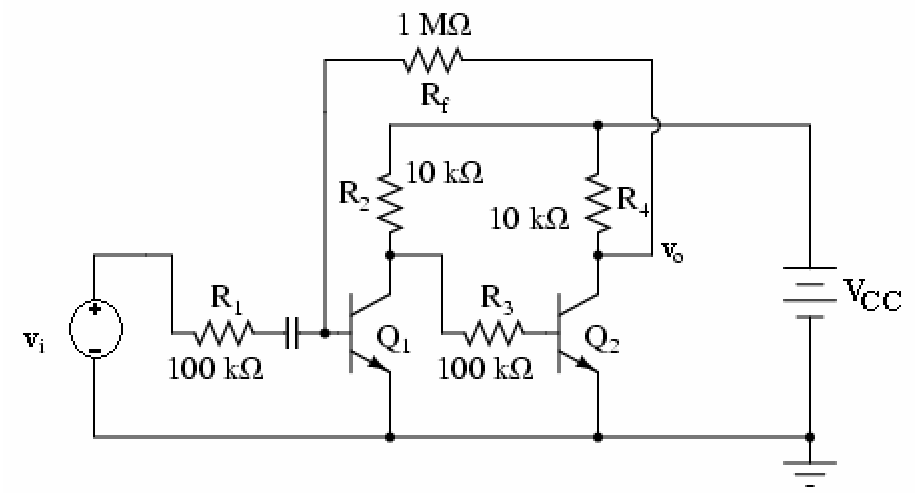
EXERCISE – Direct-coupled feedback amplifier



V_{CC} = 12 V $h_{FE} = h_{fe}$ = 200 V_{BE} = 0.7V $I_{CO} \approx 0$ A $V_{CEsat} \approx 0$ V 1/hoe = 120kΩ

a) Describe the type of feedback and find β and A_f?
b) $A_{vf} = v_o / v_i$?
c) $A_{v1} = v_{c1} / v_i$?
d) Plot the DC and AC lines.
e) v_{imax} = ?

ANSWER:

a) Voltage-shunt (voltage-parallel) feedback

$\beta = i_f / v_o \approx -1 / R_f = \underline{-1\ \mu\Omega^{-1}}$

$A_f = R_{Mf} = v_o / i_i \approx 1 / \beta = -R_f = \underline{-1\ M\Omega}$

Note: $A = R_M \approx h_{fe1} R_2 / R_3\, h_{fe2} R_4 = 40M\Omega$ and $A_v = R_M / R_1 = 400$.

b) $A_{vf} = v_o / v_i = (v_o / i_i)(i_i / v_i) = R_{Mf} / R_1 \approx \underline{-10}$

c) Let's consider the following equalities

$$v_o = A_{vf}\, v_i$$

$$i_{c2} \approx -v_o / R_4$$

$$i_{c2} \approx h_{fe}\, i_{b2}$$

$$i_{b2} \approx v_{c1} / R_3$$

$$A_{v1} = \frac{v_{c1}}{v_i}$$

$$= \frac{v_{c1}}{v_o}\frac{v_o}{v_i} = \frac{v_{c1}}{i_{b2}}\frac{i_{b2}}{v_o}\frac{v_o}{v_i}$$

$$= \frac{v_{c1}}{i_{b2}}\frac{i_{b2}}{i_{c2}}\frac{i_{c2}}{v_o}\frac{v_o}{v_i}$$

$$= R_3 \frac{1}{h_{fe}}\frac{-1}{R_4} A_{vf}$$

= 100K / 200 / -10K x -10 = <u>0.5</u>

d) **DC equations**

<u>Base-emitter loop</u>

$V_{CC} – I_{BQ1} R_f – (I_{CQ2} + I_{BQ1})R_4 – V_{BE1} = 0$
$V_{CC} – I_{BQ2} R_3 – (I_{CQ1} + I_{BQ2}) R_2 – V_{BE2} = 0$

$V_{CC} – I_{BQ1} R_f – h_{FE} I_{BQ2} R_4 – V_{BE1} = 0$ … $R_f >> R_4$
$V_{CC} – I_{BQ2} R_3 – h_{FE} I_{BQ1} R_2 – V_{BE2} = 0$ … $R_3 >> R_2$

$1.00M\ I_{BQ1} + 2M\ I_{BQ2} = 11.3$
$100K\ I_{BQ2} + 2M\ I_{BQ1} = 11.3$

Solving these three equations give us
$I_{BQ1} = 5.51\ \mu A$ $I_{BQ2} = 2.90\ \mu A$

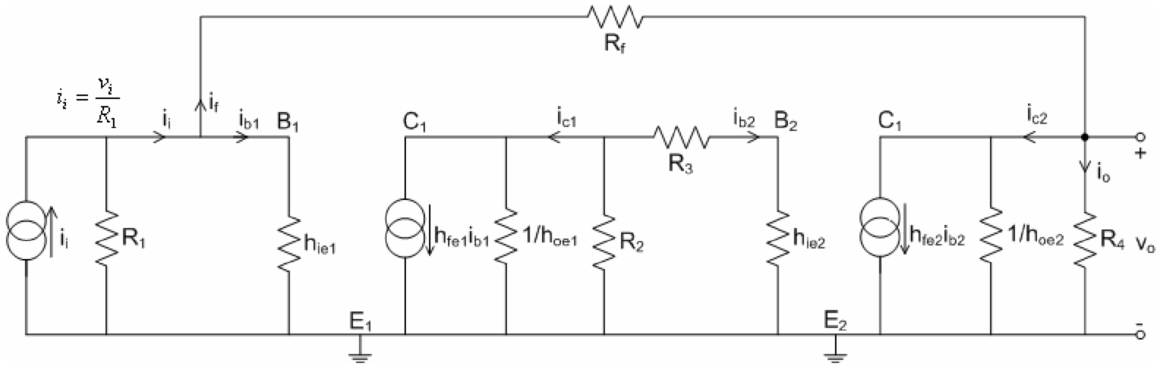
Consequently the collector currents will be
$I_{CQ1} = h_{FE}\ I_{BQ1} = 1.10\ mA$ $I_{CQ2} = h_{FE}\ I_{BQ2} = 0.58\ mA$

<u>Collector-emitter loop</u>

$V_{CC} – (I_{CQ1} + I_{BQ2})R_2 – V_{CEQ1} = 0$
$V_{CC} – (I_{CQ2} + I_{BQ1})R_4 – V_{CEQ2} = 0$

$12 – 11.0 – V_{CEQ1} = 0$
$12 – 5.8 – V_{CEQ2} = 0$

Hence
$V_{CEQ1} = 1\ V$ $V_{CEQ2} = 6.2\ V$



AC equations

$$\ldots.h_{ie1} = h_{fe1}\ 26mV / I_{EQ1} = 4.73\ k\Omega$$
$$\ldots.h_{ie2} = h_{fe2}\ 26mV / I_{EQ2} = 8.96\ k\Omega$$

$$v_{CE} = v_{ce} + V_{CEQ}, \qquad i_C = i_c + I_{CQ}$$

$$v_{ce1} = -i_{c1}\,(R_2 \,||\, (R_3 + h_{ie2})) \approx -R_2\,(i_{C1} - I_{CQ1})$$
$$v_{ce2} \approx -i_{c2}\,R_4 = -R_4\,(i_{C2} - I_{CQ2})$$

$$v_{CE1} = V_{CEQ1} + R_2\,(I_{CQ1} - i_{C1})$$
$$v_{CE2} = V_{CEQ2} + R_4\,(I_{CQ2} - i_{C2})$$

As

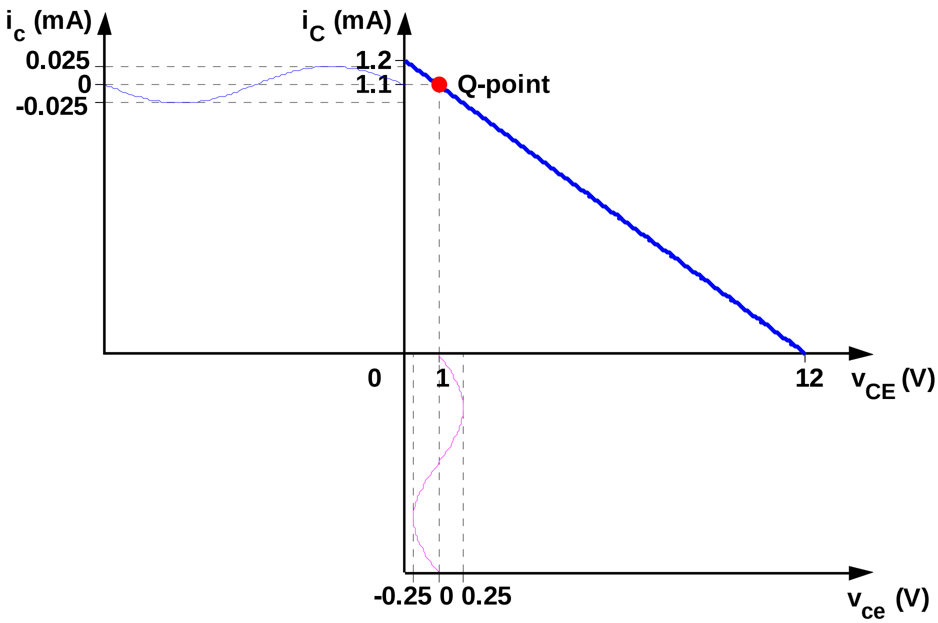
$$V_{CEQ1} = V_{CC} - I_{CQ1}\,R_2$$
$$V_{CEQ2} = V_{CC} - I_{CQ2}\,R_4$$

Hence

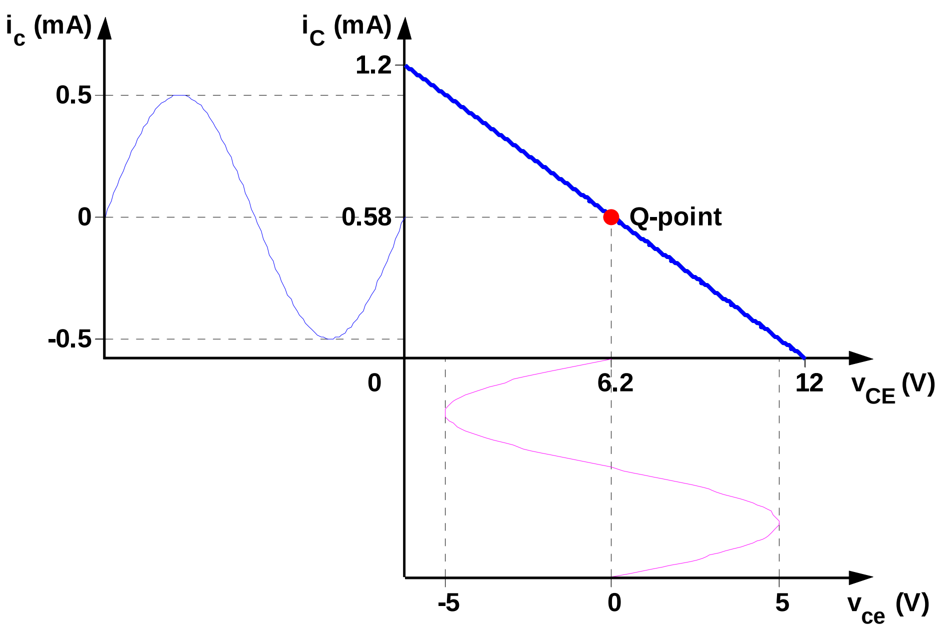
$$v_{CE1} = V_{CC} - R_2\,i_{C1}$$
$$v_{CE2} = V_{CC} - R_4\,i_{C2}$$

So AC loadline is the same as the DC the load line

For v_i = 0.5 sin(ωt) V, the AC-DC loadlines of Q1 and Q2 are given as



v_{ce1} = 0.25 sin(ωt) V



v_{ce2} = -5 sin(ωt) V

e) Maximum voltage swing for Q1 is $v_{ce1max} = V_{CEQ1} = 1V$
Maximum voltage swing for Q2 is $v_{ce2max} = V_{CC} - V_{CEQ2} = 5.8V$

For Q1, $v_{imax} = v_{ce1max} / A_{v1} = 1 / 0.5 = 2$ V
For Q2, $v_{imax} = v_{ce2max} / A_{vf} = 5.8 / 10 = 0.58$ V

So v_{imax} = <u>$0.58 \sin(\omega t)$V</u>