ELE20: Basis Elektro - Week 4

Hogeschool Rotterdam - Opleiding Elektrotechniek

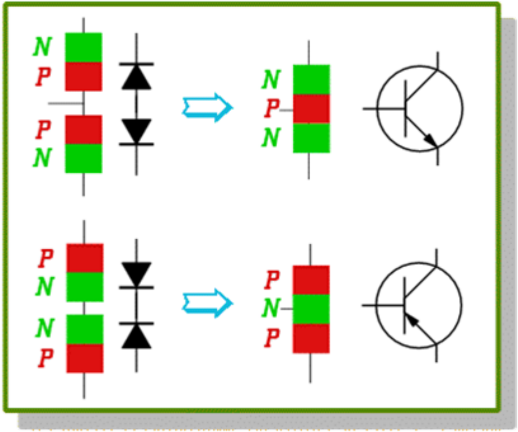
Vandaag

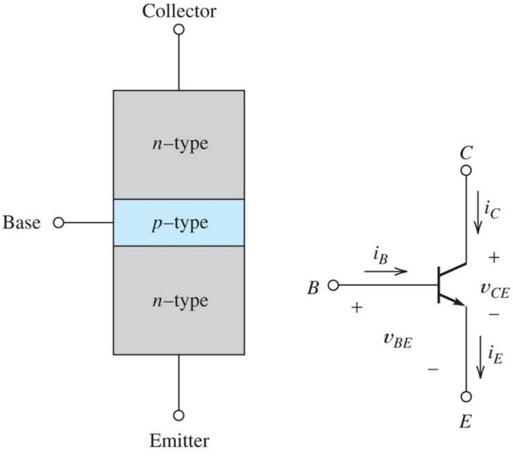
1. De Transistor
   - Opbouw en werking
   - Karakteristieken: $V_{BE} - I_B$ en $V_{CE} - I_C$ grafieken
   - Werkgebieden
   - Four Resistor Bias-circuit

2. Huiswerk

De Transistor

De transistor bestaat in feite uit twee gekoppelde dioden.





(a) Physical structure (b) Circuit symbol

HOGESCHOOL ROTTERDAM

De Transistor

- Symbool van NPN transistor en van PNP transistor
- Pijltje geeft aan hoe de elektrische stroom loopt
- NPN: Spanning op de Basis moet 0.7 V hoger zijn dan op Emitter
- PNP: Spanning op de Basis moet 0.7 V lager zijn dan op Emitter
- Onthoud: Basis-Emitter overgang is een gewone diode overgang!

Transistor parameters

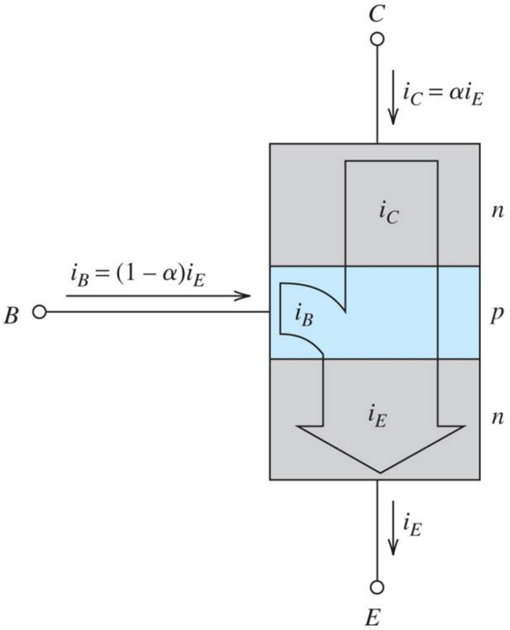
Transistor wordt gebruikt als:

- Schakelaar
- Versterker

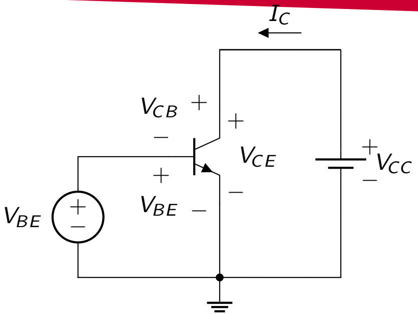
Belangrijke parameters:

- *DC current-gain*: β of h_{FE}
- $\beta = \frac{I_c}{I_B} = \frac{\alpha}{1 - \alpha}$
- $\alpha = \frac{I_C}{I_E}$
- $I_C = \beta \cdot I_B$

Vraag: In datasheet staat dat $h_{FE} = 200$.
Hoe groot is α?



$V_{BE} - I_B$ karakteristiek

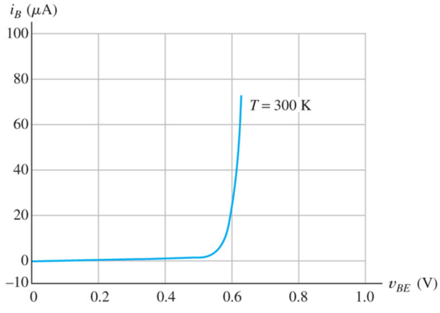


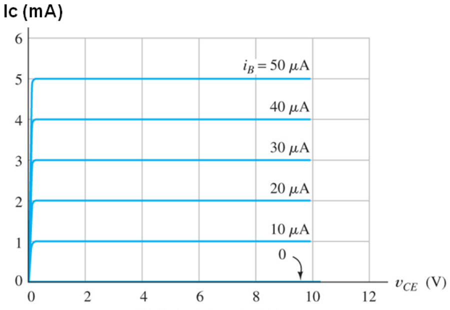
Belangrijke grafieken:

- I_B als functie van V_{BE}
- I_C als functie van V_{CE}

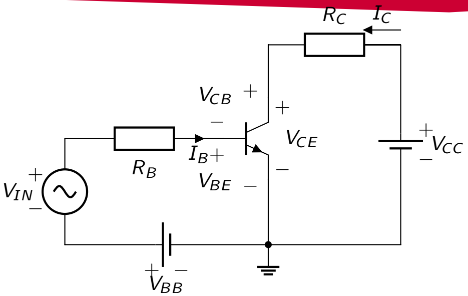
Kleine verandering in I_B => grote verandering in I_C

Vraag: hoe groot is β hier?





$V_{CE} - I_C$ karakteristiek

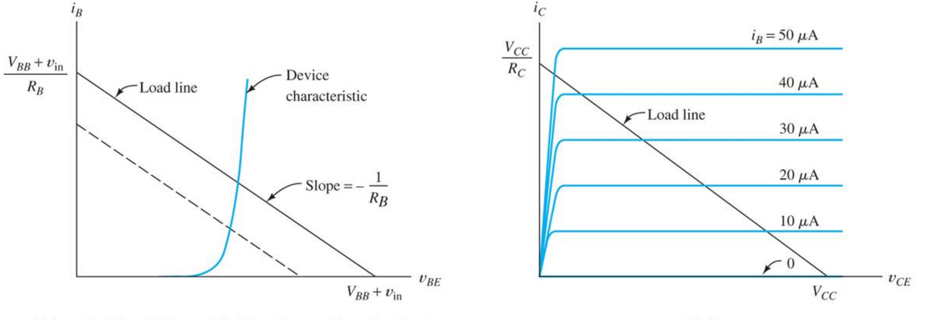


Maasmethode voor input:

$$-V_{BB} - V_{IN} + R_B I_B + V_{BE} = 0$$

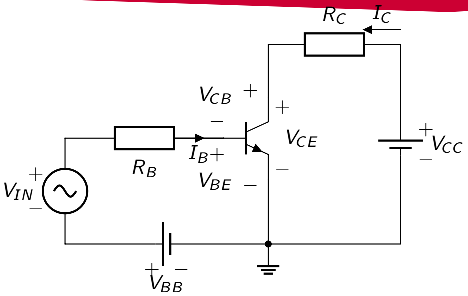
Stel $I_B = 0\,\mu\text{A} \Rightarrow V_{BE} = V_{BB} + V_{IN}$

Stel $V_{BE} = 0\,\text{mV} \Rightarrow I_B = \dfrac{V_{BB} + V_{in}}{R_B}$



(a) Input load line (shifts to dashed line for a smaller value of v_{in}) (b) Output

$V_{CE} - I_C$ karakteristiek

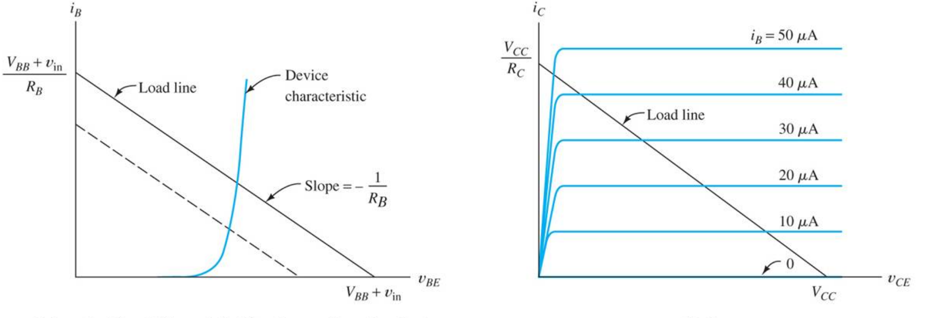


Maasmethode voor output:

$$-V_{CC} + R_C I_C + V_{CE} = 0$$

Stel $I_C = 0\,\text{mA} \Rightarrow V_{CE} = V_{CC}$

Stel $V_{CE} = 0\,\text{V} \Rightarrow I_C = \dfrac{V_{CC}}{R_C}$

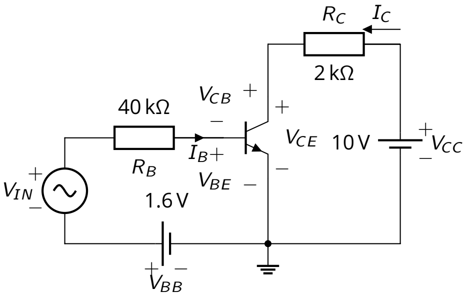


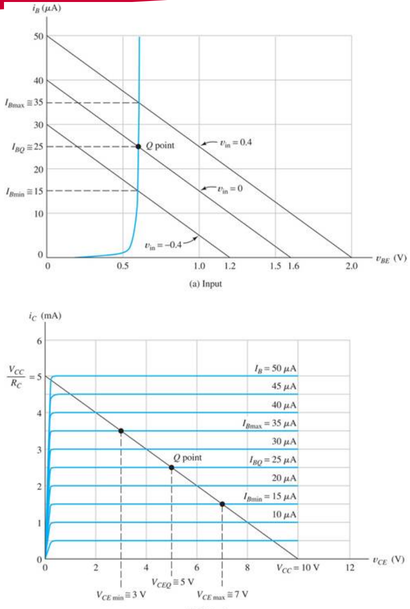
(a) Input load line (shifts to dashed line for a smaller value of v_{in}) (b) Output

Example 12.2 Hambley, pag. 627

Ingangsspanning
V_{IN} : $V_P = 0.4\,\mathrm{V}$, $f = 1\,\mathrm{kHz}$.
Stel $I_B = 0\,\mu\mathrm{A} \Rightarrow V_{BE} = V_{BB} + V_{IN}$

- $V_{IN} = +0.4\,\mathrm{V} \Rightarrow V_{BE} = 2.0\,\mathrm{V}$
- $V_{IN} = 0\,\mathrm{V} \Rightarrow V_{BE} = 1.6\,\mathrm{V}$
- $V_{IN} = -0.4\,\mathrm{V} \Rightarrow V_{BE} = 1.2\,\mathrm{V}$





(a) Input
(b) Output

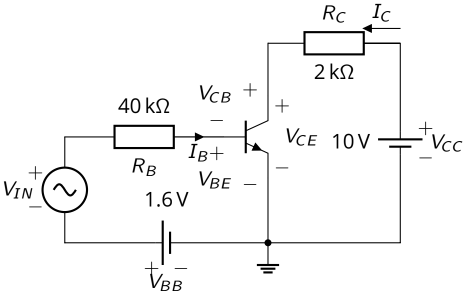
Example 12.2 Hambley, pag. 627

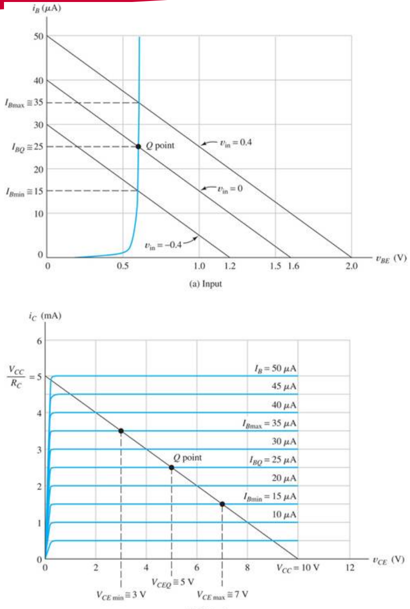
Ingangsspanning

$V_{IN} : V_P = 0.4\,\text{V}, f = 1\,\text{kHz}.$

Stel $V_{BE} = 0\,\text{mV} \Rightarrow I_B = \dfrac{V_{BB} + V_{in}}{R_B}$

- $I_B = \frac{1.6+0.4}{40\,\text{k}\Omega} = 50\,\mu\text{A}$
- $I_B = \frac{1.6+0.0}{40\,\text{k}\Omega} = 40\,\mu\text{A}$
- $I_B = \frac{1.6-0.4}{40\,\text{k}\Omega} = 30\,\mu\text{A}$



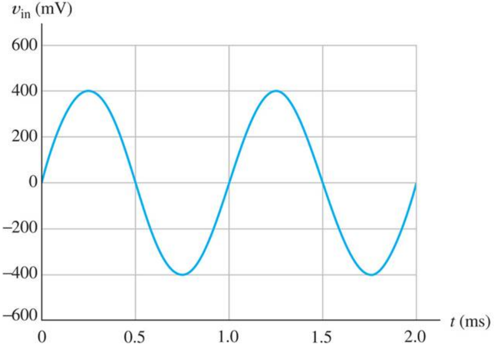


(a) Input

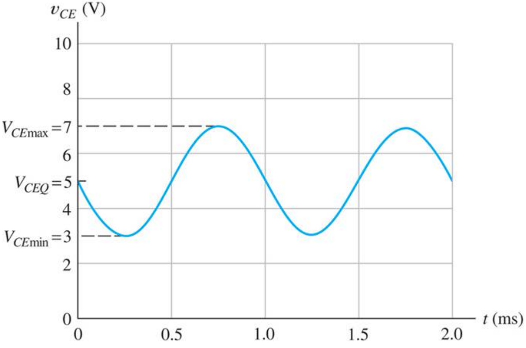
(b) Output

Example 12.2 Hambley, Waveforms

$\Delta V_{IN} = 400\,\text{mV} \Rightarrow \Delta I_B = 10\,\mu\text{A}$
Met $\beta = 100 \Rightarrow \Delta I_C = 1\,\text{mA}$
Spanningsverandering over $R_C = \Delta I_C \cdot R_C = 2\,\text{V}$
Spanning V_{CE} wordt dus 2 V kleiner!



(a) Input

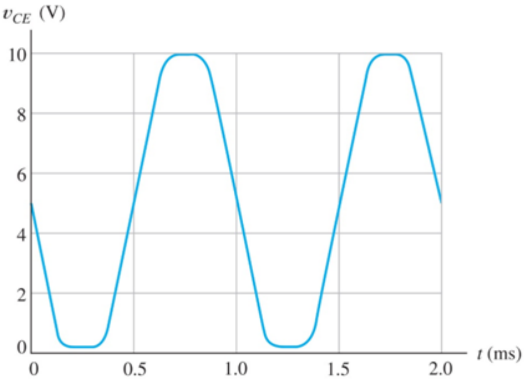


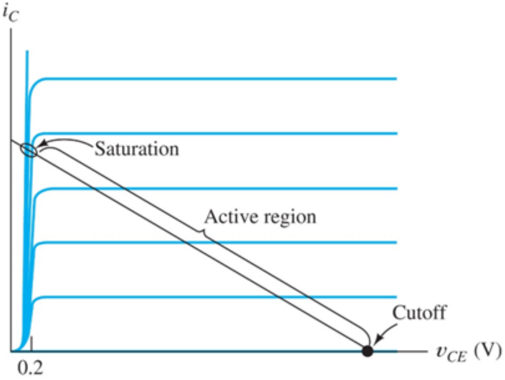
(b) Output

Example 12.2 Hambley, Distortion

Indien V_{IN} te groot wordt:

- Signaal loopt tegen GND (Saturation) of V_{CC} (Cutoff) aan
- Niet-lineaire vervorming = ongewenst!





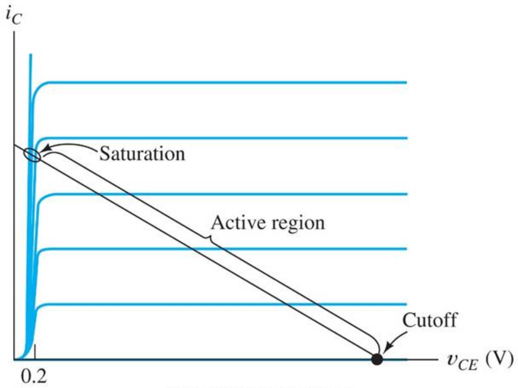
Groot-signaal DC model

Instellen transistor gaat in twee stappen:

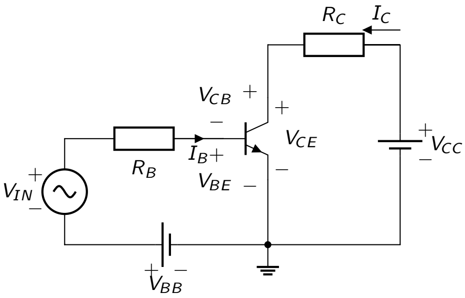
- Eerst instellen voor gelijkspanning
  - Wordt groot-signaal of DC model genoemd
  - Instelling van het werkgebied: Saturation, Active, Cutoff
- Daarna instellen voor wisselspanning
  - Wordt klein-signaal model genoemd
  - Instellen van versterking A, R_{IN} en R_{OUT}

Drie werkgebieden voor een transistor:

- Cutoff: $V_{BE} < 0.5\,\mathrm{V}$ en $V_{BC} < 0.5\,\mathrm{V}$
- Saturation: $I_B > 0\,\mu\mathrm{A}$ en $\beta I_B > I_C > 0$
- Active: $I_B > 0\,\mu\mathrm{A}$ en $V_{CE} > 0.2\,\mathrm{V}$, $U_{BE} \approx 0.7\,\mathrm{V}$



Werkgebied: Hambley example 12.3

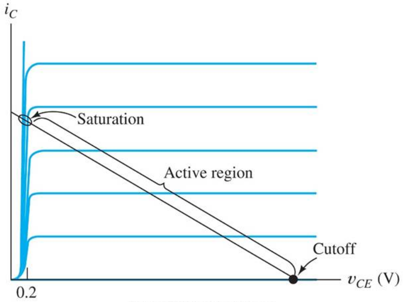


Drie werkgebieden voor een transistor:

- Cutoff: $V_{BE} < 0.5\,\mathrm{V}$ en $V_{BC} < 0.5\,\mathrm{V}$
- Saturation: $I_B > 0\,\mu\mathrm{A}$ en $\beta I_B > I_C > 0$
- Active: $I_B > 0\,\mu\mathrm{A}$ en $V_{CE} > 0.2\,\mathrm{V}$, $U_{BE} \approx 0.7\,\mathrm{V}$

Ga uit van $\beta = 100$. Welk werkgebied bij:

- $I_B = 50\,\mu\mathrm{A}$ en $I_C = 3\,\mathrm{mA}$?
- $I_B = 50\,\mu\mathrm{A}$ en $V_{CE} = 5\,\mathrm{V}$?
- $V_{BE} = -2\,\mathrm{V}$ en $V_{CE} = -1\,\mathrm{V}$?



Werkgebied: Hambley example 12.4

Cutoff gebied?

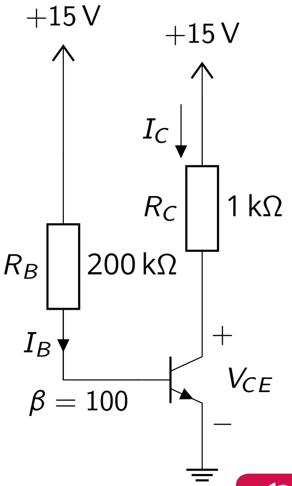
- Dan moet I_B 0 zijn. Maar dan is $V_B = V_{CC}$.
- V_B is dan groter dan 0 V, dus geen cutoff

Saturation?

- $I_C = \frac{15-0.2}{R_C} = 14.8\,\text{mA}$
- $I_B = \frac{15-0.7}{R_B} = 71.5\,\mu\text{A}$
- $\beta \cdot I_B = 7.15\,\text{mA} < I_C$, dus geen saturation

Active?

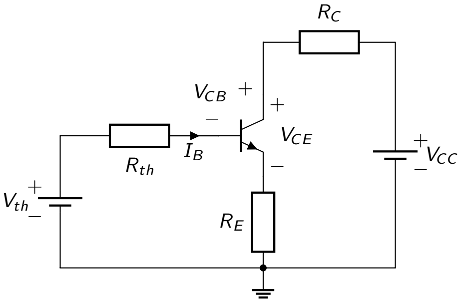
- $I_B = \frac{15-0.7}{R_B} = 71.5\,\mu\text{A}$
- $I_C = \beta \cdot I_B = 7.15\,\text{mA}$
- $V_CE = 15 - I_C R_C = 7.85\,\text{V}$
- $V_{CE} > 0.2\,\text{V}$, dus active werkgebied

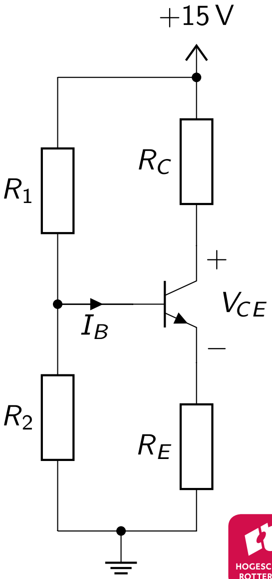


Four Resistor Bias-circuit

R_1 en R_2 vervangen m.b.v. Thévenin:

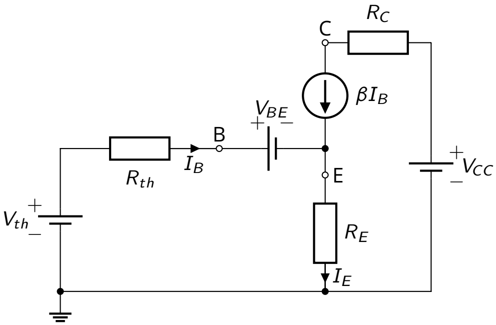
- $V_{th} = U_{OC} = \dfrac{R_2}{R_1 + R_2} V_{CC}$
- $I_{SC} = \dfrac{V_{CC}}{R_1}$
- $R_{th} = \dfrac{U_{OC}}{I_{SC}} = \dfrac{R_1 R_2}{R_1 + R_2} = R_1 // R_2$

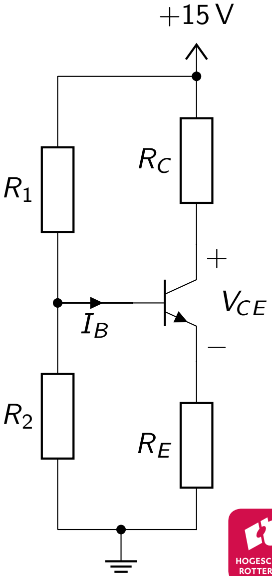




Four Resistor Bias-circuit

Transistor groot-signaal model wordt nu:





Gebruik nu de maasmethode:

$$-V_{th} + R_{th}I_B + V_{BE} + I_E R_E = 0$$

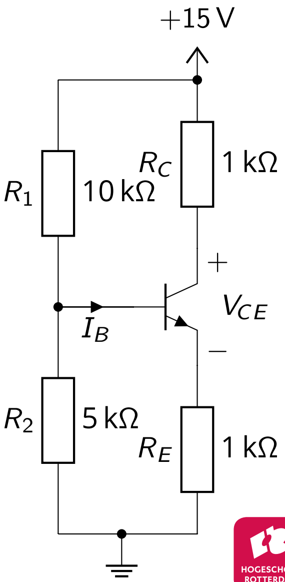
$$-V_{th} + R_{th}I_B + 0.7 + (\beta + 1)\, I_B R_E = 0$$

$$I_B = \frac{V_{th} - 0.7}{R_{th} + (\beta + 1)\, R_E}$$

Four Resistor Bias-circuit: Hambley example 12.7

Bepaal:

- V_{th} en R_{th} (Thévenin van R_1 en R_2 spanningsdeler)
- I_B en I_C
- V_C en V_E



Four Resistor Bias-circuit: Hambley example 12.7

Bepaal:

- V_{th} en R_{th} (Thévenin van R_1 en R_2 spanningsdeler)
- I_B en I_C
- V_C en V_E

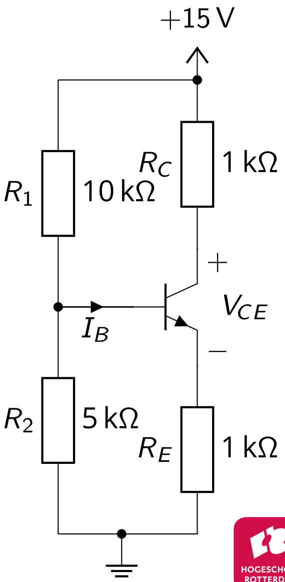
Oplossing:

$$V_{th} = \frac{R_2}{R_1 + R_2} V_{CC} = 5\,\text{V}$$

$$R_{th} = 5\,\text{k}\Omega // 10\,\text{k}\Omega = 3.33\,\text{k}\Omega$$

$$I_B = \frac{V_{th} - 0.7}{R_{th} + (\beta + 1)\,R_E} = \frac{4.3}{3.33\,\text{k}\Omega + 101\,\text{k}\Omega} = 41.2\,\mu\text{A}$$

$$I_C = 4.12\,\text{mA}, V_C = 10.88\,\text{V}, V_E = 4.16\,\text{V}$$



Huiswerk. . .

Huiswerk

- Hambley H12.1 opgaven P12.1 t/m P12.17
- Hambley H12.2 opgaven P12.18 t/m P12.21
- Hambley H12.3 opgaven P12.22 t/m P12.26
- Hambley H12.4 opgaven P12.27 t/m P12.32
- Hambley H12.5 opgaven P12.33 t/m P12.40
- Hambley H12.6 opgaven P12.41 t/m P12.52

Volgende les:

- Klein-signaal model