Rangkaian Bias DC

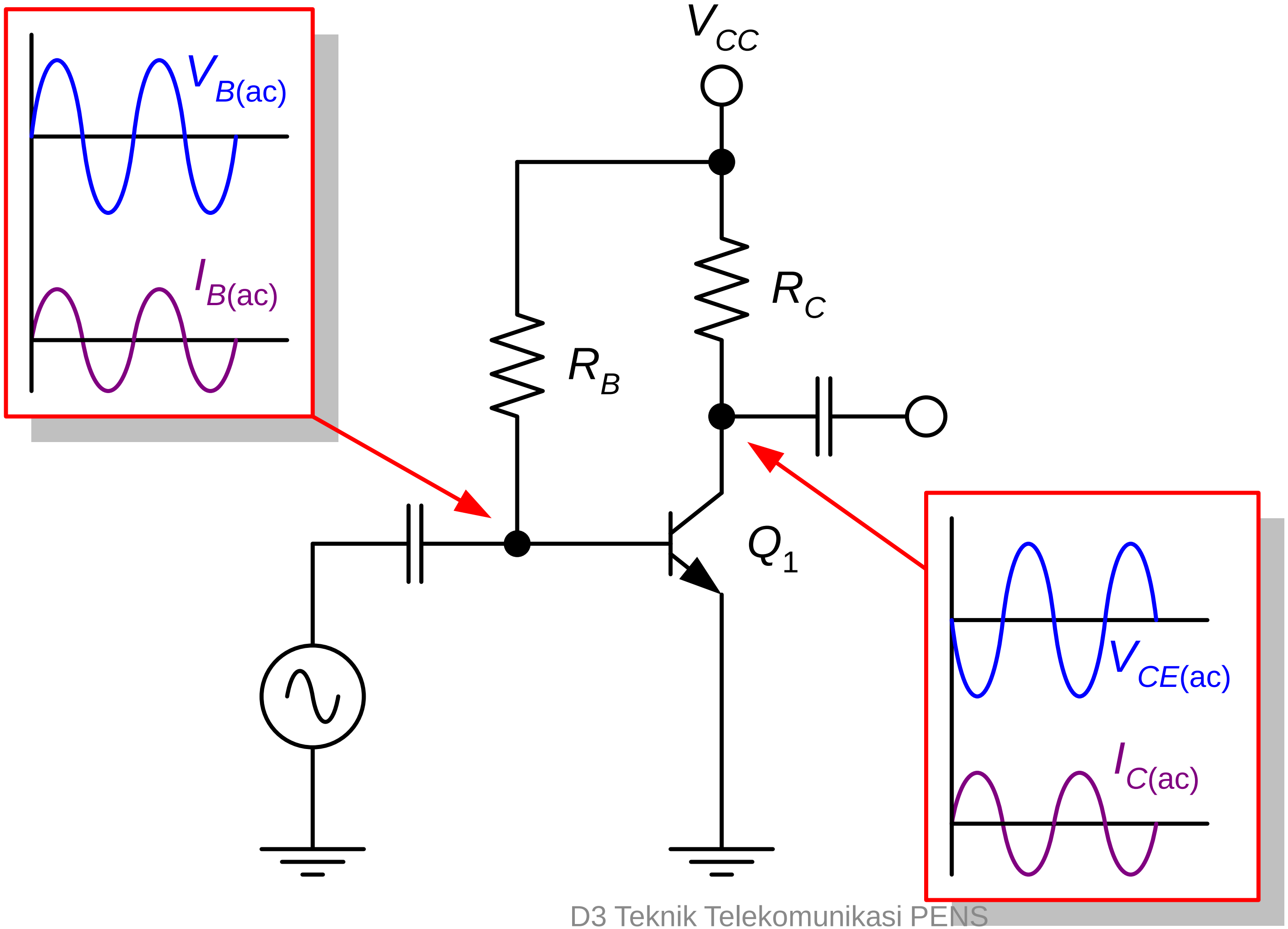
Bipolar Junction Transistor

BJT

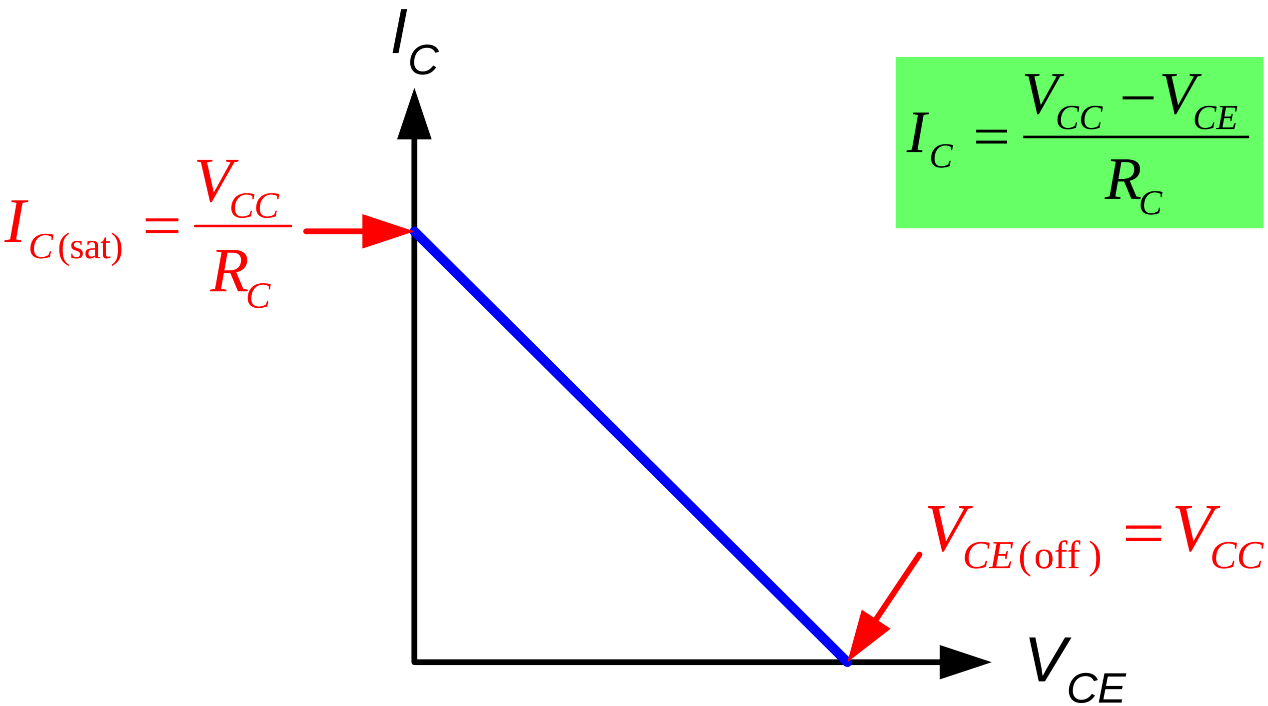
Tujuan

- Menggambar garis beban dc (dc load line) dari nilai V_{CC} yang diberikan dan rangkaian collector-emitter
- Menjelaskan titik kerja (Q-point) dari amplifier.
- Menjelaskan dan analisa Macam-macam rangkaian bias :
  - Rangkaian bias base
  - Rangkaian bias voltage-divider
  - Rangkaian bias emitter
  - Rangkaian bias collector-feedback
  - Rangkaian bias emitter-feedback bias circuits

Operasi amplifier

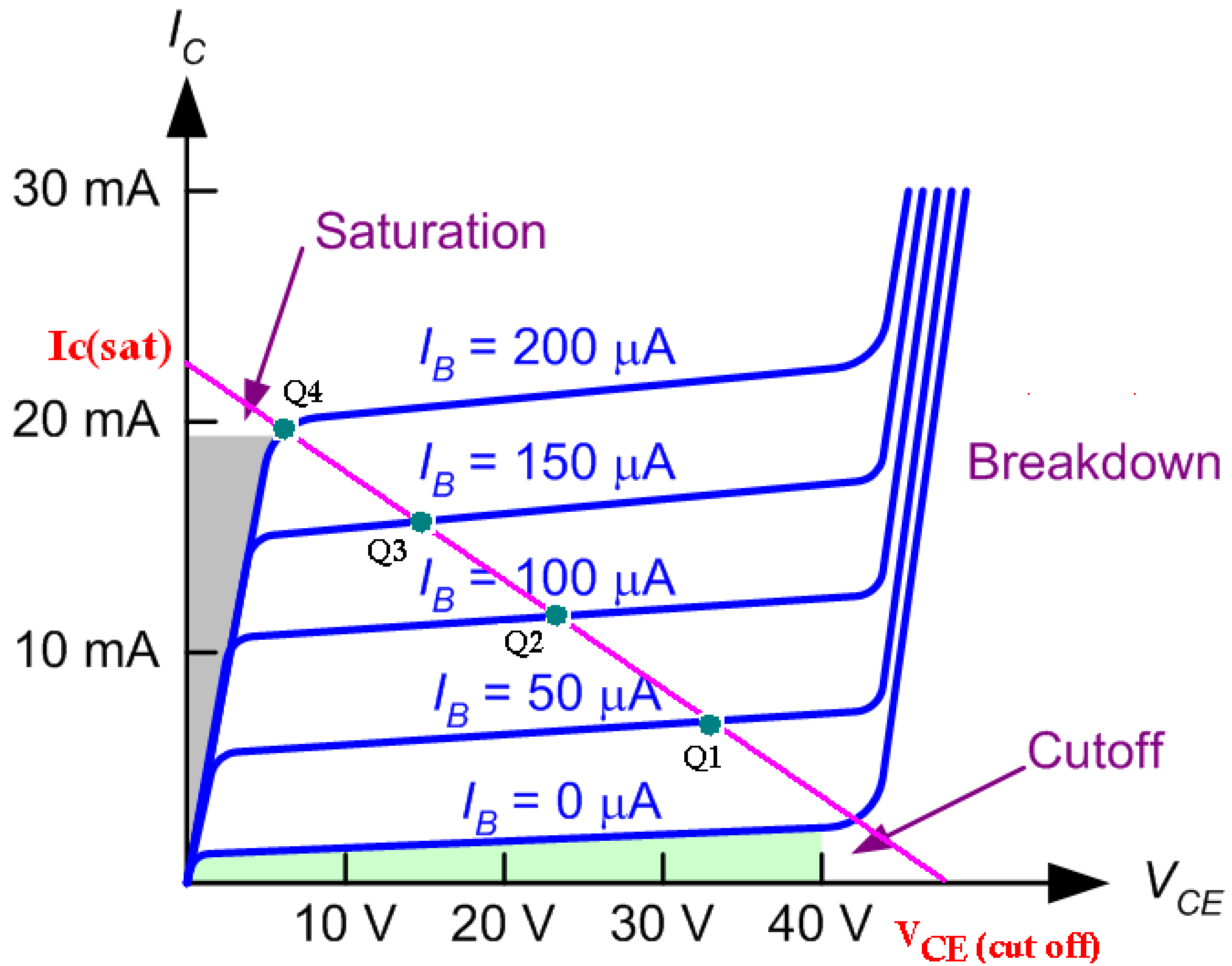


Garis beban DC



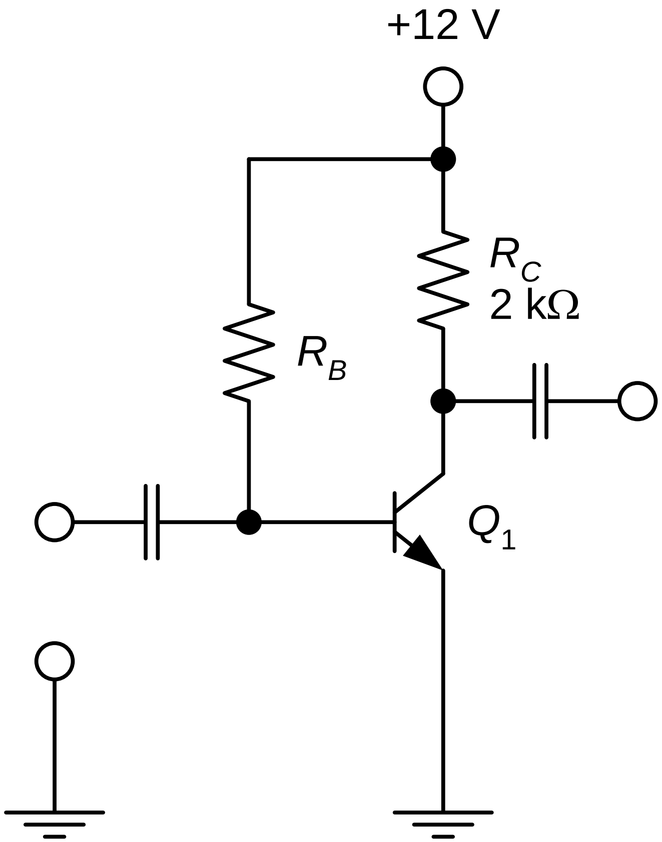
- Apabila I_B >> maka I_C >> dan V_{CE} <<
- Apabila I_B << maka I_C << dan V_{CE} >>
- Shg perubahan pada VBB → perubahan titik kerja transistor disepanjang garis lurus yang disebut dengan garis beban dc

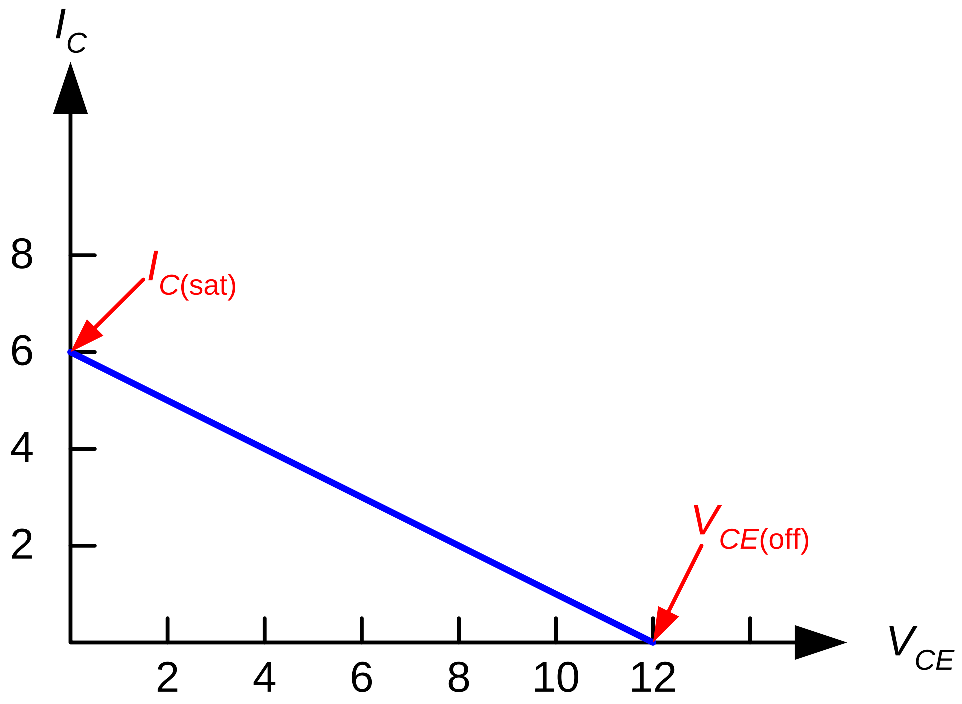
Letak titik Q pada garis beban



Contoh 1

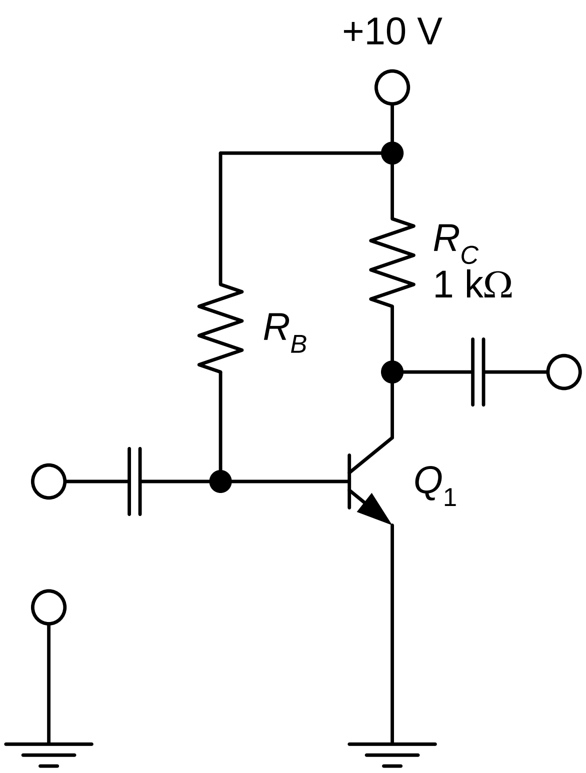
Plot garis beban dc rangkaian dibawah ini

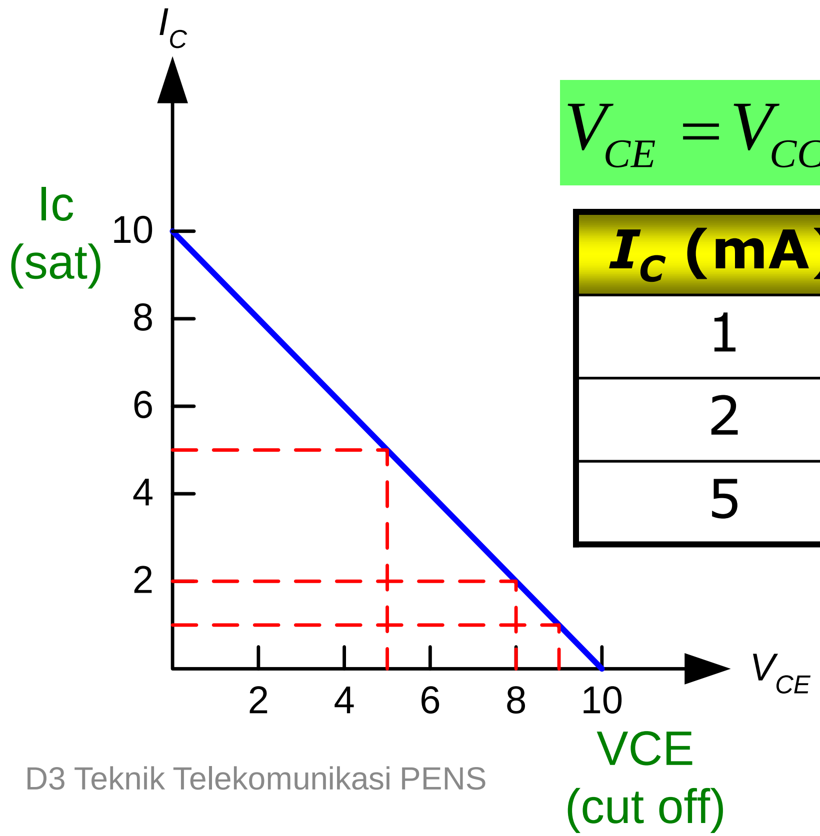




Contoh 2

Plot garis beban dc rangkaian dibawah ini, kemudian tentukan nilai V_{CE} untuk I_C = 1, 2, 5 mA

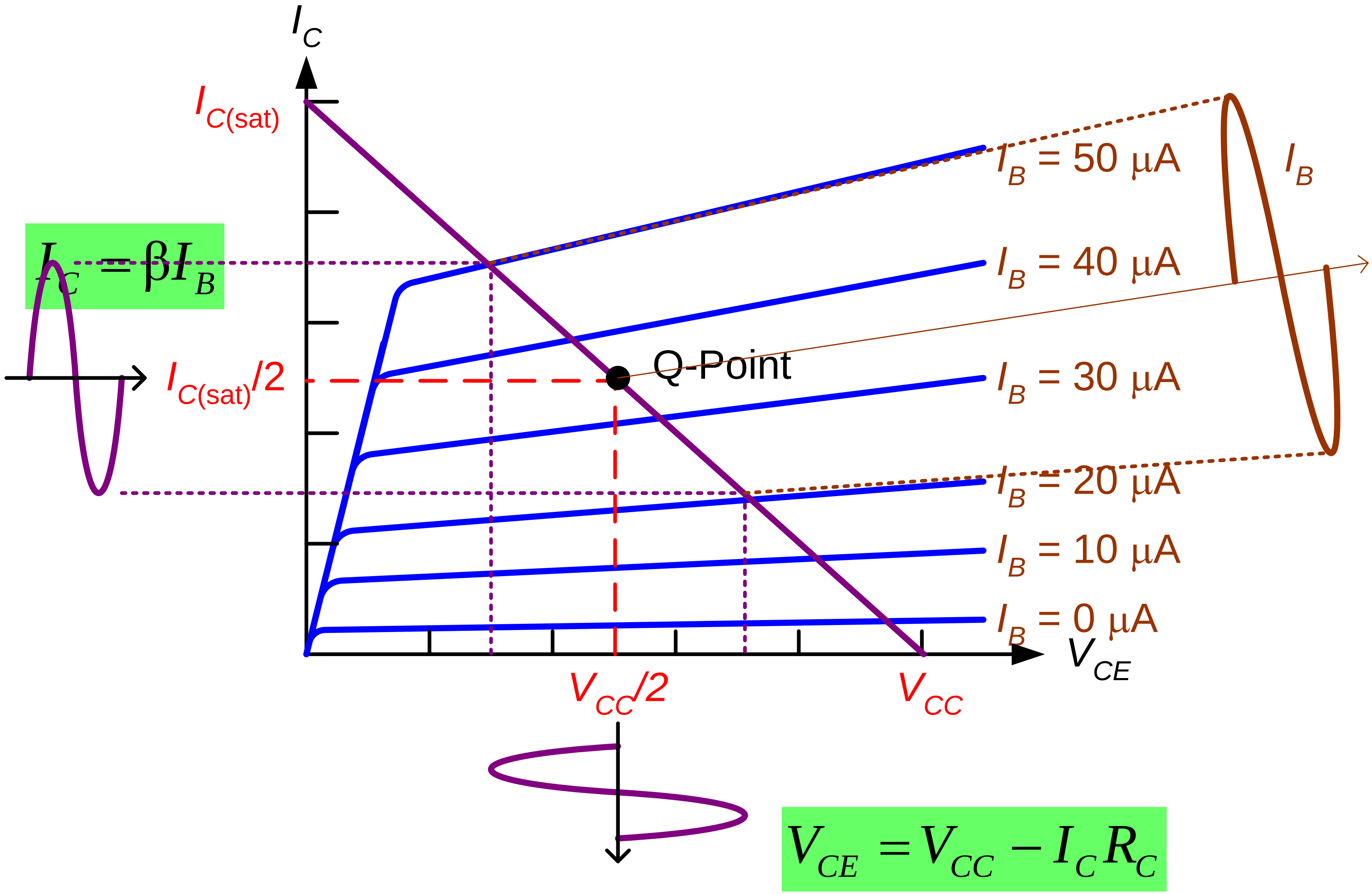




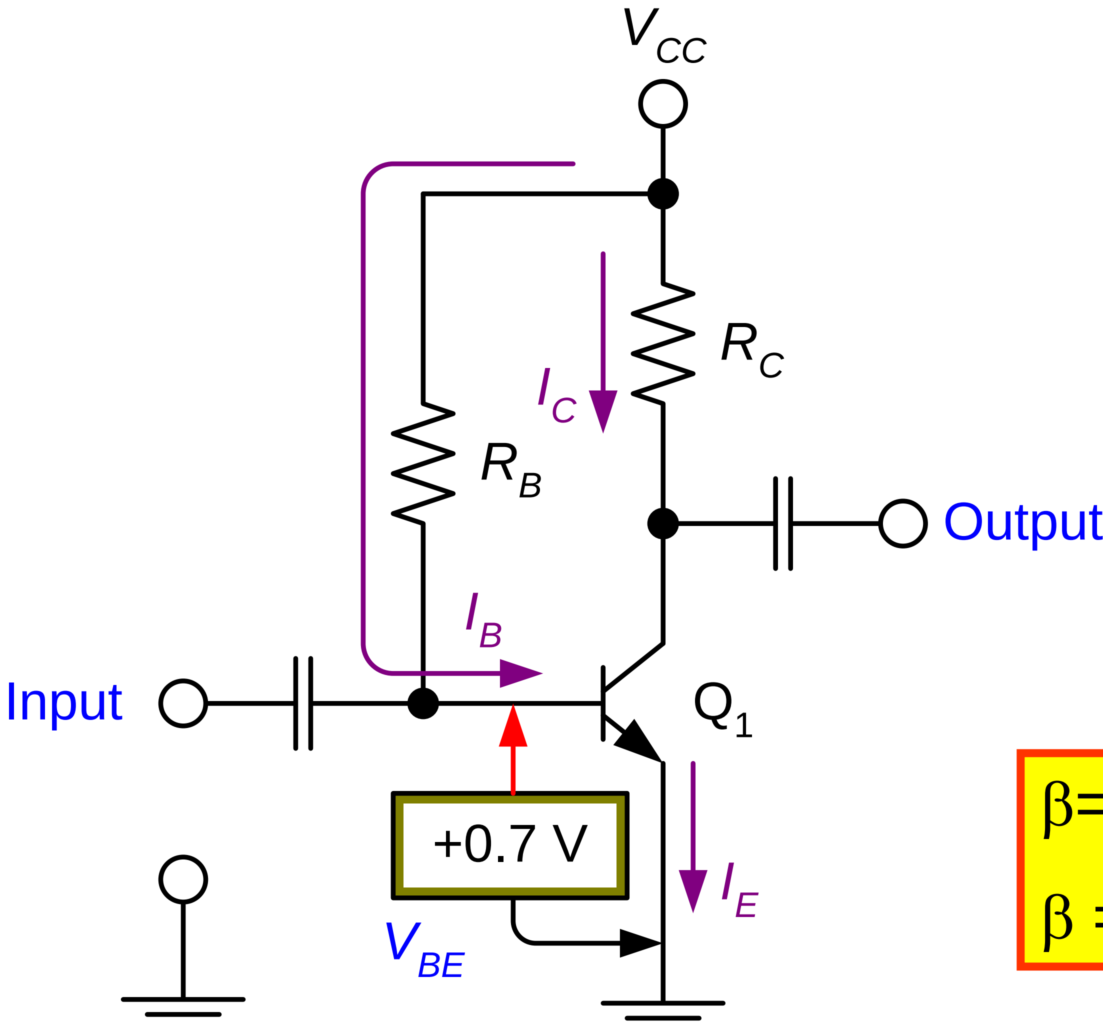
$$V_{CE} = V_{CC} - I_C R_C$$

I_C (mA)	V_{CE} (V)
1	9
2	8
5	5

Optimum Q-point pada operasi amplifier



Bias Base (fixed bias).



$$I_B = \frac{V_{CC} - V_{BE}}{R_B}$$

$$I_C = \beta I_B$$

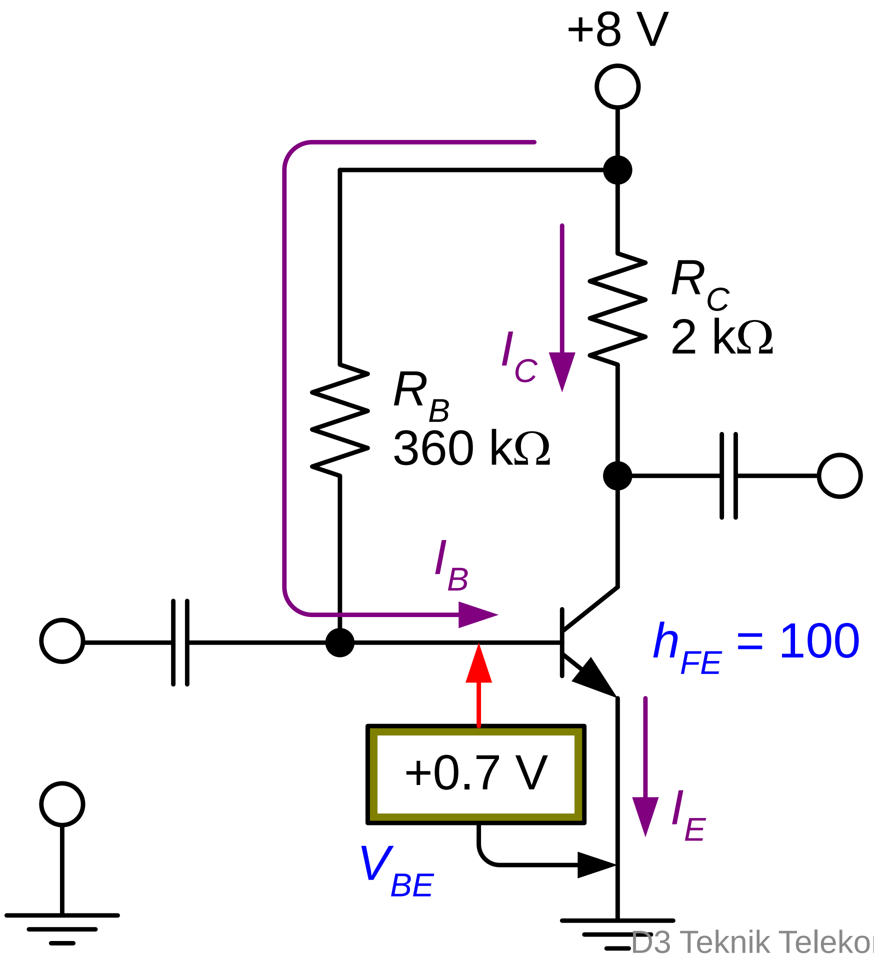
$$V_{CE} = V_{CC} - I_C R_C$$

β= penguatan arus dc

$\beta = h_{FE}$

Contoh 3

Tentukan nilai I_C dan V_{CE} dan gambarkan garis beban dc dari rangkaian dibawah ini

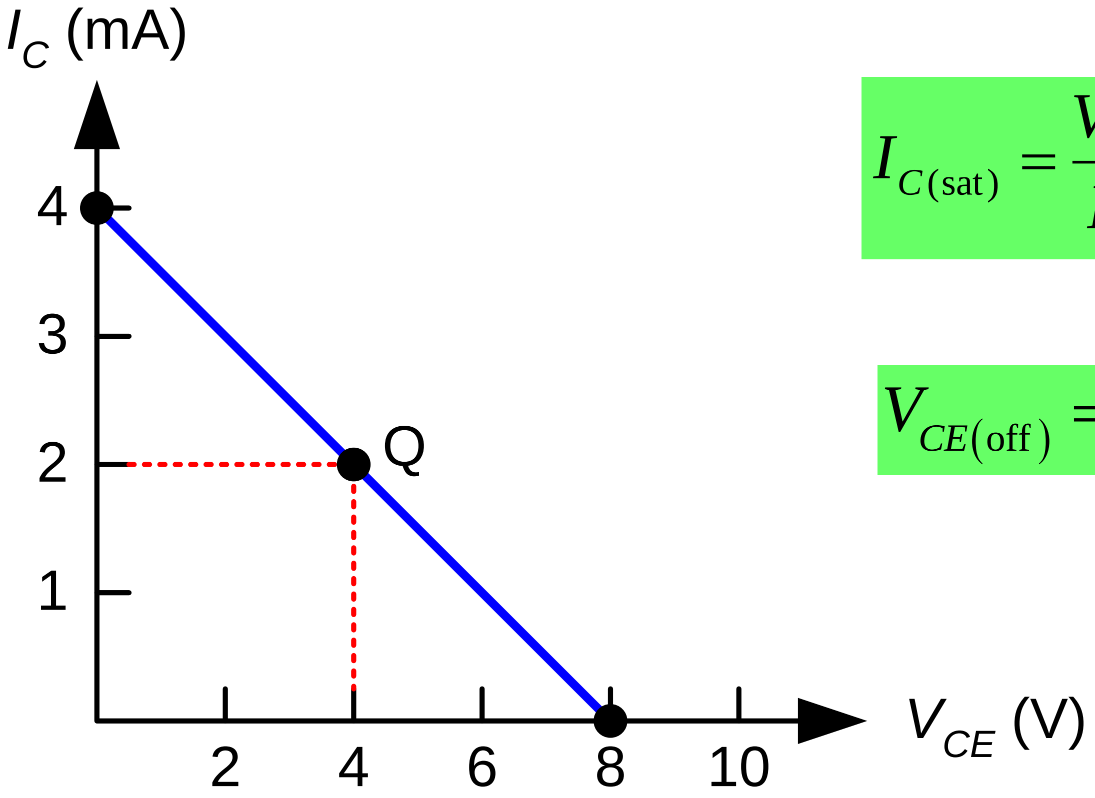


$$I_B = \frac{V_{CC} - 0.7\text{V}}{R_B} = \frac{8\text{V} - 0.7\text{V}}{360\text{k}\Omega}$$
$$= 20.28\mu\text{A}$$

$$I_C = h_{FE} I_B = (100)(20.28\mu\text{A})$$
$$= 2.028\text{mA}$$

$$V_{CE} = V_{CC} - I_C R_C$$
$$= 8\text{V} - (2.028\text{mA})(2\text{k}\Omega)$$
$$= 3.94\text{V}$$

Garis beban dc

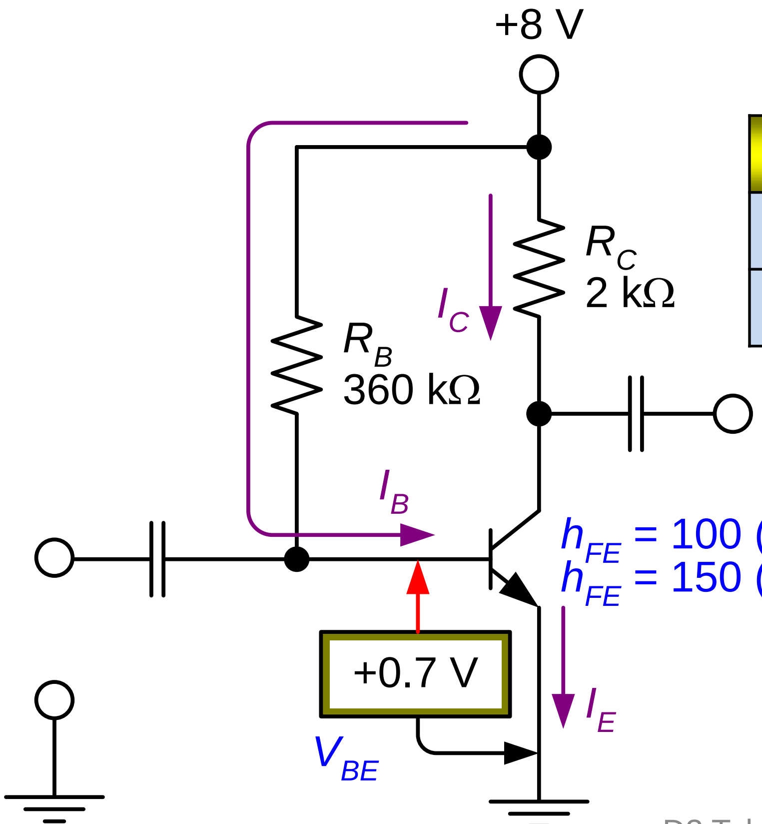


$$I_{C(\text{sat})} = \frac{V_{CC}}{R_C} = \frac{8\text{V}}{2\text{k}\Omega} = 4\text{mA}$$

$$V_{CE(\text{off})} = V_{CC} = 8\text{V}$$

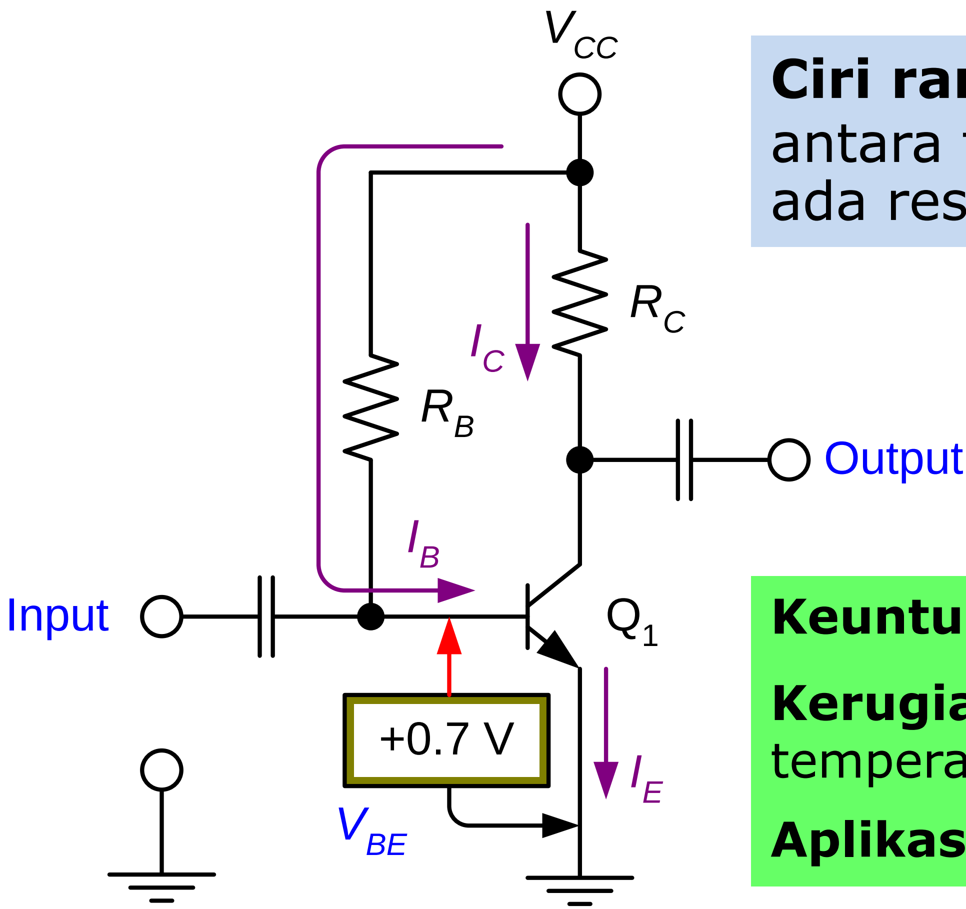
Contoh 4(Q-point shift)

Transistor pada rangkaian contoh 3 memiliki nilai h_{FE} = 100 pada T = 25 ◦C dan h_{FE} = 150 pada T = 100 ◦C. Tentukan Q-point dari nilai I_C dan V_{CE} pada kedua temperatur.



Temp(◦C)	I_B (μA)	I_C (mA)	V_{CE} (V)
25	20.28	2.028	3.94
100	20.28	3.04	1.92

Karakteristik Bias Base (Fixed Bias) (1)



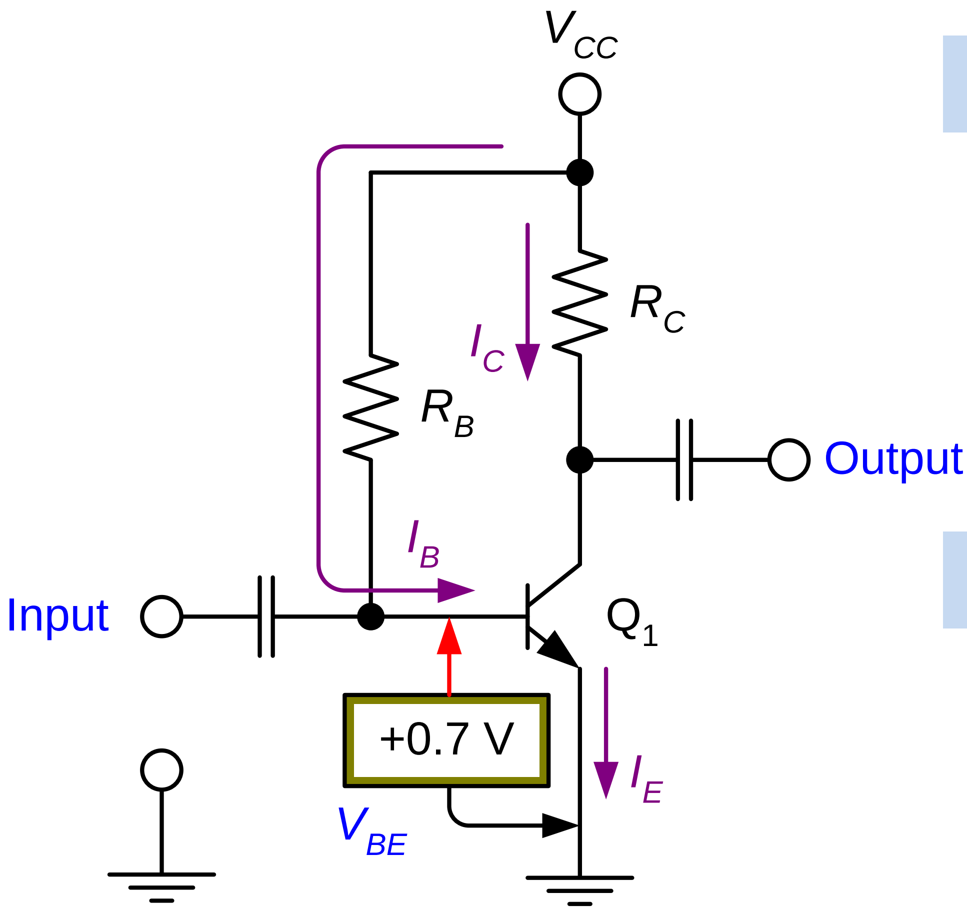
Ciri rangkaian: Satu resistor (R_B) antara terminal base dan V_{CC}. Tidak ada resistor emitter (R_E)

Keuntungan: Rangkaian sederhana

Kerugian: Q-point bergeser akibat temperatur.

Aplikasi: Hanya untuk rangkaian switching

Karakteristik Base bias (Fixed bias)(2)



Persamaan Load line :

$$I_{C(\text{sat})} \cong \frac{V_{CC}}{R_C}$$

$$V_{CE(\text{off})} = V_{CC}$$

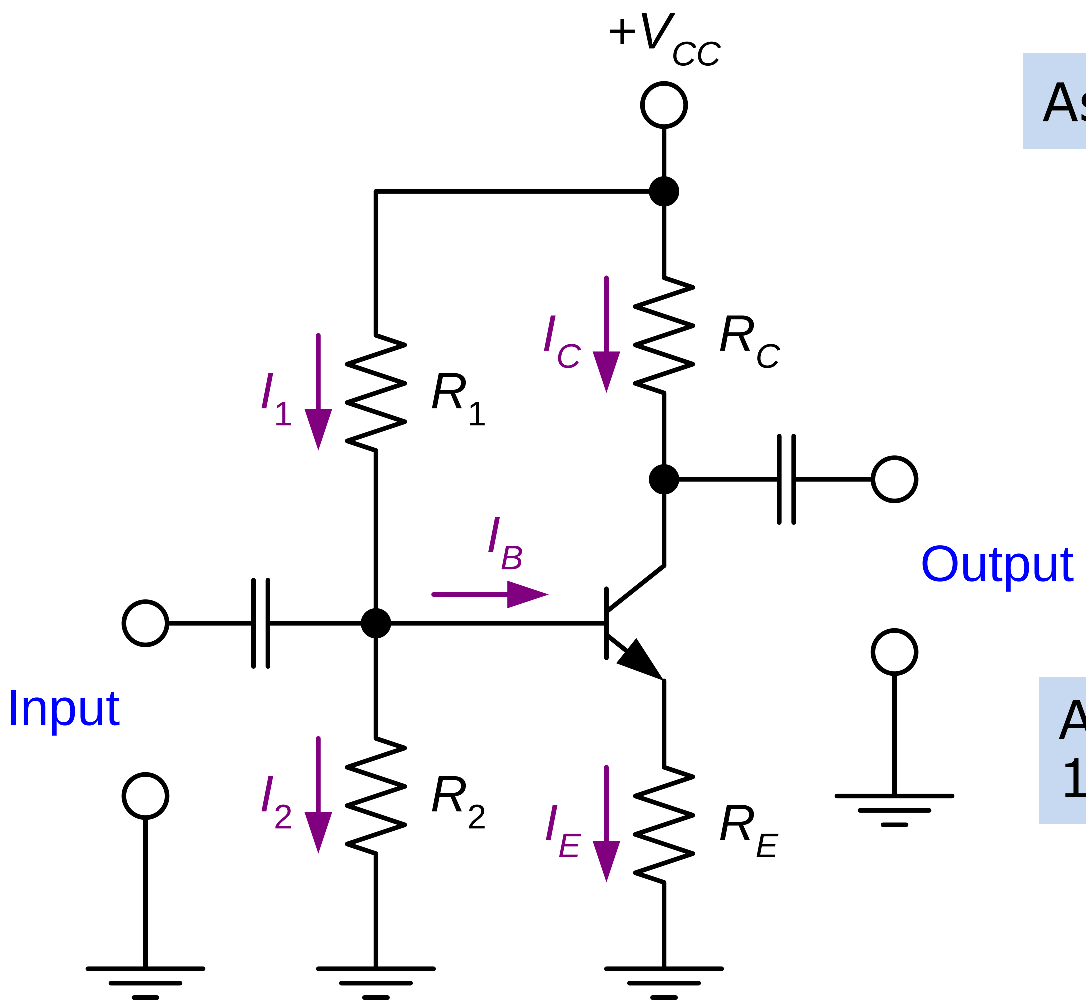
Persamaan Q-point

$$I_B = \frac{V_{CC} - V_{BE}}{R_B}$$

$$I_C = h_{FE} I_B$$

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

Voltage divider bias (1)



Asumsi I_2 > $10I_B$.

$$V_B = \frac{R_2}{R_1 + R_2} V_{CC}$$

$$V_E = V_B - 0.7\text{V}$$

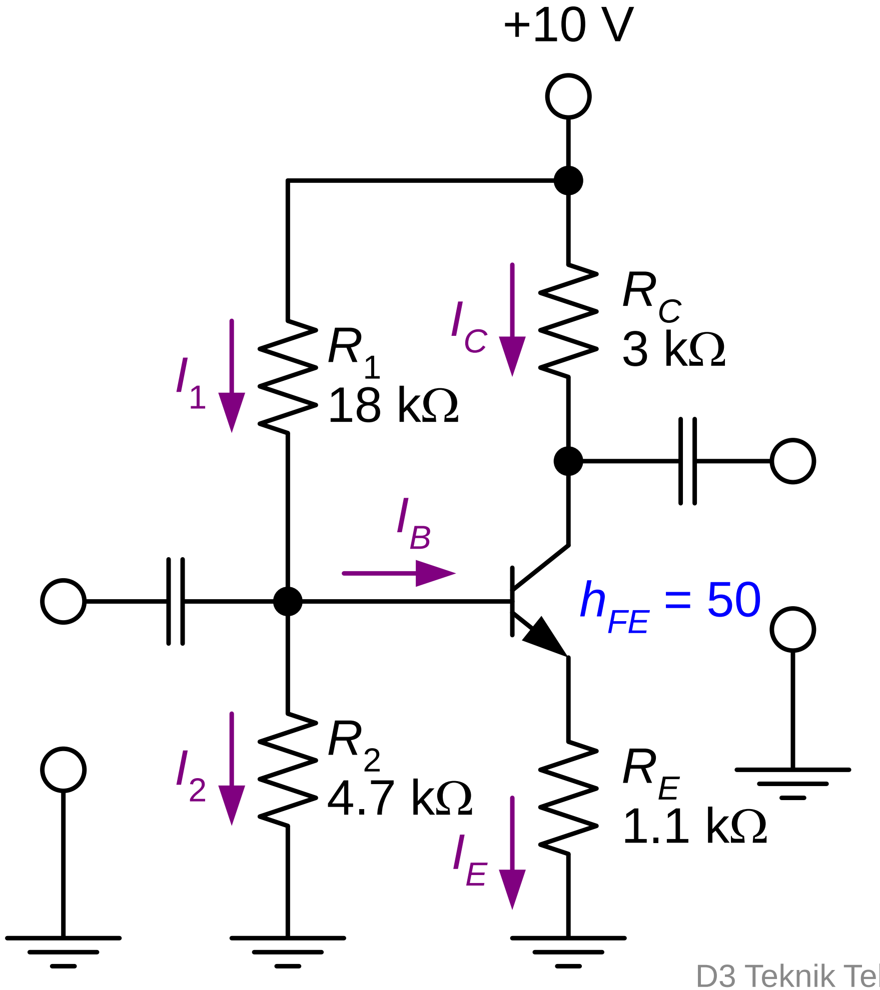
$$I_E = \frac{V_E}{R_E}$$

Asumsi $I_{CQ} \cong I_E$ (atau h_{FE} >> 1) sehingga

$$V_{CEQ} = V_{CC} - I_{CQ}\left(R_C + R_E\right)$$

Contoh 5

Tentukan nilai I_{CQ} dan V_{CEQ} untuk rangkaian dibawah ini:



$$V_B = V_{CC}\frac{R_2}{R_1+R_2}$$
$$= (10\text{V})\frac{4.7\text{k}\Omega}{22.7\text{k}\Omega} = 2.07\text{V}$$

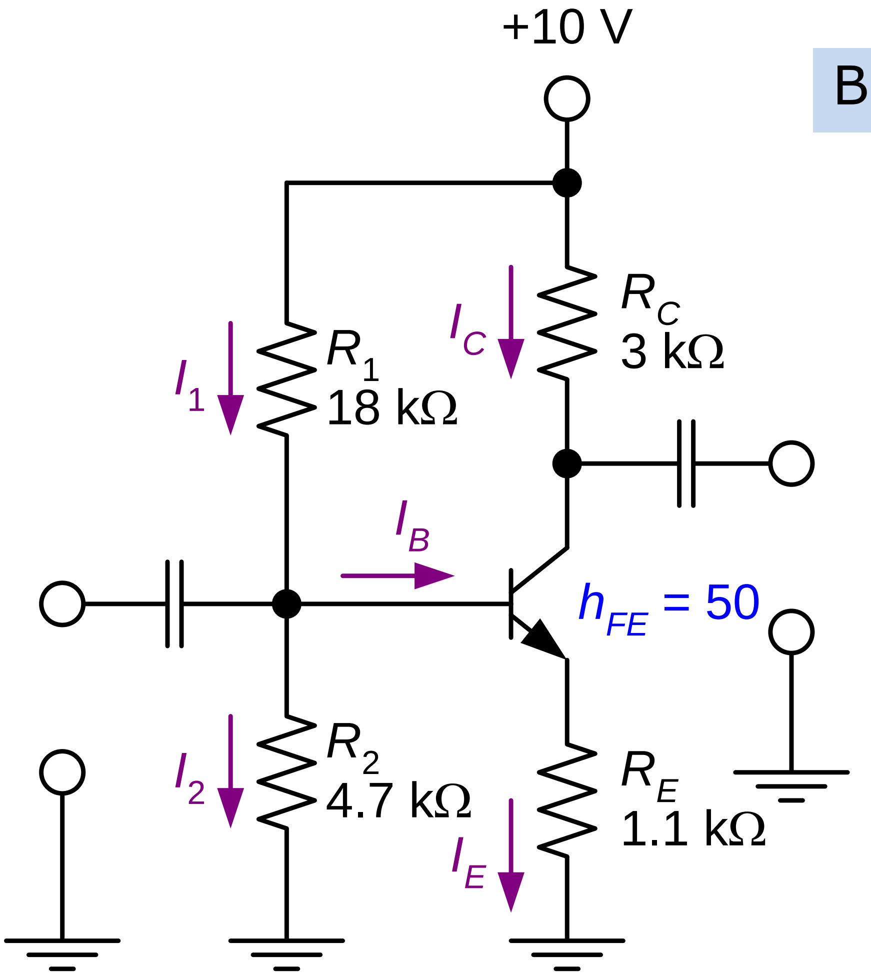
$$V_E = V_B - 0.7\text{V}$$
$$= 2.07\text{V} - 0.7\text{V} = 1.37\text{V}$$

Karena $I_{CQ} \cong I_E$ (atau $h_{FE} >> 1$),

$$I_{CQ} \cong \frac{V_E}{R_E} = \frac{1.37\text{V}}{1.1\text{k}\Omega} = 1.25\text{mA}$$

$$V_{CEQ} = V_{CC} - I_{CQ}(R_C + R_E)$$
$$= 10\text{V} - (1.25\text{mA})(4.1\text{k}\Omega) = 4.87\text{V}$$

Contoh 6



Buktikan bahwa $I_2 > 10\ I_B$.

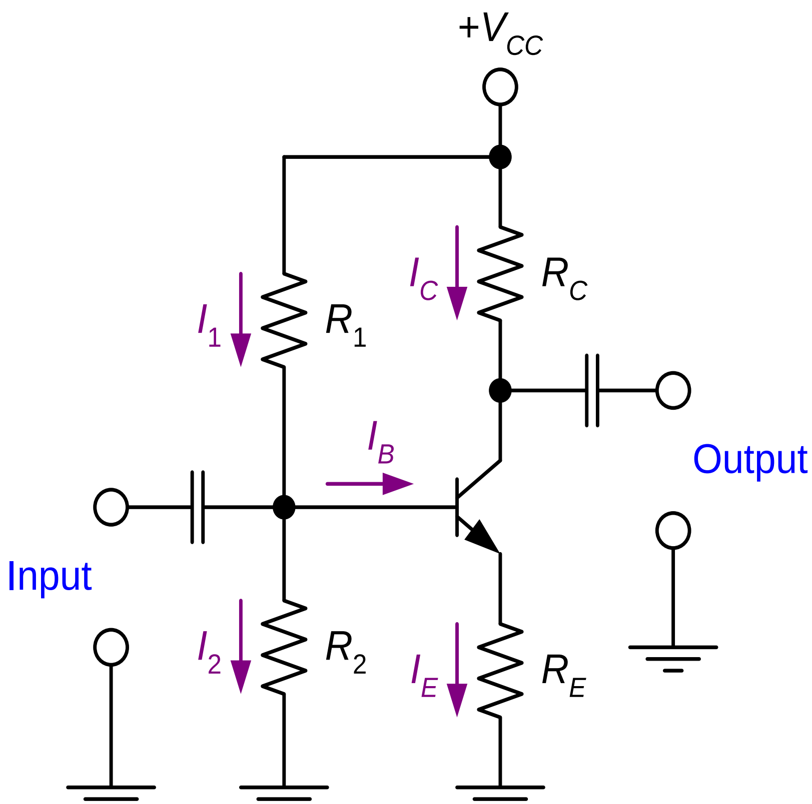
$$I_2 = \frac{V_B}{R_2} = \frac{2.07\text{V}}{4.7\text{k}\Omega} = 440.4\mu\text{A}$$

$$I_B = \frac{I_E}{h_{FE}+1} = \frac{1.25\text{mA}}{50+1}$$
$$= 24.51\mu\text{A}$$

$$\therefore I_2 > 10 I_B$$

Contoh 7

Rangkaian bias Voltage-divider dengan: R_1 = 1.5 kΩ, R_2 = 680 Ω, R_C = 260 Ω, R_E = 240 Ω dan V_{CC} = 10 V. Bilai nilai h_{FE}=173, Tentukan nilai I_B dan garis beban ari rangkaian :



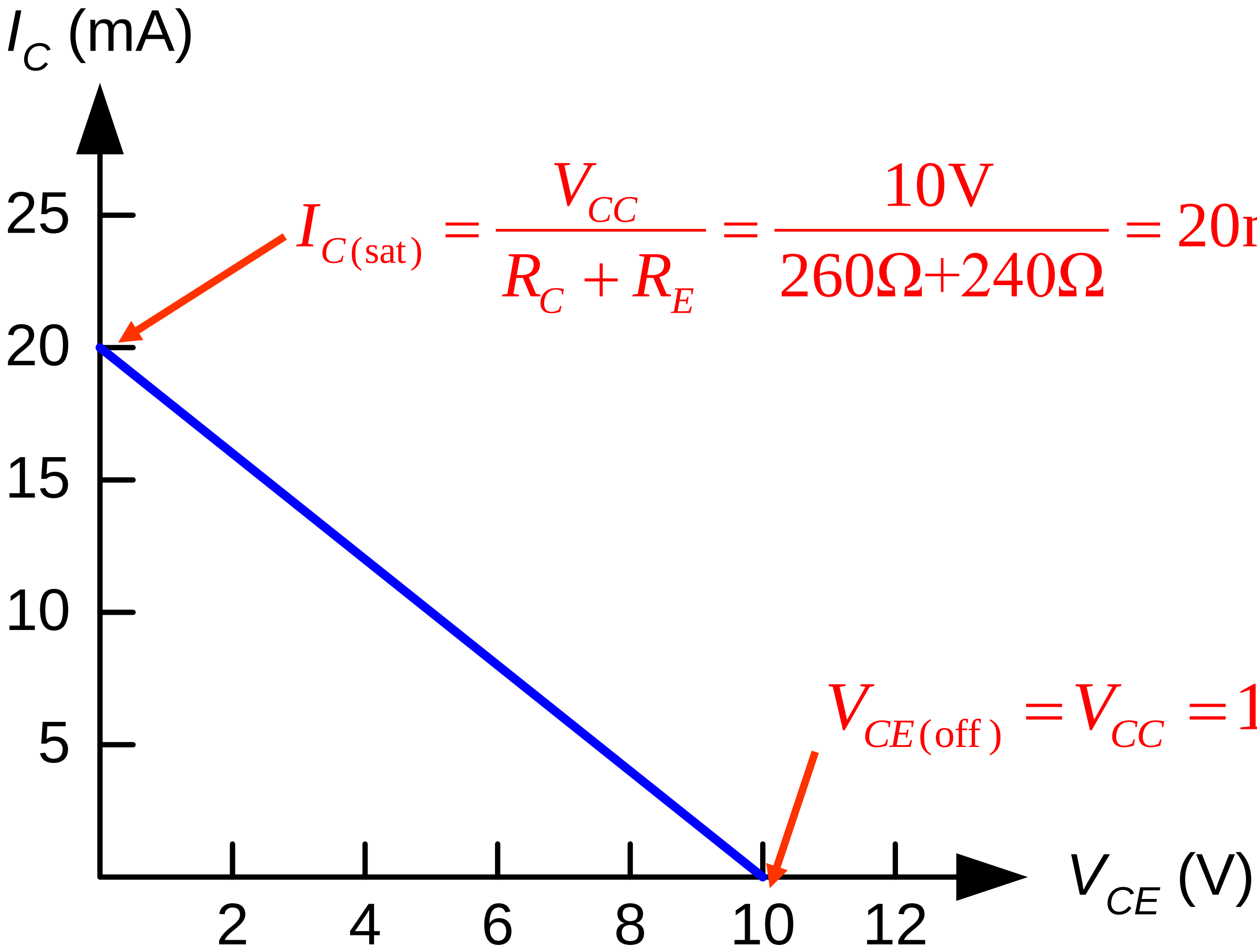
$$V_B = V_{CC}\frac{R_2}{R_1+R_2} = (10\text{V})\frac{680\Omega}{2180\Omega} = 3.12\text{V}$$

$$V_E = V_B - 0.7\text{V} = 3.12\text{V} - 0.7\text{V} = 2.42\text{V}$$

$$I_{CQ} \cong I_E = \frac{V_E}{R_E} = \frac{2.42\text{V}}{240\Omega} = 10\text{mA}$$

$$I_B = \frac{I_E}{h_{FE(\text{ave})}+1} = \frac{10\text{mA}}{174} = 57.5\mu\text{A}$$

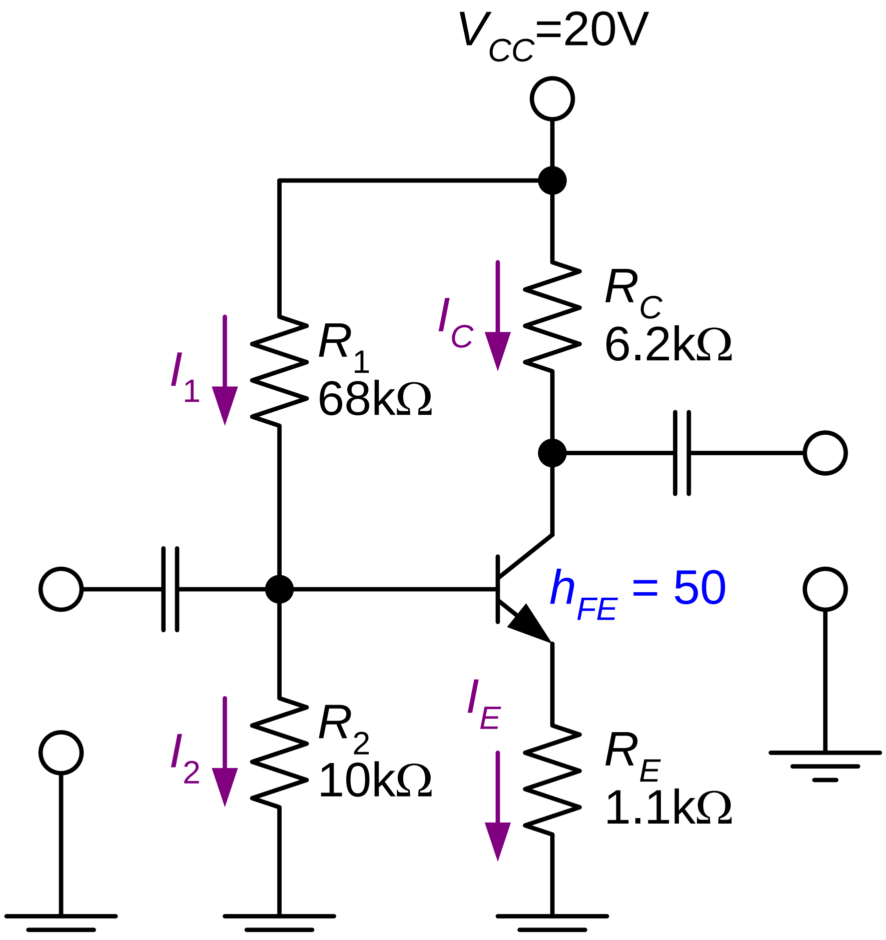
Garis Beban DC contoh 7



$$I_{C(\text{sat})} = \frac{V_{CC}}{R_C + R_E} = \frac{10\text{V}}{260\Omega + 240\Omega} = 20\text{mA}$$

$$V_{CE(\text{off})} = V_{CC} = 10\text{V}$$

Contoh 8



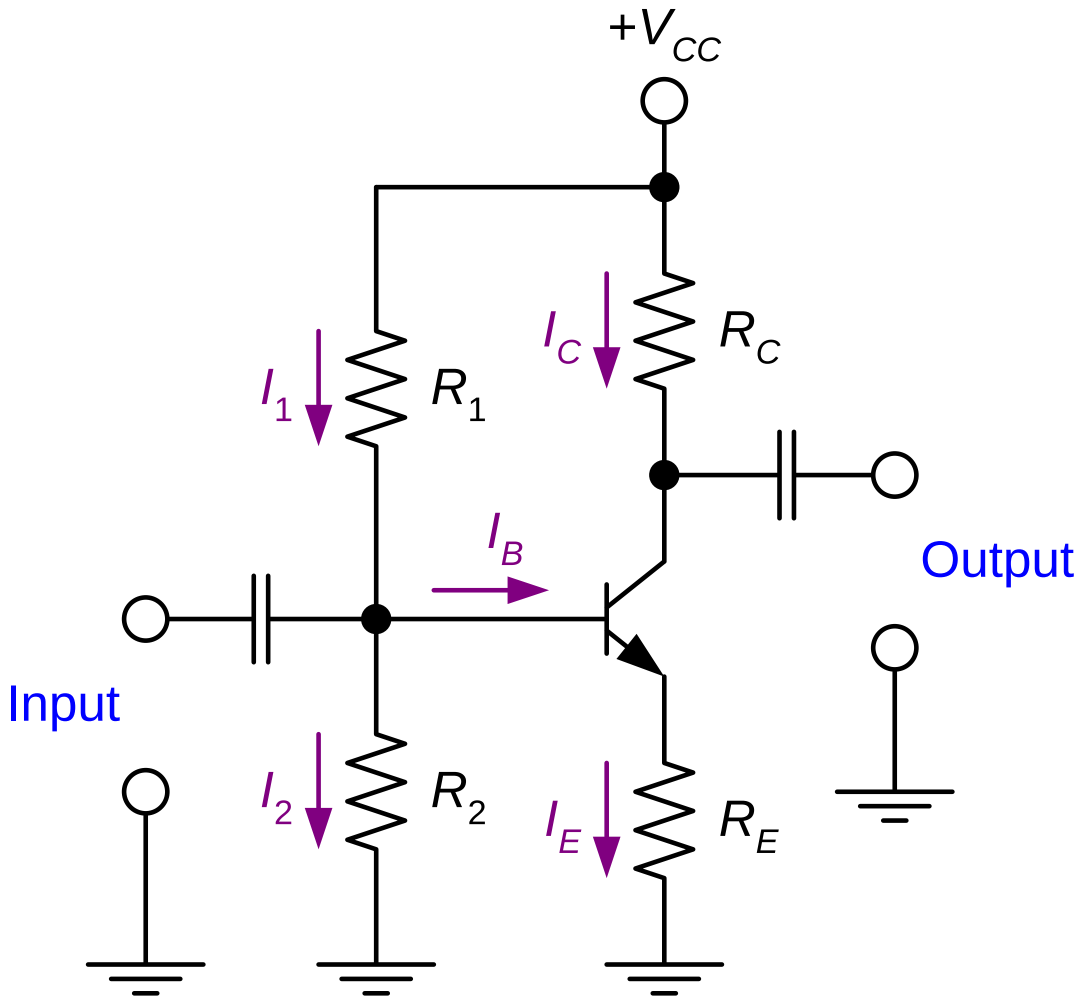
$$R_{EQ} = R_2 // \left(h_{FE} R_E\right)$$
$$= 10\text{k}\Omega // \left(50 \times 1.1\text{k}\Omega\right) = 8.46\text{k}\Omega$$

$$V_B \cong V_{CC} \frac{R_{EQ}}{R_1 + R_{EQ}}$$
$$= \left(20\text{V}\right) \frac{8.46\text{k}\Omega}{68\text{k}\Omega + 8.46\text{k}\Omega} = 2.21\text{V}$$

$$I_{CQ} \cong I_E = \frac{V_E}{R_E} = \frac{V_B - 0.7\text{V}}{R_E}$$
$$= \frac{2.21\text{V} - 0.7\text{V}}{1.1\text{k}\Omega} = 1.37\text{mA}$$

$$V_{CEQ} = V_{CC} - I_{CQ}\left(R_C + R_E\right)$$
$$= 20\text{V} - \left(1.37\text{mA}\right)\left(7.3\text{k}\Omega\right) = 9.99\text{V}$$

Karakteristik Voltage-divider bias (1)



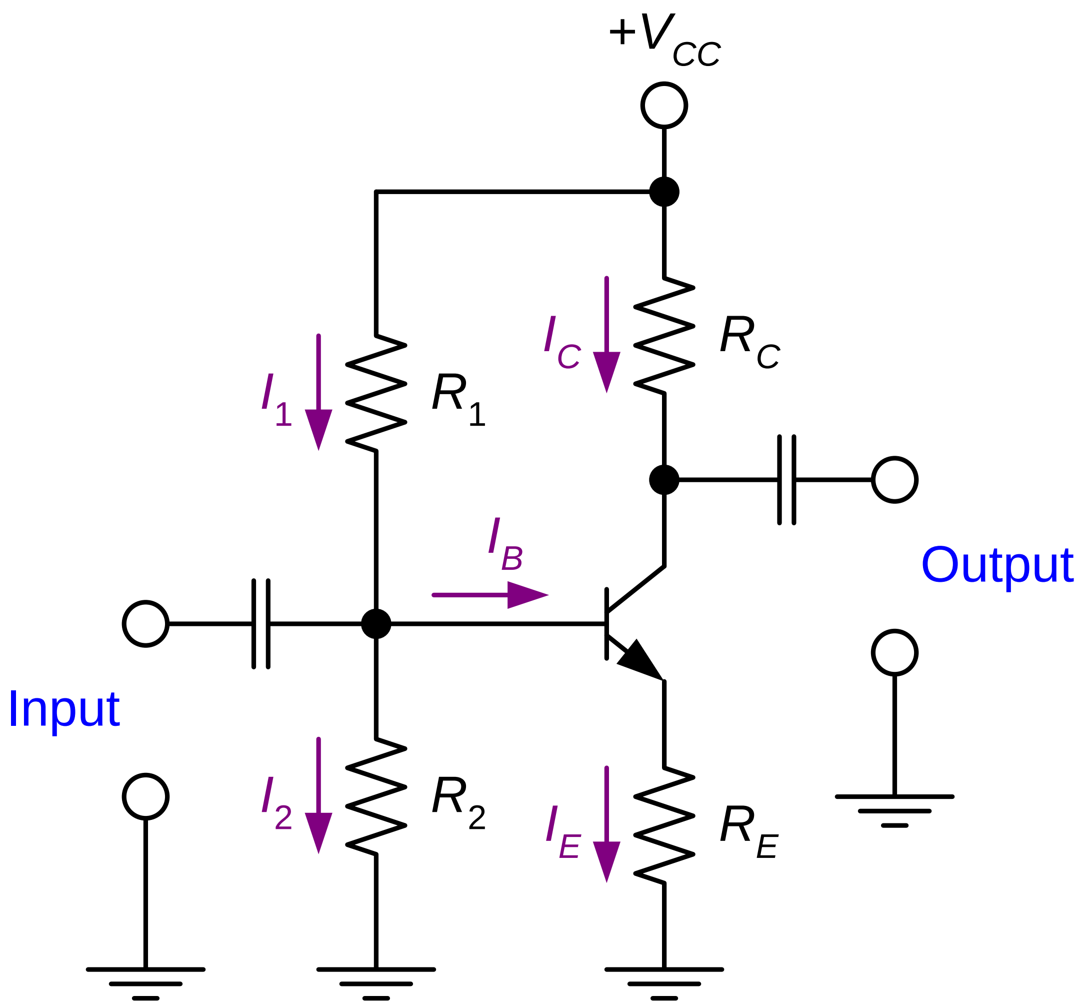
Ciri Rangkaian: Voltage divider pada rangkaian base

Keuntungan: Nilai Q-point stabil meskipun dalam perubahan h_{FE}.

Kerugian: Dibutuhkan lebih banyak komponen dibanding rangkaian bias yang lain.

Aplikasi : digunakan untuk bias linear amplifier.

Karakteristik Voltage-divider bias (2)



Persamaan garis beban dc

$$I_{C(\text{sat})} = \frac{V_{CC}}{R_C + R_E}$$

$$V_{CE(\text{off})} = V_{CC}$$

Persamaan Q-point
(Asumsi $h_{FE}R_E > 10R_2$):

$$V_B = V_{CC}\frac{R_2}{R_1 + R_2}$$

$$V_E = V_B - 0.7\text{V}$$

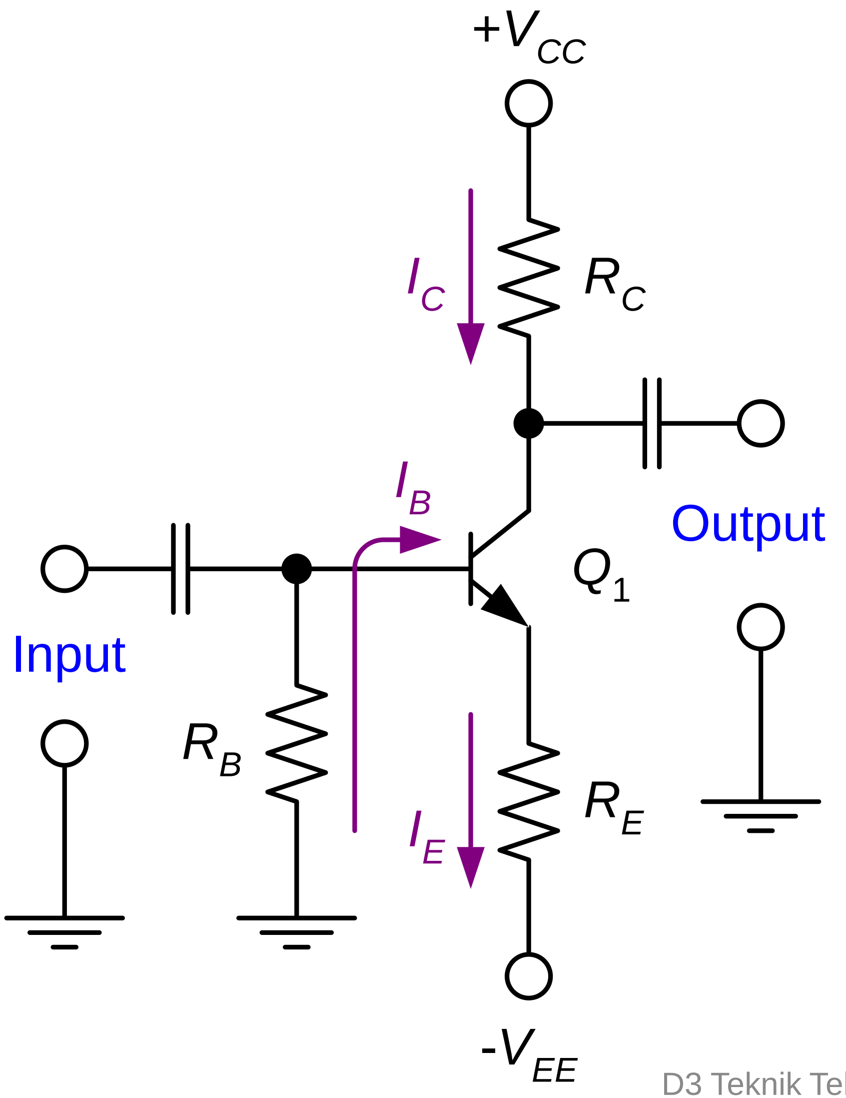
$$I_{CQ} \cong I_E = \frac{V_E}{R_E}$$

$$V_{CEQ} = V_{CC} - I_{CQ}\left(R_C + R_E\right)$$

Rangkaian Bias Transistor yang lain

- Emitter-bias circuits
- Feedback-bias circuits
  - Collector-feedback bias
  - Emitter-feedback bias

Bias Emitter



Asumsi transistor beroperasi pada active region.

$$I_B = \frac{V_{EE} - 0.7\text{V}}{R_B + (h_{FE}+1)R_E}$$

$$I_C = h_{FE} I_B$$

$$I_E = (h_{FE}+1) I_B$$

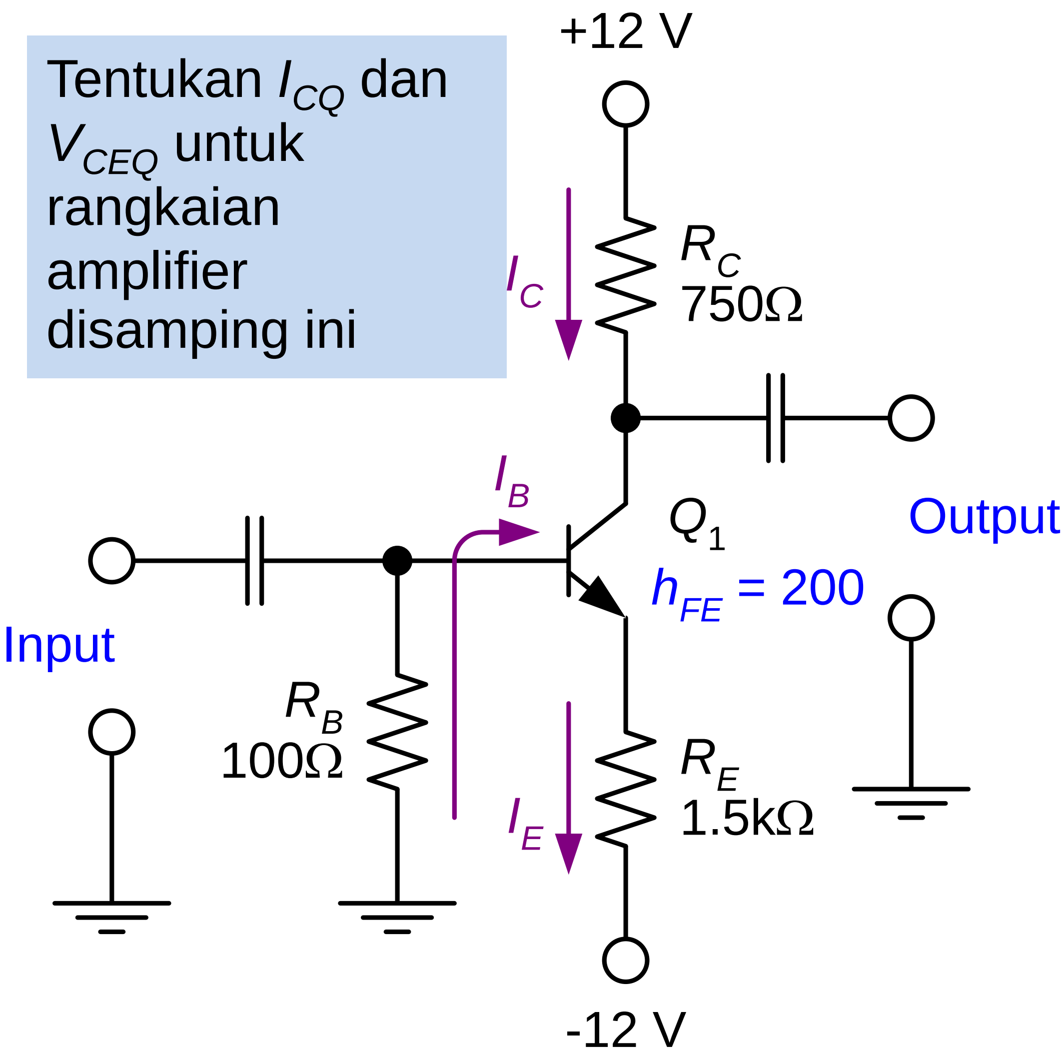
$$V_{CE} = V_{CC} - I_C R_C - I_E R_E + V_{EE}$$

Asumsi $h_{FE} >> 1$.

$$V_{CE} \cong V_{CC} - I_C (R_C + R_E) + V_{EE}$$

Contoh 9

Tentukan I_{CQ} dan V_{CEQ} untuk rangkaian amplifier disamping ini



$$I_B = \frac{12\text{V} - 0.7\text{V}}{R_B + (h_{FE}+1)R_E}$$

$$= \frac{11.3\text{V}}{100\Omega + 201 \times 1.5\text{k}\Omega} = 37.47\mu\text{A}$$

$$I_{CQ} = h_{FE} I_B = 200 \times 37.47\mu\text{A}$$

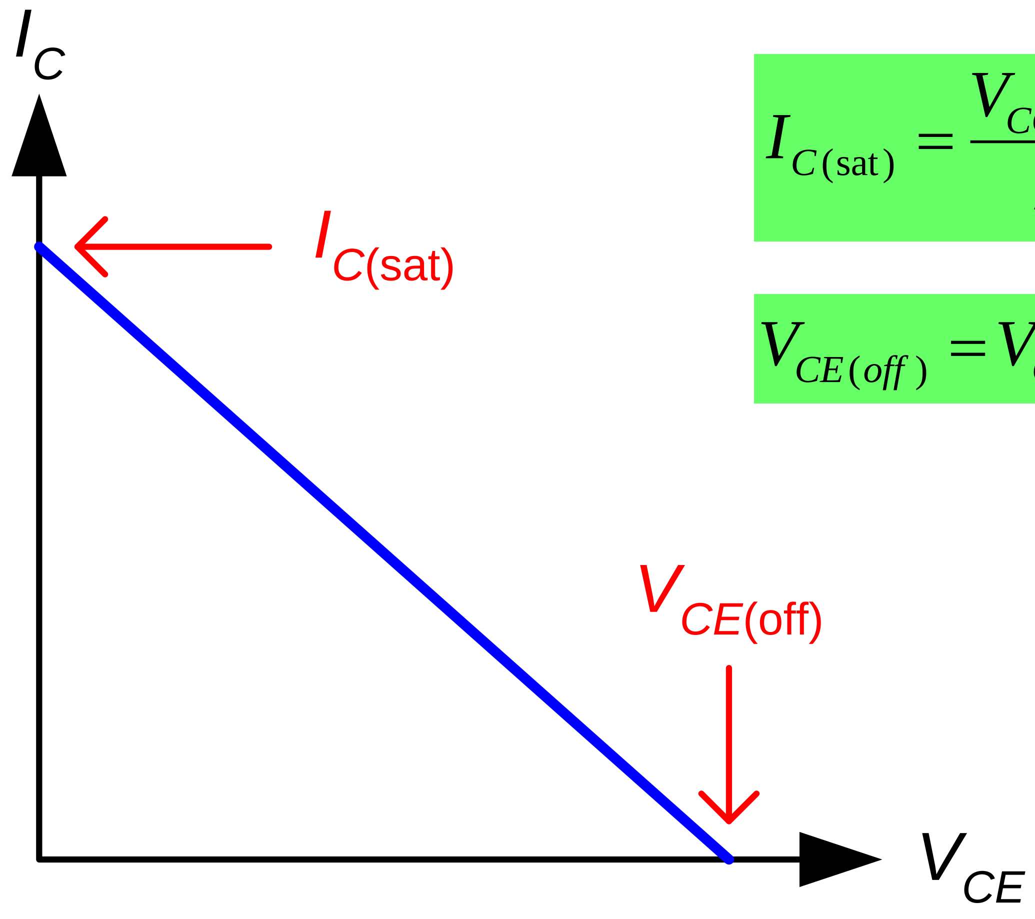
$$= 7.49\text{mA}$$

$$V_{CEQ} \cong V_{CC} - I_C\left(R_C + R_E\right) - (-V_{EE})$$

$$= 24\text{V} - 7.49\text{mA}\left(750\Omega + 1.5\text{k}\Omega\right)$$

$$= 7.14\text{V}$$

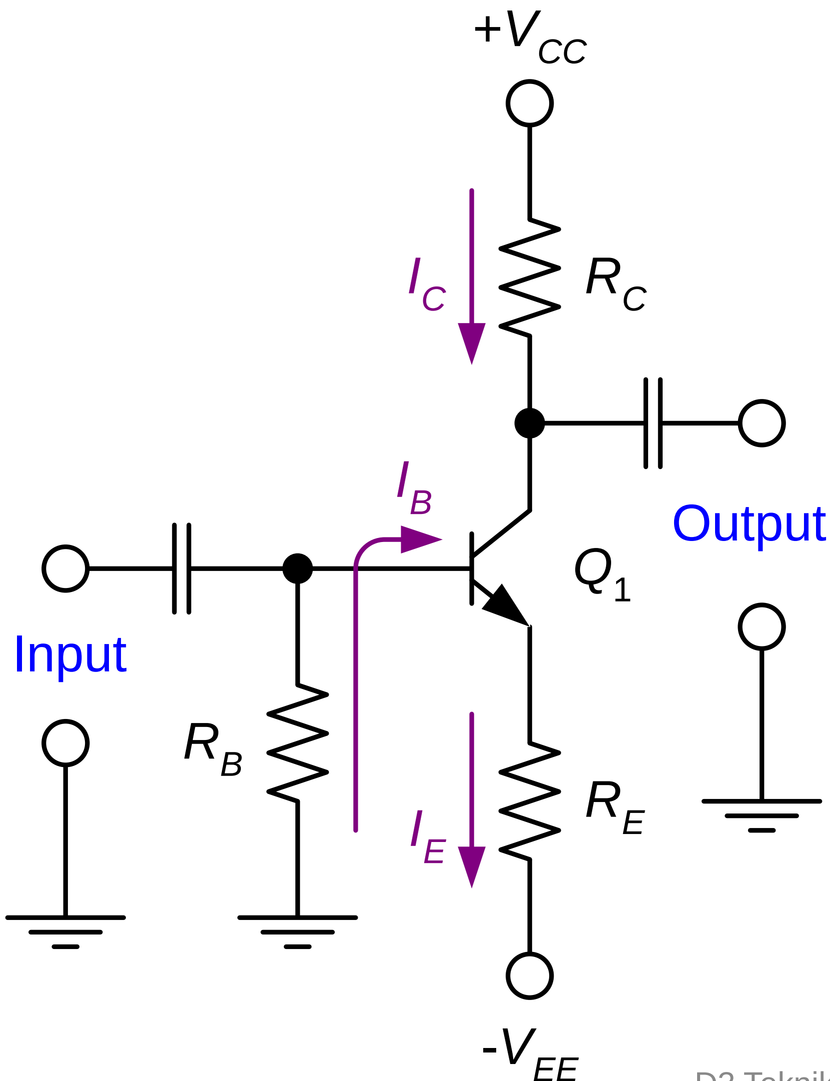
Garis beban Rangkaian Bias-Emitter



$$I_{C(sat)} = \frac{V_{CC} - (-V_{EE})}{R_C + R_E} = \frac{V_{CC} + V_{EE}}{R_C + R_E}$$

$$V_{CE(off)} = V_{CC} - \left(-V_{EE}\right) = V_{CC} + V_{EE}$$

Karakteristik Emitter-bias (1)



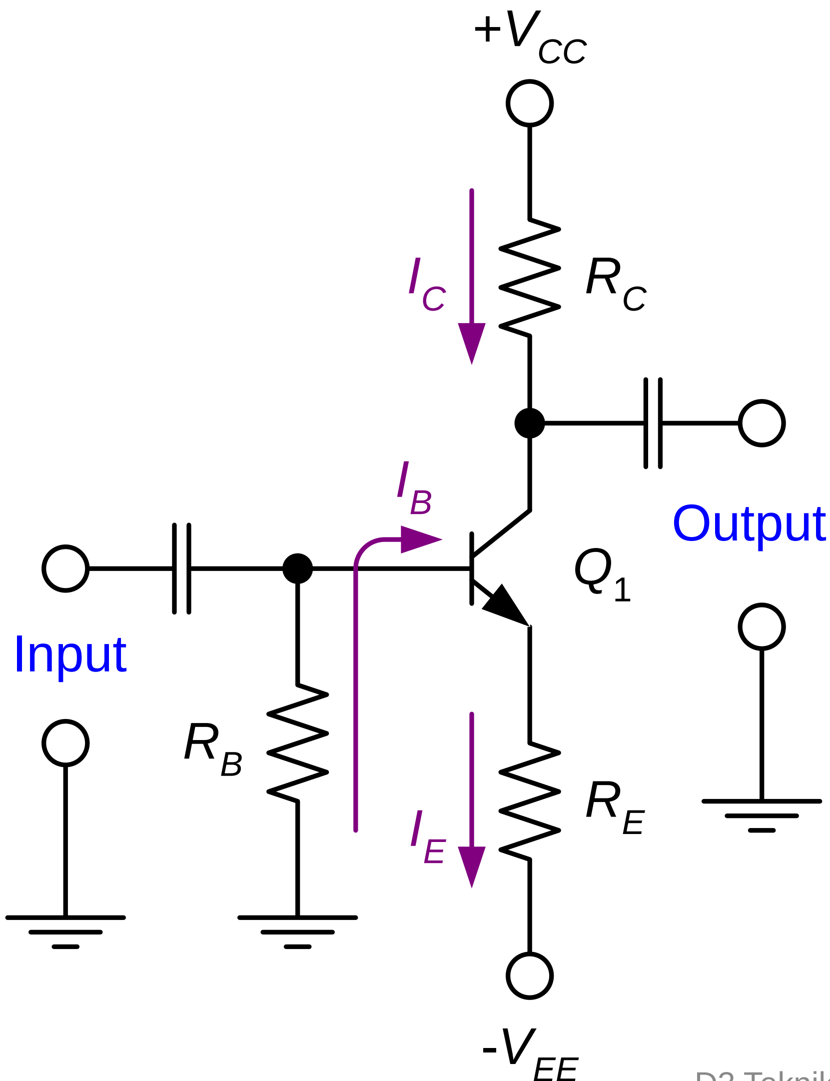
Ciri rangkaian: Dua (dual-polairty) power supply dan resistor base dihubungkan ke ground.

Keuntungan: Q-point pada rangkaian stabil terhadap perubahan h_{FE}.

Kerugian: dibutuhkan dual-polarity power supply.

Aplikasi: linear amplifiers.

Karakteristik Bias Emitter (2)



Persamaan garis beban:

$$I_{C(\mathrm{sat})} = \frac{V_{CC} + V_{EE}}{R_C + R_E}$$

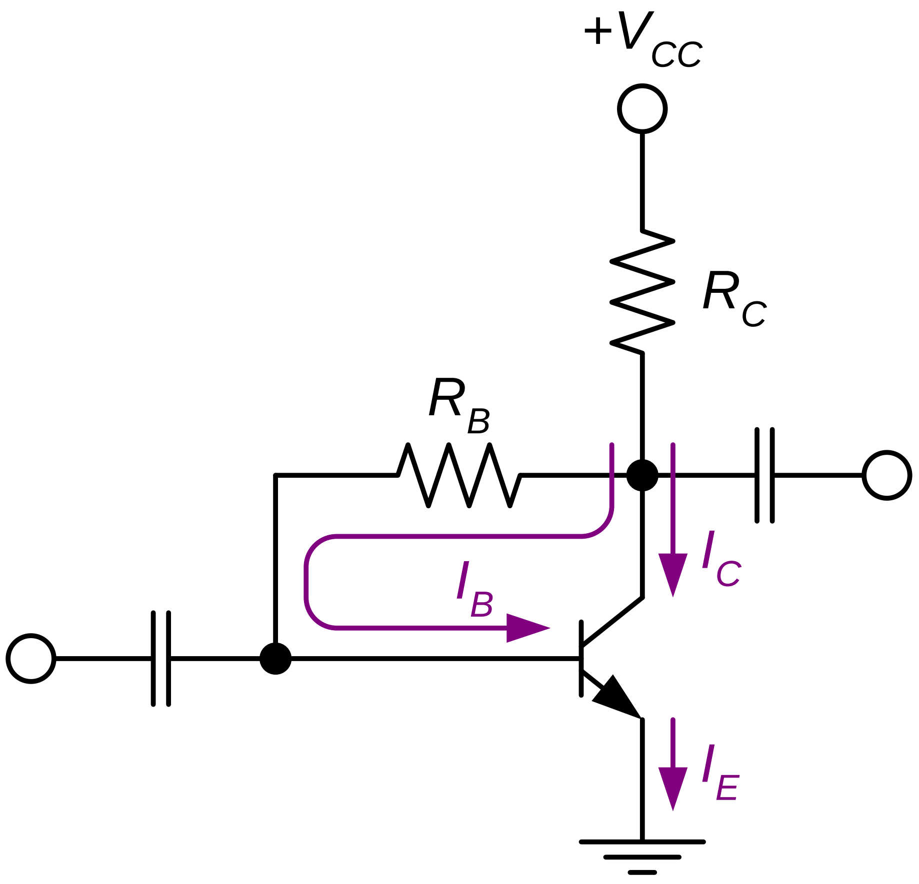
$$V_{CE(\mathrm{off})} = V_{CC} + V_{EE}$$

Persamaan Q-point :

$$I_{CQ} = (h_{FE})\frac{-V_{BE} + V_{EE}}{R_B + (h_{FE} + 1)R_E}$$

$$V_{CEQ} \cong V_{CC} - I_{CQ}(R_C + R_E) + V_{EE}$$

Bias Collector-feedback.



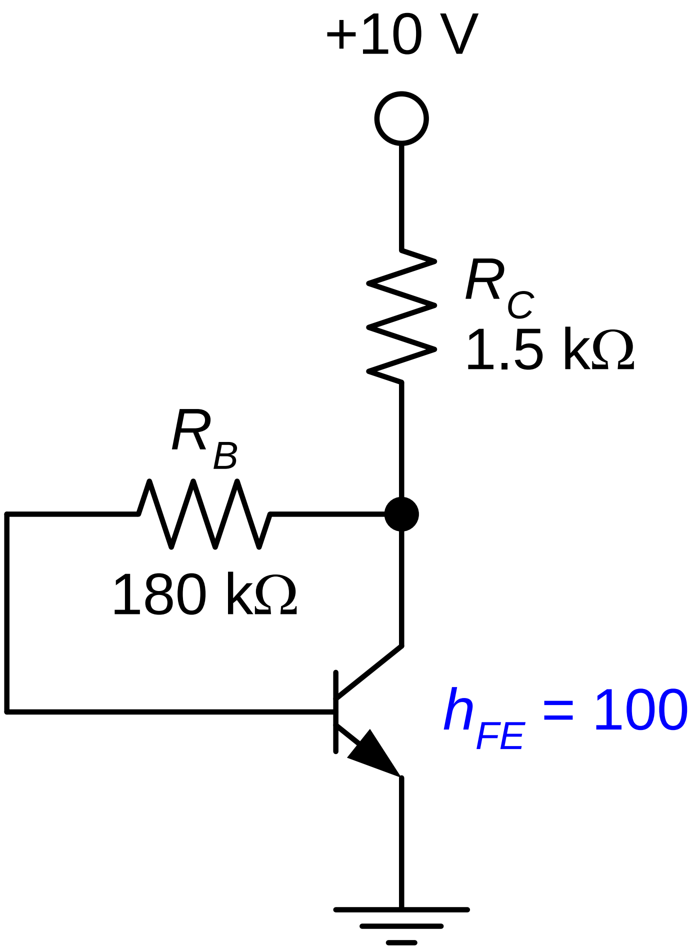
$$V_{CC} = \left(I_C + I_B\right)R_C + I_B R_B + V_{BE}$$

$$I_B = \frac{V_{CC} - V_{BE}}{(h_{FE}+1)R_C + R_B}$$

$$I_{CQ} = h_{FE} I_B$$

$$\begin{aligned} V_{CEQ} &= V_{CC} - \left(h_{FE}+1\right) I_B R_C \\ &\cong V_{CC} - I_{CQ} R_C \end{aligned}$$

Contoh10



Tentukan nilai I_{CQ} dan V_{CEQ} untuk amplifier disamping.

$$I_B = \frac{V_{CC} - V_{BE}}{R_B + (h_{FE} + 1) R_C}$$

$$= \frac{10\text{V} - 0.7\text{V}}{180\text{k}\Omega + 101 \times 1.5\text{k}\Omega} = 28.05\mu\text{A}$$

$$I_{CQ} = h_{FE} I_B = 100 \times 28.05\mu\text{A}$$

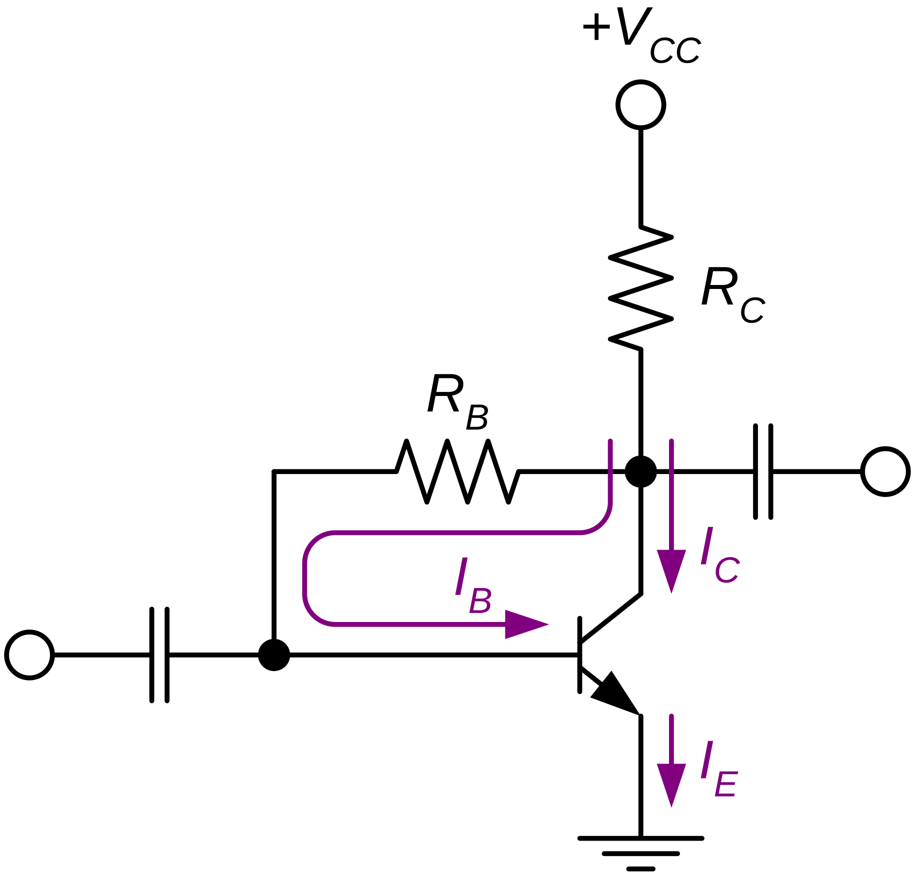
$$= 2.805\text{mA}$$

$$V_{CEQ} = V_{CC} - (h_{FE} + 1) I_B R_C$$

$$= 10\text{V} - 101 \times 28.05\mu\text{A} \times 1.5\text{k}\Omega$$

$$= 5.75\text{V}$$

Karakteristik Collector-Feedback (1)



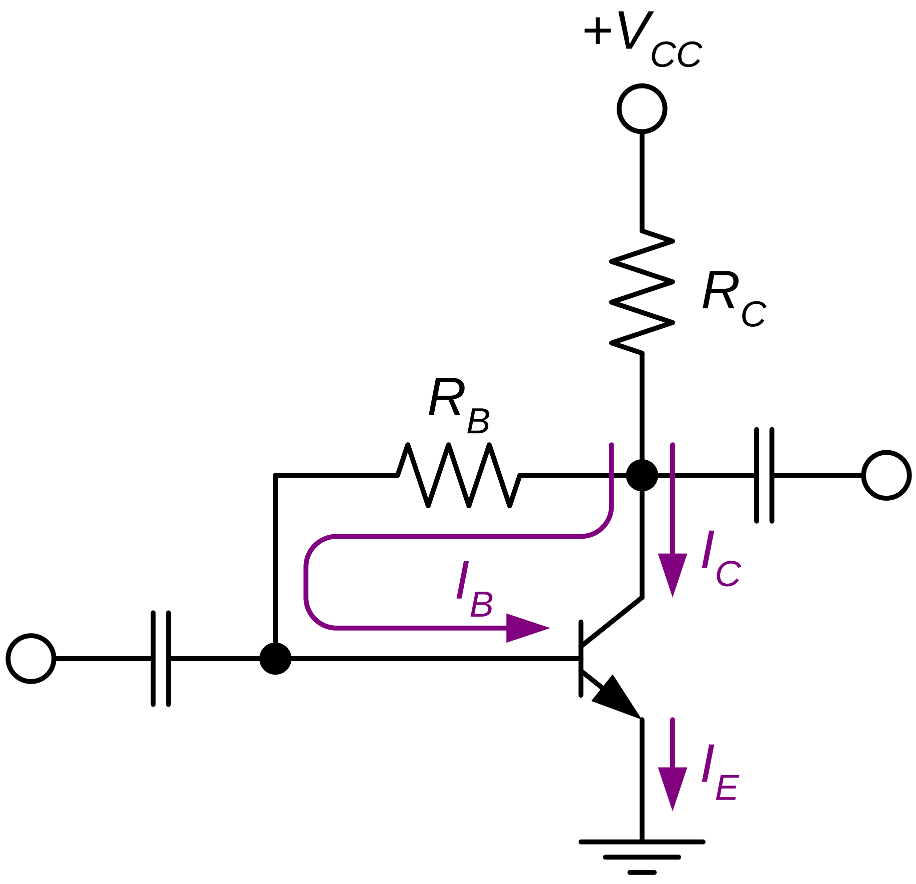
Ciri rangkaian: Resistor base dihubungkan antara terminal base dan collector transistor.

Keuntungan: Rangkaian sederhana dengan Q-point relatif stabil.

Kerugian: Karakteristik ac jelek

Applications: bias linear amplifiers.

Karakteristik Collector-Feedback (2)



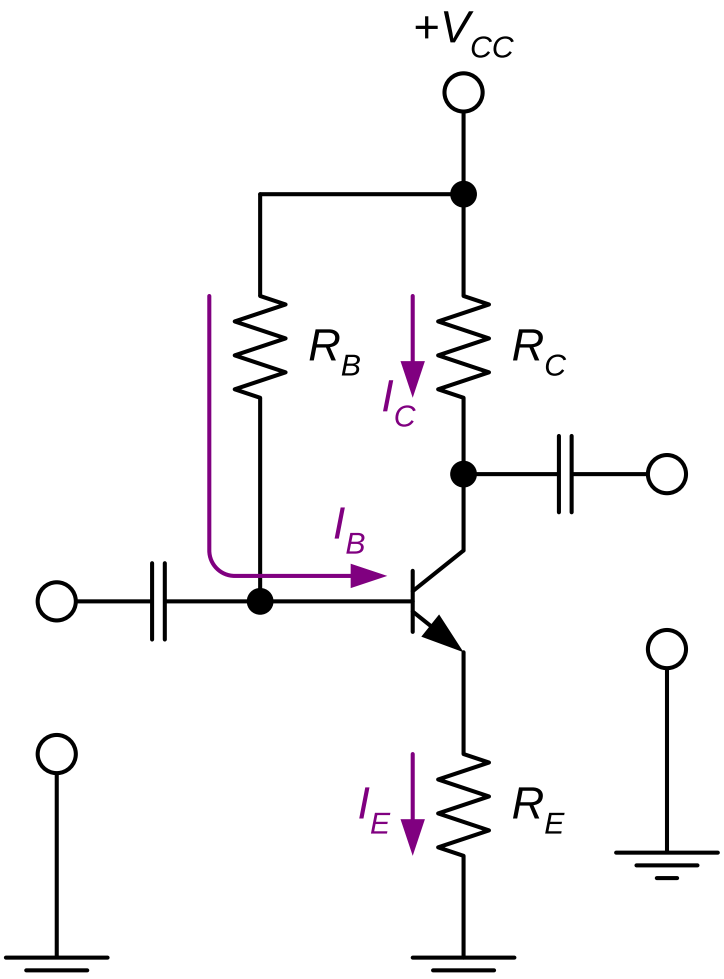
Hubungan Q-point:

$$I_B = \frac{V_{CC} - V_{BE}}{(h_{FE} + 1)R_C + R_B}$$

$$I_{CQ} = h_{FE} I_B$$

$$V_{CEQ} \cong V_{CC} - I_{CQ} R_C$$

Rangkaian Bias Emitter-feedback



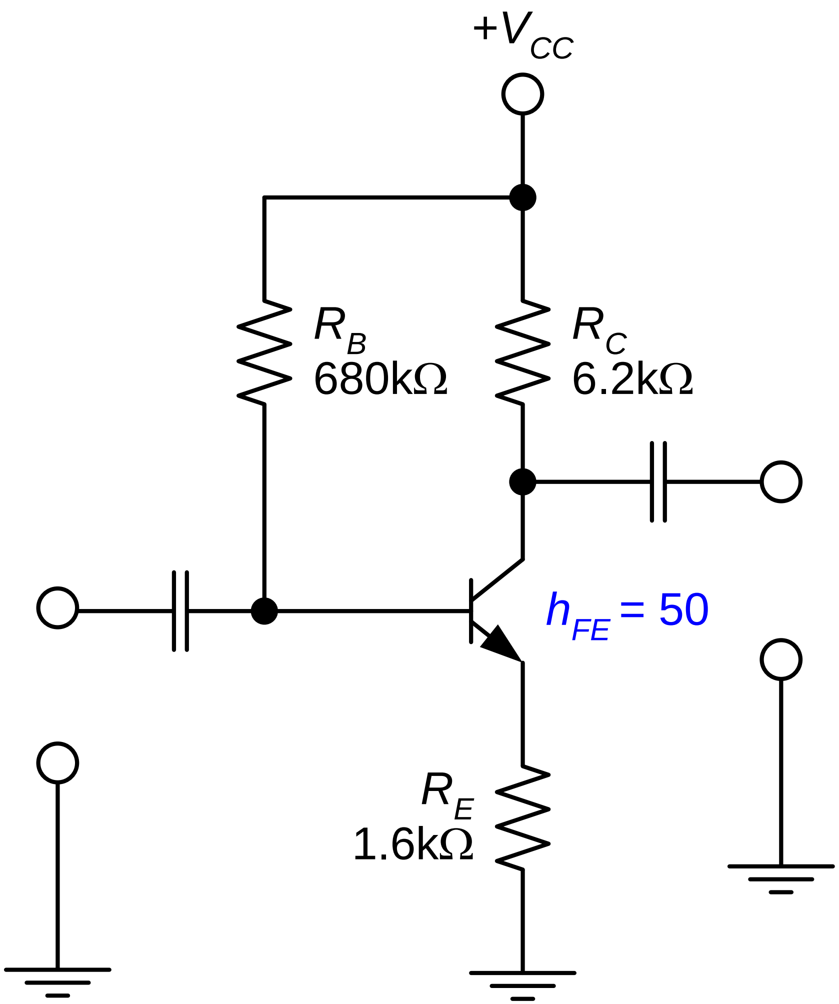
$$I_B = \frac{V_{CC} - V_{BE}}{R_B + \left(h_{FE} + 1\right) R_E}$$

$$I_{CQ} = h_{FE} I_B$$

$$I_E = \left(h_{FE} + 1\right) I_B$$

$$\begin{aligned} V_{CEQ} &= V_{CC} - I_C R_C - I_E R_E \\ &\cong V_{CC} - I_{CQ}\left(R_C + R_E\right) \end{aligned}$$

Contoh 11

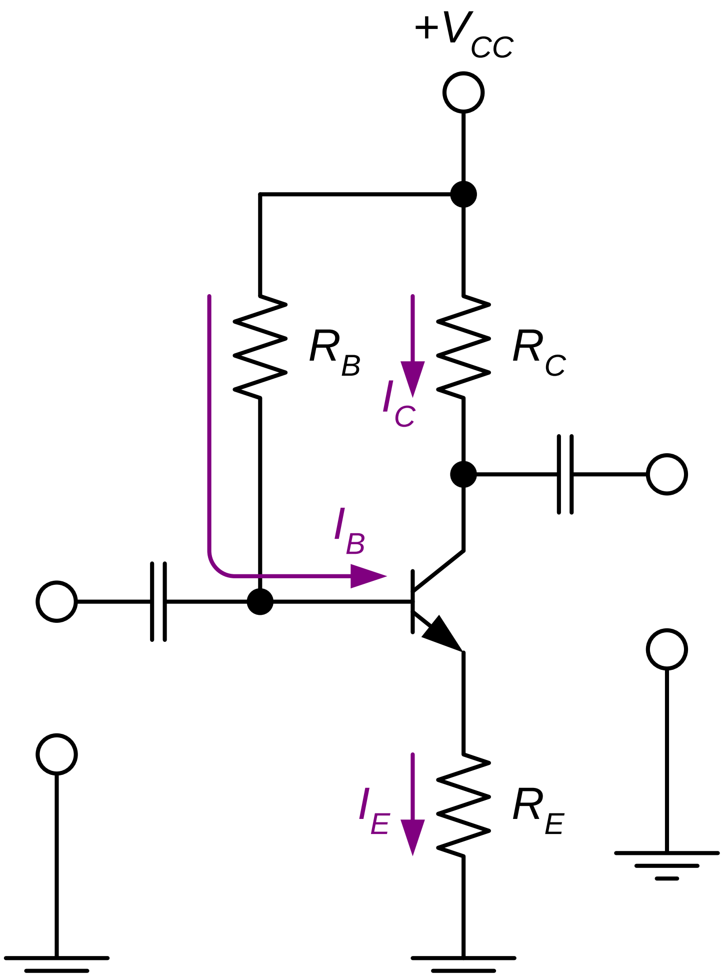


$$I_B = \frac{V_{CC} - V_{BE}}{R_B + (h_{FE} + 1) R_E} = \frac{16\text{V} - 0.7\text{V}}{680\text{k}\Omega + 51 \times 1.6\text{k}\Omega}$$
$$= 20.09\mu\text{A}$$

$$I_{CQ} = h_{FE} I_B = 50 \times 20.09\mu\text{A} = 1\text{mA}$$

$$V_{CEQ} \cong V_{CC} - I_{CQ}(R_C + R_E)$$
$$= 16\text{V} - (1\text{mA})(7.8\text{k}\Omega) = 8.2\text{V}$$

Karakteristik Emitter-Feedback (1)



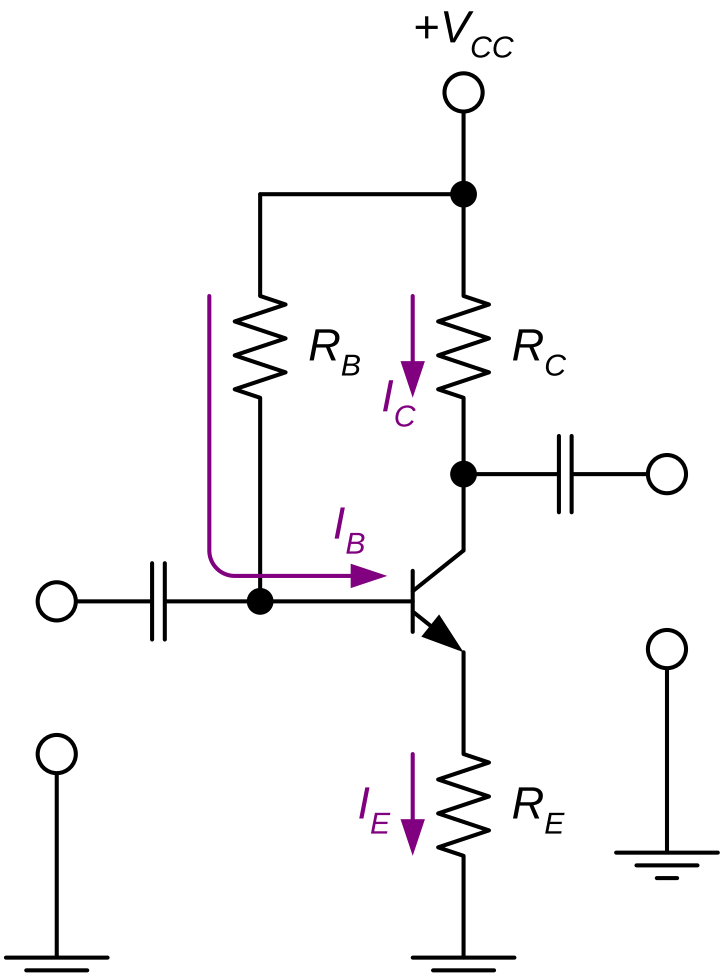
Ciri rangkaian: sama seperti voltage divider bias dengan R_2 hilang (atau base bias dengan penambahan R_E).

Keuntungan: Rangkaian sederhana dengan nilai Q-point stabil

Kerugian: membutuhkan banyak komponen dibanding collector-feedback bias.

Aplikasi: bias linear amplifiers.

Karakteristik Emitter-Feedback(2)



Hubungan Q-point :

$$I_B = \frac{V_{CC} - V_{BE}}{R_B + (h_{FE} + 1)R_E}$$

$$I_{CQ} = h_{FE} I_B$$

$$V_{CEQ} \cong V_{CC} - I_{CQ}\left(R_C + R_E\right)$$