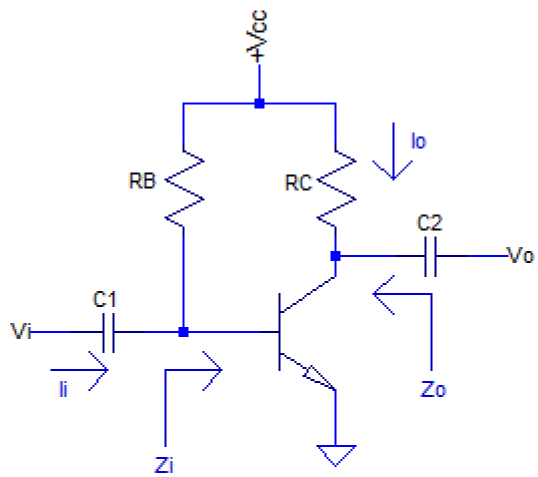
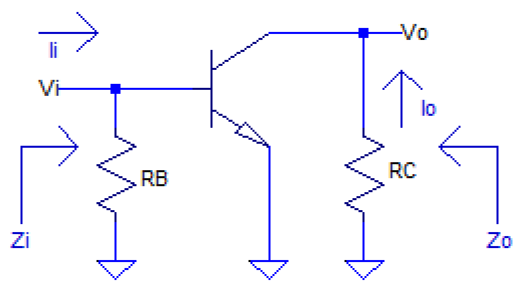
BAB VII ANALISIS SINYAL KECIL BJT

6.1 Model r_e
6.1.1 Konfigurasi *Common – Emittor* Prategangan Tetap

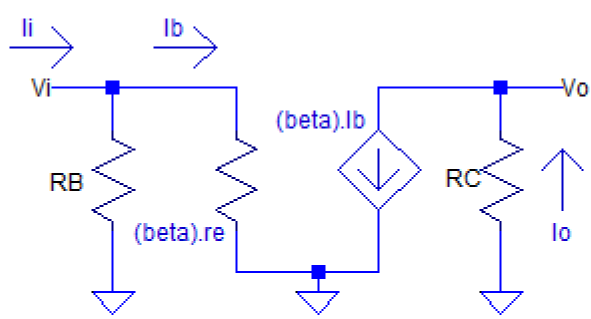


Gambar 6.1 CE prategangan tetap

Analisis ac : (dimana sumber DC diganti tahanan dalam idealnya dan komponen kapasitor sangat besar/*short circuit*)



Model r_e (abaikan r_o) :



Impedansi Input

$$Z_i = R_B // \beta r_e$$

Impedansi Output

Set sinyal input samadengan nol, sehingga arus pada basis juga samadengan nol maka nilai arus tak bebasnya samadengan nol atau open circuit.

$$Z_o = R_C$$

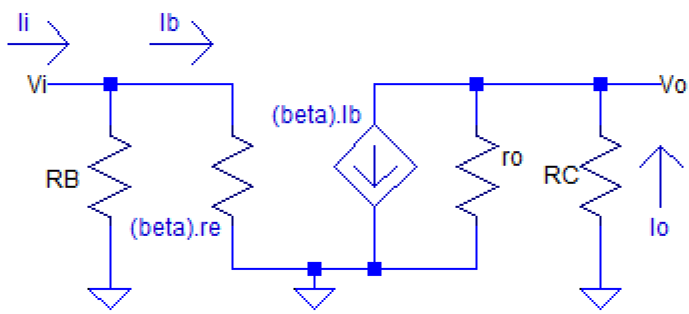
Penguatan Tegangan (A_v)

$$A_v = \frac{V_o}{V_i} = \frac{-\beta I_b R_C}{\beta r_e I_b} = -\frac{R_C}{r_e}$$ → perubahan phasa 180° antara input dan output.

Penguatan Arus (A_i)

$$A_i = \frac{I_o}{I_i} = \frac{\beta I_b}{\frac{R_B + \beta r_e}{R_B} I_b} = \frac{\beta}{1 + \beta r_e / R_B}$$

Model r_e dengan nilai r_o :



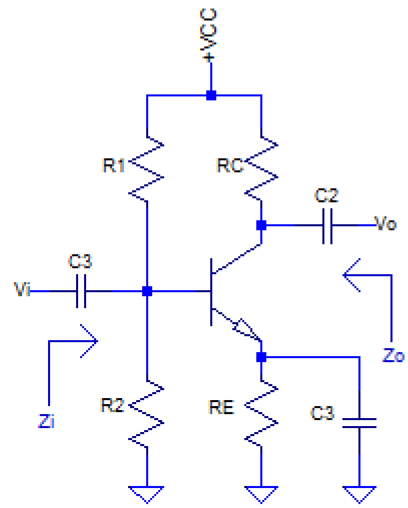
$$Z_i = R_B // \beta r_e$$

$$Z_i = R_C // r_o$$

$$A_v = \frac{V_o}{V_i} = \frac{-\beta I_b R_C // r_o}{\beta r_e I_b} = \frac{-R_C // r_o}{r_e}$$

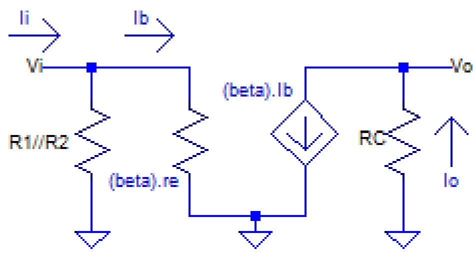
$$A_i = \frac{I_o}{I_i} = \frac{I_o}{I_b}\frac{I_b}{I_i} = \frac{r_o \beta}{r_o + R_C}\frac{R_B}{R_B + \beta r_e}$$

6.1.2 Konfigurasi Pembagi Tegangan



Gambar 6.2 CE pembagi tegangan

Model r_e (abaikan r_o) :



Impedansi Input

$Z_i = R_1 // R_2 // \beta r_e$

Impedansi Output

Set sinyal input samadengan nol, sehingga arus pada basis juga samadengan nol maka nilai arus tak bebasnya samadengan nol atau open circuit.

$Z_o = R_C$

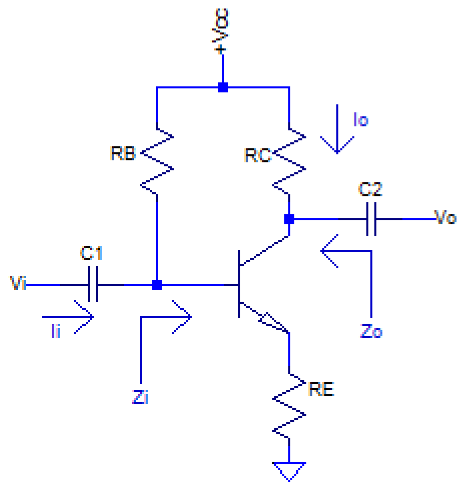
Penguatan Tegangan (A_v)

$A_v = \frac{V_o}{V_i} = \frac{-\beta I_b R_C}{\beta r_e I_b} = -\frac{R_C}{r_e}$ → perubahan phasa 180° antara input dan output.

Penguatan Arus (A_i)

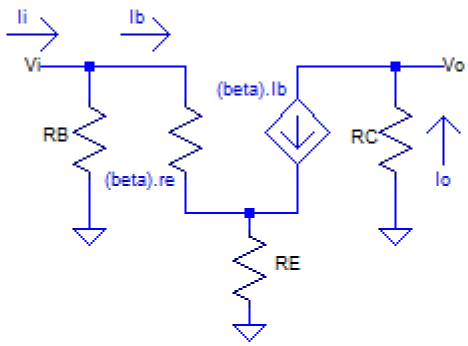
$$A_i = \frac{I_o}{I_i} = \frac{\beta I_b}{\frac{R_1 // R_2 + \beta r_e}{R_1 // R_2} I_b} = \frac{\beta}{1 + \beta r_e / R_1 // R_2}$$

6.1.3 Konfigurasi *Common – Emittor* dengan Prategangan *Emittor*



Gambar 6.3 CE prategangan *emittor*

Model r_e (abaikan r_o) :



Impedansi Input

$$Z_i = R_B // Z_b$$

$$Z_b = \frac{V_i}{I_b} = \beta r_e + (1+\beta)R_E$$

Impedansi Output

Set sinyal input samadengan nol, sehingga arus pada basis juga samadengan nol maka nilai arus tak bebasnya samadengan nol atau open circuit.

$$Z_o = R_C$$

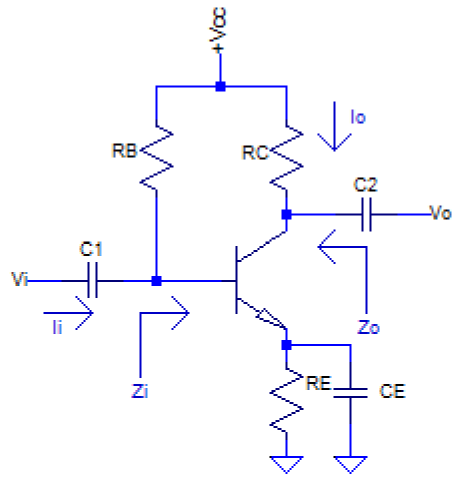
Penguatan Tegangan (A_v)

$$A_v = \frac{V_o}{V_i} = \frac{-\beta I_b R_C}{I_b Z_b} = -\frac{\beta R_C}{Z_b}$$ → perubahan phasa 180^o antara input dan output.

Penguatan Arus (A_i)

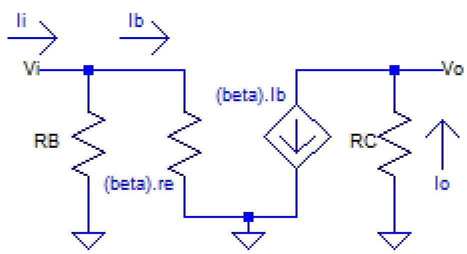
$$A_i = \frac{I_o}{I_i} = \frac{I_o}{I_b}\frac{I_b}{I_i} = \beta \frac{R_B}{R_B + Z_b}$$

Bypass Kapasitor



Gambar 6.4 Bypass kapasitor

Model r_e (abaikan r_o) :



Impedansi Input

$Z_i = R_B // \beta r_e$

Impedansi Output

Set sinyal input samadengan nol, sehingga arus pada basis juga samadengan nol maka nilai arus tak bebasnya samadengan nol atau open circuit.

$Z_o = R_C$

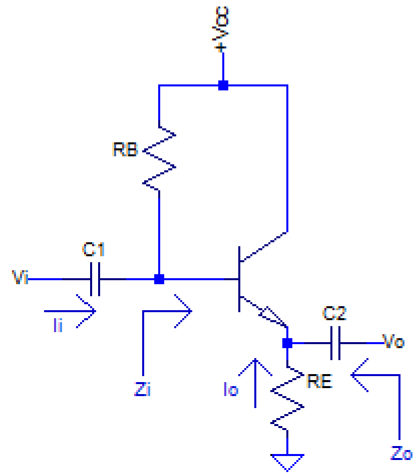
Penguatan Tegangan (A_v)

$A_v = \frac{V_o}{V_i} = \frac{-\beta I_b R_C}{\beta r_e I_b} = -\frac{R_C}{r_e}$ → perubahan phasa 180° antara input dan output.

Penguatan Arus (A_i)

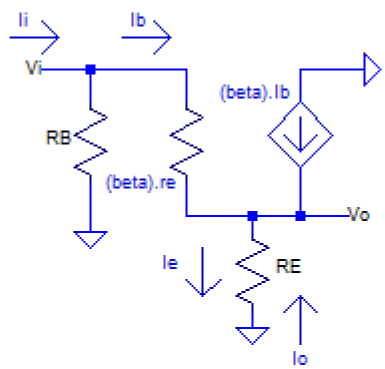
$$A_i = \frac{I_o}{I_i} = \frac{\beta I_b}{\frac{R_B + \beta r_e}{R_B} I_b} = \frac{\beta}{1 + \beta r_e / R_B}$$

6.1.4 Konfigurasi *Emittor Follower*



Gambar 6.5 *Emittor follower*

Model r_e (abaikan r_o) :



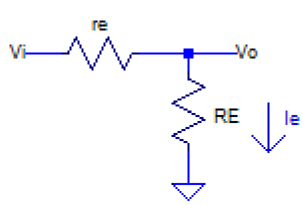
Impedansi Input

$$Z_b = \frac{V_i}{I_b} = \frac{I_b \beta r_e + (I_b + I_c) R_E}{I_b} = \beta r_e + (1+\beta) R_E$$

$$Z_i = R_B \,//\, Z_b$$

Impedansi Output

$$I_e = (1+\beta) I_b = (1+\beta)\frac{V_i}{Z_b} = \frac{(1+\beta)}{\beta r_e + (1+\beta) R_E} V_i = \frac{1}{\frac{\beta r_e}{(1+\beta)} + R_E} V_i = \frac{1}{r_e + R_E} V_i$$



Set sinyal input samadengan nol, sehingga arus pada basis juga samadengan nol maka nilai arus tak bebasnya samadengan nol atau open circuit.

$Z_o = R_E // r_e$

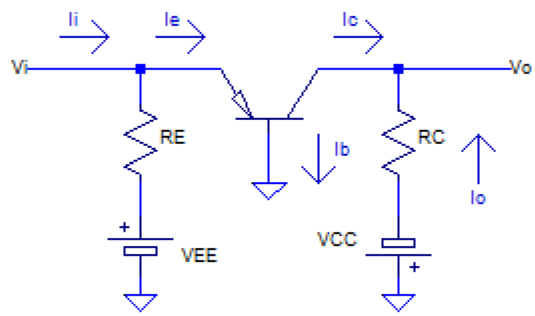
Penguatan Tegangan (A_v)

$$A_v = \frac{V_o}{V_i} = \frac{R_E}{R_E + r_e}$$

Penguatan Arus (A_i)

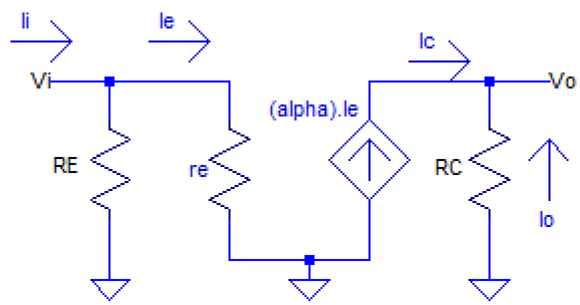
$$A_i = \frac{I_o}{I_i} = \frac{-I_e}{I_i} = -(1+\beta)\frac{R_B}{R_B + Z_b}$$

6.1.5 Konfigurasi *Common - Base*



Gambar 6.6 *Common base*

Model r_e (abaikan r_o) :



Impedansi Input

$Z_i = R_E // r_e$

Impedansi Output

Set sinyal input samadengan nol, sehingga arus pada basis juga samadengan nol maka nilai arus tak bebasnya samadengan nol atau open circuit.

$Z_o = R_C$

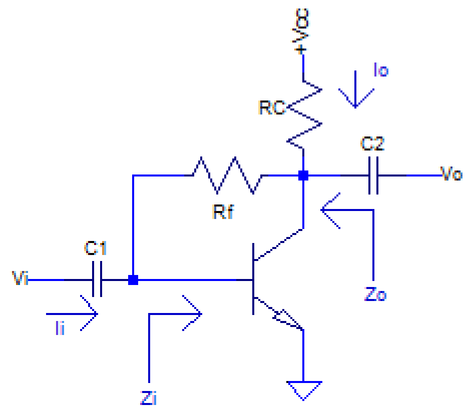
Penguatan Tegangan (A_v)

$$A_v = \frac{V_o}{V_i} = \frac{-I_o R_C}{I_e r_e} = \frac{I_c R_C}{I_e r_e} = \frac{\alpha I_e R_C}{I_e r_e} = \frac{\alpha R_C}{r_e}$$

Penguatan Arus (A_i)

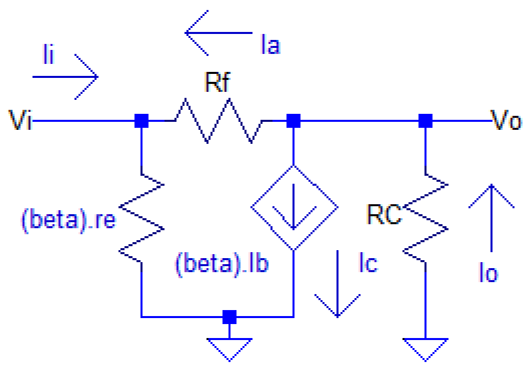
$$A_i = \frac{I_o}{I_i} = \frac{-I_c}{I_i} = -\alpha \frac{R_E}{R_E + r_e}$$

6.1.6 Konfigurasi *Collector* – Umpan Balik



Gambar 6.7 *Collector* umpan balik

Model r_e (abaikan r_o) :



Penguatan Tegangan (A_v)

$$I_o = I_C + I' = \beta I_b + I'$$

Asumsi $\beta I_b >> I'$, maka : $I_o \approx \beta I_b$

$$A_v = \frac{V_o}{V_i} = \frac{-I_o R_C}{V_i} = \frac{-\beta I_b R_C}{V_i} = \frac{-\beta\left(\frac{V_i}{\beta r_e}\right)R_C}{V_i} = -\frac{R_C}{r_e}$$

Penguatan Arus (A_i)

$$-V_o + V_{Rf} + V_i = 0$$

$$I_o R_C + I' R_f + I_b \beta r_e = 0 \Rightarrow I_o R_C + (I_b - I_i)R_f + I_b \beta r_e = 0$$

dengan menggunakan $I_o \approx \beta I_b$, maka :

$$I_o R_C + \left(\frac{I_o}{\beta} - I_i \right) R_f + \frac{I_o}{\beta} \beta r_e = 0$$

$$A_i = \frac{I_o}{I_i} = \frac{R_f}{R_C + {R_f}/{\beta} + r_e} = \frac{\beta R_f}{R_f + \beta (R_C + r_e)}$$

dengan mengabaikan βr_e, maka :

$$A_i = \frac{\beta R_f}{R_f + \beta R_C}$$

$\beta R_C >> R_f$:

$$A_i = \frac{R_f}{R_C}$$

Impedansi Input

$$I_b = I_i + I' = I_i + \frac{V_o - V_i}{R_f}$$

$$asumsi : V_o >> V_i \Rightarrow I_b \approx I_i + \frac{V_o}{R_f}$$

$$V_i = I_b \beta r_e = \left(I_i + \frac{V_o}{R_f} \right) \beta r_e = \left(I_i + \frac{A_v V_i}{R_f} \right) \beta r_e$$

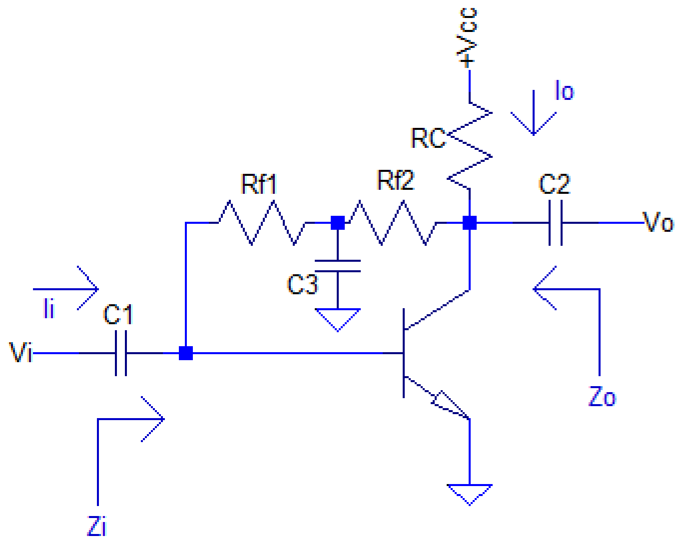
$$V_i \left(1 - \frac{A_v V_i}{R_f} \beta r_e \right) = I_i \beta r_e \Rightarrow Z_i = \frac{V_i}{I_i} = \frac{\beta r_e}{\left(1 - \frac{A_v}{R_f} \beta r_e \right)}$$

Impedansi Output

Set sinyal input samadengan nol, sehingga arus pada basis juga samadengan nol maka nilai arus tak bebasnya samadengan nol atau open circuit.

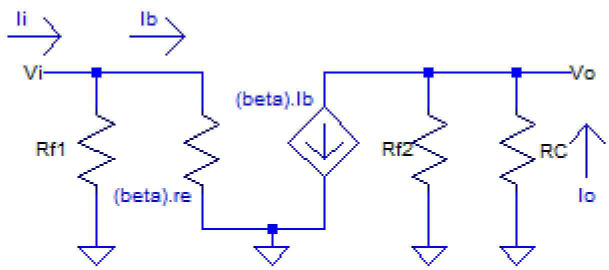
$$Z_o = R_C // R_f$$

6.1.7 Konfigurasi *Collector* – Umpan Balik Lainnya



Gambar 6.8 *Collector* umpan balik lainnya

Model r_e (abaikan r_o) :



Impedansi Input

$$Z_i = R_{f1} // \beta r_e$$

Impedansi Output

Set sinyal input samadengan nol, sehingga arus pada basis juga samadengan nol maka nilai arus tak bebasnya samadengan nol atau open circuit.

$$Z_o = R_C // R_{f2}$$

Penguatan Tegangan (A_v)

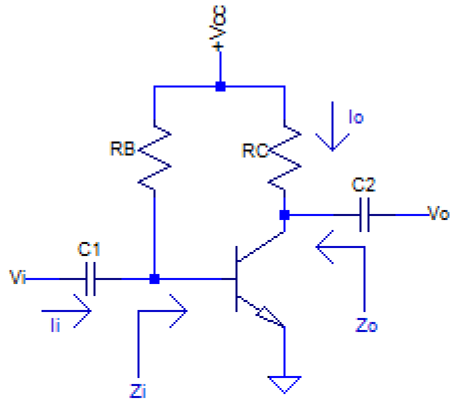
$$A_v = \frac{V_o}{V_i} = \frac{-I_o R_C}{\beta r_e I_b} = \frac{-R_{f2}}{R_{f2} + R_C}\beta I_b \frac{1}{\beta r_e I_b} = \frac{-R_{f2}}{(R_{f2} + R_C) r_e}$$

Penguatan Arus (A_i)

$$A_i = \frac{I_o}{I_i} = \frac{R_{f2}}{R_{f2} + R_C}\frac{\beta I_b}{I_b}\frac{I_b}{I_i} = \frac{R_{f2}}{R_{f2} + R_C}\beta \frac{R_{f1}}{R_{f1} + \beta r_e}$$

6.2 Model Ekivalen Hybrid

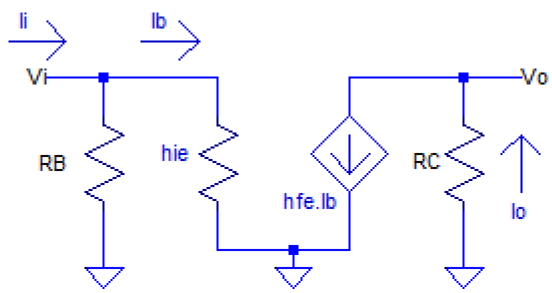
6.2.1 Konfigurasi *Common – Emittor* Prategangan Tetap



Gambar 6.9 CE prategangan tetap

Analisis ac : (dimana sumber DC diganti tahanan dalam idealnya dan komponen kapasitor sangat besar/*short circuit*)

Model ekivalen hybrid (abaikan h_{oe}) :



Impedansi Input

$$Z_i = R_B // h_{ie}$$

Impedansi Output

Set sinyal input samadengan nol, sehingga arus pada basis juga samadengan nol maka nilai arus tak bebasnya samadengan nol atau open circuit.

$$Z_o = R_C$$

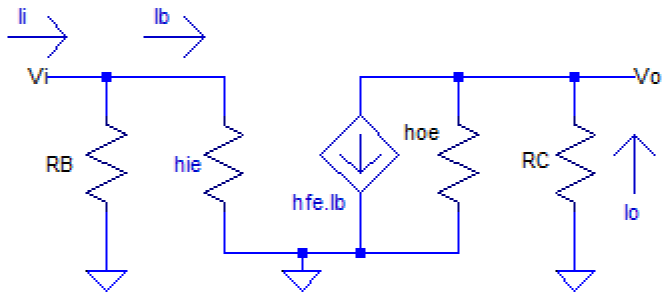
Penguatan Tegangan (A_v)

$$A_v = \frac{V_o}{V_i} = \frac{-h_{fe} I_b R_C}{h_{ie} I_b} = \frac{-h_{fe} R_C}{h_{ie}}$$ → perubahan phasa 180° antara input dan output.

Penguatan Arus (A_i)

$$A_i = \frac{I_o}{I_i} = \frac{h_{fe} I_b}{I_b} \frac{I_b}{I_i} = h_{fe} \frac{R_B}{R_B + h_{ie}} = \frac{h_{fe}}{1 + h_{ie}/R_B}$$

Model ekivalen hybrid dengan nilai h_{oe} :



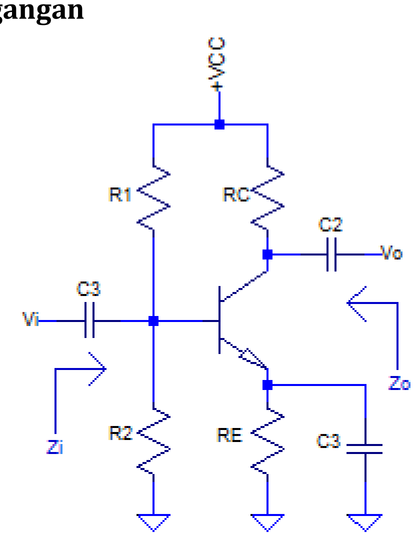
$$Z_i = R_B // h_{ie}$$

$$Z_o = R_C // \frac{1}{h_{oe}}$$

$$A_v = \frac{V_o}{V_i} = \frac{-I_o R_C}{I_b h_{ie}} = \frac{-1/h_{oe}}{1/h_{oe} + R_C} h_{fe} I_b \frac{R_C}{I_b h_{ie}} = \frac{-1/h_{oe}\, h_{fe} R_C}{1/h_{oe} + R_C}$$

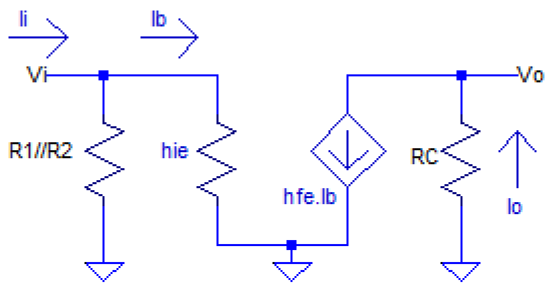
$$A_i = \frac{I_o}{I_i} = \frac{1/h_{oe}}{1/h_{oe} + R_C} \frac{h_{fe} I_b}{I_b} \frac{R_B}{R_B + h_{ie}} = \frac{1/h_{oe}}{1/h_{oe} + R_C} \frac{h_{fe} R_B}{R_B + h_{ie}}$$

6.2.2 Konfigurasi Pembagi Tegangan



Gambar 6.10 CE pembagi tegangan

Model ekivalen hybrid (abaikan h_{oe}) :



Impedansi Input

$Z_i = R_1 // R_2 // h_{ie}$

Impedansi Output

Set sinyal input samadengan nol, sehingga arus pada basis juga samadengan nol maka nilai arus tak bebasnya samadengan nol atau open circuit.

$Z_o = R_C$

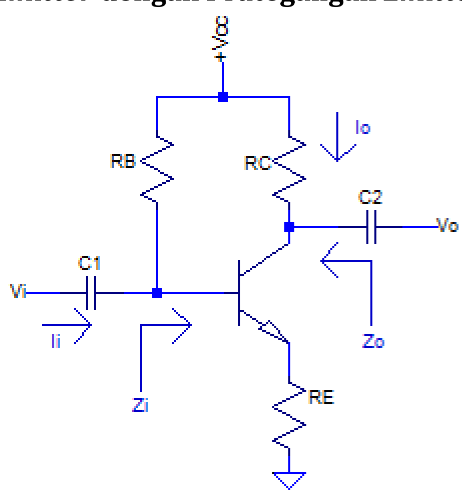
Penguatan Tegangan (A_v)

$$A_v = \frac{V_o}{V_i} = \frac{-I_o R_C}{h_{ie} I_b} = -\frac{h_{fe} I_b R_C}{h_{ie} I_b} = -\frac{h_{fe} R_C}{h_{ie}}$$

Penguatan Arus (A_i)

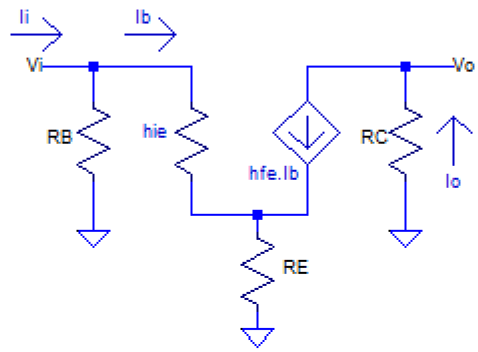
$$A_i = \frac{I_o}{I_i} = \frac{h_{fe} I_b}{I_b}\frac{I_b}{I_i} = h_{fe}\frac{R_1 // R_2}{R_1 // R_2 + h_{ie}}$$

6.2.3 Konfigurasi *Common – Emittor* dengan Prategangan *Emittor*



Gambar 6.11 CE prategangan *emittor*

Model ekivalen hybrid (abaikan h_{oe}) :



Impedansi Input

$$Z_i = R_B // Z_b$$

$$Z_b = \frac{V_i}{I_b} = h_{ie} + (1 + h_{fe})R_E$$

Impedansi Output

Set sinyal input samadengan nol, sehingga arus pada basis juga samadengan nol maka nilai arus tak bebasnya samadengan nol atau open circuit.

$$Z_o = R_C$$

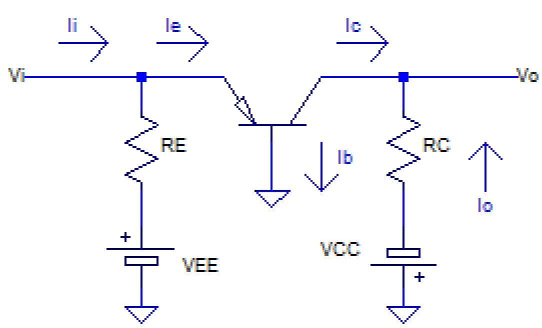
Penguatan Tegangan (A_v)

$$A_v = \frac{V_o}{V_i} = \frac{-I_o R_C}{h_{ie} I_b + R_E (I_b + h_{fe} I_b)} = \frac{-h_{fe} I_b R_C}{h_{ie} I_b + R_E (I_b + h_{fe} I_b)} = \frac{-h_{fe} R_C}{h_{ie} + R_E (1 + h_{fe})}$$

Penguatan Arus (A_i)

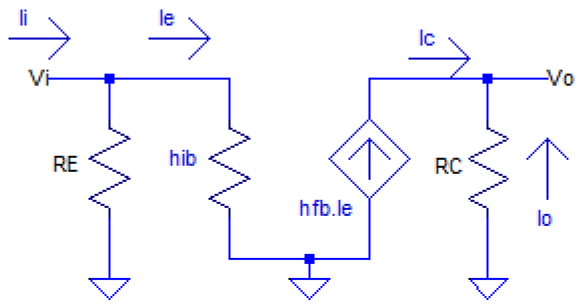
$$A_i = \frac{I_o}{I_i} = \frac{h_{fe} I_b}{I_b} \frac{I_b}{I_i} = h_{fe} \frac{R_B}{R_B + Z_b}$$

6.2.4 Konfigurasi *Common - Base*



Gambar 6.12 *Common base*

Model ekivalen hybrid (abaikan h_{oe}) :



Impedansi Input

$Z_i = R_E // h_{ib}$

Impedansi Output

Set sinyal input samadengan nol, sehingga arus pada basis juga samadengan nol maka nilai arus tak bebasnya samadengan nol atau open circuit.

$Z_o = R_C$

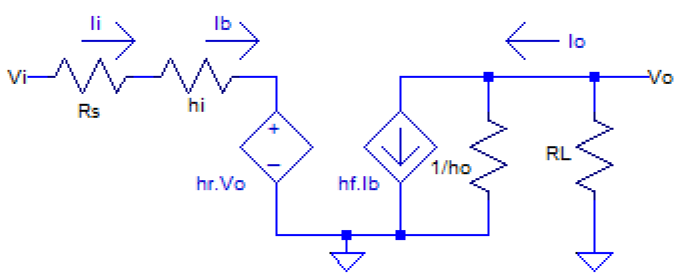
Penguatan Tegangan (A_v)

$$A_v = \frac{V_o}{V_i} = \frac{-I_o R_C}{I_e h_{ib}} = \frac{-h_{fb} I_e R_C}{I_e h_{ib}} = \frac{-h_{fb} R_C}{h_{ib}}$$

Penguatan Arus (A_i)

$$A_i = \frac{I_o}{I_i} = \frac{h_{fb} I_e}{I_e} \frac{I_e}{I_i} = h_{fb} \frac{R_E}{R_E + h_{ib}}$$

6.3 Model Lengkap Ekivalen Hybrid



Gambar 6.13 Ekivalen hybrid lengkap

Penguatan Arus

$$I_o = I + h_f I_b = \frac{V_o}{1/h_o} + h_f I_i = \frac{-I_o R_L}{1/h_o} + h_f I_i = -I_o h_o R_L + h_f I_i$$

$$A_i = \frac{I_o}{I_i} = \frac{h_f}{1 + h_o R_L}$$

Penguatan Tegangan

$$V_i = h_i I_i + h_r V_o = h_i \frac{(1 + h_o R_L)}{h_f} I_o + h_r V_o$$

$$I_o = -\frac{V_o}{R_L}$$

$$V_i = -h_i \frac{(1 + h_o R_L)}{h_f} \frac{V_o}{R_L} + h_r V_o$$

$$A_v = \frac{V_o}{V_i} = -\frac{h_f R_L}{h_i + (h_i h_o - h_r h_f) R_L}$$

Impedansi Input

$$V_i = h_i I_i + h_r V_o = h_i I_i - h_r I_o R_L = h_i I_i - h_r A_i I_i R_L$$

$$A_i = \frac{h_f}{1 + h_o R_L}$$

$$Z_i = h_i - \frac{h_r R_L h_f}{1 + h_o R_L}$$

Impedansi Output

$$I_i = \frac{V_s - h_r V_o}{R_s + h_i}$$

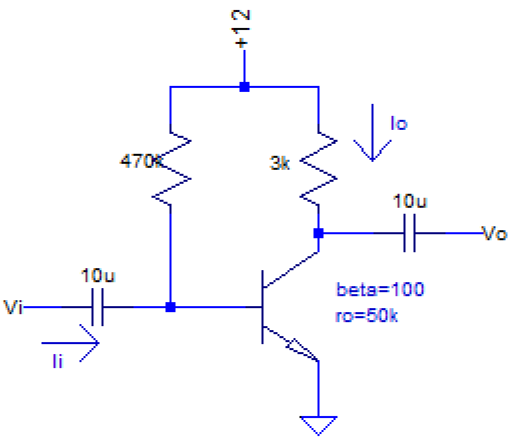
Set input $V_s = 0$, maka $I_i = -\frac{h_r V_o}{R_s + h_i}$

$$I_o = h_f I_b + I = h_f I_i + \frac{V_o}{1/h_o} = h_f I_i + V_o h_o = -h_f \frac{h_r V_o}{R_s + h_i} + V_o h_o$$

$$Z_o = \frac{V_o}{I_o} = \frac{1}{h_o - \frac{h_f h_r}{R_s + h_i}}$$

Latihan Soal :

1. Tentukan Z_i, Z_o, A_v, A_i !

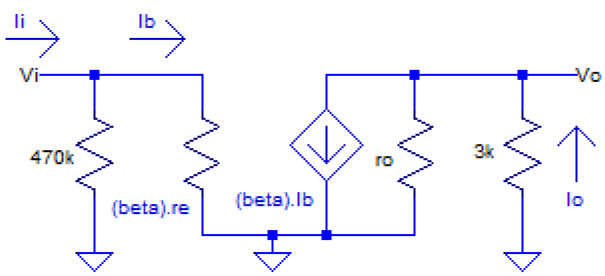


Jawaban :

Analisis DC :

$$I_B = \frac{12-0,7}{470k} = 0,024mA$$

$$r_e = \frac{26mV}{I_E} = \frac{26mV}{(1+\beta)I_B} = \frac{26mV}{(1+100)0,024mA} = 10,71\Omega$$



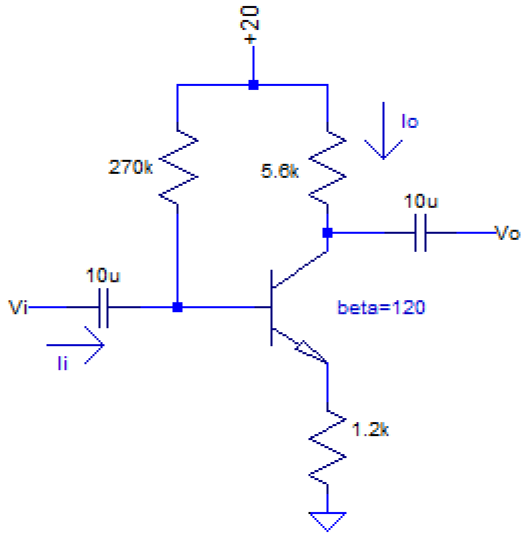
$$Z_i = 470k // \beta r_e = 470k // 100.10,71 = 470k // 1,07k = 1,069k$$

$$Z_o = r_o // 3k = 50k // 3k = 2,83k$$

$$A_v = \frac{V_o}{V_i} = \frac{-3kI_o}{I_b \beta r_e} = \frac{-r_o}{r_o + 3k}\frac{I_b \beta 3k}{I_b \beta r_e} = \frac{-50k}{50k+3k}\frac{3k}{10,71} = -264,26$$

$$A_i = \frac{I_o}{I_i} = \frac{r_o}{r_o+3k}\frac{I_b \beta}{I_b}\frac{I_b}{I_i} = \frac{\beta r_o}{r_o+3k}\frac{470k}{470k+\beta r_e} = 94,125$$

2. Tentukan Z_i, Z_o, A_v, A_i !

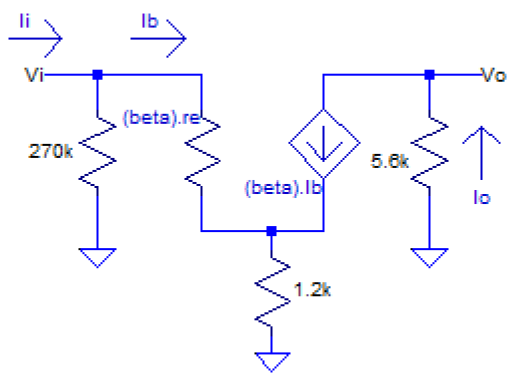


Jawaban :

Analisis DC :

$$I_B = \frac{12 - 0,7}{270k + (1+\beta)1,2k} = 0,0465mA$$

$$r_e = \frac{26mV}{I_E} = \frac{26mV}{(1+\beta)I_B} = \frac{26mV}{(1+120)0,0465mA} = 4,623\Omega$$



$$Z_b = \frac{V_i}{I_b} = \frac{\beta r_e I_b + (1+\beta) I_b 1{,}2k}{I_b} = \beta r_e + (1+\beta)1{,}2k = 120.4{,}623 + 121.1{,}2k = 145{,}75k$$

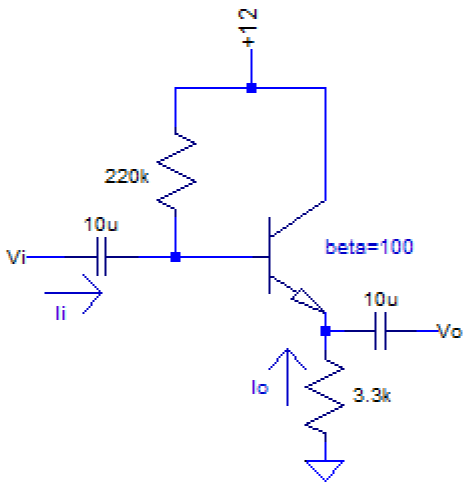
$$Z_i = 270k \,//\, Z_b = 270k \,//\, 145{,}75k = 94{,}66k$$

$$Z_o = 5{,}6k$$

$$A_v = \frac{V_o}{V_i} = \frac{-5{,}6kI_o}{0{,}626kI_b + 1{,}2k(1+\beta)I_b} = \frac{-5{,}6\beta I_b}{0{,}626kI_b + 1{,}2k(1+\beta)I_b} = -4{,}61$$

$$A_i = \frac{I_o}{I_i} = \frac{120 I_b}{\dfrac{V_i}{270k} + I_b} = \frac{120 I_b}{\dfrac{Z_b I_b}{270k} + I_b} = 77{,}93$$

3. Tentukan Z_i, Z_o, A_v, A_i !

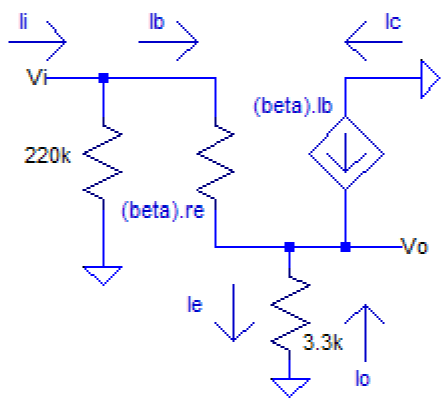


Jawaban :

Analisis DC :

$$I_B = \frac{12 - 0{,}7}{220k + (1+\beta)3{,}3k} = 0{,}0204mA$$

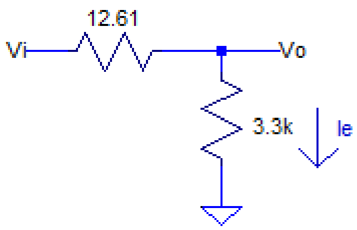
$$r_e = \frac{26mV}{I_E} = \frac{26mV}{(1+\beta)I_B} = \frac{26mV}{(1+120)0{,}0204mA} = 12{,}61\Omega$$



$$Z_b = \frac{V_i}{I_b} = \frac{\beta r_e I_b + (1+\beta) I_b 3{,}3k}{I_b} = \beta r_e + (1+\beta) 3{,}3k = 334{,}561k$$

$$Z_i = 220k // Z_b = 220k // 334{,}561k = 132{,}72k$$

$$I_e = (1+\beta) I_b = (1+\beta)\frac{V_i}{Z_b} = (1+\beta)\frac{V_i}{\beta r_e + (1+\beta) R_E} = \frac{V_i}{R_E + r_e}$$



Set tegangan input samadengan nol.

$$Z_o = r_e // R_E = 12{,}61 // 3{,}3k = 2{,}62$$

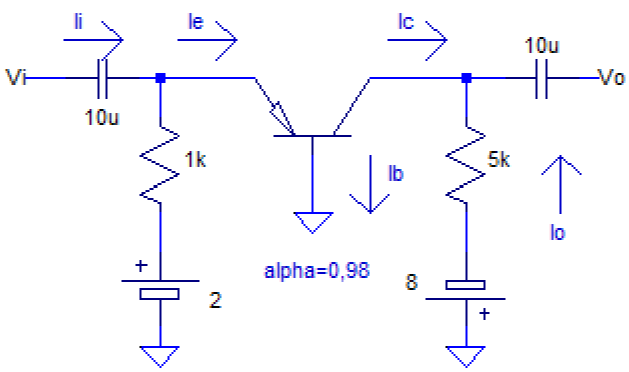
$$A_v = \frac{V_o}{V_i} = \frac{-3{,}3k I_o}{Z_b I_b} = \frac{-3{,}3k I_e}{Z_b I_b} = \frac{-3{,}3k(1+\beta) I_b}{Z_b I_b}$$

$$A_v = 0{,}996$$

$$A_i = \frac{I_o}{I_i} = \frac{-I_e}{I_b}\frac{I_b}{I_i} = \frac{-(1+\beta) I_b}{I_b}\frac{220k}{220k + Z_b}$$

$$A_i = -40{,}07$$

4. Tentukan Z_i, Z_o, A_v, A_i !



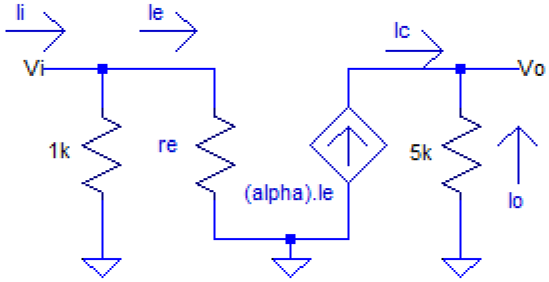
Jawaban :

Analisis DC :

$$-2 + 1k I_E + V_{EB} = 0$$

$$I_E = \frac{2 - 0{,}7}{1k} = 1{,}3mA$$

$$r_e = \frac{26mV}{I_E} = 20\Omega$$



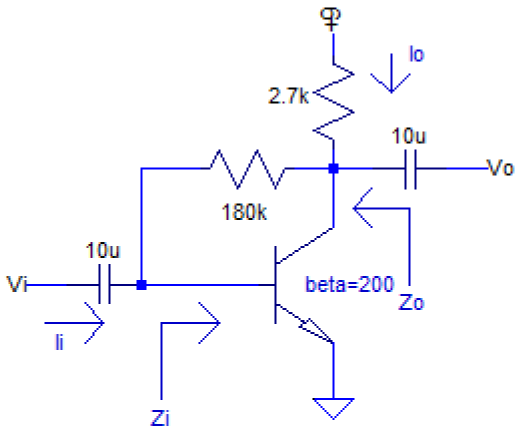
$Z_i = 1k // r_e = 1k // 20 = 19{,}61$

$Z_o = 5k$

$$A_v = \frac{V_o}{V_i} = \frac{-5kI_o}{I_e r_e} = \frac{5kI_c}{I_e r_e} = \frac{5k\alpha I_e}{I_e r_e} = 245$$

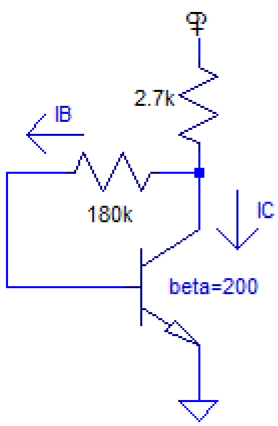
$$A_i = \frac{I_o}{I_i} = \frac{-I_c}{I_i} = \frac{-\alpha I_e}{I_e}\frac{I_e}{I_i} = -\alpha\frac{1k}{1k + r_e} = -0{,}961$$

5. Tentukan Z_i, Z_o, A_v, A_i !



Jawaban :

Analisis DC :



$$-9 + 2{,}7k(I_B + I_C) + 180kI_B = 0$$

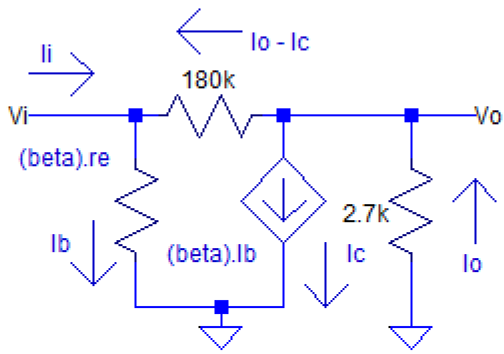
$$-9 + 2{,}7k(I_B + \beta I_B) + 180kI_B = 0$$

$$I_B = \frac{9}{2{,}7k(1+\beta) + 180k} = 0{,}0124mA$$

$$I_E = (1+\beta)I_B = 2{,}503mA$$

$$r_e = \frac{26mV}{I_E} = 10{,}39\Omega$$

Analisis ac :



$$2{,}7kI_o + 180k(I_o - I_c) + \beta r_e I_b = 0$$

$$2{,}7kI_o + 180k(I_o - \beta I_b) + \beta r_e I_b = 0$$

$$I_o = \frac{(180k\beta - \beta r_e)I_b}{2{,}7k + 180k} = 197I_b$$

$$Z_i = \frac{V_i}{I_i} = \frac{I_b \beta r_e}{I_b - (I_o - I_c)} = \frac{I_b \beta r_e}{I_b + \beta I_b - I_o} = \frac{I_b \beta r_e}{I_b + \beta I_b - 197I_b}$$

$$Z_i = \frac{200.10{,}39}{1 + 200 - 197} = 519{,}5 = 0{,}5195k$$

$$Z_o = 180k \,//\, 2{,}7k = 2{,}66k$$

$$A_v = \frac{V_o}{V_i} = -\frac{I_o 2{,}7k}{I_b \beta r_e} = -\frac{197I_b 2{,}7k}{I_b.200.10{,}39} = -255{,}97$$

$$A_i = \frac{I_o}{I_i} = \frac{197I_b}{I_b + \beta I_b - I_o} = \frac{197I_b}{I_b + \beta I_b - 197I_b} = \frac{197}{1 + 200 - 197} = 49{,}25$$