Elektronik I

Small Signal Models (tekrar) – BJT küçük işaret modelleri ve yükselteçler

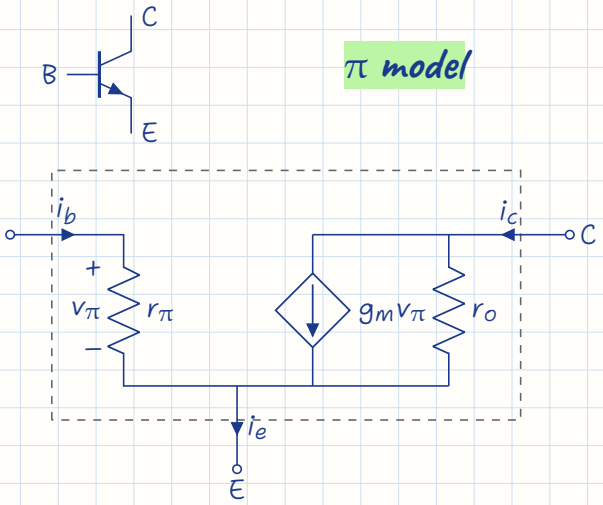
Original notes: Elektronik-1-small-signal-model-tekrar.pdf

UYARI Bu belge, el yazısı ders notlarından Claude (Anthropic) yardımıyla dijitale aktarılmıştır. Yardımcı kaynak olarak hazırlanmıştır; hata veya eksik içerebilir. Lütfen orijinal notları ve ders kaynaklarını esas alın.

NOTICE *This document was transcribed from handwritten lecture notes with the help of Claude (Anthropic). It is meant as a supplementary resource and may contain errors or omissions. Always check against the original notes and official course material.*

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Small signal Models



$v_c \ll V_T \rightarrow 0{,}025\,V$

$$i_b = \frac{v_\pi}{r_\pi}$$

Small signal model:

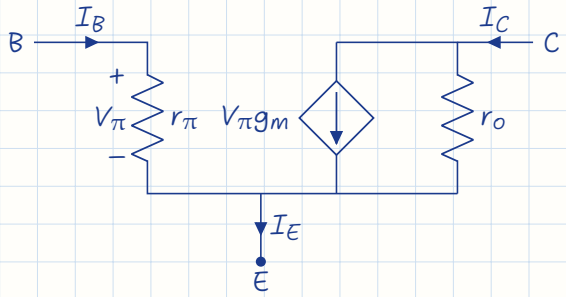
$r_o \rightarrow$ output resistance of bjt $\qquad r_o = \dfrac{|V_A|}{I_C}$

$g_m \rightarrow$ transcunductance $= g_m = \dfrac{I_C}{V_T}$

$$\alpha = \frac{\beta}{(\beta + 1)}$$

$r_\pi \rightarrow$ base resistance: $r_\pi = (\beta + 1)\, r_e$

$r_e \rightarrow$ emitter resistance $= \dfrac{V_T}{I_E} = \alpha \dfrac{V_T}{I_C} = \alpha \dfrac{1}{g_m} \approx \dfrac{1}{g_m} \qquad \underline{\underline{\alpha \approx 1}}$

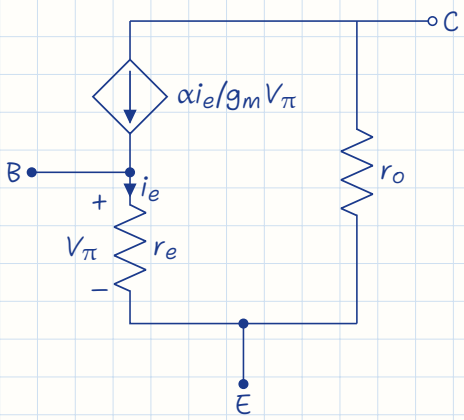


$$g_m = \frac{I_C}{V_T} \qquad r_\pi = (\beta + 1)\, r_e$$
$$r_o = \frac{|V_A|}{I_C} \qquad r_e = \frac{V_T}{I_E} = \frac{\alpha V_T}{I_C} = \frac{\alpha}{g_m}$$

$$i_C = I_S e^{v_{BE}/V_T}$$
$$i_B = \frac{i_C}{\beta}$$
$$i_E = \frac{\beta + 1}{\beta} i_C = (\beta + 1)\, i_B$$

$$r_\pi i_B = r_e i_E$$
$$r_\pi \cancel{i_B} = r_e (\beta + 1) \cancel{i_B}$$
$$r_\pi = (\beta + 1)\, r_e$$

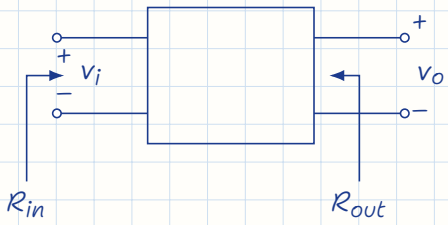
T model



$$r_o = \frac{|V_A|}{I_C} \qquad \alpha = \frac{\beta}{\beta + 1}$$
$$r_e = \frac{\alpha}{g_m} \qquad \alpha = r_e g_m$$
$$V_\pi = r_e \cdot i_e \qquad i_e = \frac{V_\pi}{r_e}$$

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$$\alpha i_e = \cancel{r_e} g_m \cdot \frac{V_\pi}{\cancel{r_e}}$$



Voltage Gain

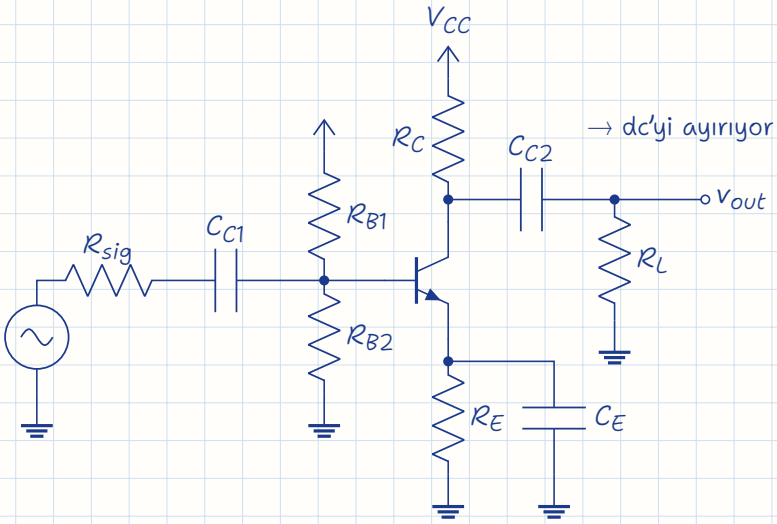
$$A_v = \frac{v_o}{v_i}$$

R_{in} → Input resistance
R_{out} → Output

Amplifier Topologies

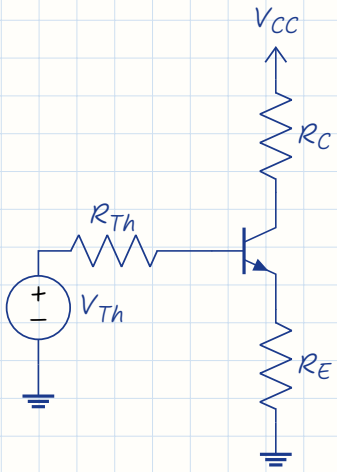
- ★ Common Emitter
- ★ Common Emitter with R_E
- ★ Common Base
- ★ Common-Collector (Emitter-Foll.)

Common Emitter Amplifier



C_{C1}, C_{C2}, C_E are high values

C are open circuit at DC ac sources short circuit

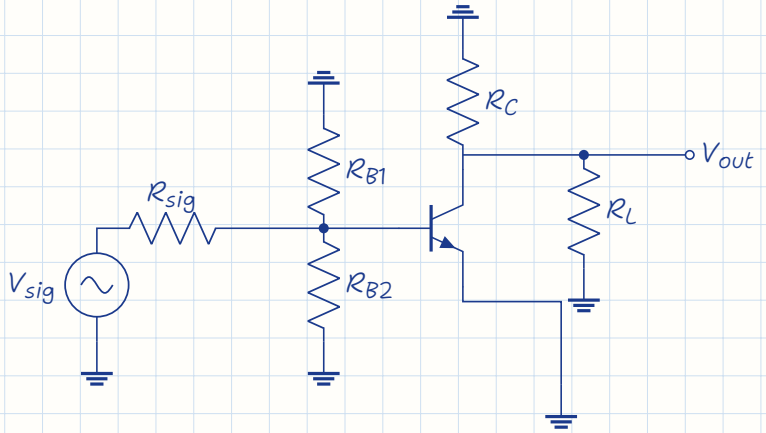


g_m, r_e, r_π, r_o

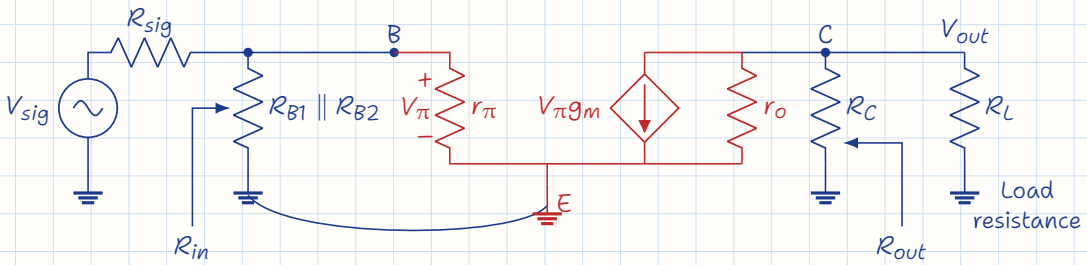
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@ AC

- Now all caps are short circuit
- DC voltage sources are short circuit
- DC current sources are open circuit



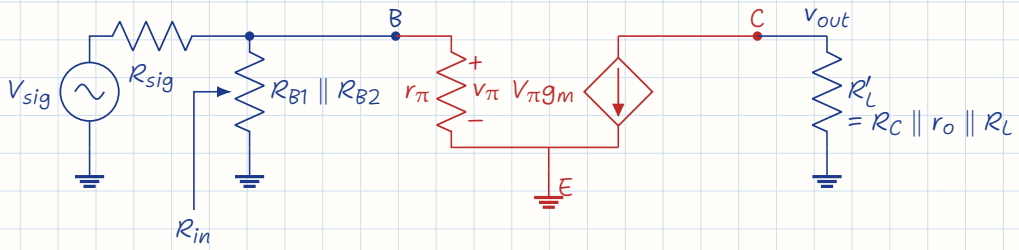
Small signal circuit



$$A_v = \frac{v_{out}}{v_{in}}, \quad R_{in}, \quad R_{out}$$

$$R_{in} = R_{B1} \parallel R_{B2} \parallel r_\pi$$

$$R_{out} = R_C \parallel r_o$$



$$v_{out} = -g_m v_\pi \cdot R'_L$$

$$v_{in} = v_{sig}$$

$$v_\pi = \frac{v_{sig} \cdot (R_{B1} \parallel R_{B2} \parallel r_\pi)}{R_{sig} + (R_{B1} \parallel R_{B2} \parallel r_\pi)}$$

orig. p. 4

$$\frac{v_{out}}{v_{sig}} = \frac{-g_m v_\pi \cdot R'_L}{v_{sig}}$$

$$= -g_m \left(\frac{\cancel{v_{sig}}\, R_{B1} \parallel R_{B2} \parallel r_\pi}{\cancel{v_{sig}}\, R_{sig} + \underbrace{(R_{B1} \parallel R_{B2} \parallel r_\pi)}_{\to R_{in}}} \right) R'_L$$

$$\text{if } R_{sig} \simeq 0 \implies = -g_m R'_L$$

→ High Voltage Gain ≈ $-g_m R'_L$

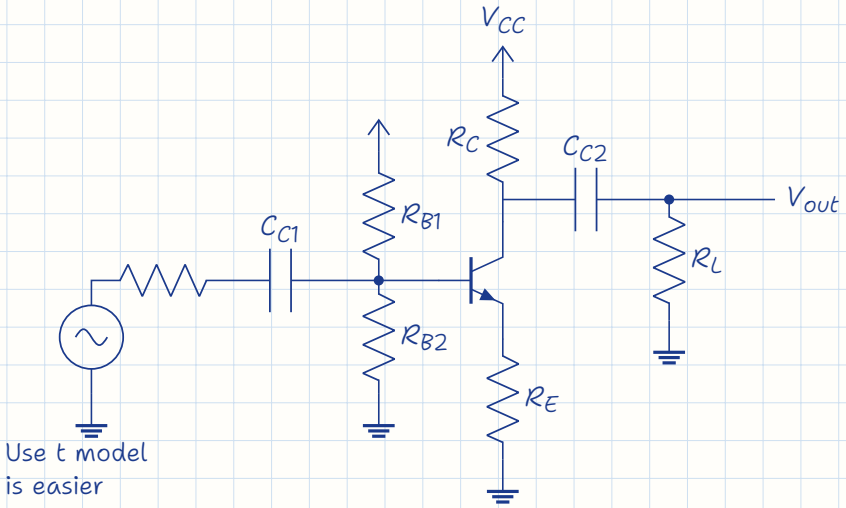
→ Moderate Input Resistance ⇒ $R_{B1} \parallel R_{B2} \parallel r_\pi$

↪ Moderate High output Resistance → $R_C \parallel r_o$

R_{in}'in büyük olmasını isteriz çok büyük olursa R_{sig} ihmal edilebilecek kadar küçük olur. ve daha yüksek kazanç sağlanır.

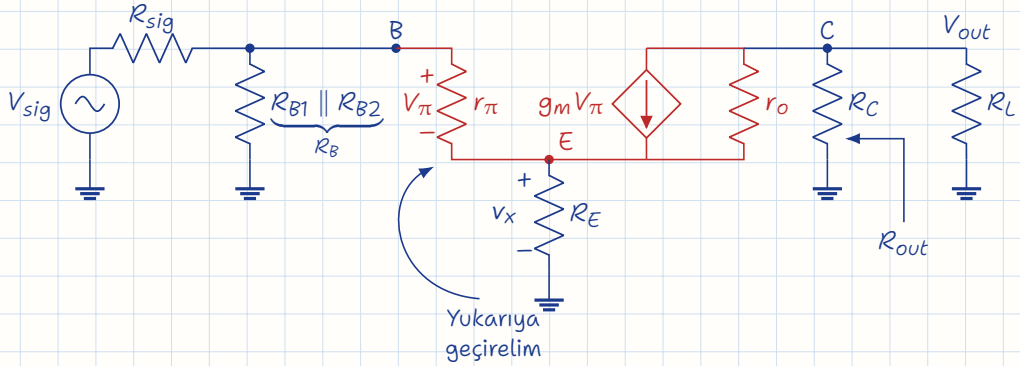
R_{out}'un küçük olmasını isteriz böylece üzerinde voltaj düşümü azalır ve singal daha kazançlı bir şekilde çıkışa aktarılabilir.

Common Emitter Amplifier with R_E



orig. p. 5

with π model



$$V_A = \infty,\ r_o = \infty$$

$$R_{in} = R_B \parallel (r_\pi + R_E(\beta + 1)) = R_B \parallel [(\beta + 1)(r_e + R_E)]$$

$$R_{out} \cong R_C$$

$$A_v = \frac{v_{out}}{v_{in}}$$

$$v_{out} = -g_m V_\pi (R_C \parallel R_L) \qquad V_\pi \overset{?}{\cong} V_{sig}$$

$$v_x = \left(g_m V_\pi + \frac{V_\pi}{r_\pi}\right) R_E = \left(\frac{V_\pi}{r_e} + \frac{V_\pi}{r_\pi}\right) R_E \cong \frac{v_\pi}{r_e} \cdot R_E$$

$$r_e = \frac{V_T}{I_E} = \frac{\alpha V_T}{I_C} = \frac{\alpha}{g_m}$$

$$v_b = v_\pi \left(1 + \frac{R_E}{r_e}\right)$$

if $R_{sig} = 0$ $v_b = v_{sig}$

$$\frac{v_{out}}{v_{in}} = \frac{-g_m V_\pi (R_C \parallel R_L)}{V_\pi \left(1 + \frac{R_E}{r_e}\right)}$$

if $R_{sig} = 0$ $v_b = v_{sig}$

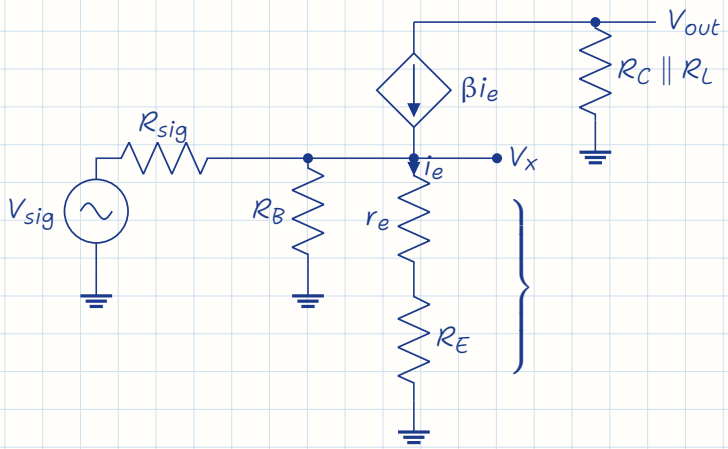
$$\frac{v_{out}}{v_{in}} = \frac{-g_m V_\pi (R_C \parallel R_L)}{V_\pi \left(1 + \frac{R_E}{r_e}\right)} \qquad r_e = \frac{1}{g_m}$$

orig. p. 6

$$\frac{v_{out}}{v_{in}} = \frac{-g_m (R_C \parallel R_L)}{r_e \left(1 + \frac{R_E}{r_e}\right)}$$

$$\cong -\frac{(R_C \parallel R_L)}{r_e + R_E}$$

$$A_v \cong -\frac{R_C \parallel R_L}{R_E + r_e}$$



$$v_x = i_e (R_E + r_e)$$

[1] Claude notu: muhtemelen paydaki r_e olmadan, yani $\frac{-g_m(R_C \parallel R_L)}{1 + R_E/r_e}$ olmalı; $g_m = 1/r_e$ ile bir sonraki satır elde edilir.