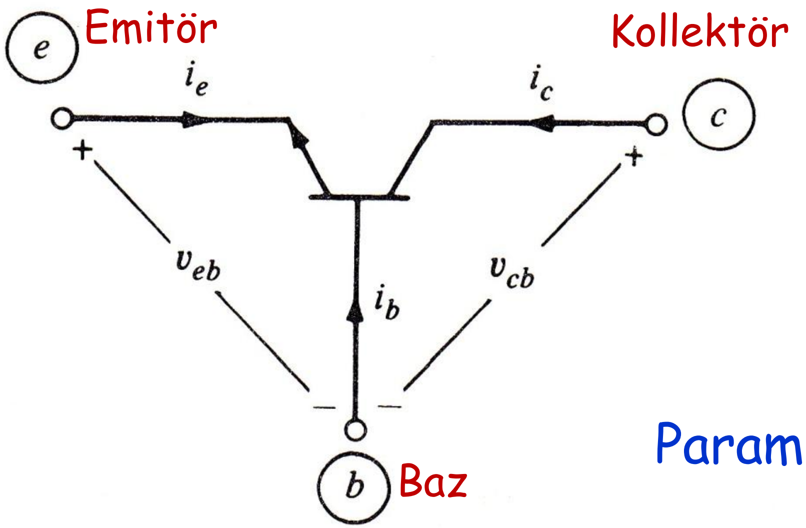
npn Bipolar Tranzistör

Hatırlatma



Alçak Frekanslardaki Eşdeğeri

Ebers-Moll Denklemleri

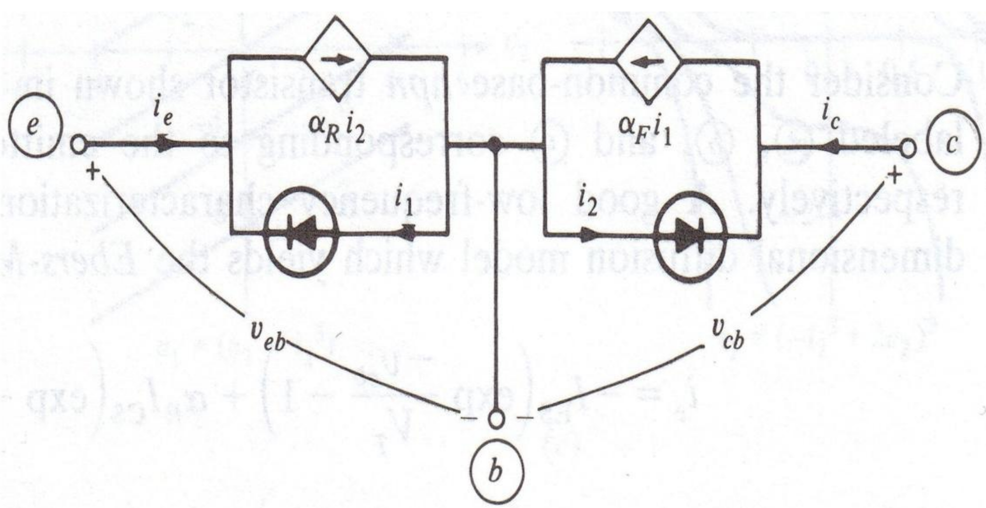
$$\begin{cases} i_e = -I_{ES}e^{-\frac{v_{eb}}{v_T}-1} + \alpha_R I_{CS}e^{-\frac{v_{cb}}{v_T}-1} \\ i_c = \alpha_F I_{ES}e^{-\frac{v_{eb}}{v_T}-1} - I_{CS}e^{-\frac{v_{cb}}{v_T}-1} \end{cases}$$

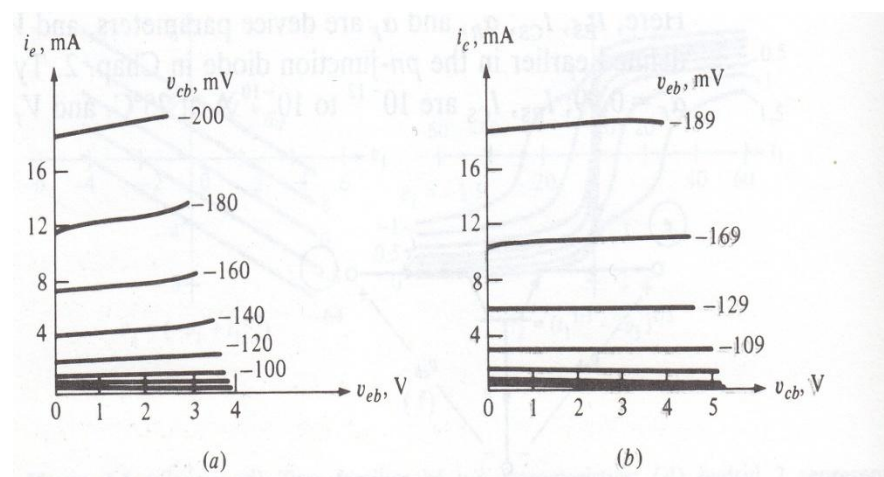
Parametreler: $I_{ES}, I_{CS}, \alpha_F, \alpha_R, V_T$

$$I_{ES}, I_{CS} \;\; 10^{-12} - 10^{-10} A, \;\; \alpha_F = 0.99, \;\; \alpha_R \;\; 0.5 - 0.8, \;\; V_T \cong 25mV \;\; (25^{\circ}C)$$

Ebers-Moll Denklemleri ile verilen tranzistör nasıl bir eleman?

3-uçlu, gerilim kontrollü





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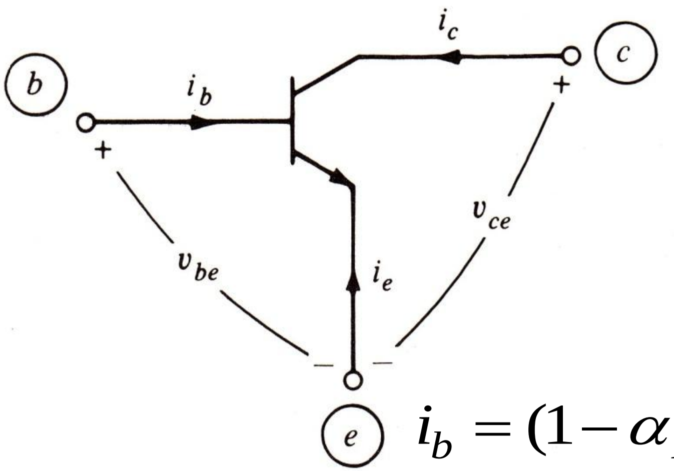
3-uçlu elemanın referansını baz yerine emitör olarak alırsak...

Hatırlatma

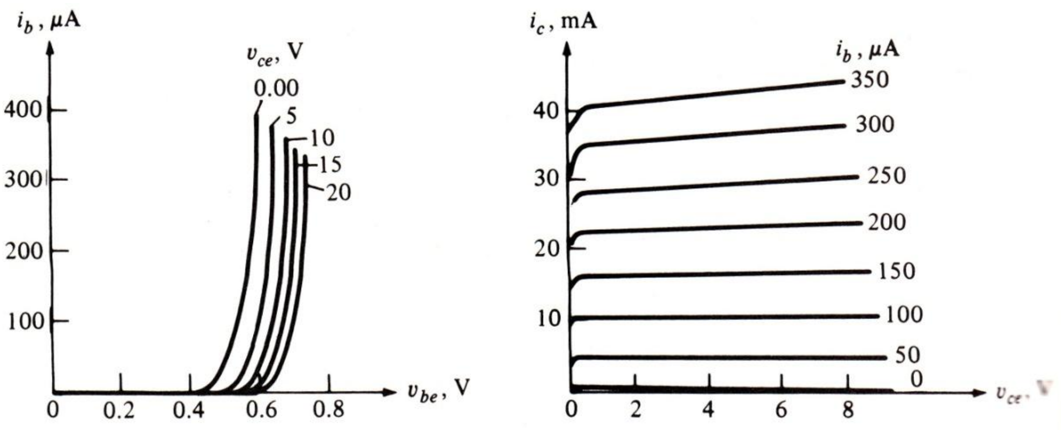


$$v_{be} = -v_{eb}$$
$$v_{ce} = v_{cb} - v_{eb}$$
$$i_b = -(i_e + i_c)$$

Ebers-Moll denklemlerine yerleştir

$$i_b = (1-\alpha_F) I_{ES} e^{\frac{v_{be}}{v_T}-1} + (1-\alpha_R) I_{CS} e^{\frac{v_{be}-v_{ce}}{v_T}-1}$$

$$i_c = \alpha_F I_{ES} e^{\frac{v_{be}}{v_T}-1} - I_{CS} e^{\frac{v_{be}-v_{ce}}{v_T}-1}$$



(a) (b)

$$v_{be} = \hat{v}_{be}(i_b, v_{ce})$$
$$i_c = \hat{i}_c(i_b, v_{ce})$$

Bu gösterim hangisi?

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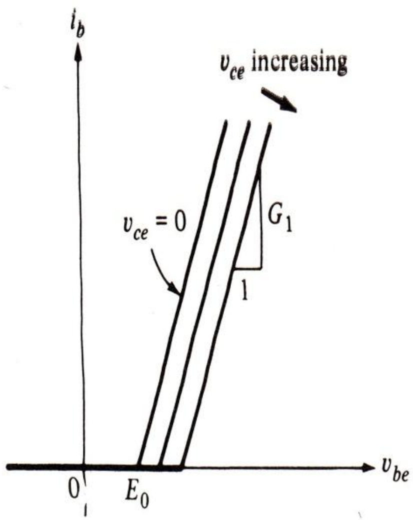
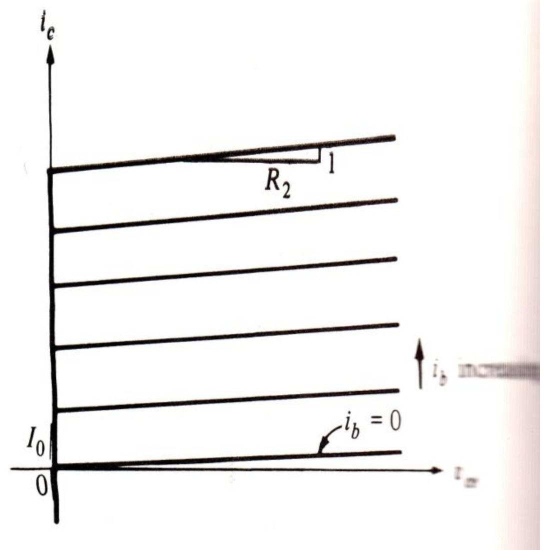
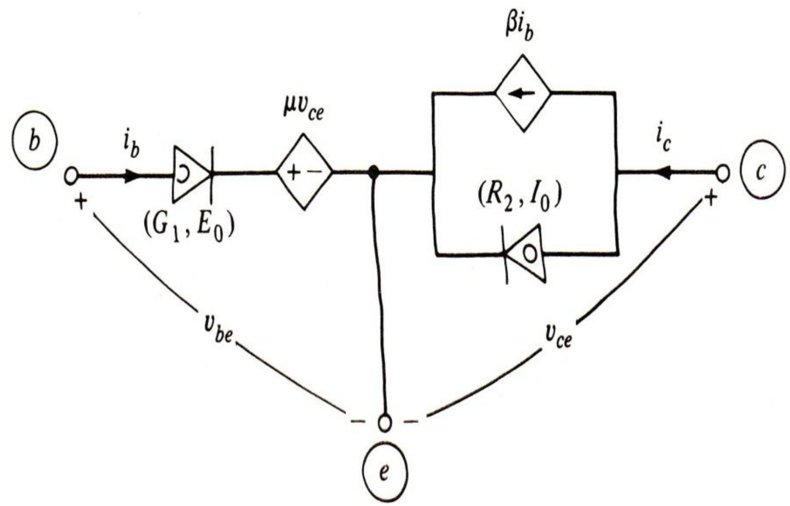
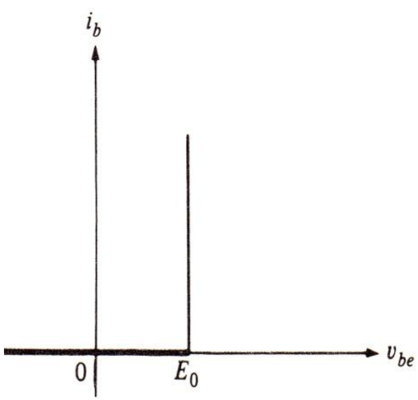
Ortak emitör karakteristiklerinin parça parça lineer eşdeğeri

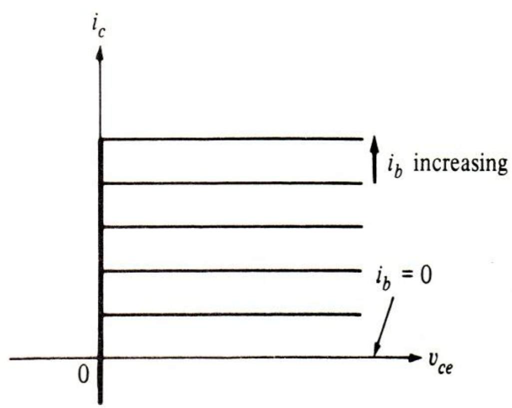


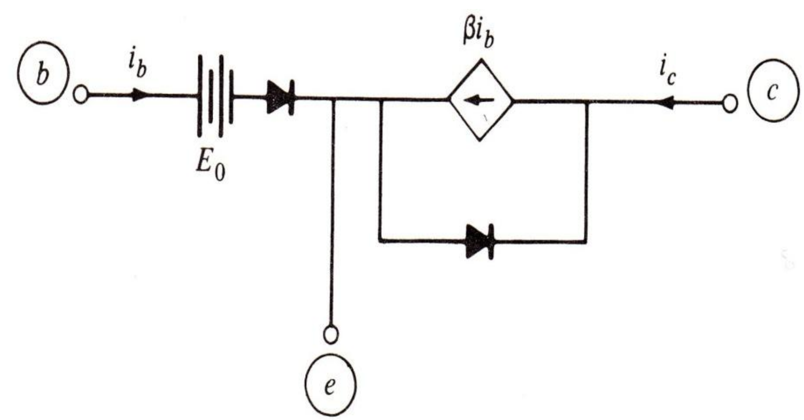




Biraz daha basitleştirirsek....







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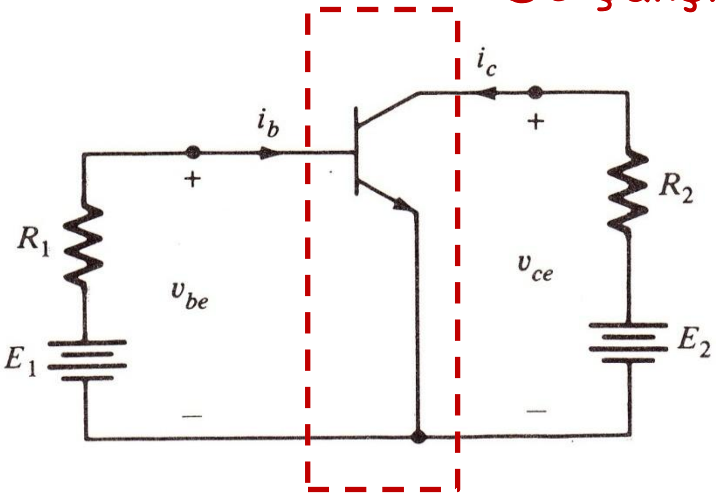
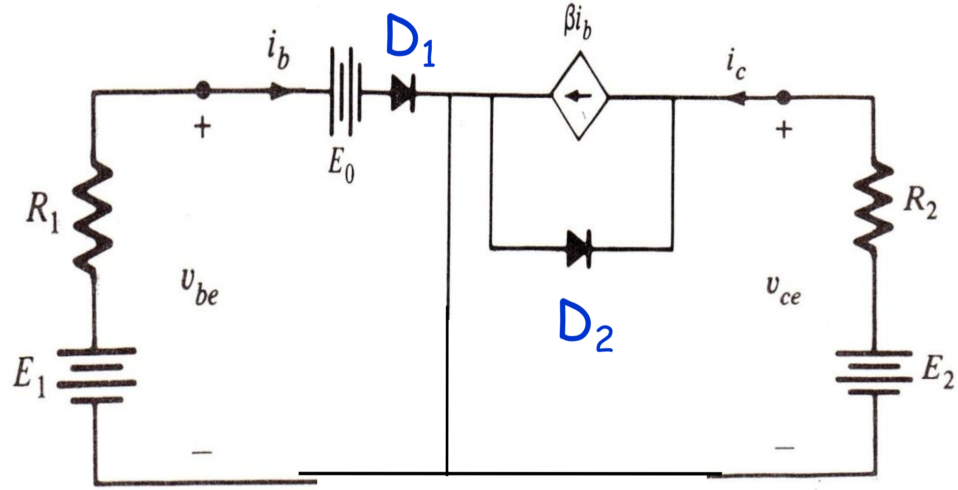
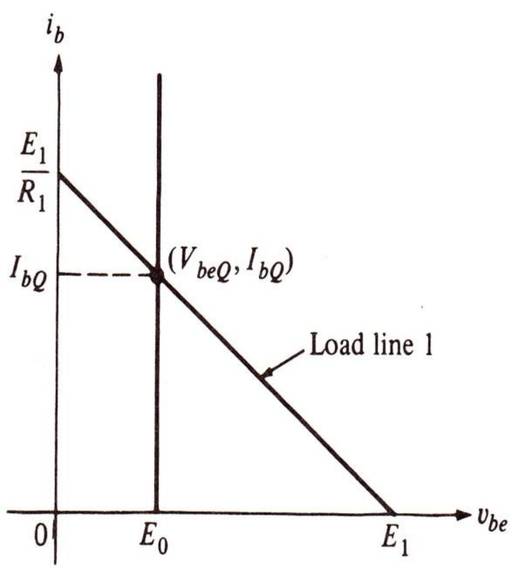
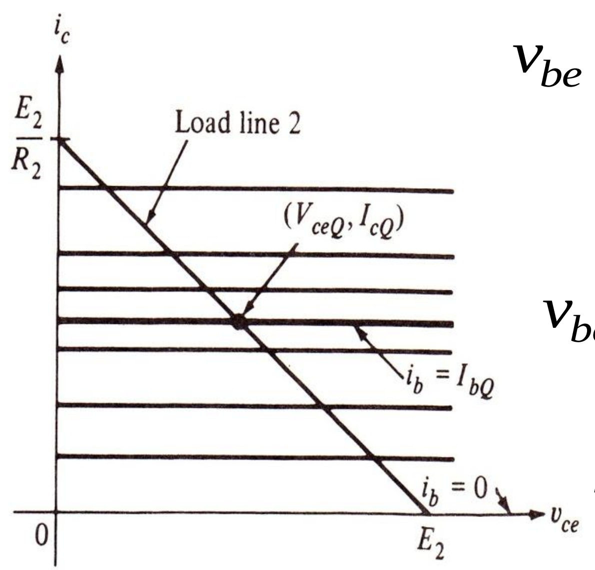
DC Çalışma Noktasının Belirlenmesi









KGY+ KAY+ETB

$$v_{be} = E_1 - R_1 i_b \quad v_{ce} = E_2 - R_2 i_c$$

Varsayım: $E_1 > 0, E_2 > 0$

D_1 kısa devre, D_2 açık devre

$$v_{be} = E_0 \rightarrow i_b = \frac{1}{R_1}(E_1 - E_0)$$

$$i_c = \beta i_b \rightarrow i_c = \frac{\beta}{R_1}(E_1 - E_0)$$

$$\rightarrow v_{ce} = E_2 - \beta \frac{R_2}{R_1}(E_1 - E_0)$$

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$$V_{be_Q} = E_0,\ \ I_{b_Q} = \frac{E_1 - E_0}{R_1},$$

$$V_{ce_Q} = E_2 - \beta\frac{R_2}{R_1}(E_1 - E_0),\ \ I_{c_Q} = \frac{\beta}{R_1}(E_1 - E_0)$$

Küçük İşaret Analizi

- Çalışma noktasını belirle.
- Lineer olmayan elemanın çalışma noktası civarında lineer eşdeğerini belirle.

$$\left.\begin{aligned} v_1 &= \hat{v}_1(i_1, i_2) \\ v_2 &= \hat{v}_2(i_1, i_2) \end{aligned}\right\} \text{Akım kontrollü eleman tanım bağıntısı} \qquad \left.\begin{aligned} V_{1_Q} &= \hat{v}_1(I_{1_Q}, I_{2_Q}) \\ V_{2_Q} &= \hat{v}_2(I_{1_Q}, I_{2_Q}) \end{aligned}\right\} \text{Çalışna Noktası}$$

$$v_1 \cong \hat{v}_1(I_{1_Q}, I_{2_Q}) + \left.\frac{\partial \tilde{v}_1}{\partial i_1}\right|_{(I_{1Q}, I_{2Q})}(i_1 - I_{1_Q}) + \left.\frac{\partial \tilde{v}_1}{\partial i_2}\right|_{(I_{1Q}, I_{2Q})}(i_2 - I_{2_Q}) + \ldots$$

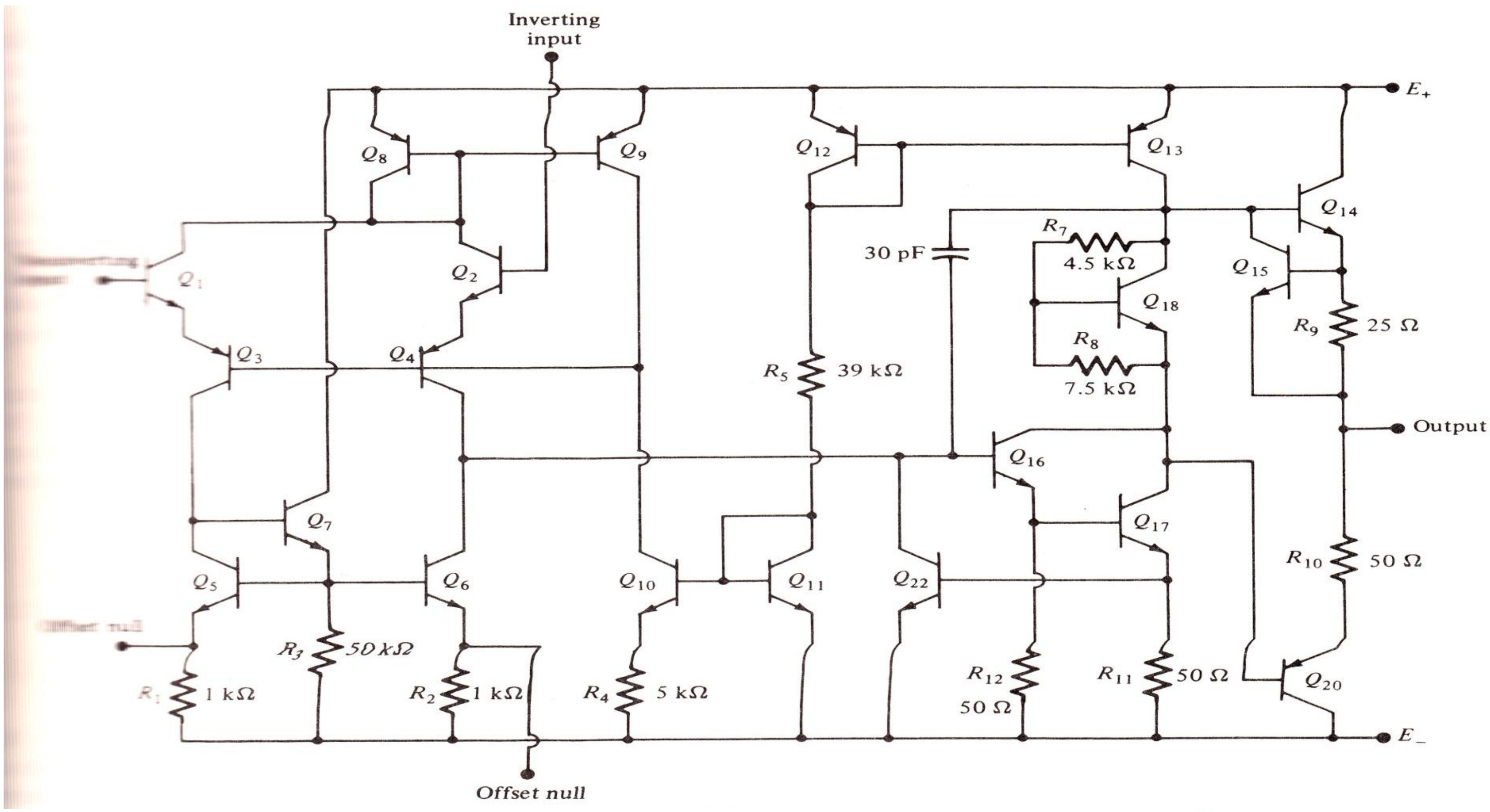
$$v_2 \cong \hat{v}_2(I_{1_Q}, I_{2_Q}) + \left.\frac{\partial \tilde{v}_2}{\partial i_1}\right|_{(I_{1Q}, I_{2Q})}(i_1 - I_{1_Q}) + \left.\frac{\partial \tilde{v}_2}{\partial i_2}\right|_{(I_{1Q}, I_{2Q})}(i_2 - I_{2_Q}) + \ldots$$

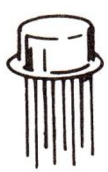
$$\begin{bmatrix} v_1 \\ v_2 \end{bmatrix} = \begin{bmatrix} V_{1_Q} \\ V_{2_Q} \end{bmatrix} + \underbrace{\begin{bmatrix} \dfrac{\partial \tilde{v}_1}{\partial i_1} & \dfrac{\partial \tilde{v}_1}{\partial i_2} \\ \dfrac{\partial \tilde{v}_2}{\partial i_1} & \dfrac{\partial \tilde{v}_2}{\partial i_2} \end{bmatrix}}_{\text{Jakobiyen Matrisi}}\Bigg|_{(I_{1_Q}, I_{2_Q})} \begin{bmatrix} i_1 - I_{1_Q} \\ i_2 - I_{2_Q} \end{bmatrix}$$

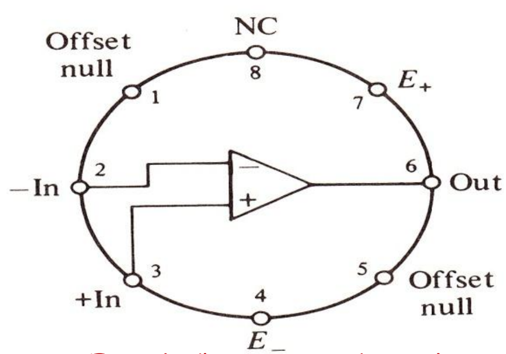
$$\begin{bmatrix} v_1 - V_{1_Q} \\ v_2 - V_{2_Q} \end{bmatrix} = \begin{bmatrix} \dfrac{\partial \tilde{v}_1}{\partial i_1} & \dfrac{\partial \tilde{v}_1}{\partial i_2} \\ \dfrac{\partial \tilde{v}_2}{\partial i_1} & \dfrac{\partial \tilde{v}_2}{\partial i_2} \end{bmatrix}\Bigg|_{(I_{1_Q}, I_{2_Q})} \begin{bmatrix} i_1 - I_{1_Q} \\ i_2 - I_{2_Q} \end{bmatrix}$$

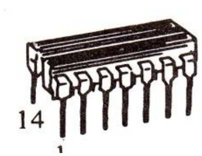
$$\begin{bmatrix} \tilde{v}_1 \\ \tilde{v}_2 \end{bmatrix} = \begin{bmatrix} \dfrac{\partial \tilde{v}_1}{\partial i_1} & \dfrac{\partial \tilde{v}_1}{\partial i_2} \\ \dfrac{\partial \tilde{v}_2}{\partial i_1} & \dfrac{\partial \tilde{v}_2}{\partial i_2} \end{bmatrix}\Bigg|_{(I_{1_Q}, I_{2_Q})} \begin{bmatrix} \tilde{i}_1 \\ \tilde{i}_2 \end{bmatrix}$$

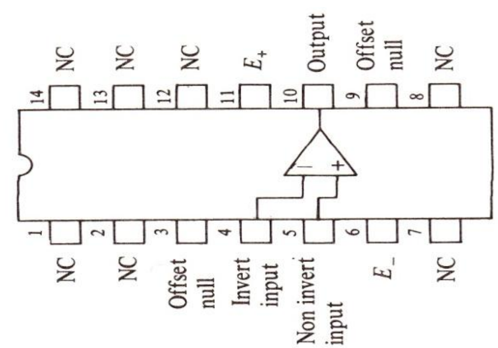
İşlemsel Kuvvetlendirici











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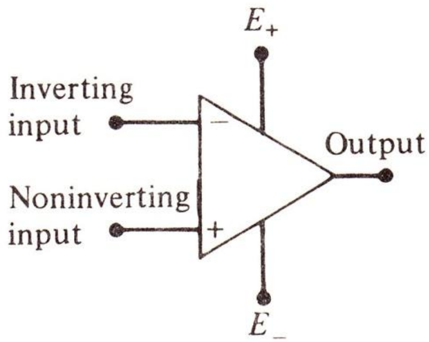
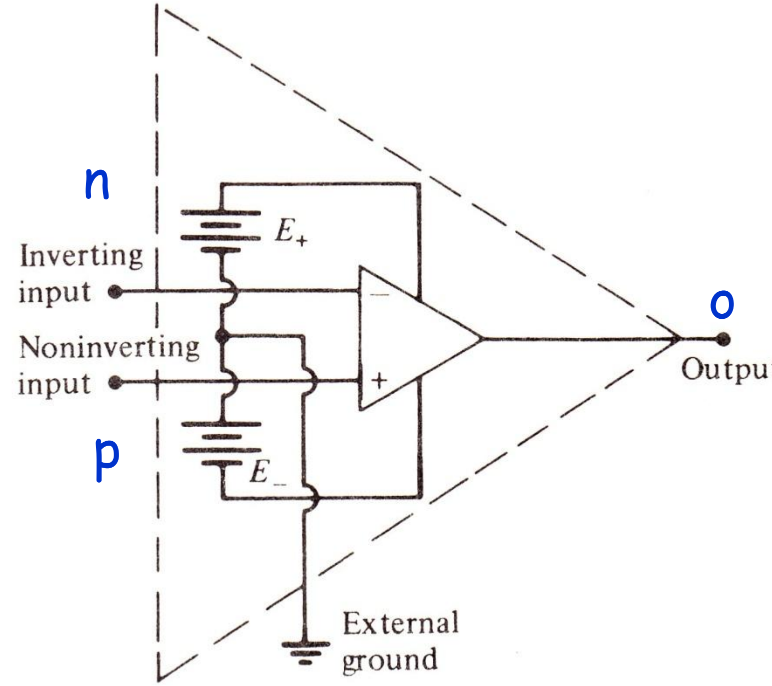


(a)



İşlemsel kuvvetlendirici kaç uçlu eleman?

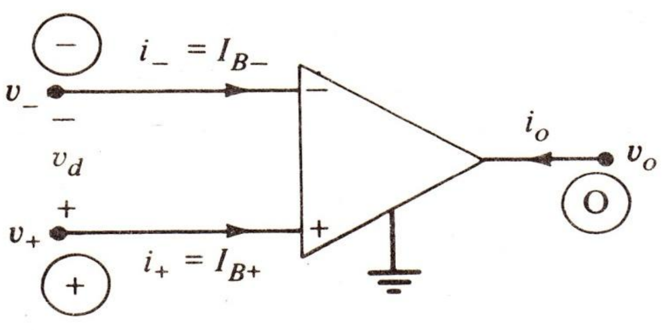
Baz akımları

Bipolar (μA741)	FET (μA740)
~0,2mA	~0,1nA

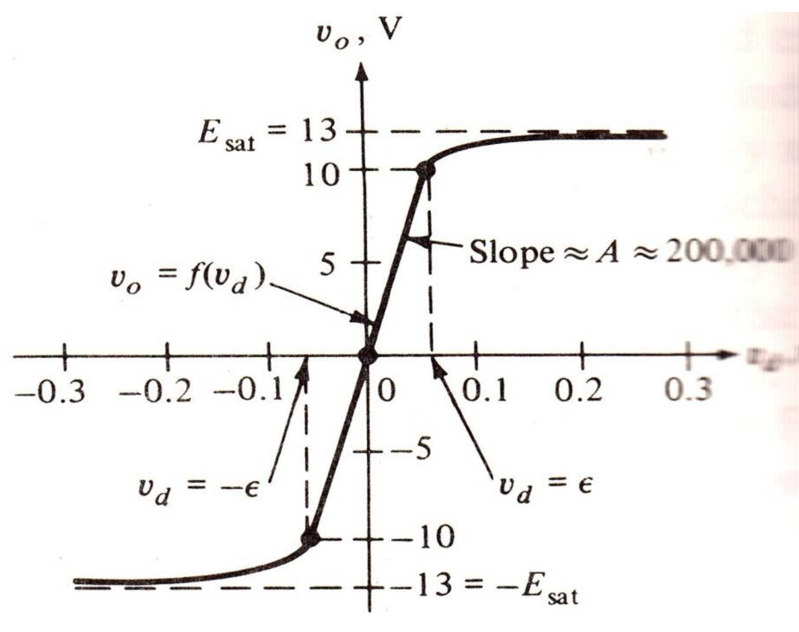
$$i_n = I_{B_n}$$

$$i_p = I_{B_p}$$

$$v_o = f(v_d)$$



(a)



(b)

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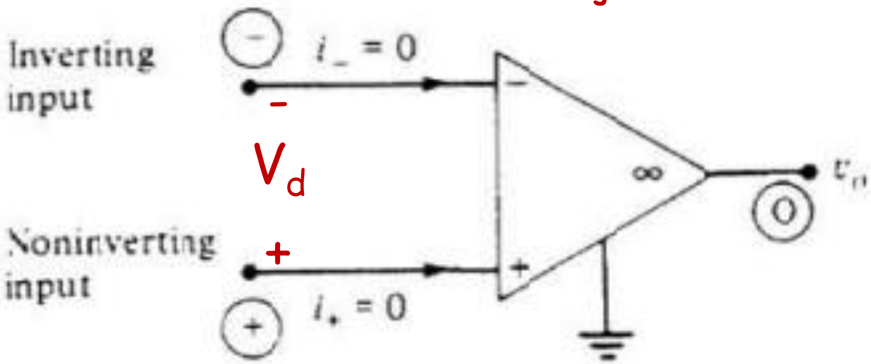
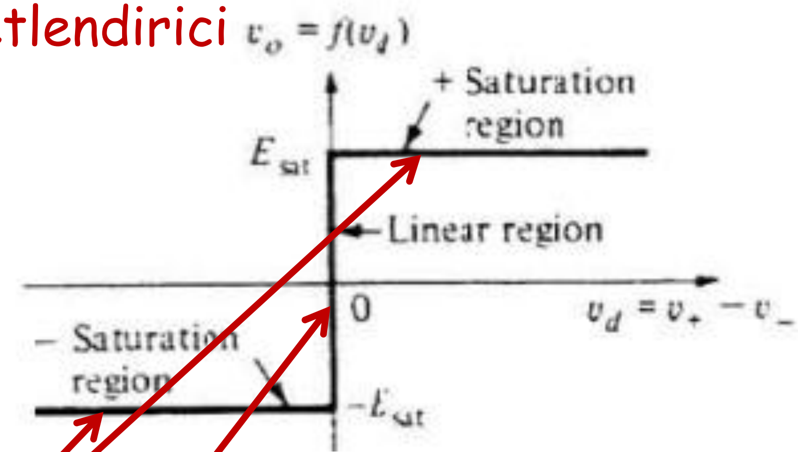
İdeal İşlemsel Kuvvetlendirici





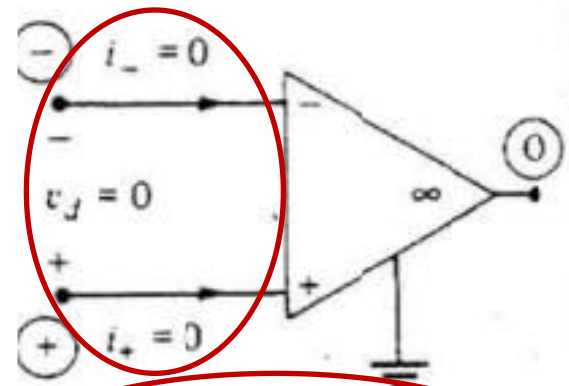
$$i_n = 0$$

$$i_p = 0$$

$$v_o = E_{sat}\frac{|v_d|}{v_d}, \quad v_d \neq 0$$

$$-E_{sat} < v_0 < E_{sat}$$

Lineer çalışma bölgesi



$-E_{sat} < v_o < E_{sat}$

(c) Equivalent circuit for linear region

$$i_n = 0$$

$$i_p = 0$$

$$v_p - v_n = 0$$

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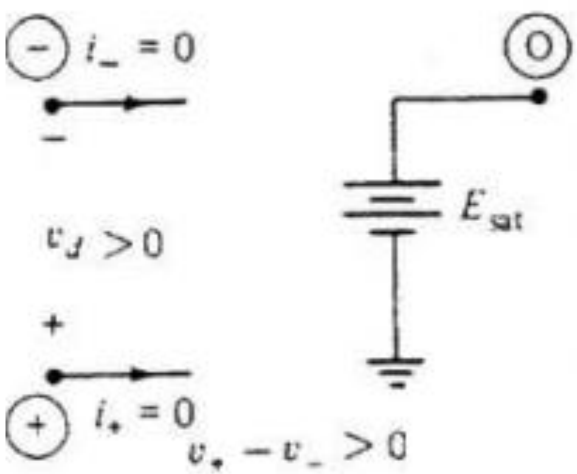
Pozitif Doyma bölgesi



(d) Equivalent circuit
for + Saturation region

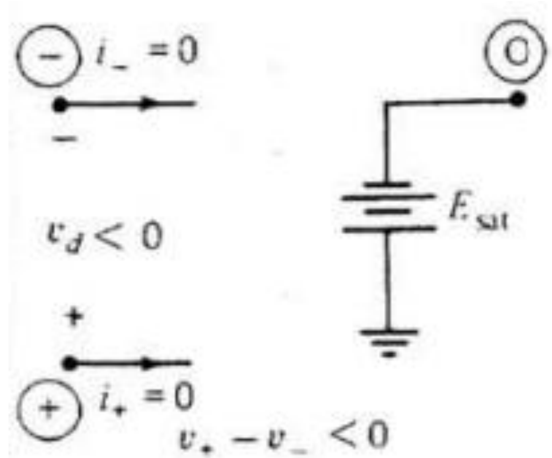
$$v_d = v_p - v_n > 0$$

$$\begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 0 \end{bmatrix} \begin{bmatrix} i_p \\ i_n \\ i_o \end{bmatrix} + \begin{bmatrix} 0 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} v_p \\ v_n \\ v_o \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \\ E_{sat} \end{bmatrix}$$

Negatif Doyma bölgesi

$$v_d = v_p - v_n < 0$$

$$\begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 0 \end{bmatrix} \begin{bmatrix} i_p \\ i_n \\ i_o \end{bmatrix} + \begin{bmatrix} 0 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} v_p \\ v_n \\ v_o \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \\ -E_{sat} \end{bmatrix}$$



(e) Equivalent circuit
for − Saturation region

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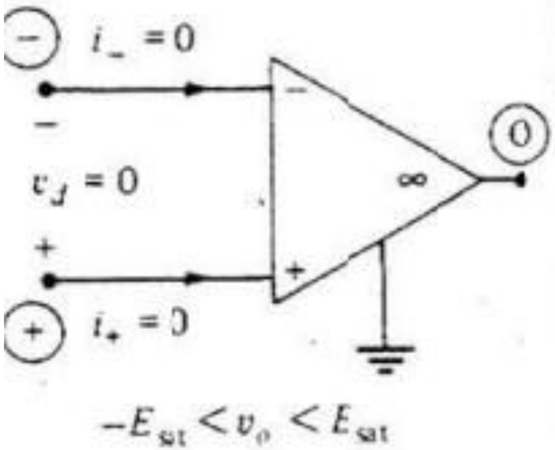
Lineer çalışma bölgesi



(c) Equivalent circuit for linear region

$$-E_{sat} < v_o(t) < E_{sat}, \quad \forall t$$

$$i_n = 0$$

$$i_p = 0$$

$$v_p - v_n = 0$$

$$\begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 0 \end{bmatrix}\begin{bmatrix} i_p \\ i_n \\ i_o \end{bmatrix} + \begin{bmatrix} 0 & 0 & 0 \\ 0 & 0 & 0 \\ 1 & -1 & 0 \end{bmatrix}\begin{bmatrix} v_p \\ v_n \\ v_o \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \\ 0 \end{bmatrix}$$

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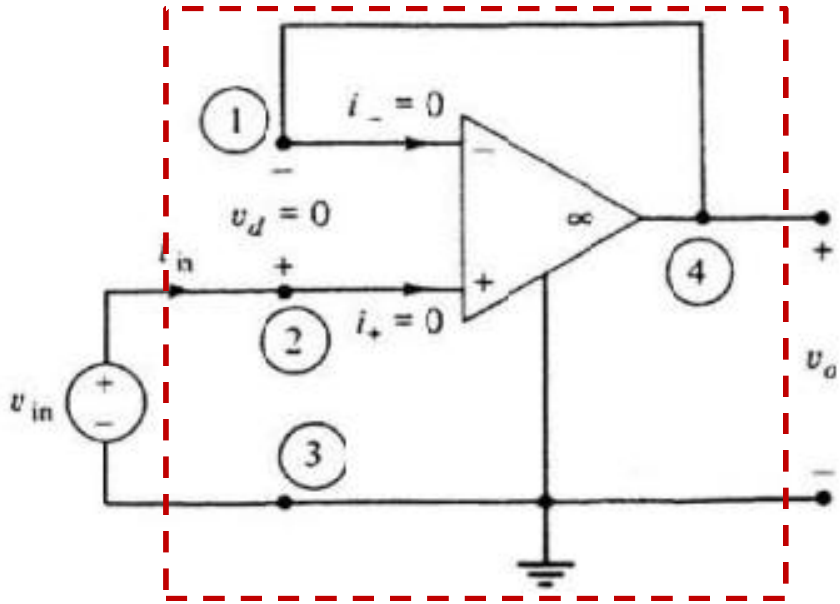
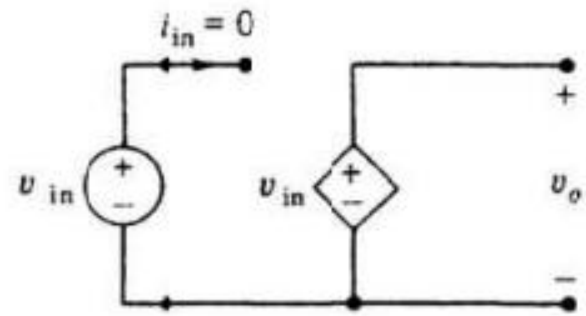
Lineer çalışma bölgesi için bazı uygulamalar

Bufer(Gerilim İzleyici)

Amaç: Çıkıştaki yük ne olursa olsun, çıkışdaki gerilim girişdeki gerilime eşit olsun. Çıkışa bağlı devre girişi etkilemesin.





Gerilim kontrollü gerilim kaynağı $\quad v_o = v_{in}$

2. Düğüm için KAY $\quad i_{in} = i_p$

\+

Eleman tanım bağıntısı $\quad i_p = 0$

$$i_{in} = 0$$

4-3-2-1-4 için KGY $\quad v_{43} + v_{32} + v_{21} + v_{14} = 0$

\+

Eleman tanım bağıntısı $\quad v_o + (-v_{in}) + v_d = 0$

$$v_d = 0$$

$$v_o = v_{in}$$

Geçerli olduğu gerilim aralığı

$$-E_{sat} < v_{in} < E_{sat}$$

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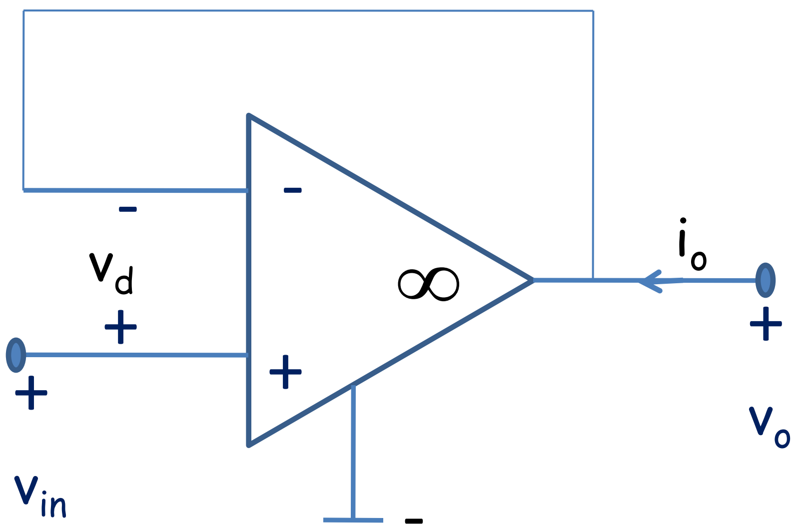
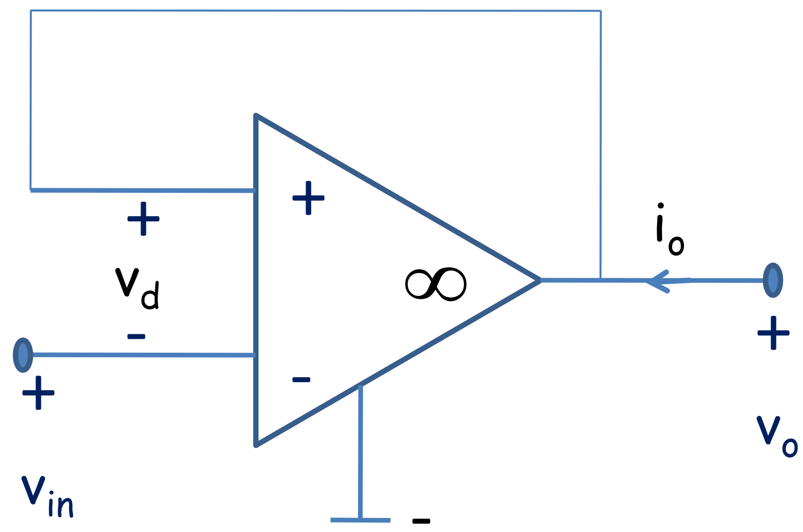
Negatif-Pozitif Geribesleme Devreleri





Lineer bölgede $|v_{in}| < E_{sat}$

$$v_d = v_p - v_n = 0$$

$$v_p = v_{in}$$

$$v_n = v_o$$

$$v_o = v_{in}$$

Lineer bölgede $|v_{in}| < E_{sat}$

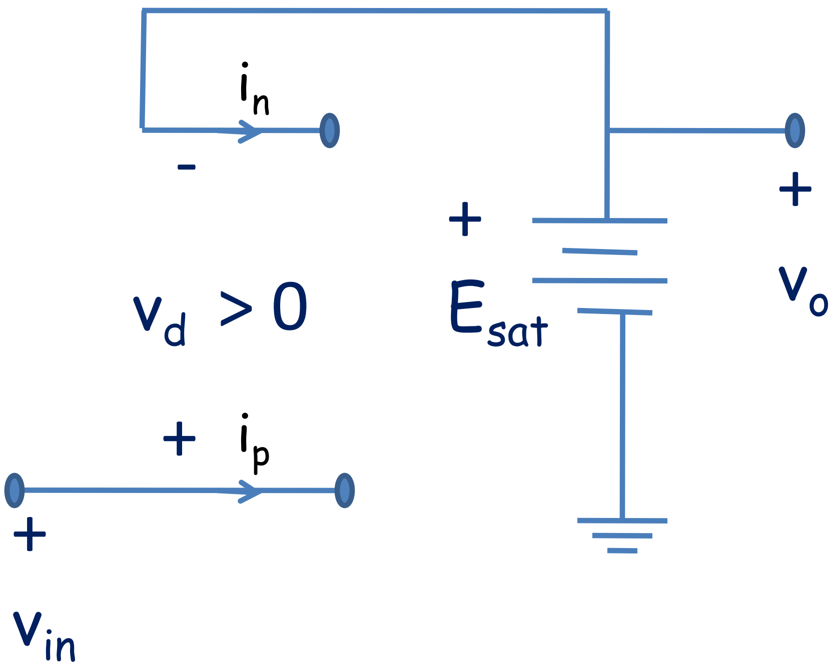
$$v_d = v_p - v_n = 0$$

$$v_p = v_o$$

$$v_n = v_{in}$$

$$v_o = v_{in}$$

\+ Doyma Bölgesinde $v_d > 0$



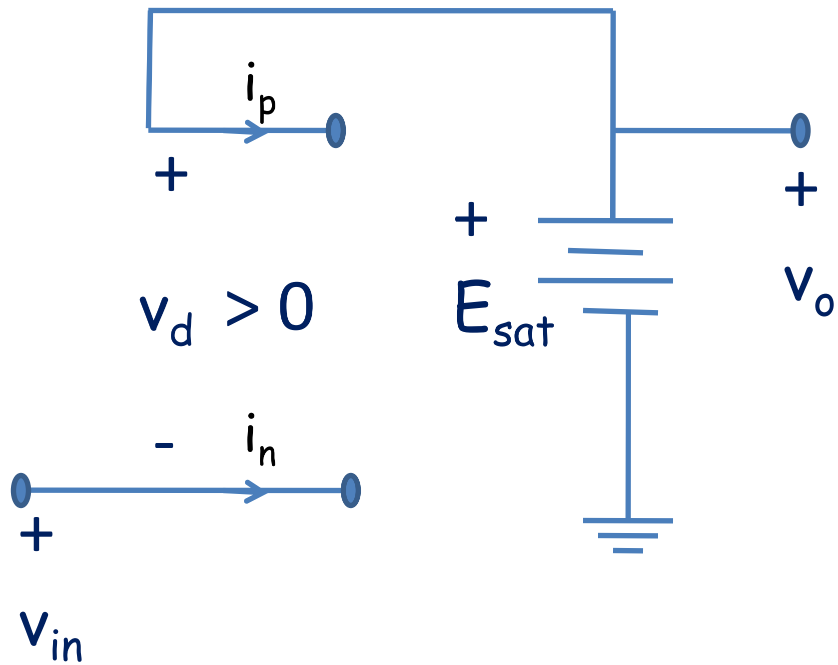
$$v_d = v_p - v_n > 0$$

$$v_p = v_{in}$$

$$v_n = E_{sat}$$

$$v_{in} > E_{sat}$$

\+ Doyma Bölgesinde $v_d > 0$



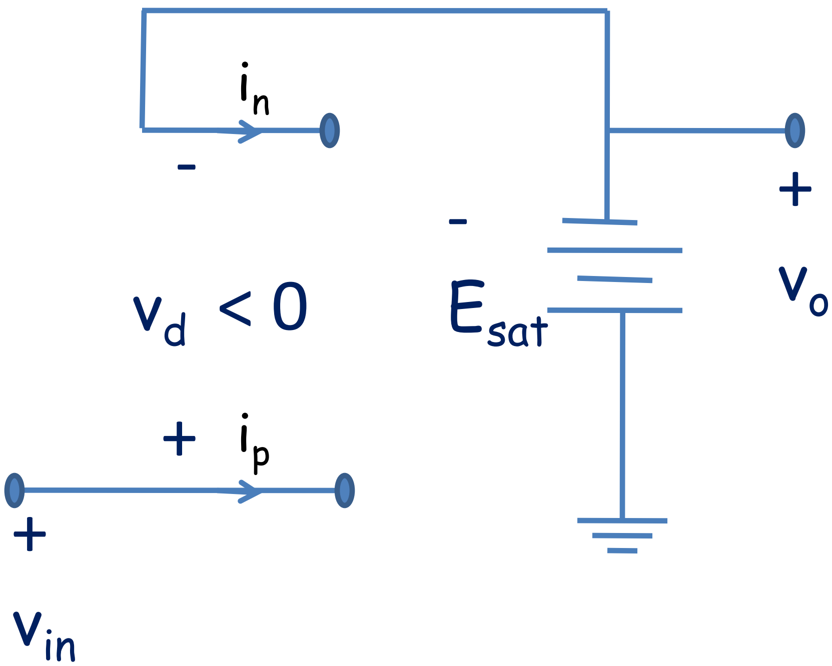
$$v_d = v_p - v_n > 0$$

$$v_p = E_{sat}$$

$$v_n = v_{in}$$

$$v_{in} < E_{sat}$$

- Doyma Bölgesinde $v_d < 0$



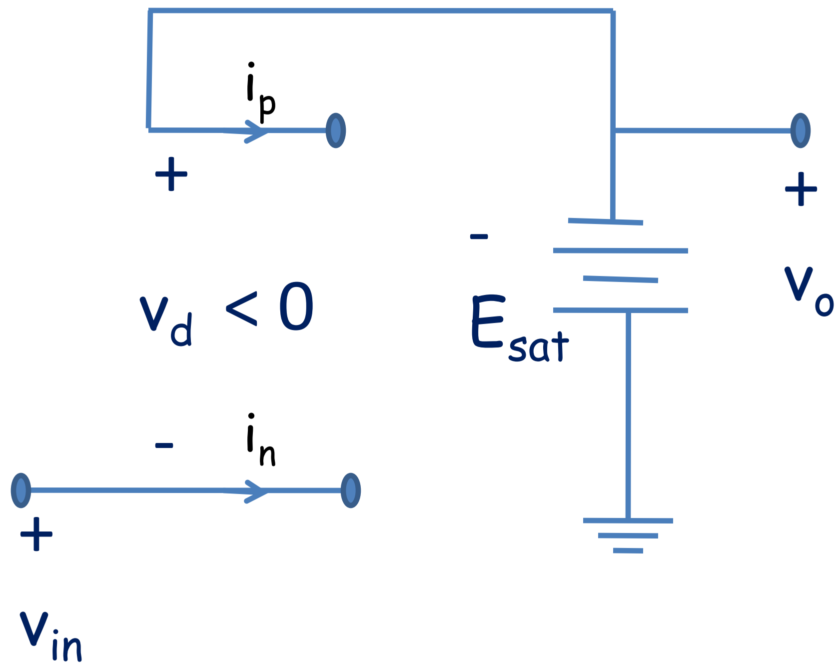
$$v_d = v_p - v_n < 0$$

$$v_p = v_{in}$$

$$v_n = -E_{sat}$$

$$v_{in} < -E_{sat}$$

- Doyma Bölgesinde $v_d < 0$



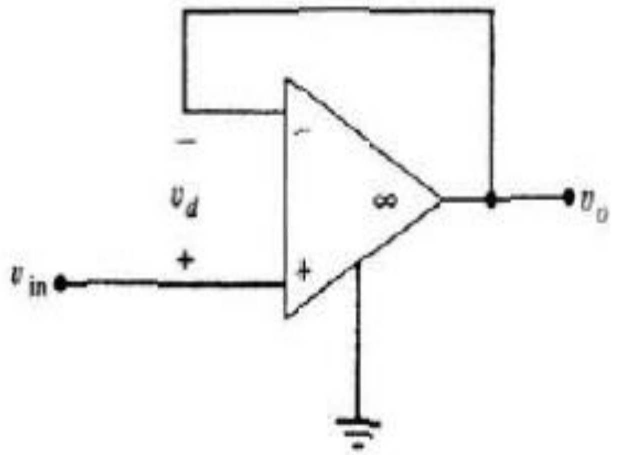
$$v_d = v_p - v_n < 0$$

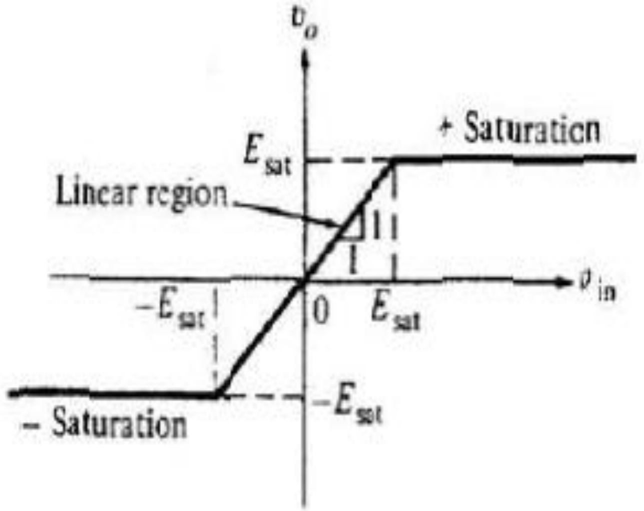
$$v_p = -E_{sat}$$

$$v_n = v_{in}$$

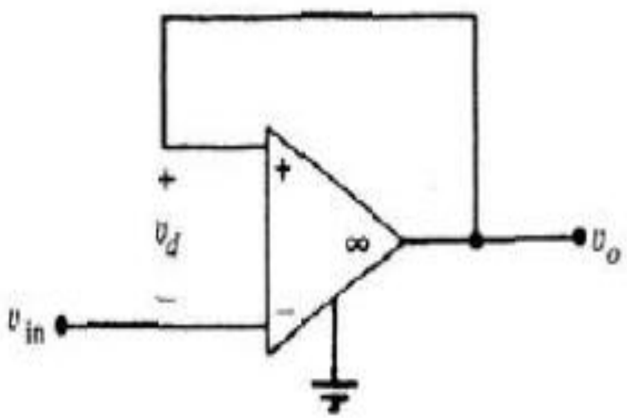
$$v_{in} > -E_{sat}$$

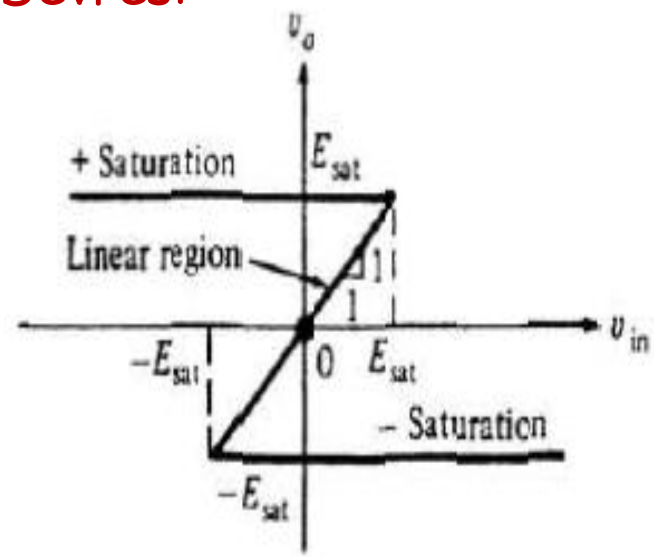
Negatif Geribesleme Devresi





Pozitif Geribesleme Devresi





L.O. Chua, C.A. Desoer, S.E. Kuh. “Linear and Nonlinear Circuits” Mc.Graw Hill, 1987, New York

Lineer Direnç Devreleri

Lineer, zamanla değişmeyen direnç elemanları

Bağımsız kaynaklar

<u>Amaç:</u> Özel bir grup direnç elemanlarından oluşmuş devrelerin çözümü için yöntem geliştirmek

<u>Yararlanılacaklar:</u>

KAY	$Ai = 0$	$n_d - 1$
KGY	$Bv = 0$	$n_e - n_d + 1$
ETB	$Mv + Ni = w$	n_e

<u>Belirlenmesi gereken büyüklükler:</u> v, i $\quad 2n_e$

Genelleştirilmiş Düğüm Gerilimleri Yöntemi

$$v = A^T e$$

Bu denklem ne söylüyor?

Düğüm gerilimleri $\xrightarrow{v = A^T e}$ Tüm eleman gerilimleri

$\downarrow$ $Mv + Ni = w$

Tüm eleman akımları

Özel Durum: lineer, zamanla değişmeyen iki uçlu direnç elemanları ve bağımsız akım kaynaklarının bulunduğu devreler.

Yararlanılacaklar:

KAY $Ai = 0$

KGY $v = A^T e$

ETB $Mv + Ni = w$ $\quad i = G_d v + i_k$

Yöntem:

1. Adım: $n_d - 1$ düğüm için KAY'nı yaz $Ai = 0$

2. Adım: eleman tanım bağıntılarını yerleştir $Ai = 0$

$$A[G_d v + i_k] = 0$$

$$AG_d v + Ai_k = 0$$

$$AG_d v = -Ai_k$$

3. Adım: eleman gerilimlerini düğüm gerilimleri cinsinden yaz

$$v = A^T e$$

$$AG_d A^T e = -Ai_k$$

4. Adım: düğüm gerilimlerini bul

$$\hat{G}_d e = i_b$$

Genel Durum: lineer, zamanla değişmeyen gerilim kontrollü direnç elemanları
bağımsız akım kaynakları Birinci grup elemanlar

lineer, zamanla değişmeyen akım kontrollü direnç elemanları
bağımsız gerilim kaynakları İkinci grup elemanlar
bağımsız gerilim kaynakları

Yöntem:

1. Adım: $n_d - 1$ düğüm için KAY'nı yaz

$$Ai = 0$$

$$\begin{bmatrix} A_1 & A_2 \end{bmatrix} \begin{bmatrix} i_1 \\ i_2 \end{bmatrix} = 0$$

2. Adım: 1. grup elemanların eleman tanım bağıntılarını yerleştir,
2. grup elemanların eleman tanım bağıntılarını yaz.

$$\begin{bmatrix} A_1 G_1 & A_2 \end{bmatrix} \begin{bmatrix} v_1 \\ i_2 \end{bmatrix} = -A_1 i_k \qquad \begin{bmatrix} M & N \end{bmatrix} \begin{bmatrix} v_2 \\ i_2 \end{bmatrix} = w$$

3. Adım: eleman gerilimlerini düğüm gerilimleri cinsinden yaz

$$v_1 = A_1^T e \qquad v_2 = A_2^T e$$

$$\begin{bmatrix} A_1 G_1 A_1^T & A_2 \\ M A_2^T & N \end{bmatrix} \begin{bmatrix} e \\ i_2 \end{bmatrix} = \begin{bmatrix} -A_1 i_k \\ w \end{bmatrix}$$

4. Adım: düğüm gerilimlerini ve ikinci grup elemanların akımlarını bul