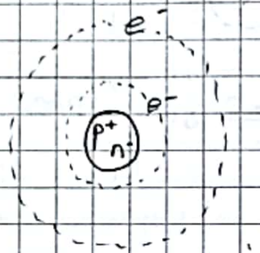
Furkan EKİCİ - 2017555017

ELECTRONICS

Fundamentals of Semiconductors

Bohr's Atom Model:



Yarı iletkenler

- Si (Silisyum, Silikon)
- Ge (Germanyum)
- GaAs (Galyum Arsenik)

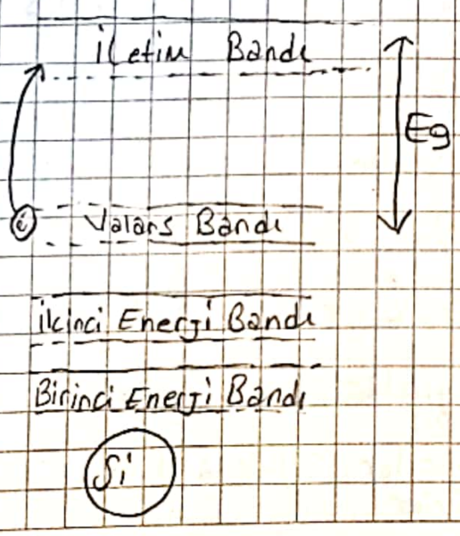
* Son yörüngeye valans bandı denir.

Yarı iletkenler (Semiconductors): Valans bandında 4 elektron bulunduran elementler yarı iletkendir. İyi bir iletken veya yalıtkan değildirler.

İletkenler (Conductors): Valans bandında 1 elektron bulunduran elementler iletkendir.

Yalıtkanlar (Insulators): Valans bandında çok sayıda elektron bulunduran elementler yalıtkandır.

Energy Bands:



* Elektronun iletim bandına geçmesi için gerekli enerji:

- Si → 1,1 eV
- Ge → 0,67 eV
- GaAs → 1,41 eV

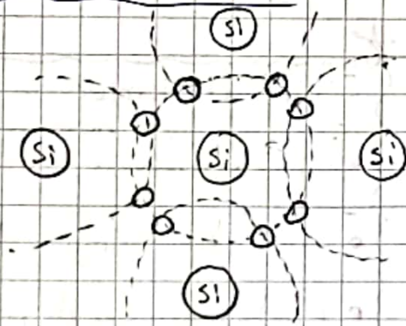
} Energy gap. (Enerji aralığı)

! Yalıtkanlar için: Eg > 5eV olmalı.

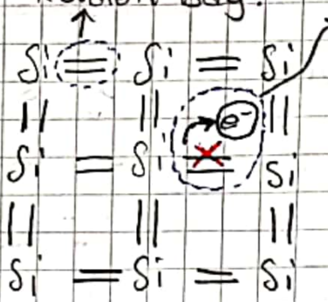
! İletkenler için: Enerji vermeye gerek yok

CamScanner ile tarandı

Covalent Bands:



Kovalent Bağ.



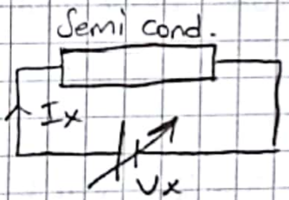
Işık verilirse bağ kopar ve e^- serbest kalır. (free electron). Kopan bağın olduğu kısma da oyuk (hole) denir.

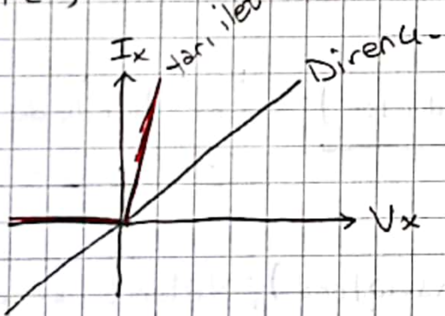
! Sadece valans bantları çizildi.

★ Oyuklara yük taşıyıcı da denir. "+" yükü taşıyor gibi görünür.

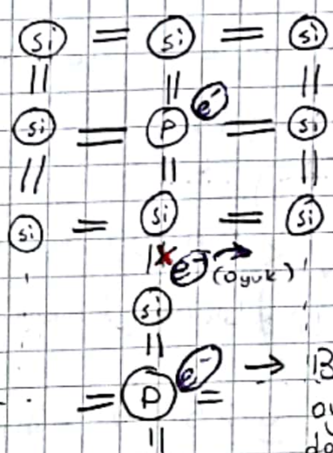
★ Saf yarı iletkenlerde oyuk sayısı, serbest elektron sayısına eşittir. $\left(\underset{(\text{oyuk})}{p} = \underset{(\text{Serbest } e^-)}{n} \right)$

Saf yarı iletkenlerde:





Doping (katkılama):



→ Bu e^- oyuğu doldurabilir.

n-type semiconductor.

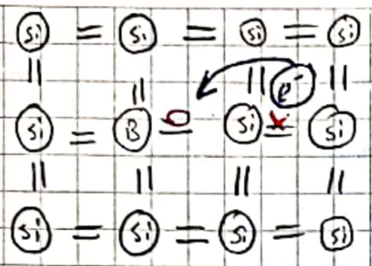
★ Katkılama ne kadar fazla olursa iletkenlik artar. Çünkü "P" atomu kadar serbest e^- olur.

★ Son yörüngesinde (valans bandı) 5 elektron bulunduran "P" gibi bir element katkılama malzemesi olarak kullanılır. (n-type).

★ Çoğunluk taşıyıcılar serbest elektronlardır. (Majority carrier)

★ Azınlık taşıyıcılar oyuklardır. (Minority carrier).

! Net yük sıfırdır. Çünkü e^-, malzemenin dışına çıkmıyor.



★ Kopan bağdan çıkan serbest elektronlar oyukların yerini doldurabilir.

★ Son yörüngesinde 3 elektron bulunduran "B" gibi bir element katkılama malzemesi olarak kullanılabilir.

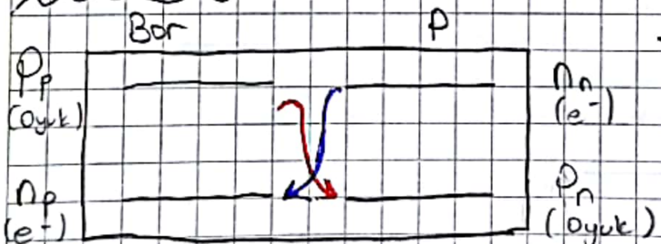
p- type semi conductor

★ Çoğunluk taşıyıcılar oyuklardır.

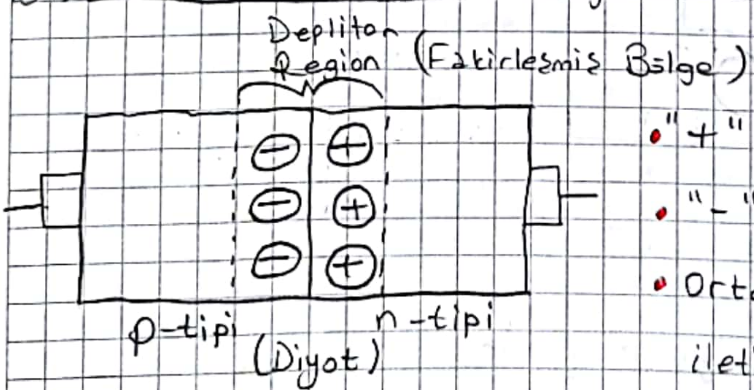
★ Azınlık taşıyıcılar serbest elektronlardır.

III	IV	V
B		
	Si	P
	Ge	

P-N Junction:



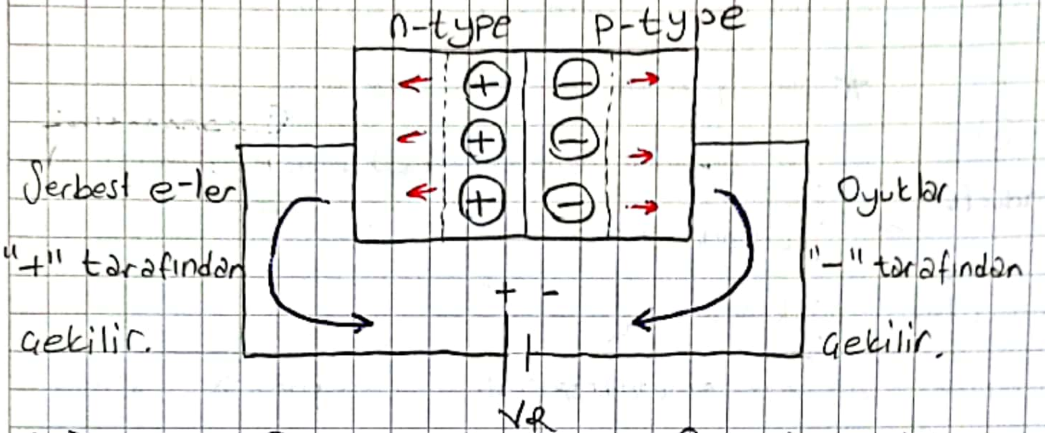
★ n-tipindeki elektronlar p-tipine, p-tipindeki oyuklar n-tipine geçer



- "+"lar oyukları itti.
- "-"ler elektronları itti.
- Orta bölgede (Depletion Region) iletim yoktur.

Denge Durumu.

Reverse Biasing (Ters Kutuplama):

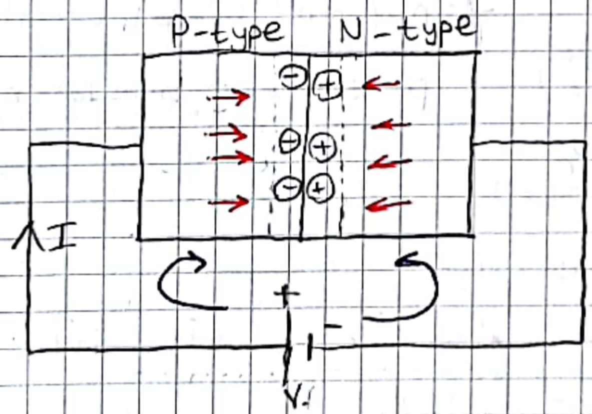


★ Depletion Region (Fakirleşmiş Bölge) genişler.

★ Malzemenin "N" kısmına "P" kısmından daha çok gerilim uygulandığı durumdur.

★ Neredeyse jonksiyonda akım akmaz.

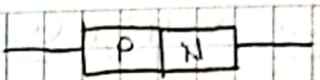
Forward Biasing (İleri Yönlü Kutuplama):



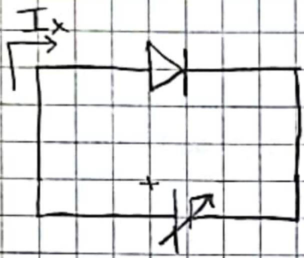
★ Deplition Region daralır.

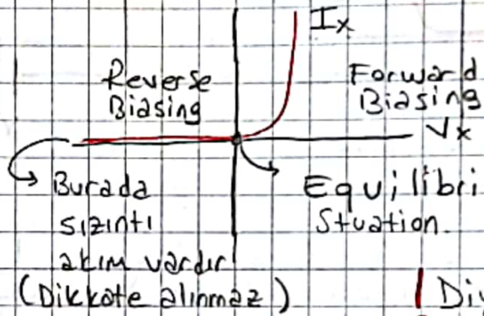
★ Elektronlar akabilecek seviyeye gelir.

Diode (Diyot):



(ikiside aynı)





Exponantial Model of Diode

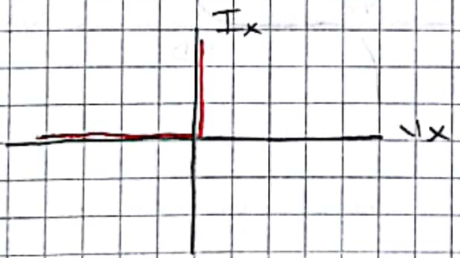
! Diyot normalde böyle davranır

$$I_x = I_S\left(e^{\frac{V_x}{V_T}} - 1\right)$$

I_S = Revers Situation Current.

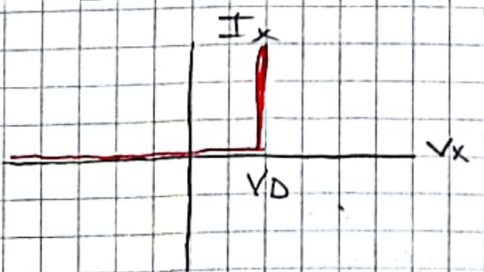
V_t = Thermal Votage (25 °C de, 26 mV)

Ideal Diode Model:



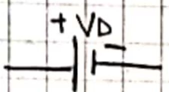
- $V_x > 0 \Rightarrow$ Diyot kısa devre gibi davranır. (tel gibi)
- $V_x < 0 \Rightarrow$ Diyot açık devre gibi davranır. (Akım akmaz).

Piecewise Linear Diode Model:

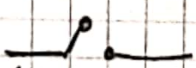


! $V_x = 0$'dan bir süre sonra iletim yapmaya başladığı için bunu çizdik.

- $V_x > V_d \Rightarrow$ Devre



- $V_x < V_d \Rightarrow$ Devre



(Açık Devre)

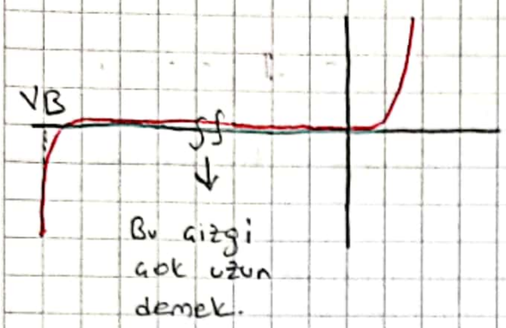
V_D Değeri:

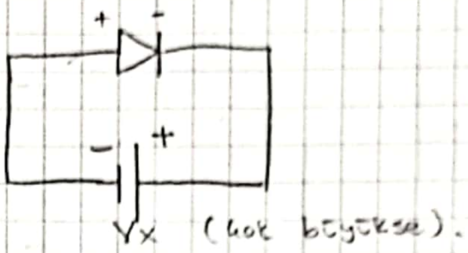
Si → 0,7 V

Ge → 0,3 V

GaAs → 1,2 V

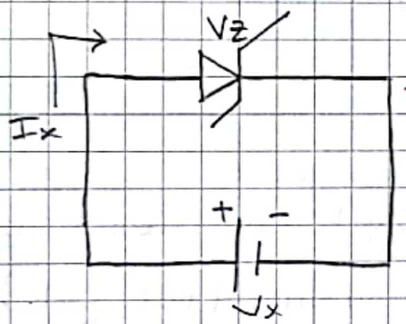
Breakdown Voltage (Kırılma Voltajı):



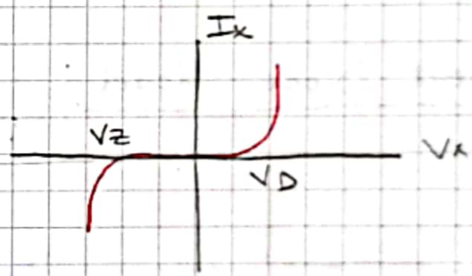


! Ters bağlanan diyota verilen Vx çok büyükse diyot akım iletmeye başlar.

Zener Diode:



! Vz değeri biliniyor.



- $V_x > V_d \Rightarrow$ (+ V_D −)
- $V_Z < V_x < V_D \Rightarrow$
- $V_Z > V_x \Rightarrow$ (− + V_Z) (Akımın yönü değişir)

LED (Light Emiting Diode):

★ Tek yönlü akım geçirirler.

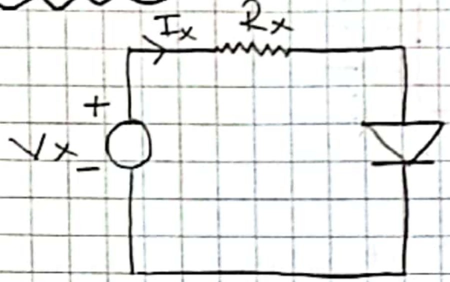
★ Üzerlerinden akım geçince ışık yayarlar.

★ V_D voltajı yaklaşık 1,5 − 2 V civarındadır.

(Normal diyot simgesi üzerine iki ok).

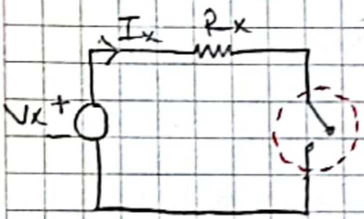
★ İleri yönlü kutuplama vardır.

Example:



1-) Diyot idealse V_x ve I_x grafiğini çiz.

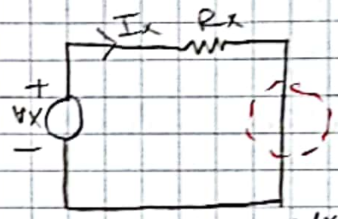
1. durum $V_x < 0$



Diyot açık devre gibi davranır.

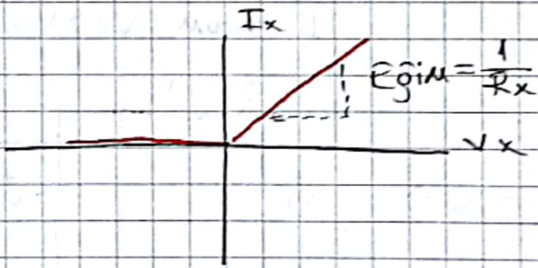
$I_x = 0$

2. durum $V_x > 0$



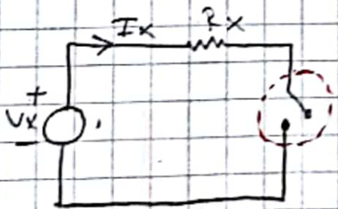
Diyot düz tel gibi davranır.

$I_x = \frac{V_x}{R_x}$



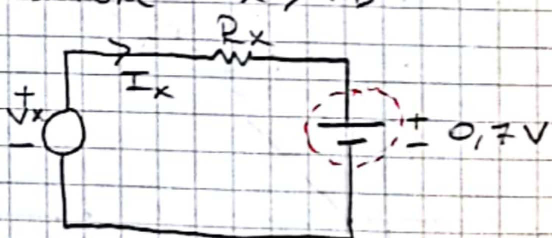
2-) Diyot ideal değilse $V_D = 0{,}7\,V$ için çöz.

1. durum $V_x < V_D$

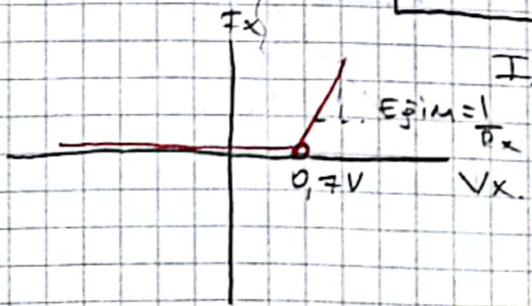


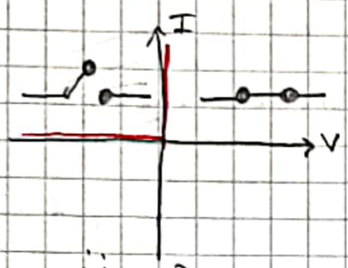
$I_x = 0$

2. durum $V_x > V_D$

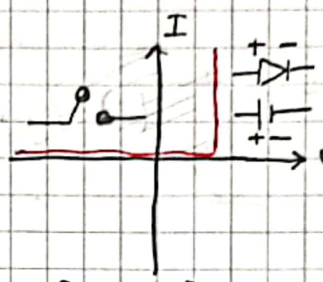


$I_x = \frac{V_x - 0{,}7}{R_x}$



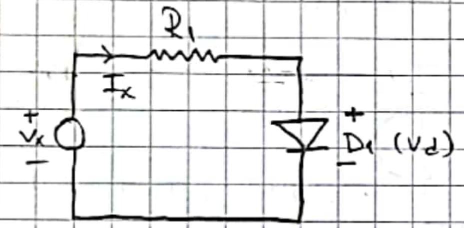


İdeal Diyot



Parçalı Diyot

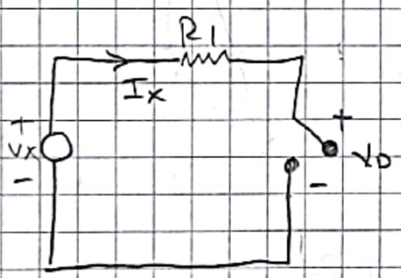
Example:



D_1 = Silisyum
$V_{D,on} = 0{,}7\,V$

$I_x - V_x$ grafiğini,
$V_D - V_x$ grafiğini,
$I_D - V_D$ grafiğini çiz.

I. durum $V_x < V_{D,on}$ ise



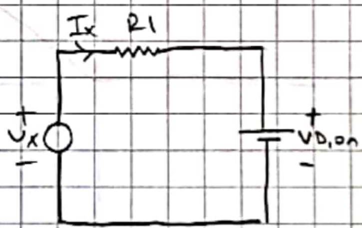
$I_x = 0$

$I_x = 0$ ise $\Rightarrow$

$V_{R1} = 0$'dır,

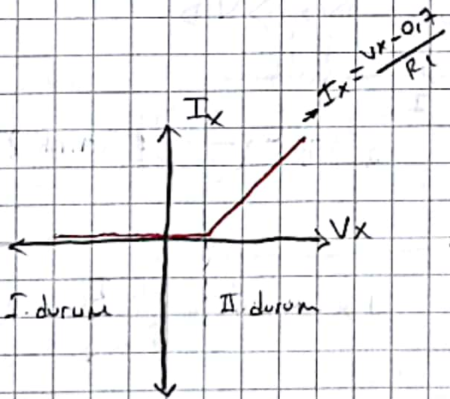
$V_D = V_x$

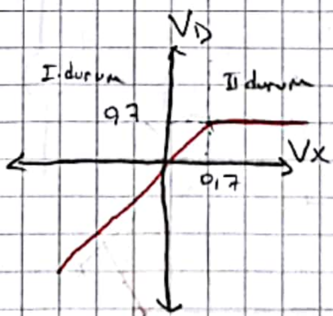
II. durum $V_x > V_{D,on}$ ise

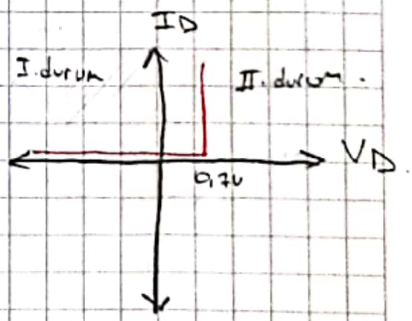


$$I_x = \frac{V_x - V_{D,on}}{R_1}$$

$$\boxed{I_x = \frac{V_x - 0{,}7V}{R_1}}$$



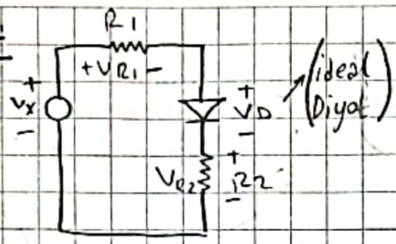




V_D 0,7'nin üzerine çıkamadığı için

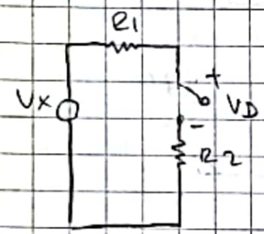
★ I_x grafiğini sorarsa mutlaka diyot durumlarına göre I_x denklemini yazılır aşağıdaki soru gibi)

Example:



$V_{R1} - V_x$
$V_{R2} - V_x$
$V_D - V_x$
} grafiklerini çiziniz.

I. durum $V_x < V_{D on}$ ise

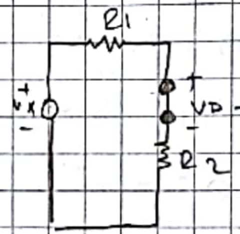


$I_x = 0$ olduğunda

$V_{R1} = 0$, $V_{R2} = 0$

$V_D = V_x$

II. durum $V_x > V_{D on} \stackrel{=0}{}$ ideal diyot



$V_D \rightarrow$ ideal olduğu için

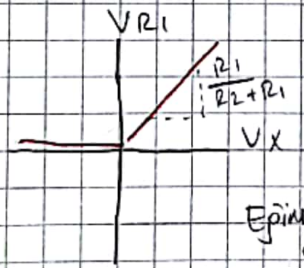
$V_D = 0$

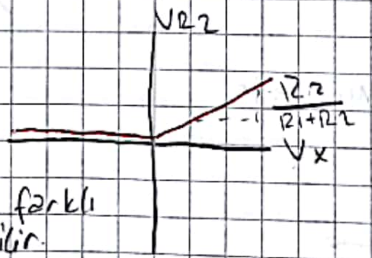
$I_x = \frac{V_x}{R_1 + R_2}$

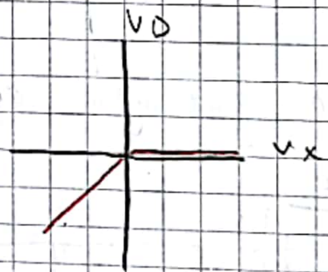
$V_{R1} = I_x \cdot R_1$ ise

$V_{R1} = V_x \cdot \frac{R_1}{R_1 + R_2}$

$V_{R2} = V_x \cdot \frac{R_2}{R_1 + R_2}$

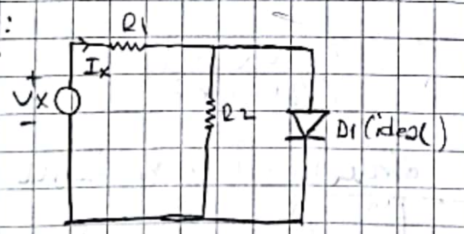






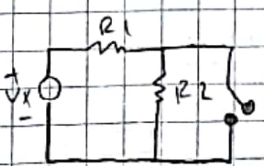
Eğimleri farklı olabilir.

Example:



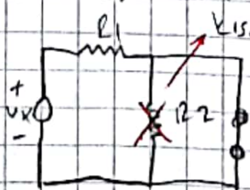
$I_x - V_x$ grafiğini çiz.

I. durum $V_x < 0$



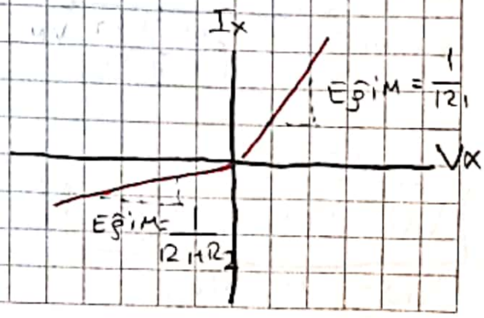
$I_x = \frac{V_x}{R_1 + R_2}$

II. durum $V_x > 0$

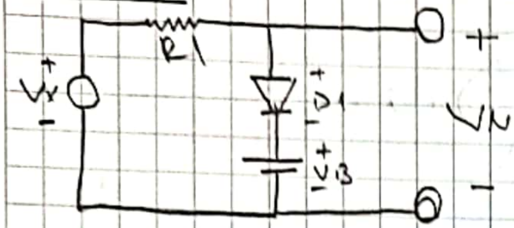


kısa devre (Short circuit)

$I_x = \frac{V_x}{R_1}$



Example:

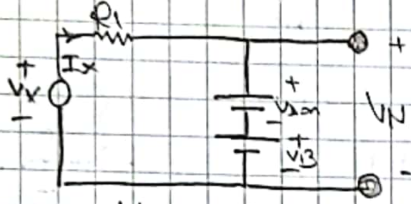


$I_x - V_x$ }
$V_N - V_x$ } Grafiğini çiziniz.

(Constant Diode Model)

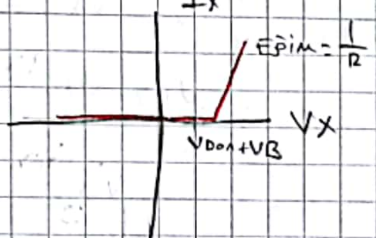
I. durum $V_x > V_{D,on} + V_B$

Forward Biasing

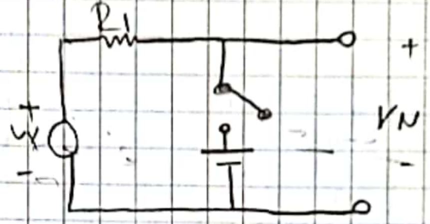


$I_x = \dfrac{V_x - V_{D,on} - V_B}{R1}$

$V_N = V_{D,on} + V_B$

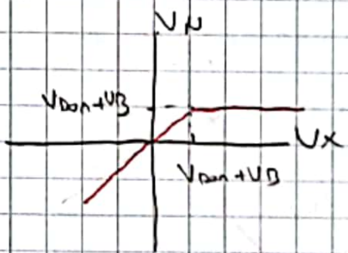


II. durum $V_x < V_{D,on} + V_B$



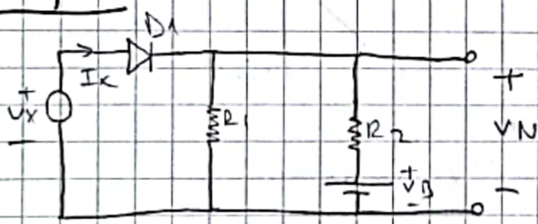
$I_x = 0$

$V_N = V_x$



★ V_x'in katsayısı eğimi verir.

Example:

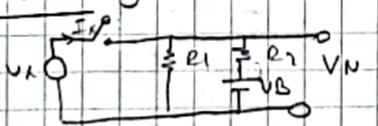


(Constant diode Model)

$I_x - V_x = ?$

$V_N - V_x = ?$

I. durum Diyot ters kutuplanmışsa.



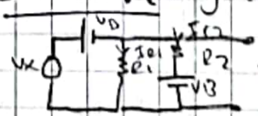
$I_x = 0$

$\boxed{V_N = V_{R1} = \dfrac{V_B}{R1+R2} \cdot R1}$

$V_N = V_B - V_{R2}$

↳ ($V_x < V_N$ olunca geçerli)

II. durum Diyot ileri yönlü kutuplanmışsa



$V_N = V_x - V_{D,on}$

$I_x = I_{R1} + I_{R2}$

$I_{R1} = \dfrac{V_N}{R_1} = \dfrac{V_x - V_{D,on}}{R1}$

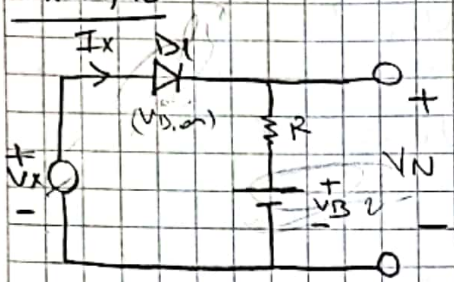
$I_{R2} = \dfrac{V_N - V_B}{R_2} = \dfrac{(V_x - V_{D,on}) - V_B}{R2}$

$$\frac{V_N - V_B}{R}$$

$$I_x = \frac{V_x - V_{D,on} - V_B}{R}$$

$$V_N - V_{D,on} - V_B$$

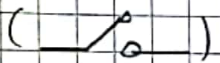
Example:



$\left.\begin{matrix} I_x - V_x \\ V_N - V_x \end{matrix}\right\}$?

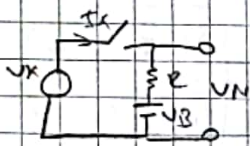
I. durum

$V_x < V_{D,on} + V_B$



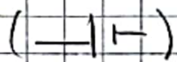
$I_x = 0$

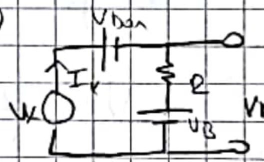
$V_N = V_B$



II. durum

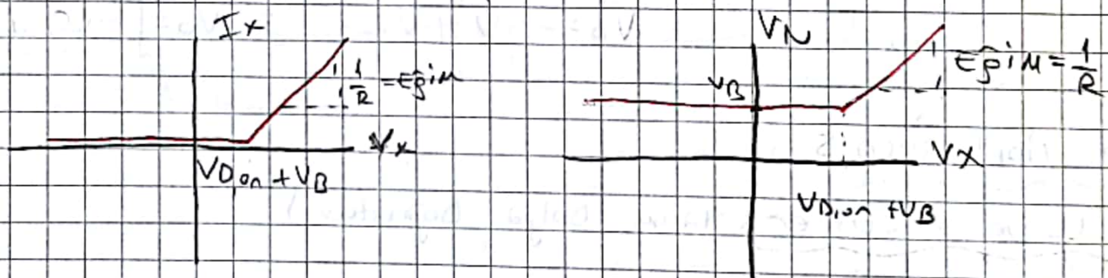
$V_x > V_{D,on} + V_B$



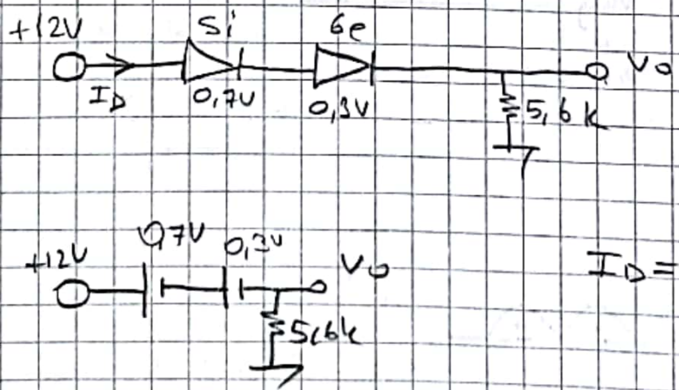


$$I_x = \frac{V_x - V_{D,on} - V_B}{R}$$

$$V_N = V_x - V_{D,on}$$



Example:



$I_D, V_o = ?$

$V_o = 12 - 0{,}7 - 0{,}3 \Rightarrow \boxed{11V}$

$$I_D = \frac{12V - 0{,}7V - 0{,}3V}{5{,}6k} = \boxed{\frac{11V}{5{,}6k}}$$

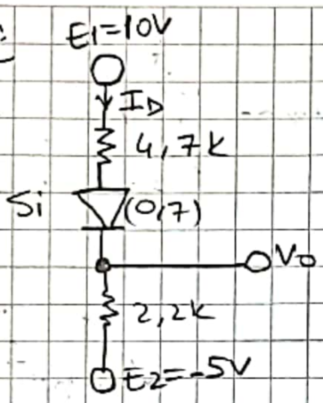
$\Rightarrow I_D \cong 1{,}96\ mA$

↳ kiloohm'a bölündüğü için.

I. 121 $V_o = 10 - 0,7 - 1,5$ $I_D = \frac{14,3}{4,2 - 2,2}$

Vo(4.3)

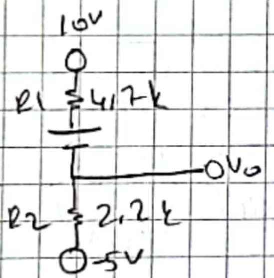
Example:



$I_D = ?$ $V_{R1} = ?$

$V_o = ?$ $V_{R2} = ?$

$\underline{V_D = 0,7\,V}$



$$I = \frac{10V - (-5V) - 0,7V}{4,7k + 2,2k} = \boxed{2,072\,mA}$$

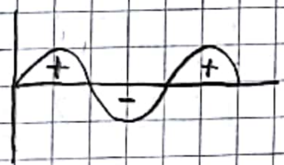
$$V_{R1} = 2,072\,mA \times 4,7k = \boxed{9,738\,V}$$

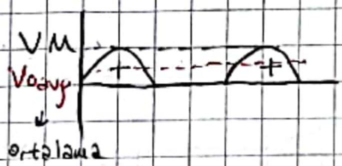
$$V_{R2} = 2,072\,mA \times 2,2k = \boxed{4,558\,V}$$

$$V_o = -5V + V_{R2} \Rightarrow V_o = \boxed{-0,442\,V}$$

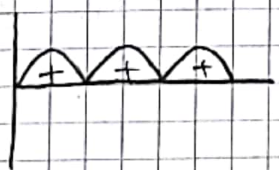
Diode Applications

Half Wave Rectifier (Yarım Dalga Doğrultucu)



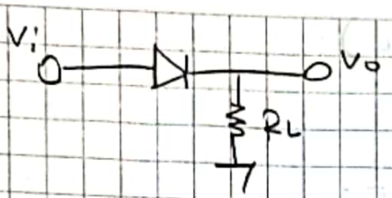


Yarım Dalga Doğrultucu



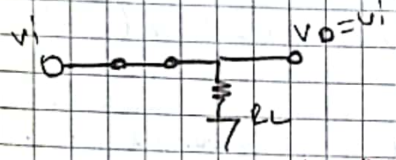
Tam Dalga Doğrultuc

ideal diode

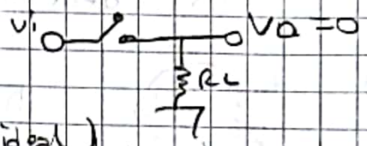


$$V_{OAvg} = \frac{1}{T}\int_0^t V_i(t)\,dt$$

$V_i > 0$ için

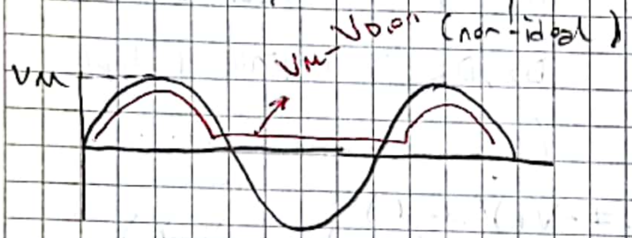


$V_i < 0$ için



$\boxed{\text{ideal}}$

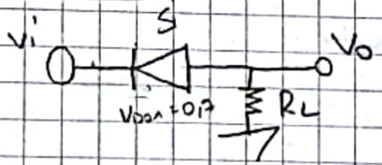
$V_{OAvg} = 0{,}318 \times V_M$



$\boxed{\text{ideal olmayan diyotta}}$

$V_{OAvg} \cong 0{,}318\,(V_M - V_{D,on})$

Example:

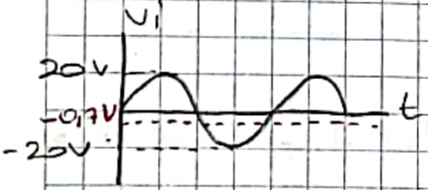


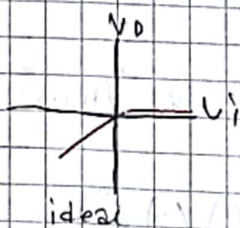
$V_O - V_i = ?$

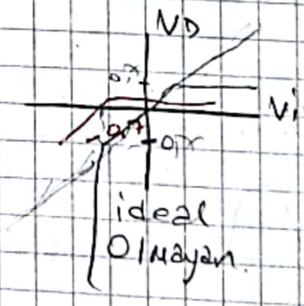
$V_D - V_i = ?$

Vort

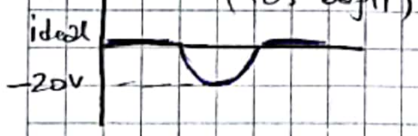
Vi	Diode ideal	Diode non-ideal
20 sin wt	0,318 x VM -0,36 V	0,318 x (VM - 0,7) -6,14 V
200 sin wt	(0,318) x 200 -63,6 V	0,318 x (200 - 0,7) -63,38 V

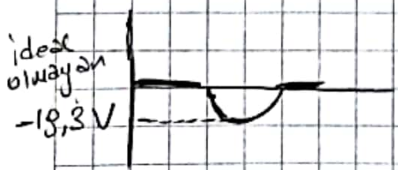






(Ters bağlı)

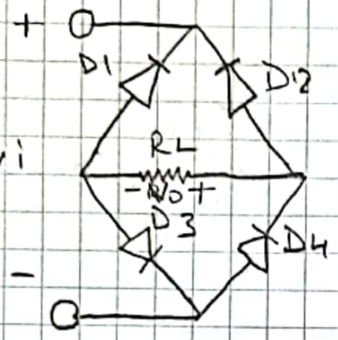




Full Wave Rectifier (Tam Dalga Doğrultucu):

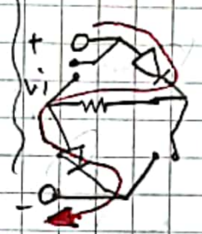
Negatifteki işareti pozitife aktarır.

1-)



I. durum: (ideal, $V_i > 0$)
(non-ideal, $V_i > 2V_{D,on}$)

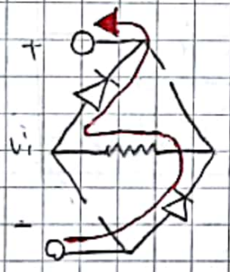
$V_o = V_i$ (ideal diyot), $V_o = V_i - 2V_{D,on}$ (non-ideal diyot)



D1, D4 ters kutuplu.

D2, D3 ileri yönlü kutuplu.

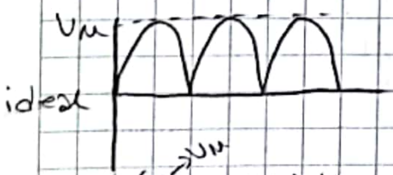
II. durum: (ideal, $V_i < 0$) ($V_o = -V_i$) (ideal)
(non-ideal, $V_i < -2V_{D,on}$) ($V_o = -V_i - 2V_{D,on}$) (non-ideal)

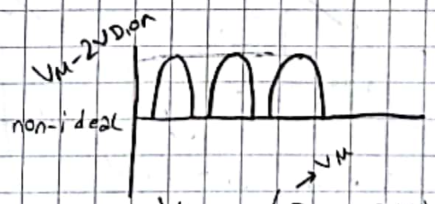


D1, D4 ileri yönlü kutuplu

D2, D3 ters yönlü kutuplu

! Yarım dalga doğrultucuda düşüş $V_{D,on}$ kadar. Burda $2V_{D,on}$ kadar.





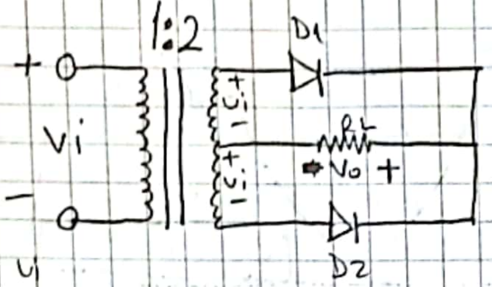
$V_{Avg} = (2 \times 0{,}318) \cdot V_m$

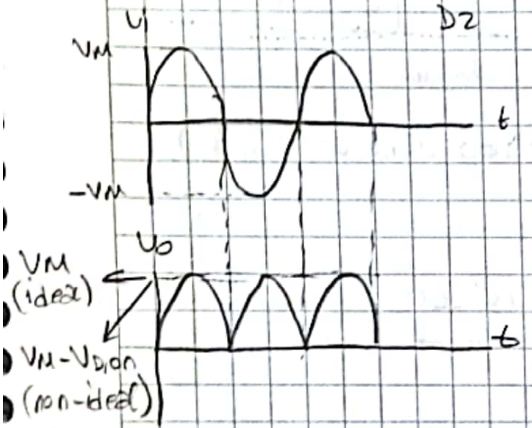
$V_{Avg} = (2 \times 0{,}318)(V_m - 2V_{D,on})$

! $-2V_{D,on} < V_i < +2V_{D,on}$

Hiçbir diyot iletime geçmez.

2-)





$V_i > 0$ için (ideal)

$V_o = V_i$

$V_i > V_D$ için (non-ideal)

$V_o = V_i - V_D$

$V_i < 0$ için (ideal)

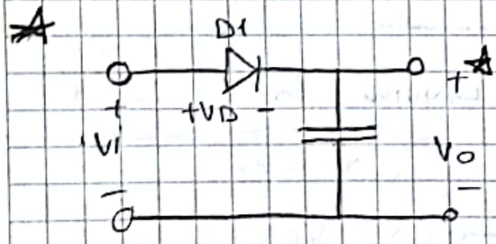
$V_o = -V_i$

$V_i < V_D$ için (non-ideal)

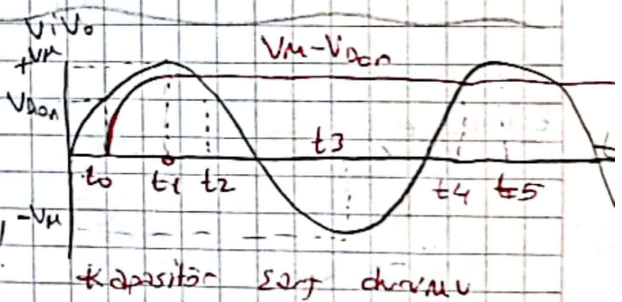
$V_o = -V_i - V_D$

$-V_{Don} < V_i < +V_{Don}$ (non-ideal)

$V_o = 0$



$V_i > V_D$ olunca kapasitör dolmaya başlar!



$V_D = V_i - V_o$

→ $t < t_0$ için ⇒ $V_o = 0$ (diyot kesimde)

→ $t_0 < t < t_1$ için ⇒ $V_o = V_i - V_{Don}$ (diyot iletimde)

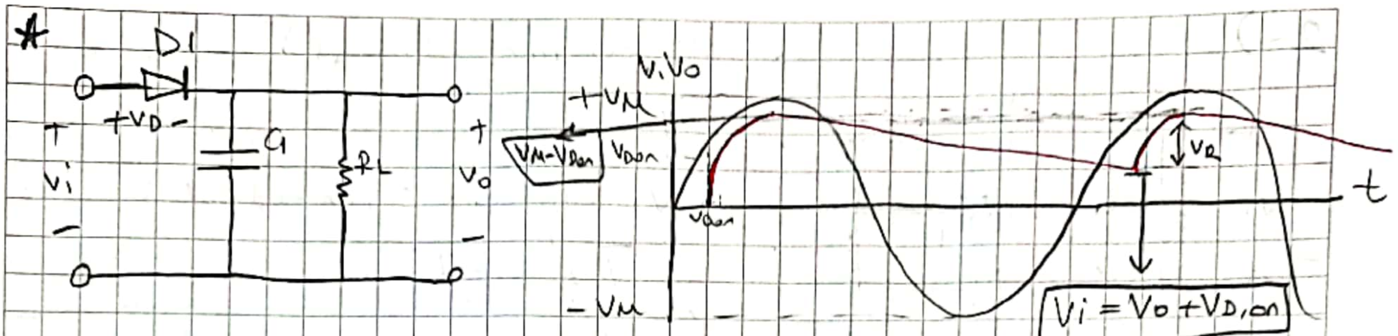
→ $t_1 < t < t_2$ için ⇒ $V_o = V_M - V_{D,on}$ (diyot kesimde) ($V_D < V_{D,on}$ olduğundan)

→ $t_2 < t < t_4$ için ⇒ $V_o = V_M - V_{D,on}$ (diyot kesimde) ($V_D < 0$)

→ $t_4 < t < t_5$ için ⇒ $V_o = V_M - V_{D,on}$ (diyot kesimde) ($V_D < V_{D,on}$)

→ $t = t_5$ için ⇒ $V_o = V_M - V_{D,on}$ (diyot iletimde) (bir anlık)

*



V_R → Ripple

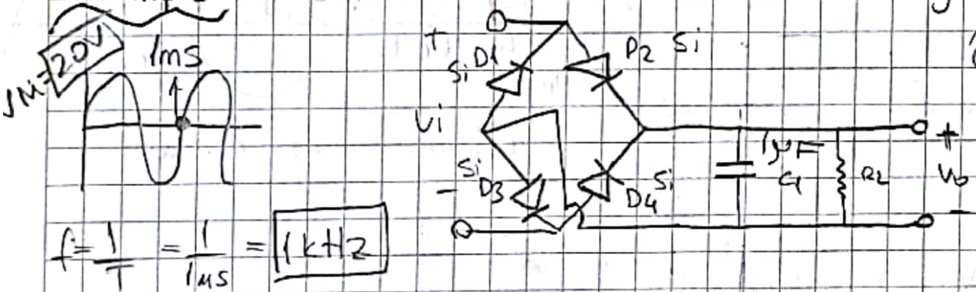
$$V_R = (V_M - V_{D,on}) \cdot \frac{1}{R_L \cdot C_1 \cdot f_{in}}$$ (Yarım Dalga Doğrultucu için)

$$V_R = (V_M - V_{D,on}) \frac{1}{2 \cdot R_L \cdot C_1 \cdot f_{in}}$$ (Tam Dalga Doğrultucu -Transformatörlü-)

$$V_R = (V_M - 2V_{D,on}) \frac{1}{2 \cdot R_L \cdot C_1 \cdot f_{in}}$$ (Tam Dalga Doğrultucu -Köprü Tipi-)

Example:

Diyotlar ideal değil

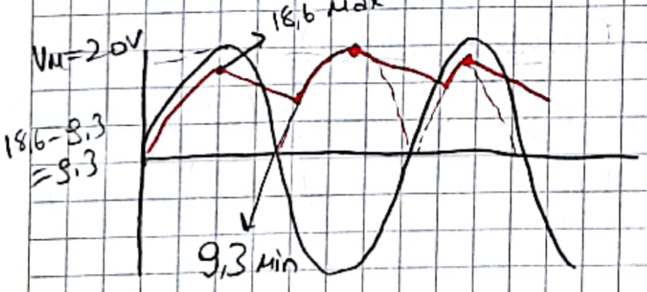


* Ezberle

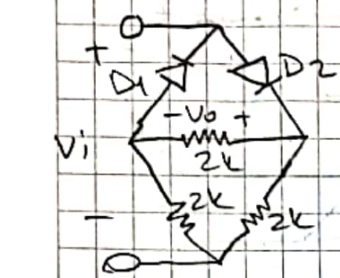
$$V_R = (V_M - 2V_{D,on}) \frac{1}{2 \cdot R_L \cdot C_1 \cdot f_{in}}$$

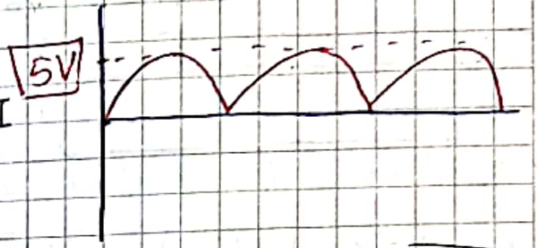
$$f = \frac{1}{T} = \frac{1}{1ms} = \boxed{1kHz}$$

$$V_R = (20 - 2 \cdot (0,7)) \cdot \frac{1}{2 \cdot 10^3 \times 1 \cdot 10^{-6} \times 1 \cdot 10^3} = \frac{18,6}{2} = \boxed{9,3 V}$$



Example: (ideal diyot)



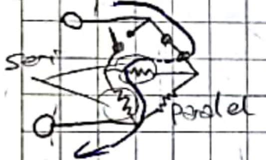


$V_{Avg} = 0{,}636 \times 5V = \boxed{3{,}18\,V}$

V_o-t grafiği = ?

Vi > 0 ise:

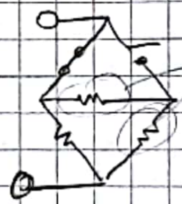
D1 ters kutuplu
D2 ileri yönlü kutuplu.

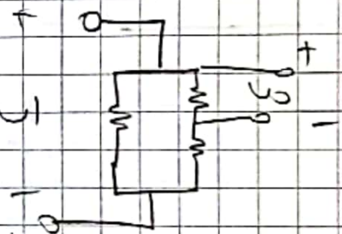


$\boxed{V_o = \frac{V_i}{2}}$

Vi < 0 ise:

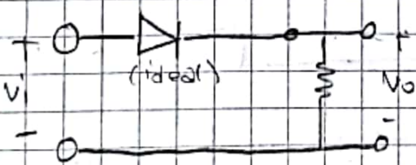
D1 ileri yönlü kutuplu
D2 ters yönlü kutuplu.

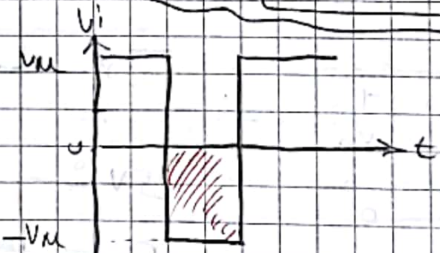


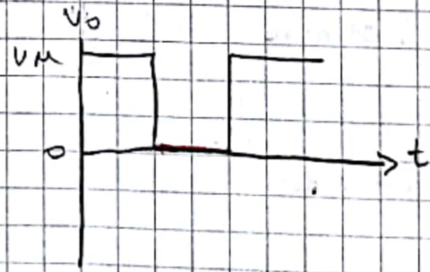


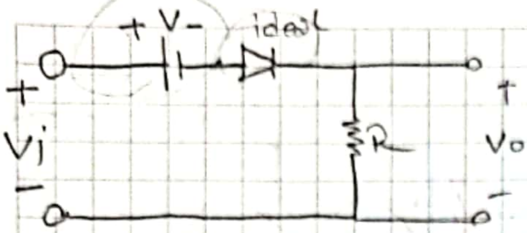
$\boxed{V_o = -\frac{V_i}{2}}$

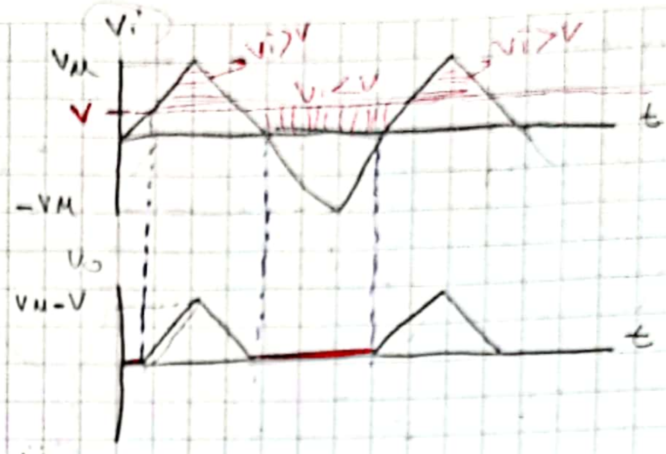
Clippers (Kırpıcılar):





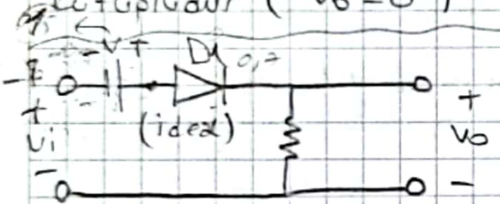


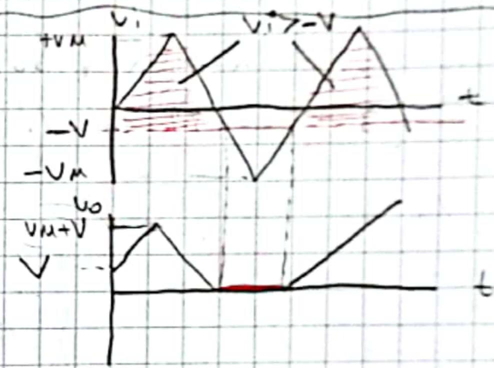




▲ $V_i > V$ ise diyot ileri yönlü kutupludur $(V_o = V_i - V)$

▲ $V_i < V$ ise diyot ters yönlü kutupludur $(V_o = 0)$

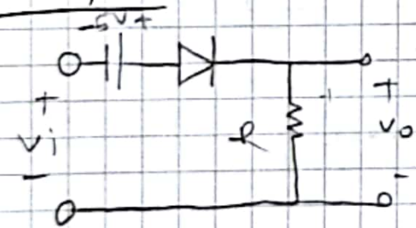


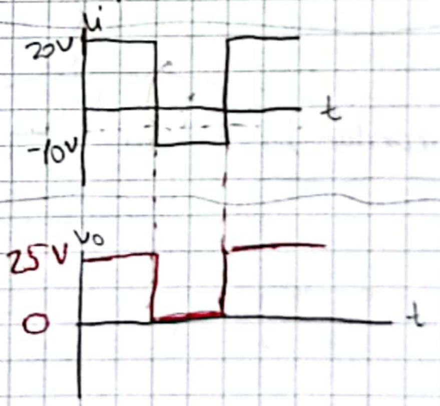


$v_i > -V$

$v_i < -V$

Example:





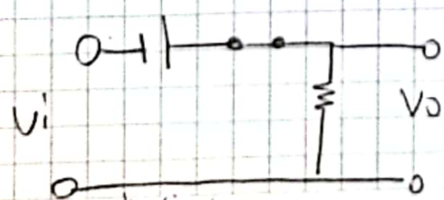
ise $V_o, t=0$

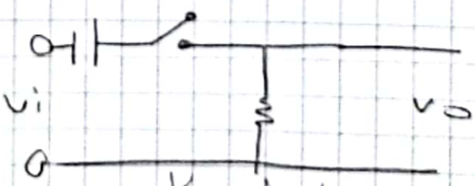
$v_i + 5V > 0 \Rightarrow D_1$ iletimde

$\boxed{V_i > -5V}$

$v_i + 5V < 0 \Rightarrow D_1$ kesimde

$\boxed{V_i < -5V}$





iletimde

$-V_i - 5V + V_o = 0$

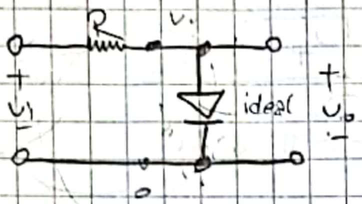
$V_o = V_i + 5V$

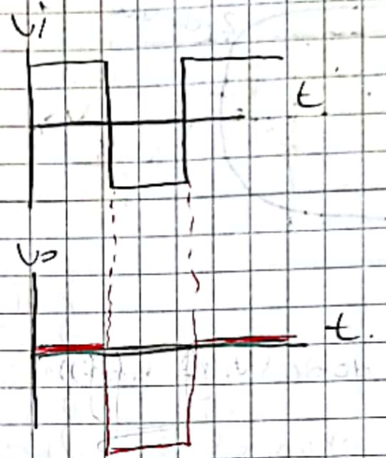
$\boxed{V_o = 20V}$

Kesimde

$\boxed{V_o = 0}$

Paralel Diyotlu Clippers :



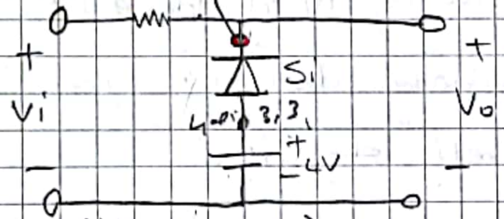


$V_i > 0$ } diyot
$V_o = 0$ } ~~kısa devre~~ düz tel

$V_i < 0$ } diyot açık
$V_o = V_i$ } devre

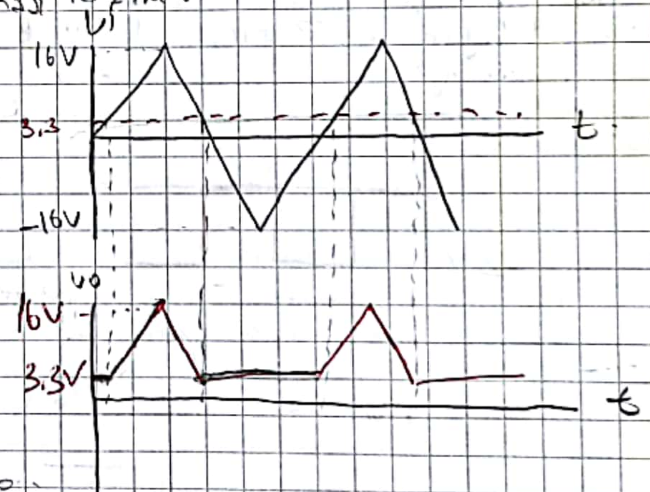
Example:

Diyotun iletime geçmesi için buranın geriliminin 3,3V den küçük olması lazım.



($V_{D,on} = 0,7$)

$\boxed{V_o - t = ?}$

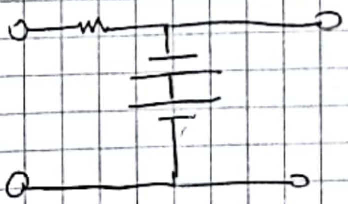


I. durum

$V_i < 3,3V$

$D_1 \rightarrow$ iletimde

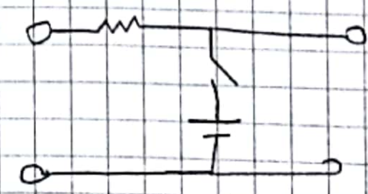
$\boxed{V_o = 3,3V}$



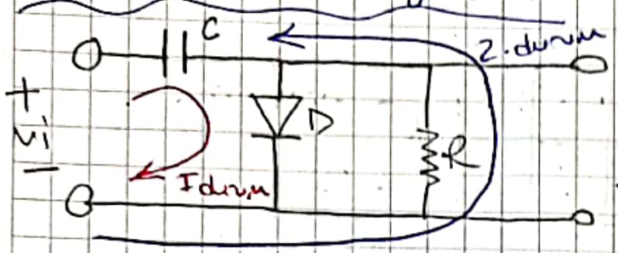
II. durum

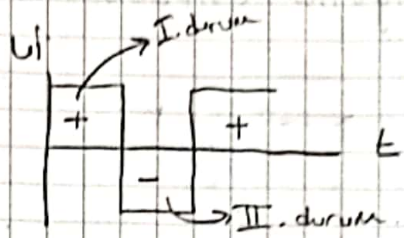
$V_i > 3,3V$
$D_1 \rightarrow$ kesimde

$\boxed{V_o = V_i}$ (Tüm gerilim V_o'a düşer.



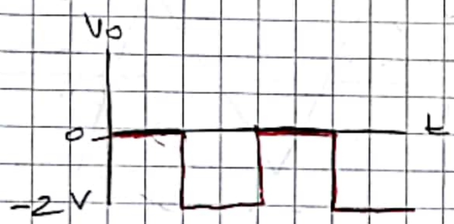
Clampers (Kenetleyiciler):





I. durum

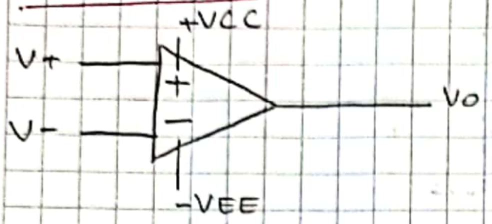
ilk önce kapasitör dolar (vi'ye kadar) diyot(ideal)'tan akım aktığı müddetçe $\boxed{V_o = 0}$ olur.
Diyot düz tel gibi davranır.



II durum

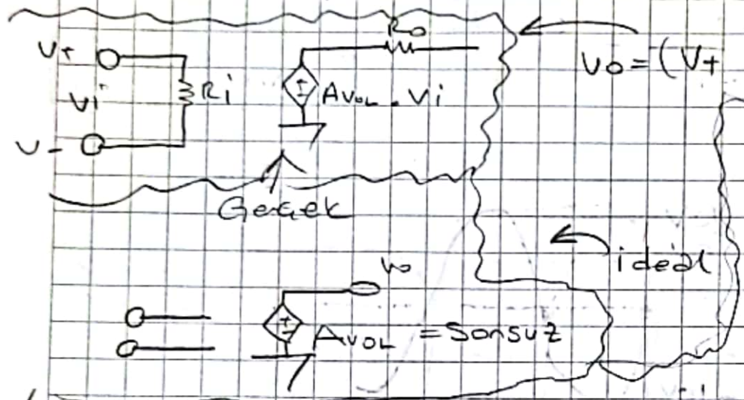
Kapasitör dolmuş olur. Diyot kesimdedir. Akım R üzerinden akar ve $\boxed{V_o = -2V}$ olur.
(1V kapasitörden, 1V vi'den gelir)
Genliğinde değişiklik yapmadan işareti değişir.

OP-AMP



	ideal	Gerçek
A_{VOL}	∞	500.000
R_i	∞	$> 15M\Omega$
R_o	0	$< 1k\Omega$
Slew Rate	0	$\cong 10$ V/ms

$V_{EE}+2 < V_o < V_{CC}-2$



$V_o = (V_+ - V_-) \cdot A_{VOL}$

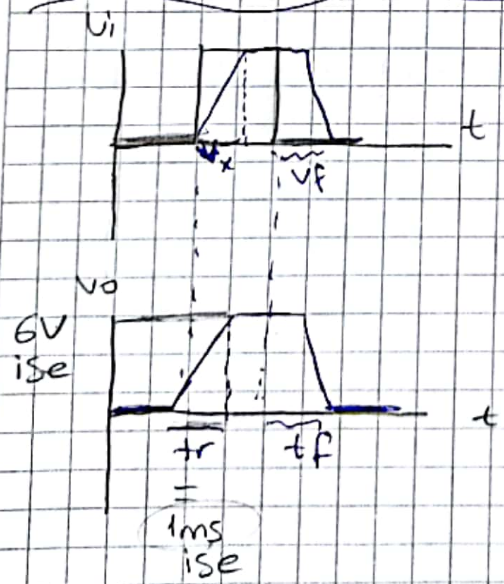
A_{VOL} idealde sonsuzdur V_i'nin en küçük değerinde bile satürasyona uğrar.

(Satürasyon: OP-AMP'ın VEE ve Vcc değerleri haricine çıkamaması

1-) $V_+ = V_-$
2-) $i_+ = i_- = 0$

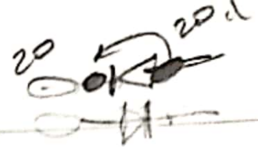
Bunlar ideal için geçerlidir. Ama biz normal devrelerde de kullanacağız.

SlewRate (Yükselme Hızı):

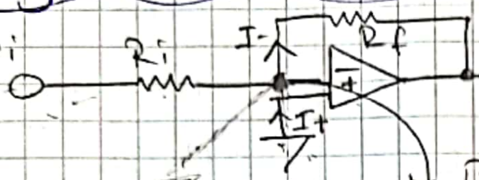


$$\boxed{SR = \frac{V}{t_r}} \therefore \frac{6V}{1ms} = \boxed{6\ V/ms}$$

olur.



Inverting Amp (Eviren kuvvetlendirici);



$I_- = I_+ = 0$

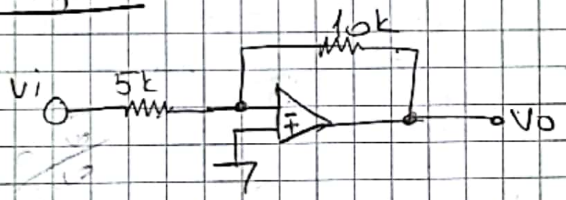
Sanal Toprak

Bu noktaya göre

voltaj kazancı.

$$\frac{V_i - 0}{R_i} = \frac{0 - V_o}{R_f} \Rightarrow \boxed{A_v = \frac{V_o}{V_i} = -\frac{R_f}{R_i}}$$

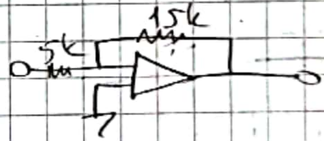
Example:



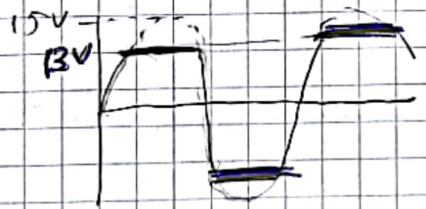
$$V_o = V_i\left(-\frac{R_f}{R_i}\right) \Rightarrow V_o = -V_i \cdot \frac{10k}{5k} \Rightarrow \boxed{V_o = -2V_i}$$

$V_{SAT} = |\pm 13V|$ olsaydı ne

satürasyon

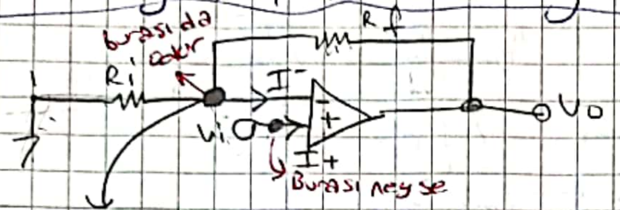


olsaydı



CamScanner ile tarandı

Non-inverting Amplifier (Evirmeyen Kuvvetlendirici) :

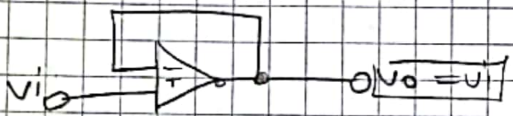


Bu noktaya göre

$$\frac{Vi-0}{Ri}+\frac{Vi-Vo}{Rf}=0 \qquad Vi\left(\frac{1}{R_1}+\frac{1}{Rf}\right)-Vo\left(\frac{1}{Rf}\right)=0$$

$$Vi\left(\frac{1}{Ri}+\frac{1}{Rf}\right)=Vo\left(\frac{1}{Rf}\right) \Rightarrow Av=\frac{Vo}{Vi}=\left(1+\frac{Rf}{Ri}\right)$$

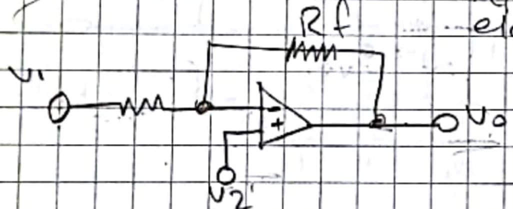
Voltage Follower (Buffer) :



$Av=1$

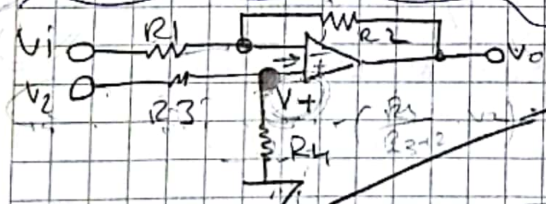
	ideal	Gerçek
Ri	∞	$\to 500.000$
Ro	0	$\approx 10\Omega$

Hepsini tek tek ele al



$$Vo=\left(-\frac{Rf}{Ri}\right)\cdot V_1+\left(1+\frac{Rf}{Ri}\right)\cdot V_2$$

Differential Amplifier (Fark kuvvetlendirici) :



V_1'in çıkışa etkisini bulmak için V_2'yi toprak kabul edelim,

$V_2 \cdot \frac{R_4}{R_3+R_4}$

$$Vo'=V_1\left(-\frac{Rf}{Ri}\right) \qquad \boxed{Vo''=V+\left(1+\frac{Rf}{Ri}\right)} \Rightarrow Vo''=V_2\cdot\frac{R_4}{R_3+R_4}\cdot\left(1+\frac{R_2}{R_1}\right)$$

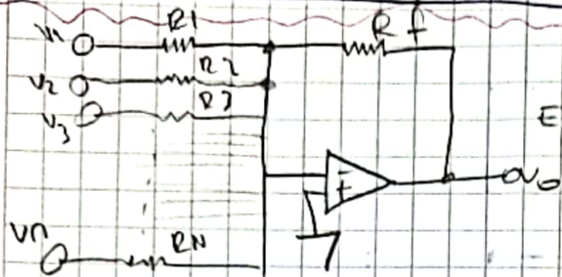
V_2'nin çıkışa etkisi

$R_1=R_3$ ve $R_2=R_4$ kabul edersek

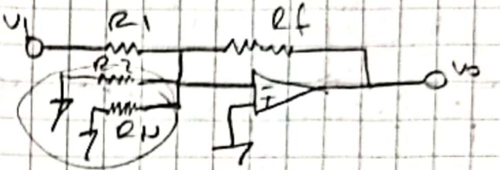
$$Vo''=V_2\left(\frac{R_2}{\cancel{R_2+R_1}}\right)\cdot\left(\frac{\cancel{R_1+R_2}}{R_1}\right) \Rightarrow Vo'' \Rightarrow V_2\left(\frac{R_2}{R_1}\right)$$

$$Vo=V'+Vo'' \Rightarrow Vo=\left(\frac{R_2}{R_1}\right)\cdot(V_2-V_1)$$

Evireren Toplayıcı (Inverting Adder)



Eş değeri $\equiv$



V_1 hariç süperpozisyon yaptık

V1'in çıkışa etkisi $V_{01} = V_1\left(-\frac{R_f}{R_1}\right)$

$V_{02} = V_2\left(-\frac{R_f}{R_2}\right)$

$\vdots$

$V_{0N} = V_N\left(-\frac{R_f}{R_N}\right)$

$V_0 = V_{01} + V_{02} + \dots + V_{0N}$

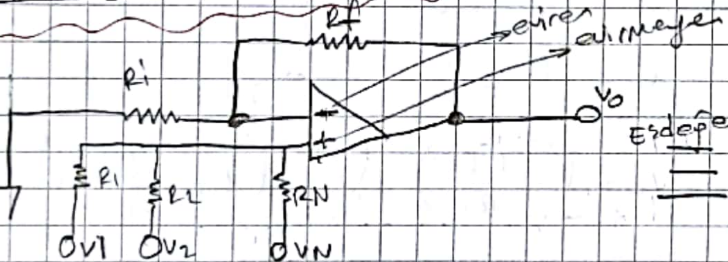
Gerçek ifade

$$\boxed{V_0 = -R_f\left(\frac{V_1}{R_1} + \frac{V_2}{R_2} + \dots + \frac{V_N}{R_N}\right)}$$

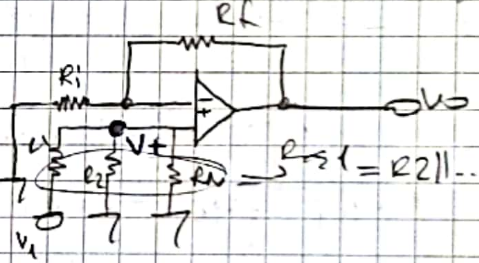
$R_1 = R_2 = R_3 = \dots = R_n = \underline{R_i}$ olsaydı

$$V_0 = -\frac{R_f}{R_i}\left(V_1 + V_2 + V_3 + \dots + V_N\right)$$

Evirmeyen ~~T~~ Toplayıcı:



Eşdeğer $\equiv$



$R_{eş1} = R_2 \| \dots \| R_N$

$V_{01} = V_+ \cdot \left(1 + \frac{R_f}{R_i}\right)$

$V_+ = V_1 \cdot \left(\frac{R_{eş1}}{R_1 + R_{eş1}}\right)$

$V_{01} = V_1\left(\frac{R_{eş1}}{R_1 + R_{eş1}}\right) \cdot \left(1 + \frac{R_f}{R_i}\right)$

$\vdots$

$V_{0N} = V_N\left(\frac{R_{eşN}}{R_{eşN} + R_N}\right) \cdot \left(1 + \frac{R_f}{R_i}\right)$

$$\boxed{R_{eş} = \frac{R}{n-1}}$$

2 giriş varsa $R_{eş} = R$

3 giriş varsa $R_{eş} = R/2$

4 giriş varsa $R_{eş} = R/3$

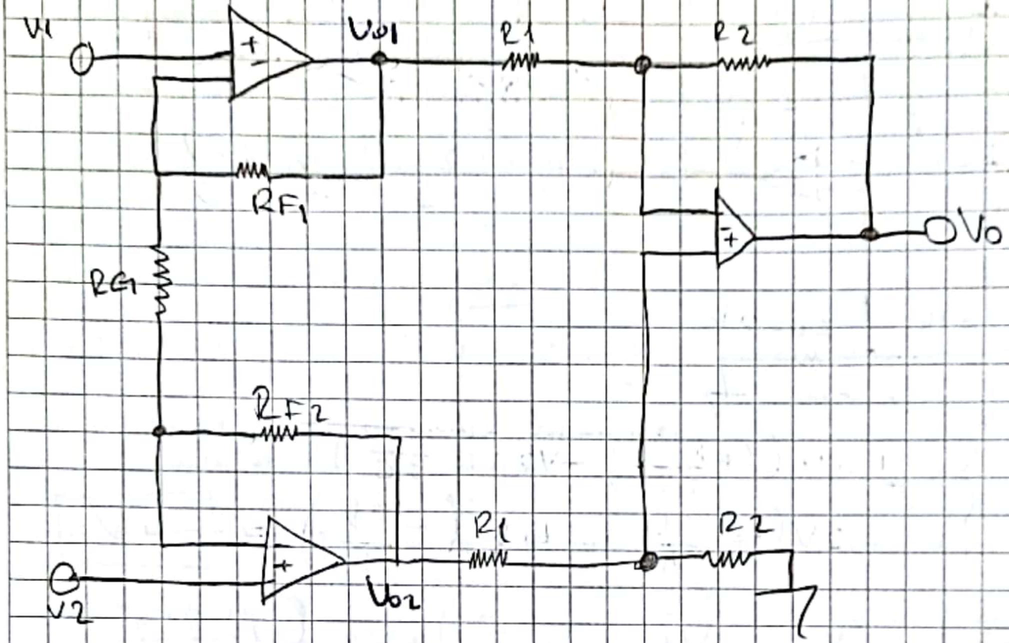
$V_0 = V_{01} + V_{02} + V_{03} + \dots + V_{0N}$

$V_0 = \left(1 + \frac{R_f}{R_i}\right) \cdot \left(V_1 \cdot \frac{R_{eş1}}{R_{eş1} + R_1} + \dots + V_N \frac{R_{eşN}}{R_{eşN} + R_N}\right)$

$R_1 = R_2 = R_3 = R_N = \underline{\underline{R}}$ olsun

$$V_0 = \left(1 + \frac{R_f}{R_i}\right) \cdot \left(\frac{1}{n}\right) \cdot \left(V_1 + V_2 + V_3 + \dots + V_N\right)$$

Enstrumantasyon Kuvvetlendiricisi



$V_o = (V_{o2} - V_{o1}) \cdot \left(\frac{R_2}{R_1}\right)$

$\left(\begin{smallmatrix} V_2 \\ \text{toprak} \end{smallmatrix}\right)$ $V_{o1}' = V_1 \cdot \left(1 + \frac{RF_1}{RG}\right)$ (V_1'in V_{o1}'e etkisi) (evirmeyen)

$\left(\begin{smallmatrix} V_1 \\ \text{toprak} \end{smallmatrix}\right)$ $V_{o1}'' = V_2 \cdot \left(-\frac{RF_1}{RG}\right)$ (V_2'nin V_{o1}'e etkisi) (eviren)

$V_{o1} = V_{o1}' + V_{o1}'' \Rightarrow V_{o1} = V_1 \cdot \left(1 + \frac{RF_1}{RG}\right) + V_2 \cdot \left(-\frac{RF_1}{RG}\right)$

$\left(\begin{smallmatrix} V_1 \\ \text{toprak} \end{smallmatrix}\right)$ $V_{o2}'' = V_2 \left(1 + \frac{RF_2}{RG}\right)$ (V_2'nin V_{o2} ye olan etkisi) (evirmeyen)

$\begin{smallmatrix} V_2 \\ \text{toprak} \end{smallmatrix}$ $V_{o2}' = V_1 \left(-\frac{RF_2}{RG}\right)$ (V_1'in V_{o2}'ye etkisi) (eviren)

$V_{o2} = V_{o2}' + V_{o2}'' \Rightarrow V_{o2} = V_2 \left(1 + \frac{RF_2}{RG}\right) + V_1 \left(-\frac{RF_2}{RG}\right)$

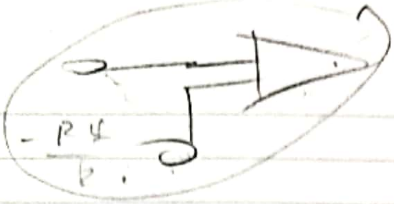
$RF_1 = RF_2 = RF$ ise

$V_o = \frac{R_2}{R_1} \left[V_2 \left(1 + \frac{2RF}{RG}\right) - V_1 \left(1 + \frac{2RF}{RG}\right) \right]$

$$\boxed{V_o = \left(\frac{R_2}{R_1}\right) \cdot \left(1 + \frac{2RF}{RG}\right) \cdot (V_2 - V_1)}$$

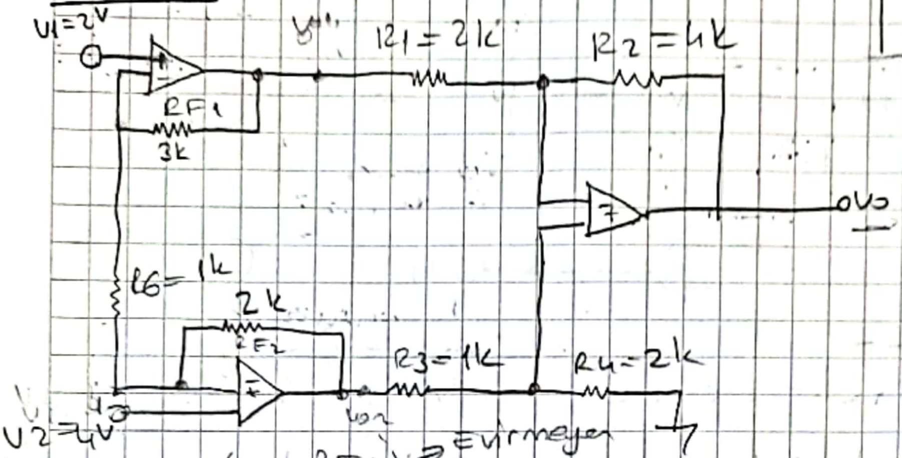
CamScanner ile tarandı

4



★★★ **SORU :**

$$\boxed{V_{SAT} = \pm 13V}$$



$V_o \Rightarrow ?$ Vo nedir?

$\Rightarrow$ Evirmeyen

(V2 toprak) $V_{o1}' = V_1\left(1+\frac{R_{F1}}{R_G}\right)$

(V1 toprak) $V_{o1}'' = V_2\left(-\frac{R_{F1}}{R_G}\right)$

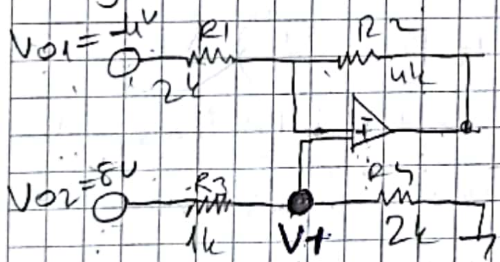
$$\left\{ \begin{aligned} V_{o1} &= V_1\left(1+\frac{R_{F1}}{R_G}\right) + V_2\left(-\frac{R_{F1}}{R_G}\right) \\ &= 2V\left(1+\frac{3k}{1k}\right) + 4V\left(-\frac{3k}{1k}\right) = \boxed{-4V} \end{aligned} \right.$$

(V2 top) $V_{o2}' = V_1\left(-\frac{R_{F2}}{R_G}\right)$

(V1 toprak) $V_{o2}'' = V_2\left(1+\frac{R_{F2}}{R_G}\right)$

$$\left\{ \begin{aligned} V_{o2} &= V_1\left(-\frac{R_{F2}}{R_G}\right) + V_2\left(1+\frac{R_{F2}}{R_G}\right) \\ &= 2V\left(-\frac{2k}{1k}\right) + 4V\left(1+\frac{2k}{1k}\right) = \boxed{8V} \end{aligned} \right.$$

Sağ tarafı analiz et! (Fark kuvvetlendirici)



(Vo2 toprak) $\Rightarrow V_o' = -\frac{R_2}{R_1}\cdot V_{o1} \Rightarrow \boxed{8V}$

(Vo1 toprak) $\Rightarrow V_o'' = \left(1+\frac{R_2}{R_1}\right)\underbrace{\left(\frac{R_4}{R_4+R_3}\right)\cdot V_{o2}}_{V+} \Rightarrow 16V$

$V_o = V_o' + V_o'' = 24\,V > 13\,V$ olduğundan satürasyona uğrar.

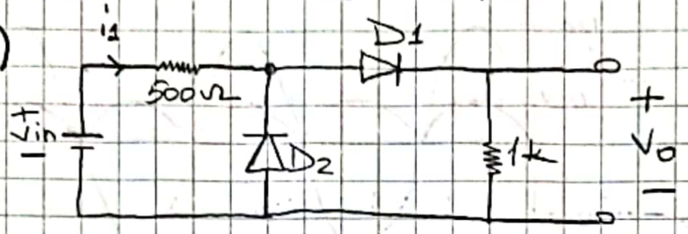
$$\boxed{V_o = +V_{sat} = 13V}$$

$(V_+)\left(1+\frac{R_2}{R_1}\right) = 16$

$V_{o2}\cdot\frac{R_4}{R_{3+4}}$

- 2019 VİZE SORULARI -

1-)



* 2V ile sınırlı. (V_{in})

$V_{D,on} = 0,7$

$V_o - V_{in} = ?$

$i_1 - V_{in} = ?$

I. durum

$V_{in} > 0,7$ V ise

D1 iletimde
D2 kesimde

$$V_o = \frac{V_{in} - 0,7V}{1,5k} \cdot 1k$$

$$V_o = \frac{2(V_{in} - 0,7)}{3}$$

$$i_1 = \frac{V_{in} - 0,7V}{1,5k}$$

II. durum

$V_{in} < -0,7$ V ise

D1 kesimde
D2 iletimde

$V_o = 0$

$$i_1 = \frac{V_{in} + 0,7V}{500\Omega}$$

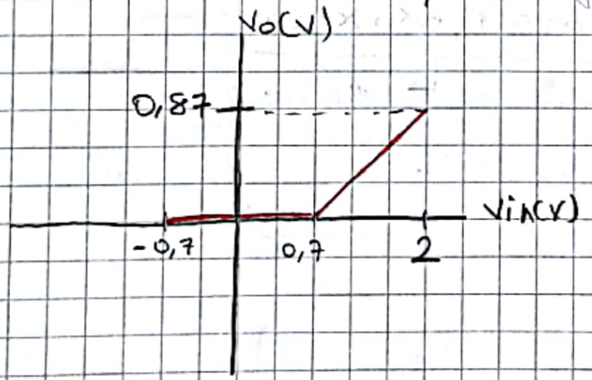
III. durum

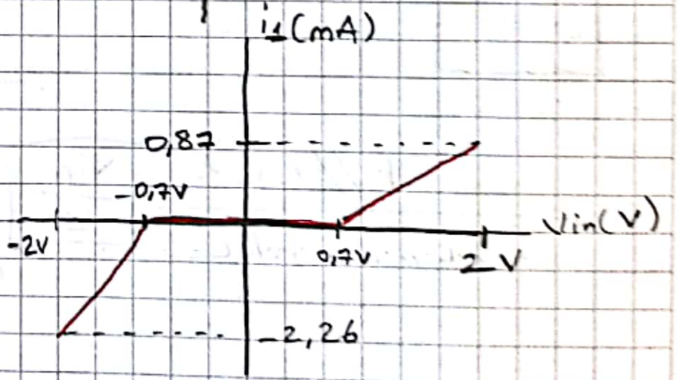
$-0,7V < V_{in} < 0,7V$ ise

D1 kesimde
D2 kesimde

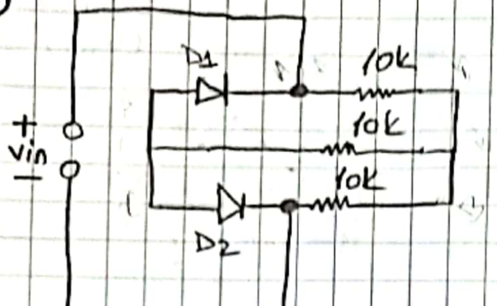
$i_1 = 0$

$V_o = 0$

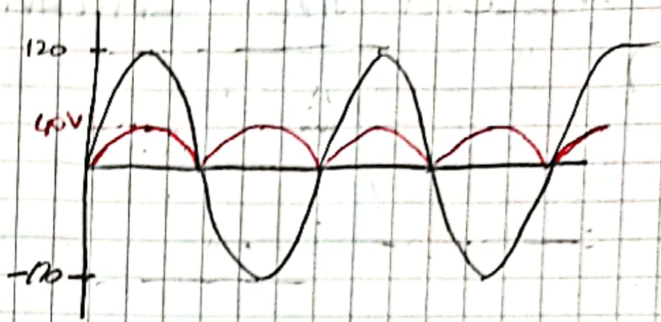




2-)



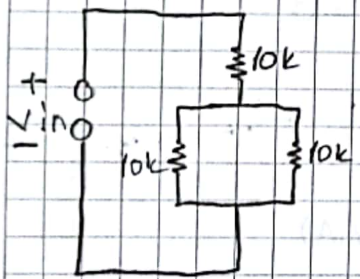
D1, D2, ideal,



Pozitif Alternansta

D1 kesimde

D2 iletimde



$$V_o = \frac{V_{in}(10k // 10k)}{(10k // 10k) + 10k} = \boxed{\frac{V_{in}}{3}}$$

Negatif Alternans

D1 iletimde

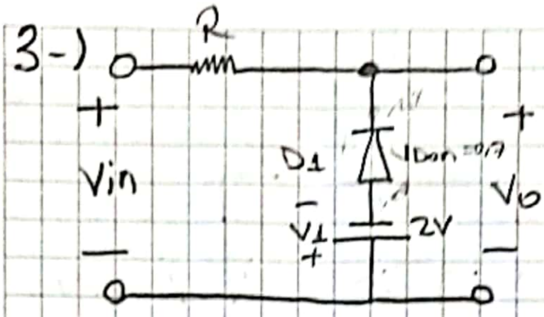
D2 kesimde

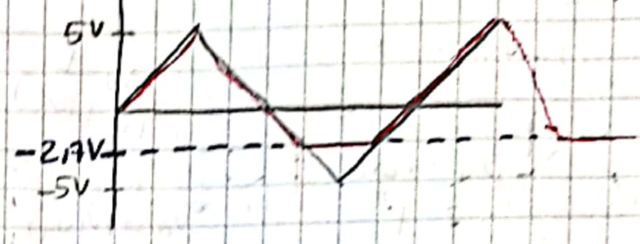
$$\boxed{V_o = -\frac{V_{in}}{3}}$$

$$\boxed{V_{o_{AVG}} = 0,636 \times 40V}$$

→ Fullwave

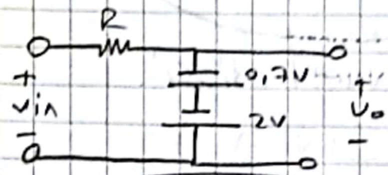
3-)





$V_{in} < -2,7V$ ise

D1 iletimde



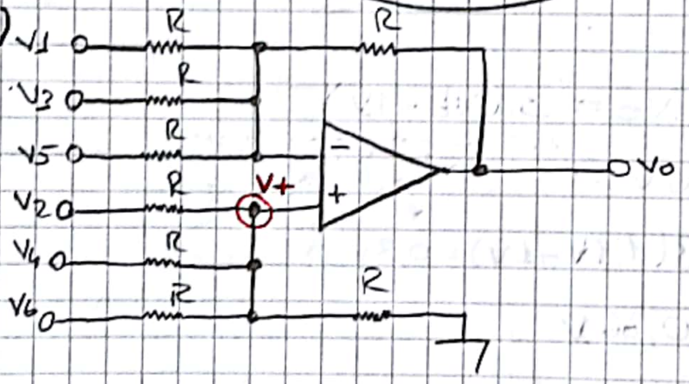
$$\boxed{V_o = -2,7V}$$

$V_{in} > -2,7V$ ise

D1 kesimde

$$\boxed{V_o = V_{in}}$$

4-)



$$V_o' = -\frac{R}{R}\left(V_1+V_3+V_5\right)$$

$$V_o'' = \frac{V_2+V_4+V_6}{4}\underbrace{\left(1+\frac{R}{R/3}\right)}_{4}$$

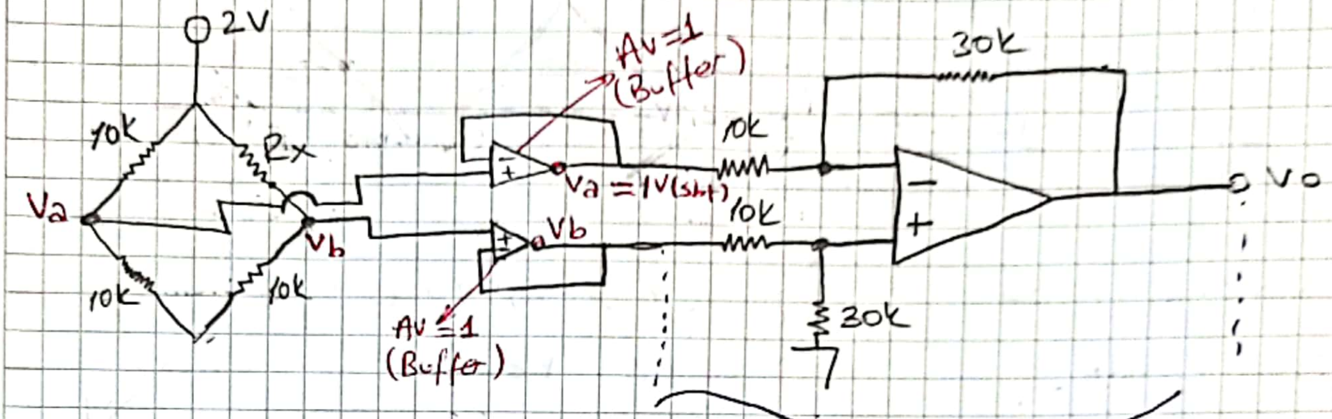
$$V_+ = \frac{(V_2+V_4+V_6)\cdot\left(\frac{R}{3}\right)}{R+\frac{R}{3}}$$

$$V_+ = \frac{V_2+V_4+V_6}{4}$$

$$\boxed{V_o = V_o' + V_o'' = V_2+V_4+V_6-V_1-V_3-V_5}$$

Sınav Sonu

Example: (Köprü kuvvetlendirici)



Fark Kuvvetlendirici

$V_o = 3(V_b - V_a)$

Sıcaklık (°C)	Rx
25	10
30	8,15
35	6,63
40	5,22
45	4,27
50	3,5

ise $V_o - T = ?$

$$V_b = \frac{2V \cdot 10k}{R_x + 10k}$$

$$V_o = 3(V_b - 1V)$$

25 $V_b = 1V$ | $V_o = 0V$

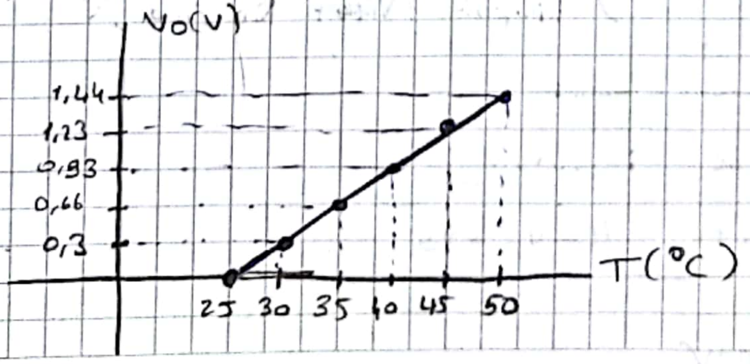
30 $V_b = \frac{2V \cdot 10k}{8{,}15 + 10k} = 1{,}1V$ | $V_o = 3(1{,}1V - 1V) = 0{,}3V$

35 $V_b = 1{,}22V$ | $V_o = 0{,}66V$

40 $V_b = 1{,}31V$ | $V_o = 0{,}93V$

45 $V_b = 1{,}41V$ | $V_o = 1{,}23V$

50 $V_b = 1{,}48V$ | $V_o = 1{,}44V$

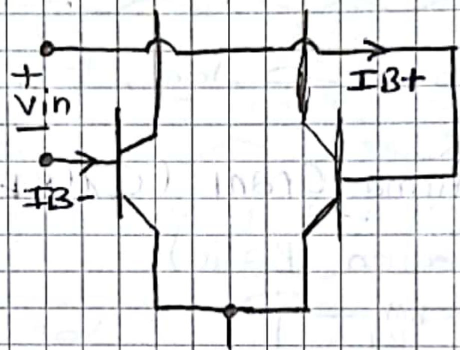


OP-Amp Karakteristikleri

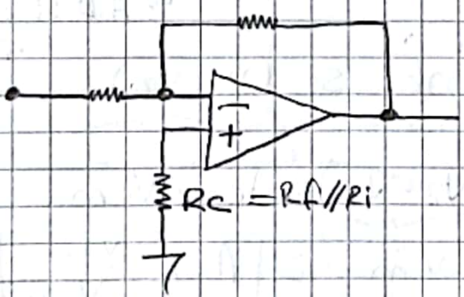
(i) Slew Rate

(ii) Giriş Dengesizlik Akımı (Input offset Current, I_{io}) → Transistörlerin aynı olmaması → $I_{io} = |I_{B+} - I_{B-}|$

Giriş Kutuplama Akımı (Input biasing Current, I_b) → Giriş dirençlerinin sonsuz olamaması.

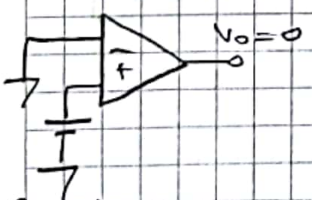


Kompanzasyon:

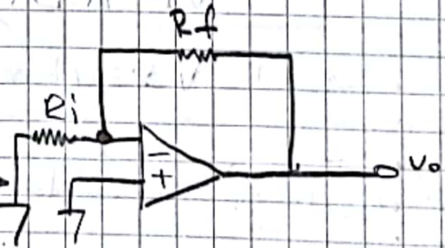


Akım akmasını istemiyoruz.

Aksa bile kompanze ediyoruz.



Giriş offset voltajının kompanzasyonu



$$V_o = \left(1 + \frac{R_F}{R_i}\right) V_{io}$$

(iii) Giriş Dengesizlik Voltajı (Input offset Voltage, V_{io})

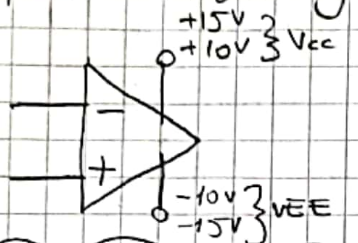
(iv) Drift (Kayma, Sürüklenme)

I_{io} veya V_{io} sıcaklıkla değişimi

$$V_{io\,drift} = \frac{\Delta V_{io}}{\Delta t}, \quad I_{io\,drift} = \frac{\Delta I_{io}}{\Delta T}$$

Güç Kaynaklı Bastırma Oranı (PSRR)
(Power Supply Rejection Ratio)

* Kutuplama voltajına göre offset voltajı değişir.

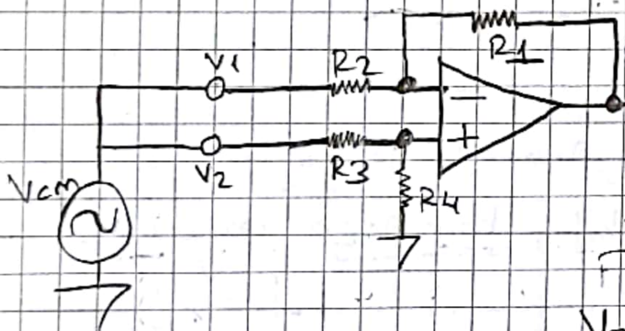


$$PSRR = \frac{\Delta V_{io}}{\Delta V_{cc}} \rightarrow \mu V/V \text{ (birim)}$$

$$PSRR = \frac{\Delta V_{io}}{V_{EE}}$$

$$P.S.R (dB) = 20 . \log . \left(\frac{1}{P.S.R.R} \right)$$

Ortak Mod Bastırma Oranı (CMRR)
(Common Mode Rejection Ratio)



$$V_o = (V_2 - V_1) \frac{R_1}{R_2}$$

↳ A.D (fark kazancı)

Aynı kaynak ise ($V_1 = V_2$)

$$V_o = A.D \underbrace{(V_2 - V_1)}_{0} + A_{cm} \cdot V_{cm}$$

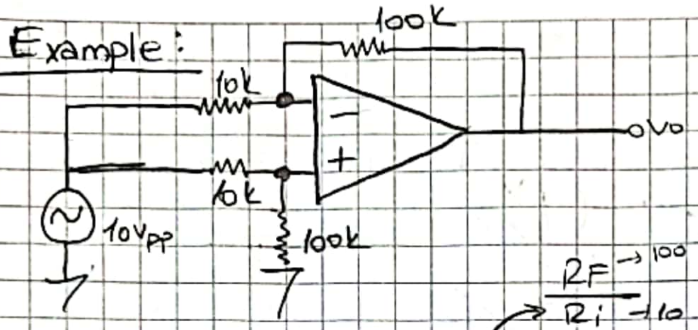
$$V_o = A_{cm} \cdot V_{cm} \Rightarrow \boxed{A_{cm} = \frac{V_o}{V_{cm}}}$$

$$CMRR = \frac{AD}{A_{cm}} \quad , \quad CMRR(dB) = 20 . \log . \left(\frac{AD}{A_{cm}} \right)$$

! A_{cm}'nin ölçüsü ne kadar küçükse o kadar iyi.

! CMRR ne kadar büyükse ideale o kadar yakındır.

Example:



CMRR(dB) = 90dB ise,

$\boxed{V_o = ?}$

$\frac{R_F}{R_i} \rightarrow \frac{100}{10}$

$$CMRR(dB) = 20 \cdot \log\left(\frac{A_D}{A_{CM}}\right) = 90dB$$

$$\log\left(\frac{10}{A_{CM}}\right) = 4,5 \Rightarrow \frac{10}{A_{CM}} = 10^{4,5} \Rightarrow A_{CM} = \frac{10}{31622} \cong 3,16 \times 10^{-4}$$

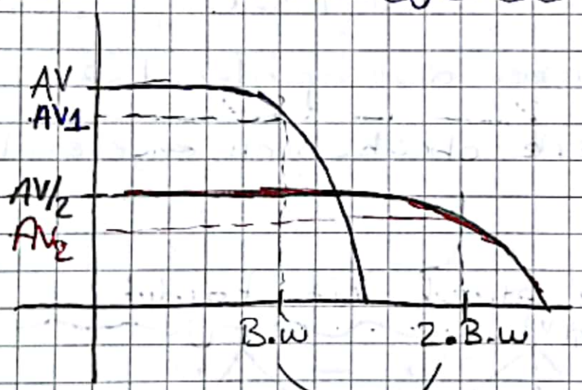
$\rightarrow$ Giriş voltajı.

$$V_o = \cancel{A_D (V_2 - V_1)} + A_{CM} \cdot V_{CM} = (3,16 \times 10^{-4} \cdot 10V)$$

$\cancel{V_2 - V_1} = 0$ (Aynı kaynak)

$$\Rightarrow \boxed{V_o \cong 3,16 \times 10^{-3} \, V_{pp}}$$

Kazanç Bant Genişliği Çarpımı:



Bant Genişliği

$$\boxed{A_{V1} \cdot Bw_1 = A_{V2} \cdot Bw_2}$$

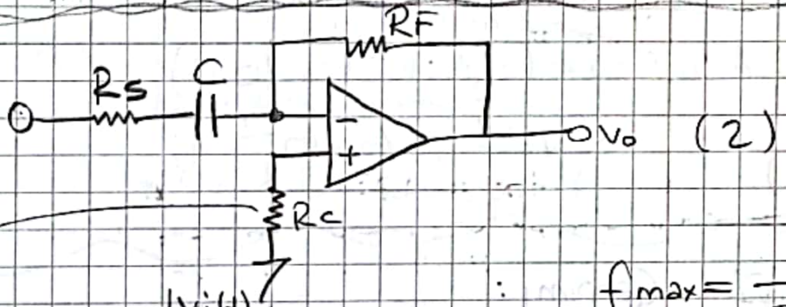
Av ne kadar büyükse Bant genişliği o kadar azdır.

Türev Alıcı Devre

$$I_C = C \cdot \frac{d\,V_i(t)}{dt}$$

$$I_C + I_{RF} = 0$$

$$\frac{C \cdot d\left(V_i(t) - 0\right)}{dt} + \frac{V_o - 0}{R_f} = 0 \Rightarrow \boxed{V_o = -C \cdot R_F \cdot \frac{d\left(V_i(t)\right)}{dt}}$$

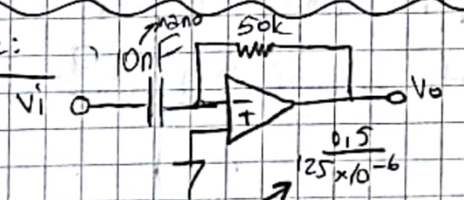


$$V_o = -C \cdot R_F \frac{dV_i(t)}{dt} \qquad f_{max} = \frac{1}{2\pi \cdot R_s \cdot C}$$

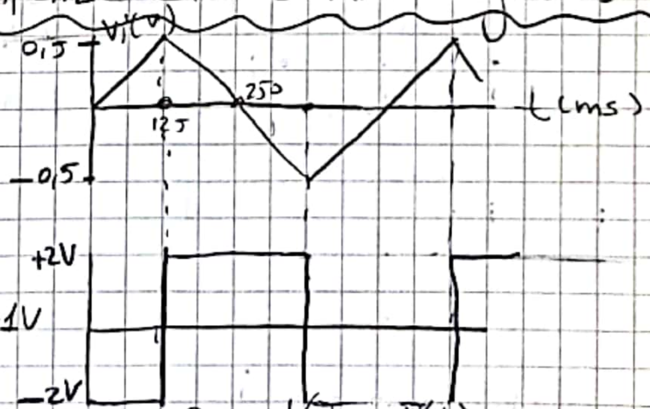
→ Yüksek frekansta C empedansı düşeceğinden kazanç çok yüksek seviyelere gelip satüre olacak. Bunu engelemek için 2'yi çizdik.

→ Giriş offset voltajını kompanze etmek için koyduk.

Example:



$$\frac{0{,}5}{125 \times 10^{-6}}$$



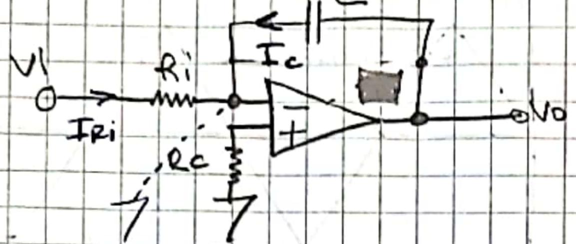
$0 \leq t < 125 \Rightarrow V_i(t) = 4000\ V/s \cdot t$

$125ms \leq t < 375 \Rightarrow V_i(t) = -4000\ V/s \cdot t + 1V$

$$V_o = -C \cdot R_F \cdot \frac{dV_i(t)}{dt} = -10 \times 10^{-9} \cdot 50 \times 10^3 \cdot \frac{d(4000\ V/s\ t)}{dt} = \boxed{-2V}$$

$$V_o = -C \cdot R_F \cdot \frac{dV_i(t)}{dt} = -10 \times 10^{-9} \cdot 50 \times 10^3 \cdot \frac{d(-4000\ V/s \cdot t)}{dt} = \boxed{+2V}$$

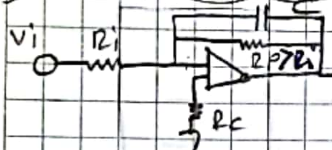
İntegral Alıcı Devre:



$$\frac{V_i(t)}{R_i} + C \cdot \frac{d\,V_o(t)}{dt} = 0$$

$$\frac{-V_i(t)}{R_i} = C \cdot \frac{d\,(V_o(t))}{dt}$$

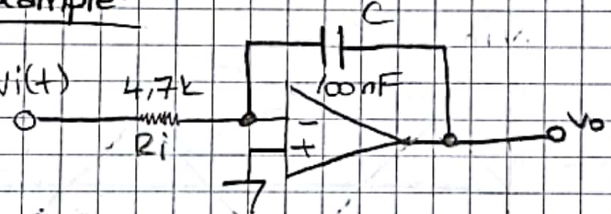
$$\int -\frac{1}{R_i . C} \cdot V_i(t) = \int \frac{d\,V_o(t)}{dt} \Rightarrow \boxed{V_o = -\frac{1}{R.C} \cdot \int V_i(t) \cdot dt}$$

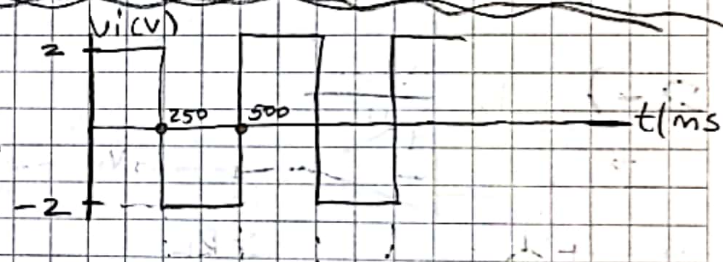


$$(2) \quad f_{min} = \frac{1}{2\pi \cdot R_p \cdot C}$$

→ Türev alıcıyla benzer sebepten dolayı (2)'yi çizdik.

Example:





$0 < t < 250$ için

$$V_o(t) = -\frac{1}{R_i . C} \cdot \int v_i(t) \cdot dt$$

$$= -\frac{1}{4{,}7\times10^{-3} \cdot 100\times10^{-9}} \cdot \int_0^{250ms} 2 \cdot dt = \boxed{-1{,}06}$$

1,06

-1,06

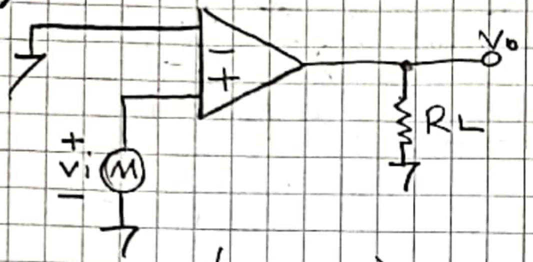
$250 < t < 500$ için

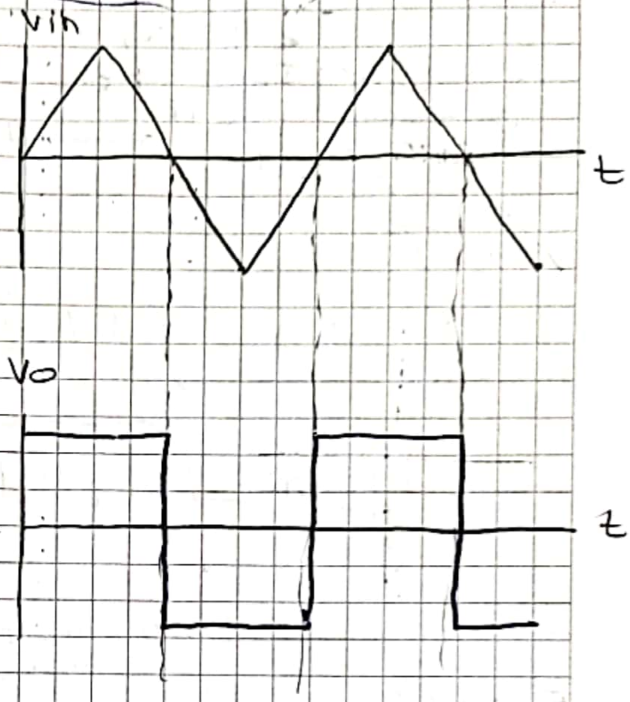
$V_o = 1{,}06$ olur.

(Başka bişey değişmedi)

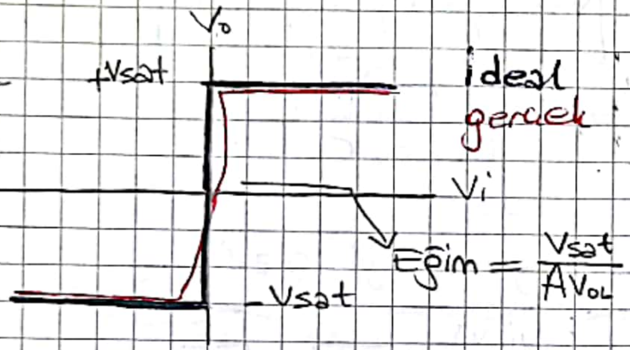
Voltaj Karşılaştırıcı (Comparators)

1-)

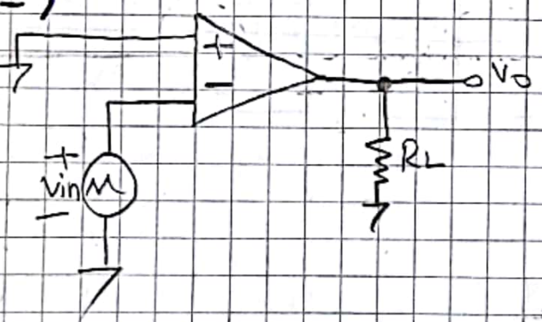


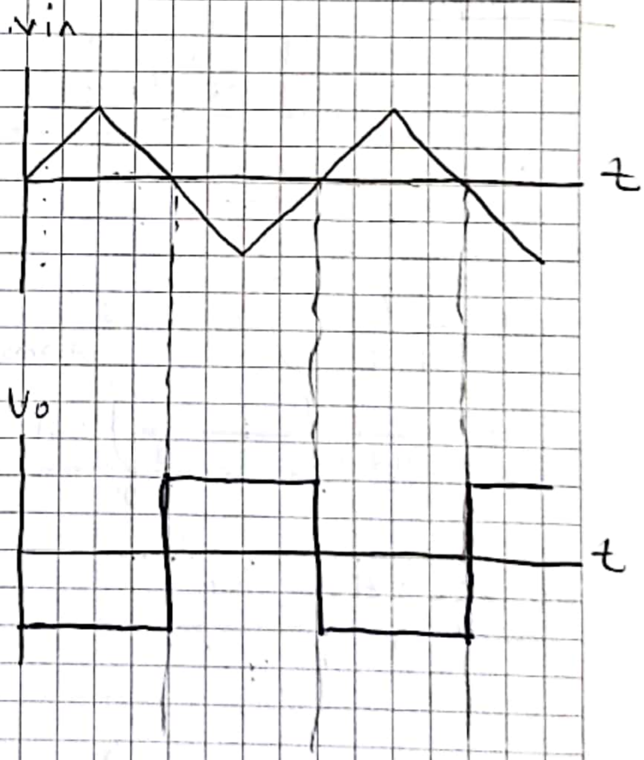


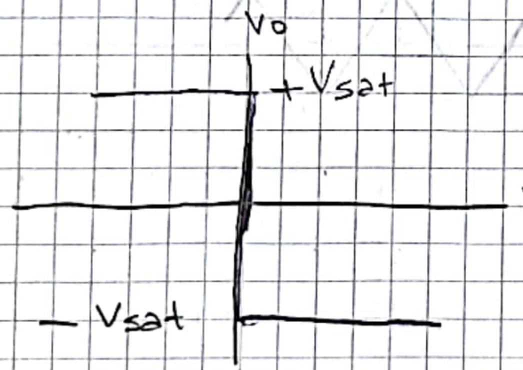
$V_o = A_{VOL} \cdot (V^+ - V^-)$

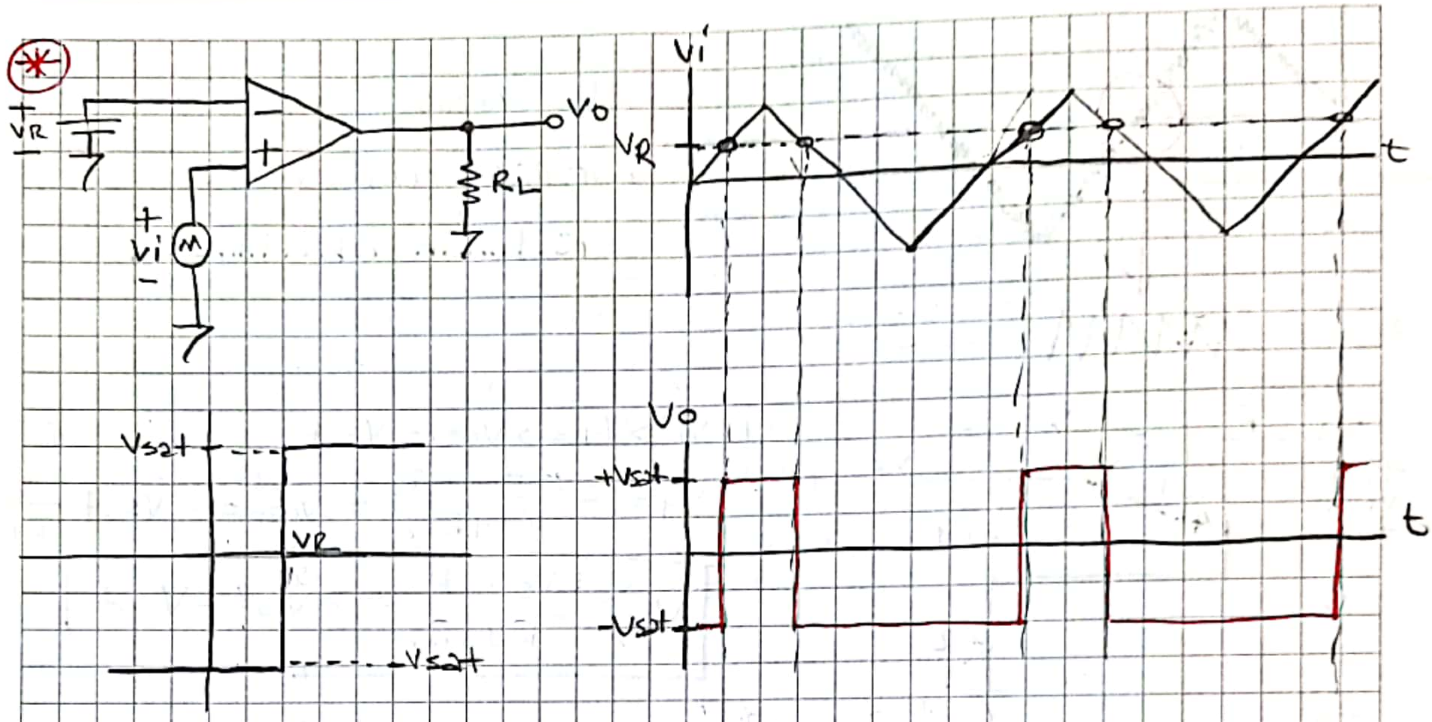


2-)

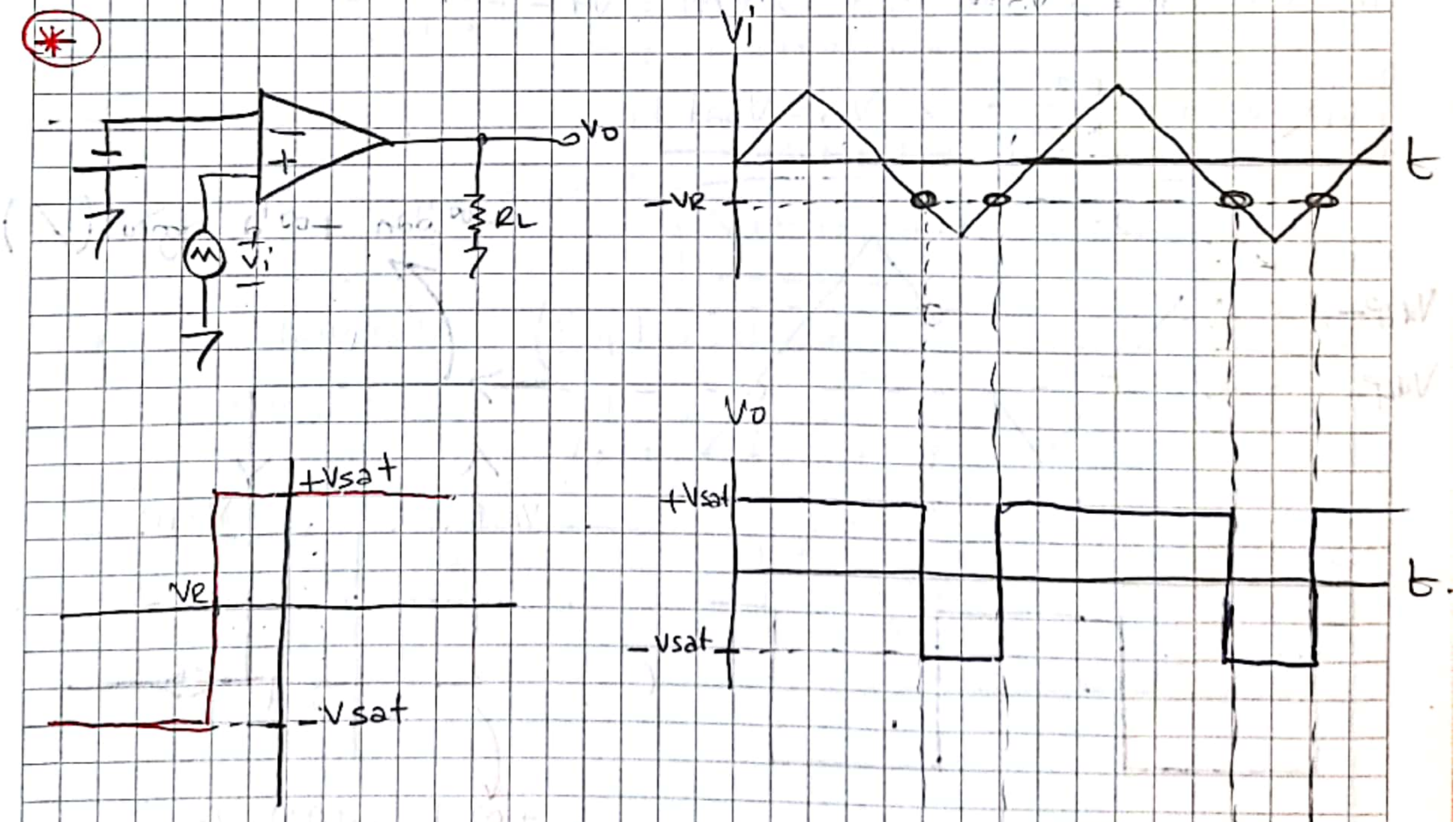




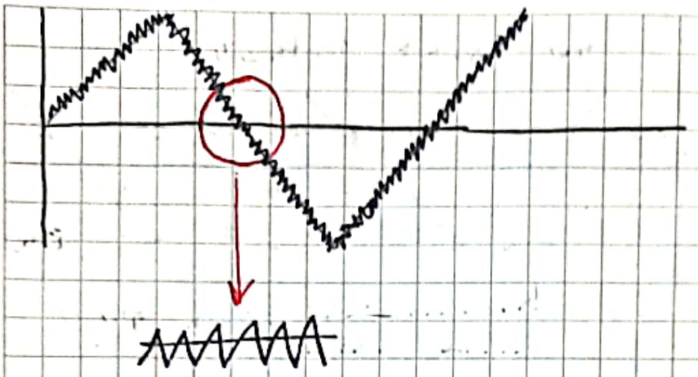




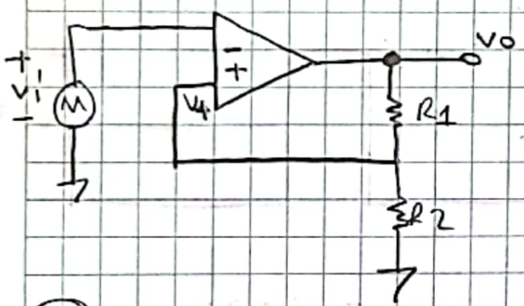
Vo
VR
RL
Vi
M
Vi'
t
Vsat
-Vsat
+Vsat
Vo



Vo
RL
M
Vi'
-VR
t
+Vsat
Vsat
VR
-Vsat



Histeresiz ile karşılaştırıcılarda gürültünün azaltılması.



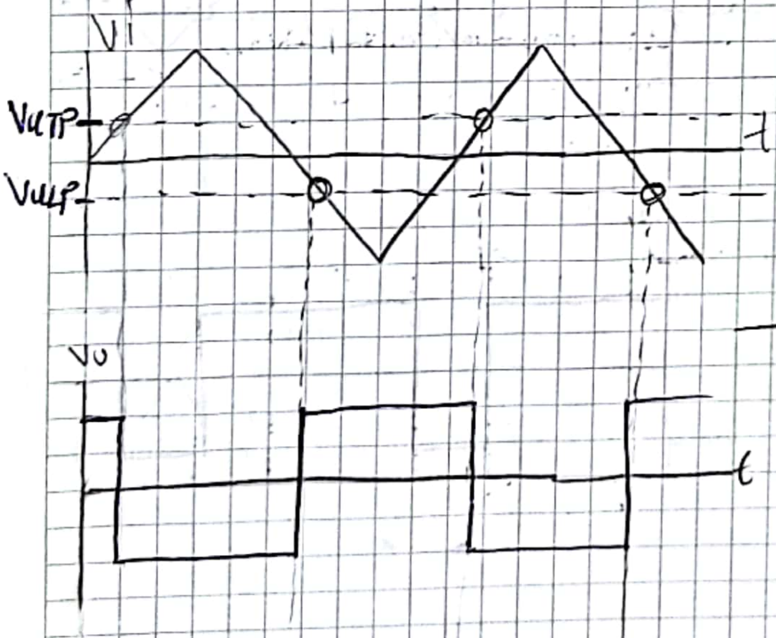
(i) $V_i > V_+ \Rightarrow V_o = -V_{sat}$

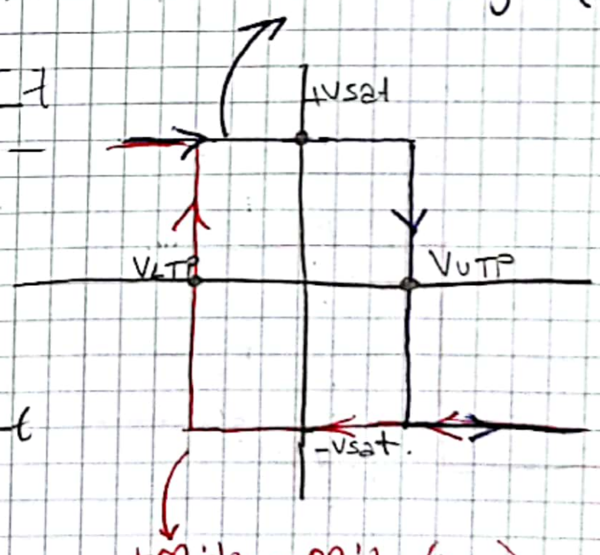
$$V_+ = \frac{-V_{sat} \cdot R_2}{R_1 + R_2} \Rightarrow V_{LTP} = -V_{sat} \frac{R_2}{R_1+R_2}$$

$$\boxed{V_i > \frac{-V_{sat} \cdot R_2}{R_1+R_2} \Rightarrow V_o = -V_{sat}}$$

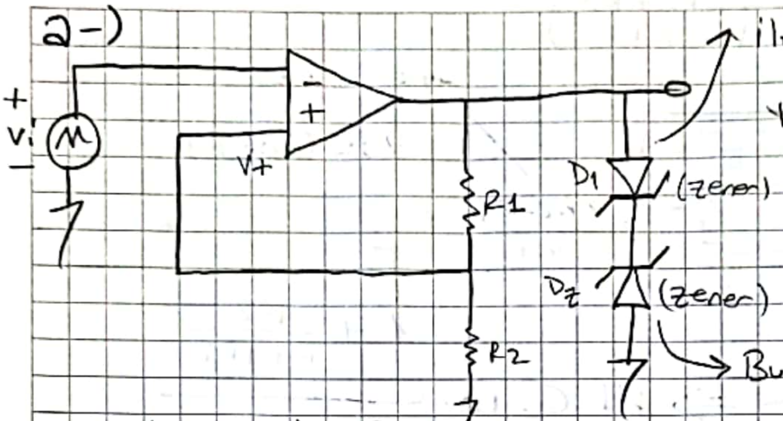
(ii) $V_i < V_+ \Rightarrow V_o = V_{sat} \Rightarrow V_{UTP} = V_+ = \frac{V_{SAT} \cdot R_2}{R_1+R_2}$

$$\boxed{V_i < V_{sat} \cdot \frac{R_2}{R_1+R_2} \Rightarrow V_o = V_{sat}}$$





a-)



ileri yönlü kutuplu o yüzden 0,7 V düşer üstüne.

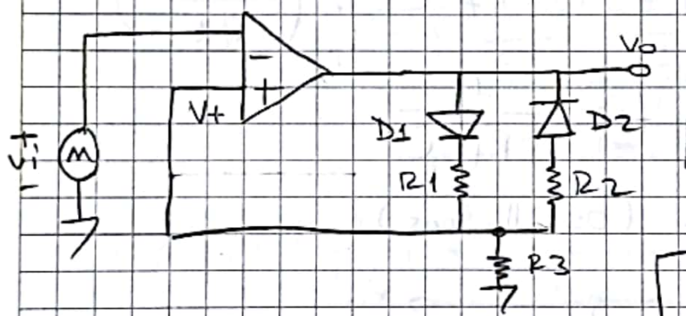
$$\boxed{\begin{array}{l} V_i > V_+ \Rightarrow V_o = -V_{D1} - V_{Z2} \\ V_i < V_+ \Rightarrow V_o = V_{D1} + V_{Z2} \end{array}}$$

Bu diyot ters yönlü kutuplu olduğu için üstüne zener voltajı düşer.

$$V_{UTP} = (V_{D1} + V_{Z2}) \cdot \frac{R_2}{R_1+R_2}$$

$$V_{LTP} = (-V_{D1} - V_{Z2}) \cdot \frac{R_2}{R_1+R_2}$$

b-)



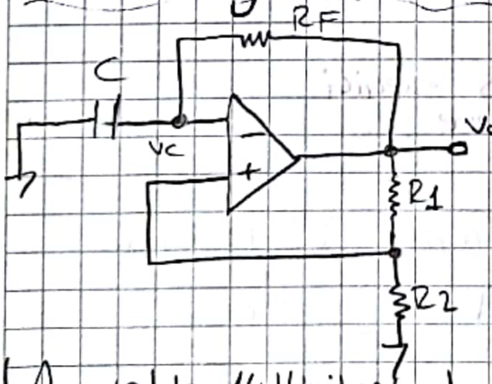
$V_i > V_+ \Rightarrow V_o = -V_{sat}$

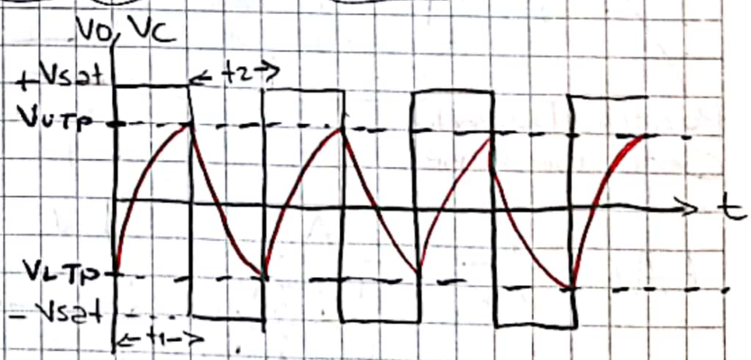
$$\boxed{V_{LTP} = V_+ = (-V_{sat} + V_{D2}) \cdot \frac{R_3}{R_2+R_3}}$$

$V_i < V_+ \Rightarrow V_o = +V_{sat}$

$$\boxed{V_{UTP} = V_+ = (+V_{sat} - V_{D1}) \cdot \frac{R_3}{R_1+R_3}}$$

Kare Dalga Üreticisi (Square Wawe Generator):





(A stable Multivibrator)

$$V_{LTP} = -V_{sat} \cdot \frac{R_2}{R_1+R_2}$$

$$V_{UTP} = +V_{sat} \frac{R_2}{R_1+R_2}$$

$$T = t_1 + t_2 = 2 R_F \cdot C \cdot \ln\left(\frac{2R_2 + R_1}{R_1}\right)$$

$$f = \frac{1}{T} = \frac{1}{2 \cdot R_F \cdot C \cdot \underbrace{\ln\left(\frac{2R_2+R_1}{R_1}\right)}_{1}}$$

$$1 = \frac{2R_2 + R_1}{R_1} \rightarrow e = R_2$$

$$R_2 = 0{,}86 R_1$$

$$t = R_f \cdot C \cdot \ln \frac{\text{hedef} - \text{başlangıç}}{\text{hedef} - \text{bitiş}}$$

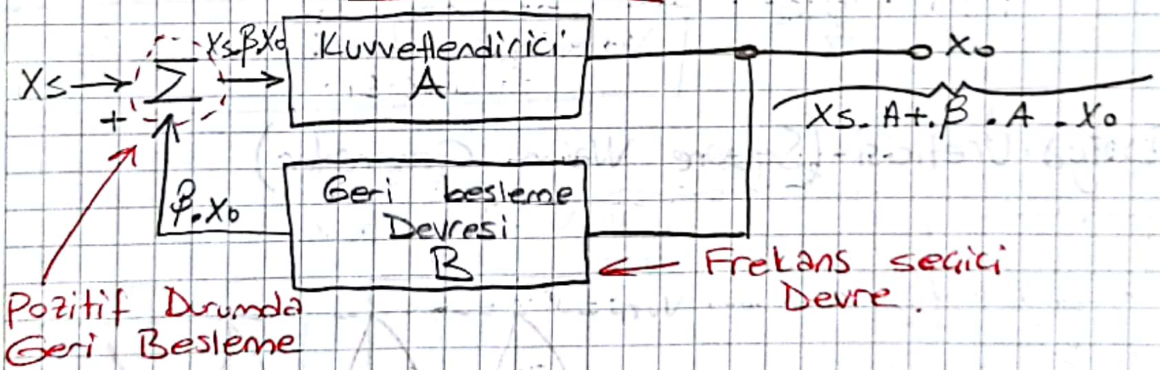
$$t_1 = R_F \cdot C \cdot \ln \frac{V_{sat} - V_{LTP}}{V_{sat} - V_{UTP}} \Rightarrow R_f \cdot C \cdot \ln \frac{1 + \frac{R_2}{R_1+R_2}}{1 - \frac{R_2}{R_1+R_2}}$$

$$t_1 = R_F \cdot C \cdot \ln\left(\frac{2R_2+R_1}{R_1}\right)$$

$$t_2 = R_F \cdot C \cdot \ln\left(\frac{-V_{sat} - V_{UTP}}{-V_{sat} - V_{LTP}}\right) \Rightarrow t_2 = R_f \cdot C \cdot \ln\left(\frac{2R_2+R_1}{R_1}\right)$$

Eğer $R_2 = 0{,}86 R_1 \Rightarrow f = \dfrac{1}{2R_f \cdot C}$

– Osilatörler – (oscillators)



$$A_f = \frac{X_o}{X_s} = \frac{A}{1 - \underbrace{\beta \cdot A}_{|\beta . A| = 1}}$$

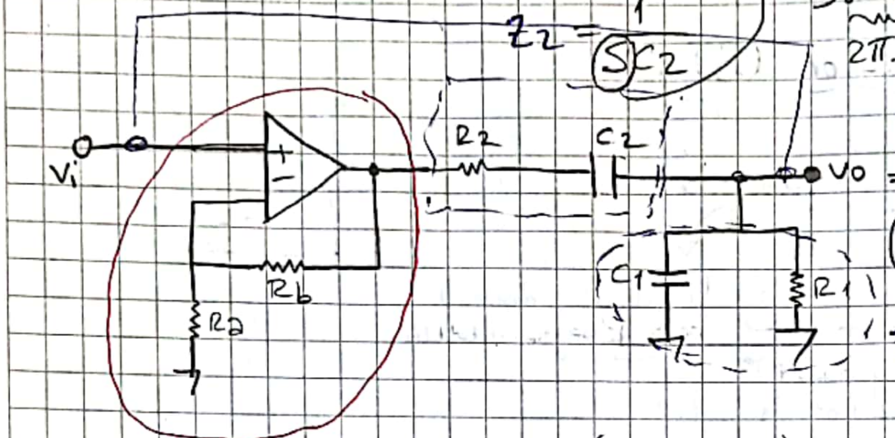
1 olmalı. Çünkü osilatörde sonsuz kazanç olur.

Berkhausen kriteri

★ Giriş işaretiyle çıkış işaretinin fazı aynı olmalı.

Giriş = ∿ ise çıkış = −∿ olmamalı

Wien Köprü Osilatörü



$\rightarrow j.\underset{2\pi f}{\underbrace{w}} = \boxed{Z_2 = \frac{1}{jwC_2} + R_2}$

$\Rightarrow \boxed{V_a . \frac{Z_1}{Z_1+Z_2}}$

$\left(1+\frac{R_b}{R_a}\right)\frac{1}{1+\frac{Z_2}{Z_1}} \cdot V_i$

$Z_1 \Rightarrow \frac{1}{Z_1} = \frac{1}{R_1} + \frac{1}{\frac{1}{jwC_1}} \Rightarrow \frac{1}{R_1} + jwC_1$

Evirmeyen Kuvvetlendirici $V_a = \left(1+\frac{R_b}{R_a}\right) V_i$

$$V_o = V_i\left(1+\frac{R_b}{R_a}\right)\frac{1}{1+\underbrace{\left(R_2+\frac{1}{jwC_2}\right)}_{Z_2}\underbrace{\left(\frac{1}{R_1}+jwC_1\right)}_{Z_1}}$$

$$\cancel{V_o} = \cancel{V_i}\left(1+\frac{R_b}{R_a}\right)\left(\frac{1}{1+\left(\frac{R_2}{R_1}+jwC_1R_2+\frac{C_1}{C_2}+\frac{1}{jwC_2R_1}\right)}\right)$$

$$1 = \left(1+\frac{R_b}{R_a}\right)\left(\frac{1}{1+\frac{R_2}{R_1}+jwC_1R_2+\frac{C_1}{C_2}+\frac{1}{jwC_2R_1}}\right)$$

$$\underbrace{1+\frac{R_2}{R_1}+\frac{C_2}{C_1}}+jwC_1R_2+\frac{1}{jwC_2R_1} = \underbrace{1+\frac{R_b}{R_a}}$$

Atılır, işlem yapılırsa

$$\frac{R_b}{R_a} = \frac{R_2}{R_1}+\frac{C_1}{C_2} \Big\} \text{ osilasyon şartı.}$$

$$j\underset{2\pi f}{w}C_1R_2 + \frac{1}{jw.C_2.R_1} = 0 \Big\} f = \frac{1}{2\pi\sqrt{R_1.R_2.C_1.C_2}} \text{ (osilasyon frekansı)}$$

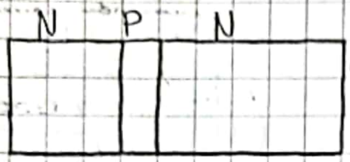
CamScanner ile tarandı

- TRANSİSTÖRLER -

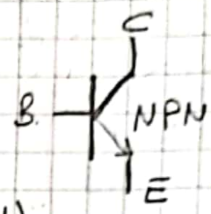
Bipolar Jonksiyon Transistor (BJT):

(*)

Emitter



Collector



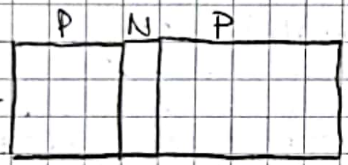
Emitter → (heavely doped) yüksek katkılı

Base → (lightly doped) En az katkılı

Collector → (modeate doped) orta düzeyde katkılı.

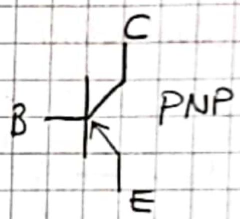
(*)

Emitter



Collector

Base



Active Region: (Aktif Bölge):

$V_C > V_B > V_E$.

Base emitter jonksiyonu ileri yönlü kutuplanmış olmalı.

Base collector jonksiyonu ters yönlü kutuplanmış olmalı.

$V_{BE} = 0{,}7V$, $I_C = \beta . I_B$, $I_E = I_B + I_C$, $I_E = (1+\beta) . I_B \cong I_C$

Cut off Region: (Kesim)

B.E jonksiyonu ters yönlü kutuplanış olmalı.

B.C jonksiyonu ters yönlü kutuplanmış olmalı.

Saturation Region: (Doyum)

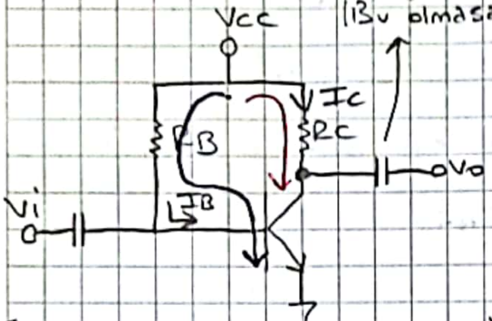
B.E jonksiyonu ileri yönlü kutuplanmış olmalı.

B.C jonksiyonu ileri yönlü kutuplanmış olmalı.

BJT'lerin DC kutuplanması

Fixed Bias Config. (Sabit kutuplamalı devre):

(IB'u olmasaydı sinyal "~" sıfır seviyesinde olmazdı)



$V_{CC} = I_B \cdot R_B + V_{BE}$ I. Gevre (mavi)

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

$V_{CC} = R_C \cdot I_C + V_{CE}$ II. Gevre (kırmızı)

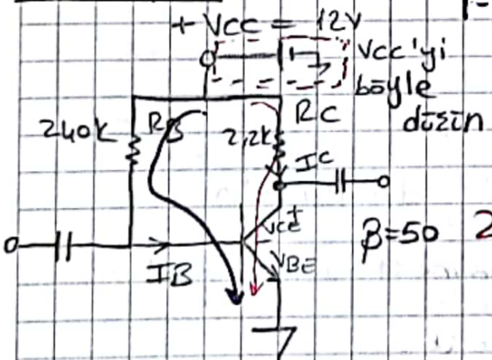
$$\boxed{V_{CE} = V_{CC} - \beta \cdot I_B \cdot R_C}$$

! iki ayrı devre yazılarak tüm gerilimler ve akımlar bulunur.

$\boxed{V_E = 0}$, $\boxed{V_B = V_{BE}}$, $\boxed{V_C = V_{CE}}$

! Bulunan bu devre analizi sonuçları yalnızca bu devreye özeldir. (V_{CE}, I_B vs formülleri her devrede değişebilir.)

Example:



$\beta = 50$

1-) $-V_{CC} + R_B \cdot I_B + V_{BE} = 0$

$-12V + 240k \cdot I_B + 0,7 = 0$

$$\boxed{I_B = \frac{12V - 0,7k}{240k} = 47,08\ \mu A}$$ $\{I_C = \beta \cdot I_B \cdot R_C\}$

2-) $-V_{CC} + I_C \cdot R_C + \underbrace{V_{CE}}_{\to V_C - V_E} = 0$

$-12V + 50 \times 47,08 \times 2,2k + V_{CE} = 0$

$$\boxed{V_{CE} = 6,82\ V}$$

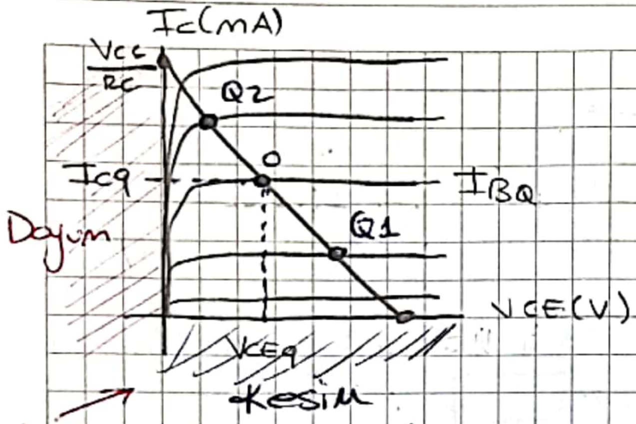
$\{V_{BE} = 0,7V\} \Rightarrow \{V_B = 0,7V\}$ $\{V_C = 6,82V\}$ (Emitter E toprakta = 0 olduğundan)

$\{I_C = 2,35\ mA\}$ $\{I_E = 2,397\ mA\}$! $I_E = I_B + I_C \Rightarrow I_B$ çok küçük olduğundan $I_E \cong I_C$

$\{V_E = 0\}$

$V_C > V_B > V_E$ olduğundan → Aktif bölgede kutuplanmıştır.

CamScanner ile tarandı



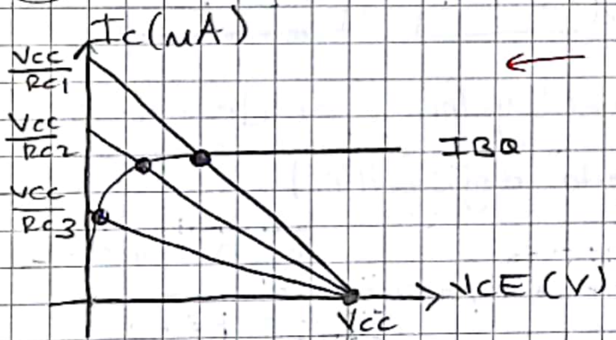
$V_{CE} = V_{CC} - I_C . R_C$

$V_{CE_{max}} = V_{CC} \quad (I_C = 0)$

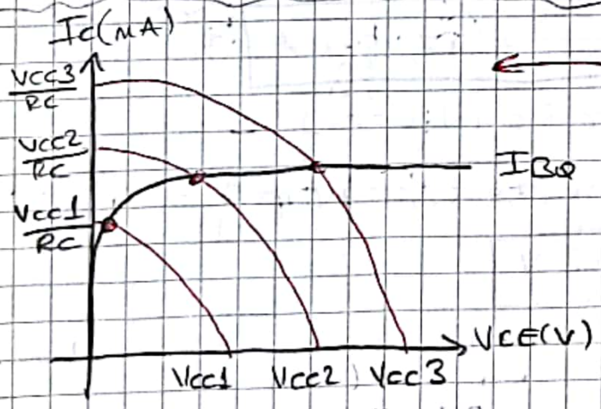
$I_{C_{max}} = \frac{V_{CC}}{R_C} \quad (V_{CE} = 0)$

→ Öyle bir IB akımı olmalı ki kesime ve doyuma en uzak noktada bulunmalı.

! IB akımına göre çalışma noktasının dağılımı. (Yani Rb değişimine göre çalışm noktası değişimi.)



← ! Rc değişimine göre de kutuplama noktası değişebilir.

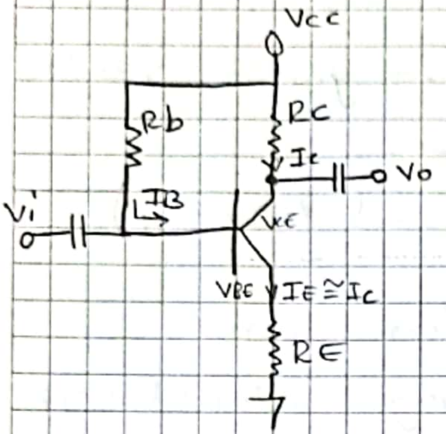


← ! Vcc'deki değişimin Q çalışma noktasına etkisi.

★ Q çalışma noktası 3 şeyden etkilenir.

Rb , Rc , Vcc !!!

Emitter Bias Config:



Yine çevre yazıyoruz.

$$-V_{CC} + I_B \cdot R_B + V_{BE} + \underbrace{(1+\beta) \cdot I_B}_{I_E} \cdot R_E = 0$$

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

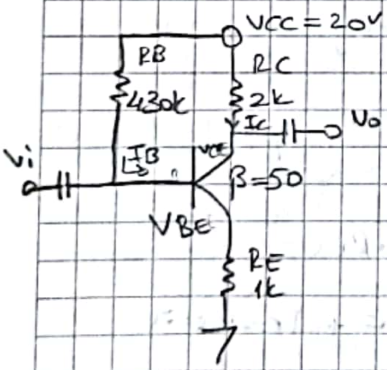
$$-V_{CC} + I_C \cdot R_C + V_{CE} + \underbrace{I_C}_{\cong I_E} \cdot R_E = 0$$

$$V_{CE} = V_{CC} - I_C (R_C + R_E)$$

$\boxed{V_E = I_C \cdot R_E}$ $\boxed{V_B = V_{BE} + V_E}$ $\boxed{V_C = V_{CC} - I_C \cdot R}$

veya I_E

Example:



$$-V_{CC} + R_B \cdot I_B + V_{BE} + (1+\beta) \cdot I_B \cdot R_E = 0$$

$$\boxed{I_B = \frac{V_{CC} - V_{BE}}{R_B + (1+\beta) \cdot R_E}} \Rightarrow \frac{20 - 0{,}7}{430k + 51{,}1k}$$

$V_{BE} = 0{,}7$ dir hep.

$I_B = 40{,}1\ \mu A$ (micro) $\Rightarrow I_C = \beta \cdot I_B = 2{,}005\ mA$

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

$$V_{CE} = V_{CC} - I_C (R_C + R_E) \Rightarrow 20 - 2{,}005(3k)$$

$$V_{CE} \cong 14$$

$\boxed{V_E \cong 2V}$

$V_E = I_C \times R_E$

$2{,}005 \times 1 \cong 2$

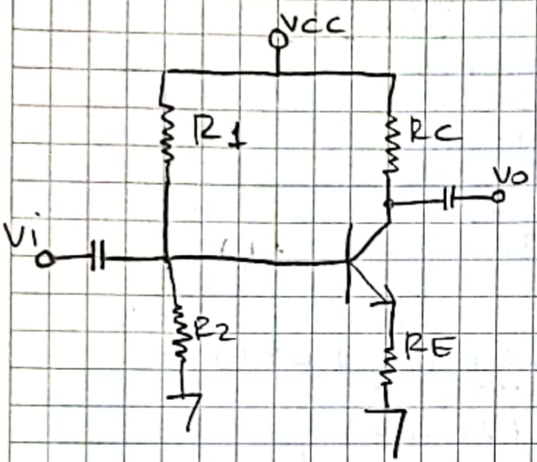
$\boxed{V_B \cong 2{,}7V}$

$2{,}005 + 0{,}7$

$\boxed{V_C \cong 16V}$

$20V - 2k \times 2{,}005\ mA$

Voltage Divider Bias Config:

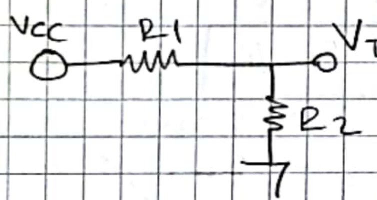


iki tane çözüm yöntemi vardır.

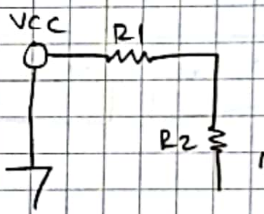
(i) kesin çözüm.

(ii) Yaklaşık çözüm ($10R_2 \leq R_1$)

→ Kesin çözümde Thevenin yaparak devreyi sadeleştiririz.

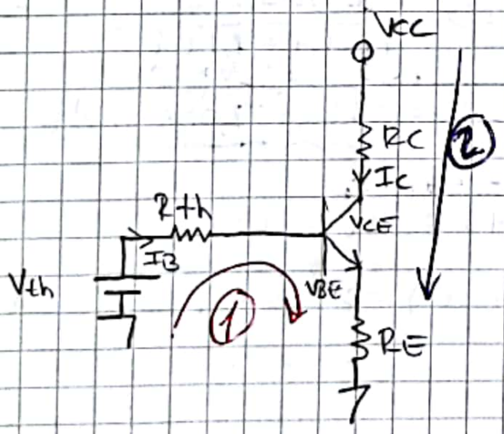


$V_{TH} = \boxed{\dfrac{V_{CC} \cdot R_2}{R_1 + R_2}}$



$R_{th} = R_1 // R_2$

→ Bu iki parçayı değiştirerek sade devreyi oluştur.



1-) $-V_{th} + I_B \cdot R_{TH} + V_{BE} + (1+\beta) \cdot I_B \cdot R_E = 0$

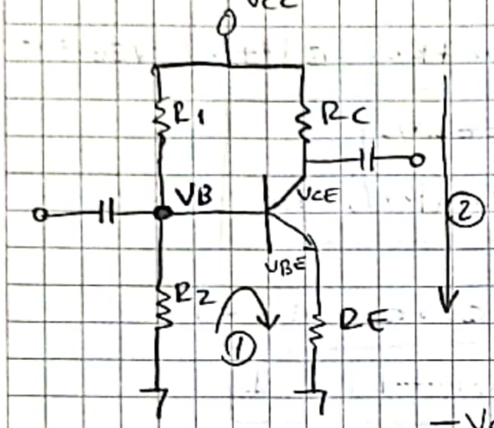
$$I_B = \frac{V_{th} - V_{BE}}{R_{th} + (1+\beta) \cdot R_E}$$

2-) $-V_{CC} + R_C \cdot I_C + V_{CE} + I_C \cdot R_E = 0$

$V_{CE} = V_{CC} - I_C (R_C + R_E)$

→ Bu yapılan kesin çözümdür.

→ Yaklaşık çözüm ise şöyle yapılır: $(10R_2 \leq R_1)$,
$(10R_2 \leq \beta . R_E)$



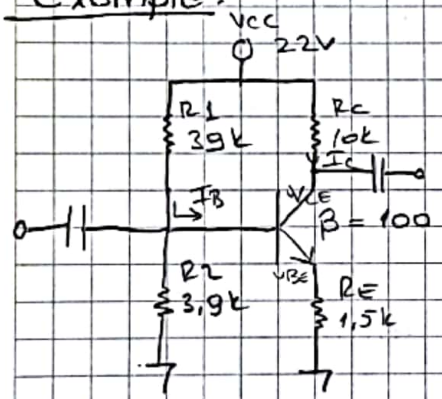
$$V_B = \frac{V_{CC} . R_2}{R_1 + R_2}$$

$$-V_B + V_{BE} + (\beta + 1) . I_B . R_E = 0$$

$$\boxed{I_B = \frac{V_B - V_{CC}}{(1+\beta) . R_E}} \qquad I_C \cong I_E = \beta . I_B$$

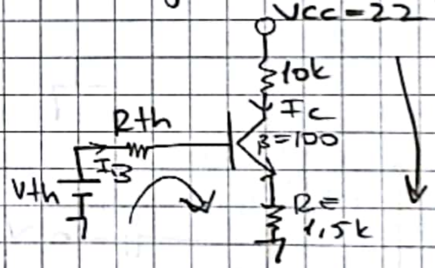
$$-V_{CC} + V_{CE} + I_C (R_E + R_C) = 0$$

Example:



Kesin Çözüm:

(*) Thevenin eşdeğerini çiz.



$$V_{th} = \frac{V_{CC} . R_2}{R_1 + R_2} = \boxed{2V}$$

$$R_{th} = R_1 // R_2 = \boxed{3,55k}$$

$$-2V + I_B . 3,55k + 0,7V + (100+1) . 1,5k = 0$$

$$\boxed{I_B = 8,38 \mu A}$$

$$V_{CE} = V_{CC} - (R_E + R_C) . I_C = 22V - (11,5k) . 0,838$$

$$\boxed{V_{CE} = 12,36 V}$$

Yaklaşık Çözüm: $(10 \times 3,9 \leq 100 \times 1,5)$ ⇒ şartı sağlar.

$$V_B = \frac{22 . 3,9k}{39k + 3,9k} = \boxed{2V}$$

① $-V_B + V_{BE} + (1+\beta) . I_B . R_E = 0$

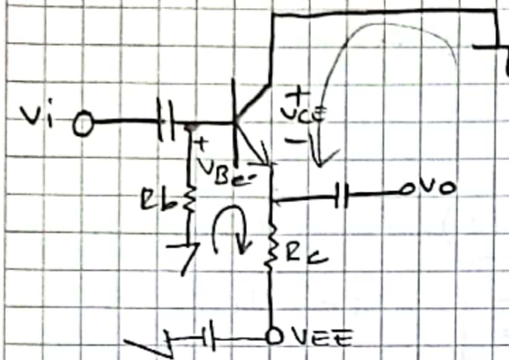
$$\boxed{I_B = 8,6 \mu A} \qquad \boxed{I_C = \beta . I_B = 0,86 mA}$$

② $V_{CE} = V_{CC} - (R_C + R_E) . I_C$

$$V_{CE} = 22V - 11,5k \times 0,86 mA$$

$$\boxed{V_{CE} = 12,04 V}$$

Emitter Follower: (Common Collector) Config:



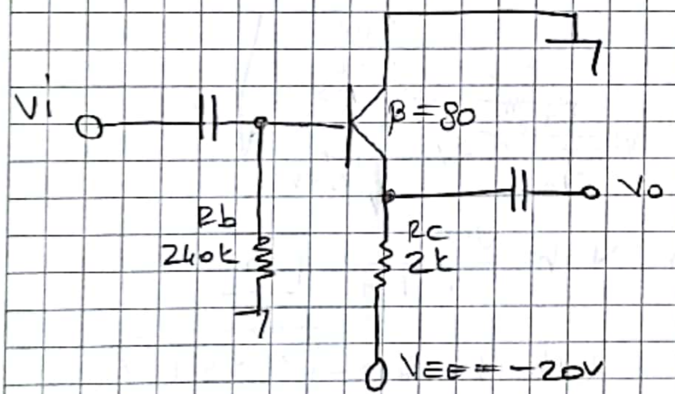
$I_B \cdot R_B + V_{BE} + R_C \cdot I_B (1+\beta) + V_{EE} = 0$

$$\boxed{I_B = \frac{-V_{EE} - V_{BE}}{R_B + (\beta+1) \cdot R_C}}$$

$0 - V_{CE} - R_C \cdot I_C - V_{EE} = 0$

$$\boxed{V_{CE} = -V_{EE} - R_C \cdot I}$$

Example:

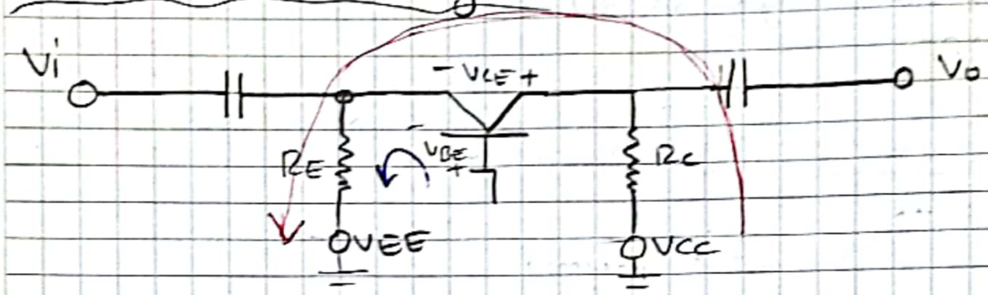


$$I_B = \frac{-(-20V) - 0,7}{240k + (90+1) \cdot 2k} = \boxed{45,7\,\mu A} \qquad I_E = (1+\beta) \cdot I_B = \boxed{4,16\,mA}$$

$$V_{CE} = -(-20V) - 2k \cdot 4,16\,mA$$

$$\boxed{V_{CE} = 11,67\,V}$$

Common Base Config.:



1-) $0 + V_{BE} + R_E \cdot (1+\beta) \cdot I_B + V_{EE} = 0$

$$\boxed{I_{BQ} = \frac{-V_{EE} - V_{BE}}{R_E \cdot (1+\beta)}}$$

2-) $-V_{CC} + R_C \cdot I_C + V_{CE} + I_C \cdot R_E + V_{EE} = 0$

$$\boxed{V_{CE_Q} = V_{CC} - V_{EE} - I_C \cdot (R_C + R_E)}$$

$I_C \rightarrow \beta \cdot I_B$

V_{CE_Q} → çalışma noktası

- AC analiz - önceki hafta DC analizdi.

BJT'li Kuvvetlendiriciler
(BJT'lerin AC analizi, küçük sinyal analizi)

re Transistörü :

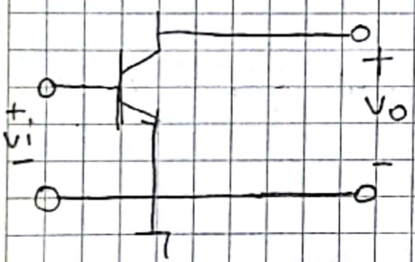
$$re = \frac{V_T}{I_E}$$

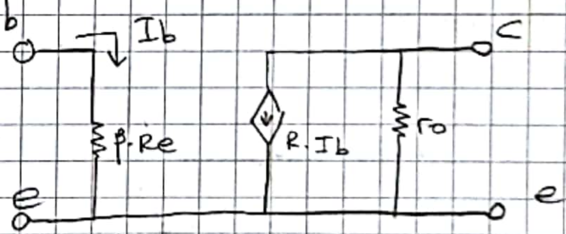
$V_T \rightarrow$ (Termal gerilim (26 mV))

$I_E \rightarrow$ (Emitter akımı)
(DC analiz)

Temel Kuvvetlendirici Yapıları :

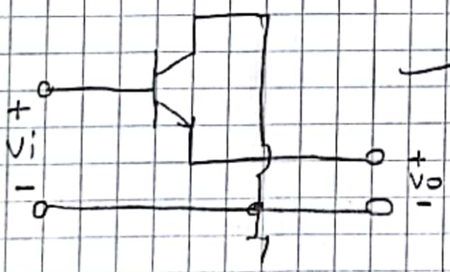
Ortak Emitterli Yapı :



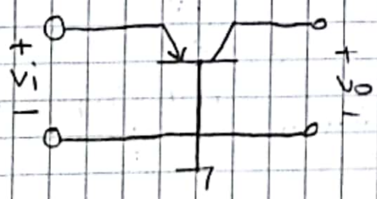


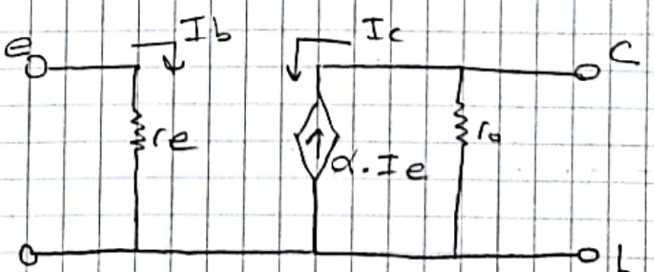
(Eşdeğer devre)

Ortak Kollektörlü Yapı : ortak



Ortak Baseli Yapı :





(Eşdeğer devre)

$\beta = \frac{I_C}{I_B}$ ⇒ Geçen hafta

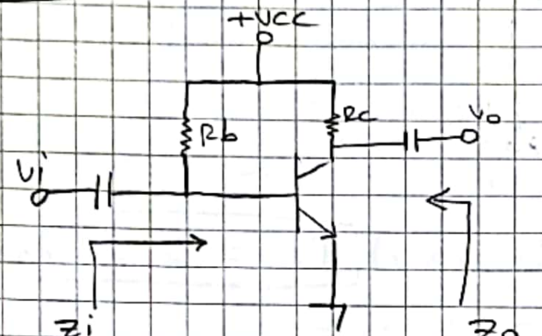
$I_e = (1+\beta).I_b$

$$\alpha = \frac{I_C}{I_e} = \frac{\beta.\cancel{I_b}}{(1+\beta).\cancel{I_b}} = \frac{\beta}{\beta+1} \cong 1$$

⊛ Dc kaynaklar toprak kabul edilir.

⊛ Kapasitörler kısa devre kabul edilir.

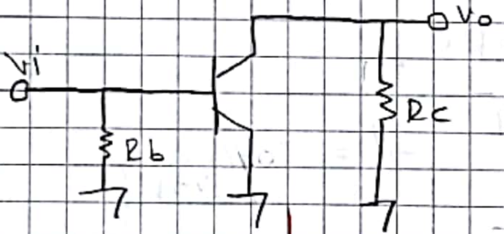
Ortak Emitterli Devre:



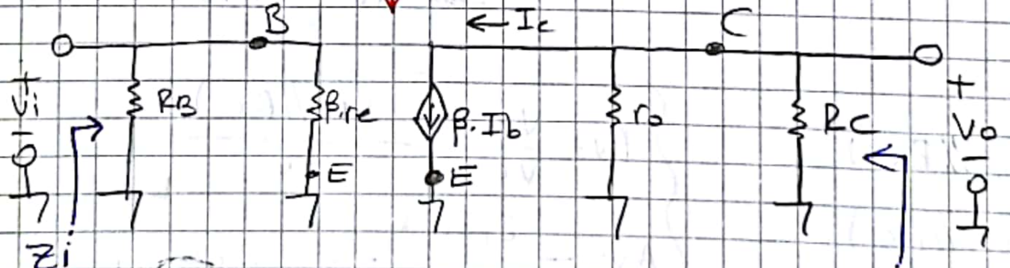
Zi (Soldaki dirençler) (Girişteki)

Zo (Sağdaki dirençler) (Çıkıştaki)

↓ Dc analiz (Yukarıdaki iki kurala göre)



↓ re ekleme



Zi

$Z_i = R_B // \beta.r_e$ → (çok küçük)

$\Rightarrow \boxed{Z_i \cong \beta.r_e}$ ($10.\beta.r_e \leq R_B$ ise)

Zo (giriş kısadevre) çok küçük.

$Z_o = r_o // R_c$

$\Rightarrow \boxed{Z_o \cong R_c}$ ($10.R_c \leq r_o$ ise)

$V_o = -I_c.(R_c // r_o)$

$V_o = -\beta.I_B (R_c // r_o)$

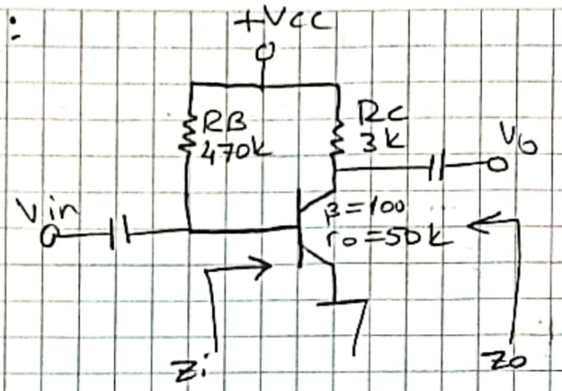
$I_B = \dfrac{V_i}{\beta.r_e}$ ise → $V_o = -\cancel{\beta}.\dfrac{V_i}{\cancel{\beta}.r_e}(R_c // r_o)$

$$\boxed{A_v = \frac{v_o}{v_i} = -\frac{(R_c // r_o)}{r_e}}$$

Bu şart sağlanırsa

$$\boxed{A_v = -\frac{R_c}{r_e}}$$

Example:

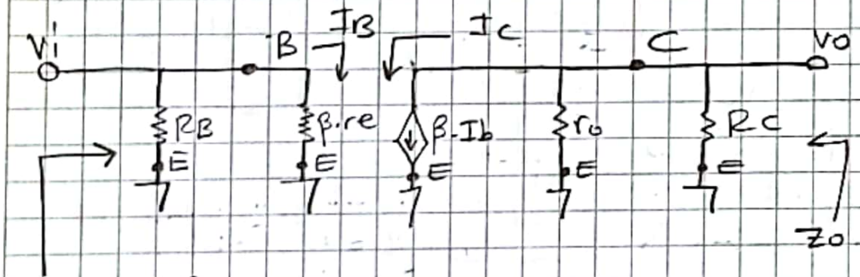


$re, Av, Zo, Zi = ?$

$re, Av, Zo, Zi = ?\ (r_o = \infty)$

DC analizde (geçen haftaki konu) $\boxed{Ie = 2{,}42\,mA}$

$$re = \frac{VT}{Ie} = \frac{26\,mV}{2{,}42\,mA} = \boxed{10{,}74\,\Omega} \Rightarrow \beta.re = 1{,}074\,k$$



$Zo = ro // Rc$

$50k // 3k$

$Zo = 2{,}83\ k\ (r_o = 50k$ iken$)$

$Zo = 3k\ (r_o = \infty$ ise$)$

$Zi = Rb // \beta.re$

$470k // 1{,}074k$

$Zi \cong 1{,}074\,k$

$Vo = -Ic \times (ro // Rc)$

$Vo = -\beta . Ib (ro // Rc)$

⚠ $I_B = \frac{Vi}{\beta.re}$

$Vo = -\beta . \frac{Vi}{\beta.re} (ro // Rc)$

$Av = \frac{Vo}{Vi}$

$$Av = \frac{Vo}{Vi} = -\frac{(ro // Rc)}{re}$$

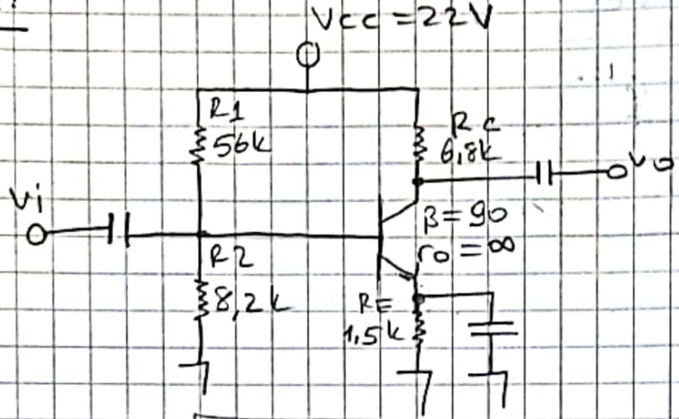
$$Av = -\frac{2{,}83\,k}{10{,}74\,\Omega} = -264\ (ro = 50k)$$

$$Av = -\frac{3k}{10{,}74\,\Omega} = -280\ (ro = \infty)$$

$$Av = -\frac{Rc}{re}$$

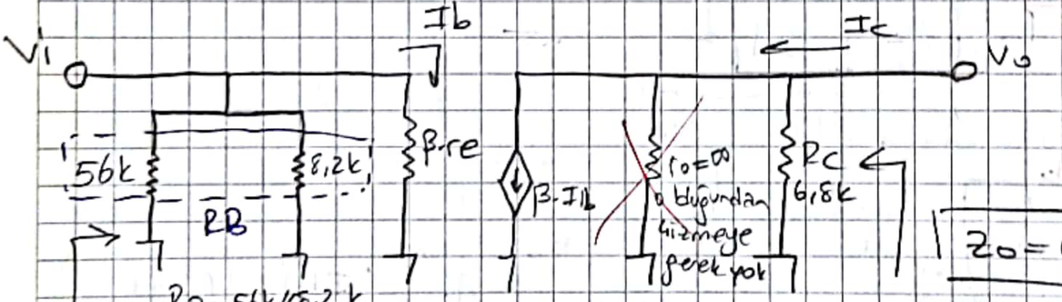
Example:

$r_o, Z_i, Z_o, A_v = ?$



DC analizden $\boxed{I_E = 1,33\ mA}$

$$\boxed{r_e = \frac{V_T}{I_E} = \frac{26mV}{1,33mA} = 19,45\ \Omega} \Rightarrow \boxed{\beta \cdot r_e = 90 \times 19,45 = 1,75\ k}$$



$R_B = 56k // 8,2k$
$= \boxed{7,15k}$

$\boxed{Z_o = 6,8k}$

$Z_i = R_B // \beta . r_e$
$7,15k // 1,75k \Rightarrow \boxed{Z_i = 1,4k}$

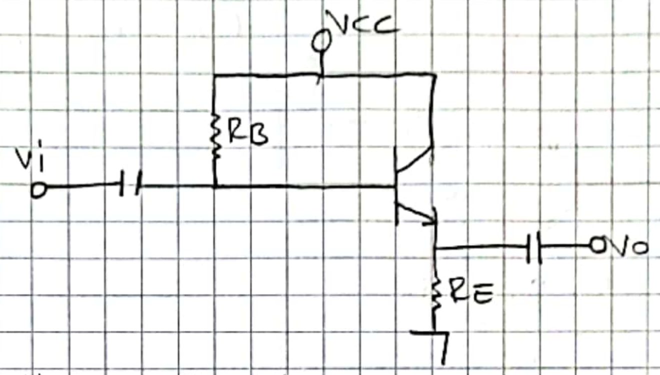
$V_o = - I_c . R_c$

$V_o = -\beta . I_b . R_c$

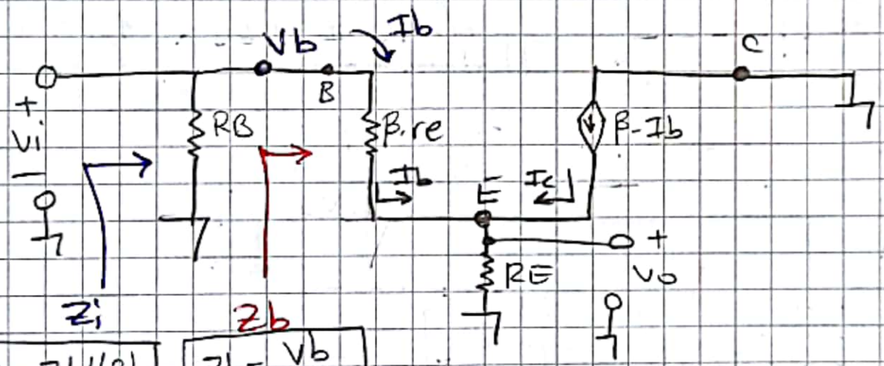
$V_o = -\beta . \frac{V_i}{\beta . r_e} . R_c \Rightarrow A_v = \frac{V_i}{V_o} = -\frac{R_c}{R_e}$

$\Rightarrow A_v = -\frac{6,8k}{19,45\ \Omega}$

Ortak Kollektörlü Devre



★ Emitter ile ortak devre.



$\boxed{Z_i = Z_b // R_b}$ $\boxed{Z_b = \frac{V_b}{I_b}}$

$V_b = I_b.\beta.r_e + (\overset{\text{ihmal}}{1}+\beta).I_b.R_E$

$V_b = I_b.\beta(r_e+R_E) \rightarrow Z_b = \frac{V_b}{I_b} = \frac{\cancel{I_b}\beta.(r_e+R_E)}{\cancel{I_b}}$

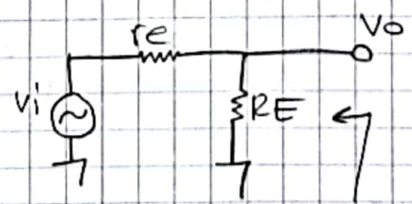
$\boxed{Z_b = \beta.(r_e+R_E)}$

$I_b = \frac{V_b}{\beta(r_e+R_E)}$

$V_o = (1+\beta).I_b \times R_E$

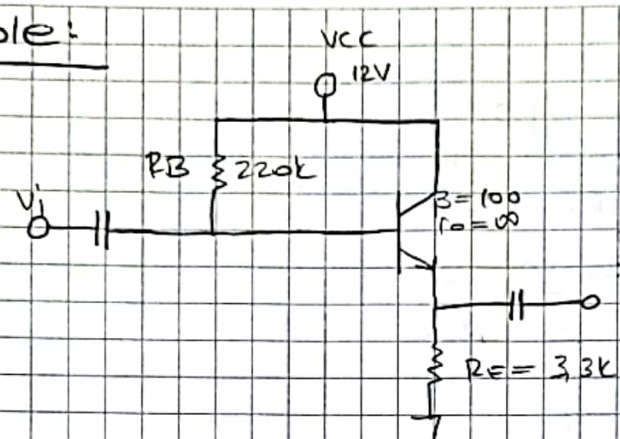
$V_o = \overset{\text{ihmal}}{\cancel{(1+\beta)}}.\frac{V_i}{\cancel{\beta}(r_e+R_E)}.R_E$

$\boxed{V_o = \frac{V_i.R_E}{r_e+R_E}}$ → bunun devresi



$Z_o = R_E // r_e$

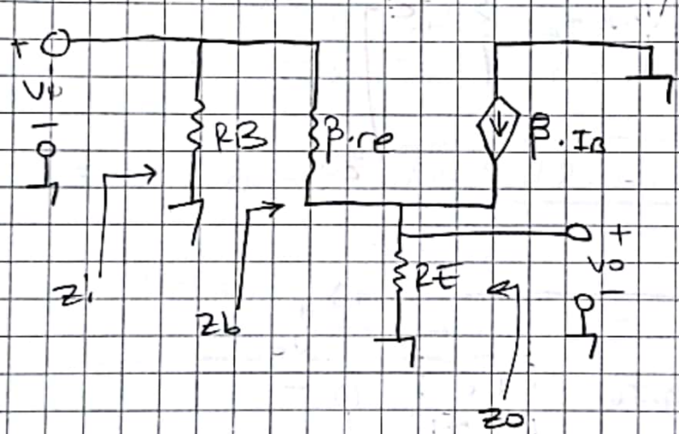
Example:



DC analizden $I_E = 2{,}06\ mA$

$$r_e = \frac{V_T}{I_E} = \frac{26mV}{2{,}06mA} = \boxed{12{,}6\ \Omega}$$

$$\boxed{\beta . r_e = 1{,}26\ k}$$



$$Z_b = \frac{V_b}{I_b}$$

$$V_b = I_b . \beta . r_e + (1+\beta) . I_b . R_E$$

$$V_b = I_b . \beta . r_e + (r_e + R_E)$$

$$Z_b = \frac{V_o}{I_b} = \beta . (r_e + R_E)$$

$$Z_b = 100 \times (12{,}6\ \Omega + 3{,}3k)$$

$$\boxed{Z_b = 331\ k}$$

$$Z_i = R_B // Z_b \Rightarrow Z_i = 220k // 331k = \boxed{132\ k}$$

$$V_o = R_E . (1+\beta) . I_b$$

$$Z_o = R_E // r_e$$

$$V_o = R_E \underbrace{\cancel{(1+\beta)}}_{\text{ihmal}} . \frac{V_i}{\cancel{\beta}(r_e + R_E)}$$

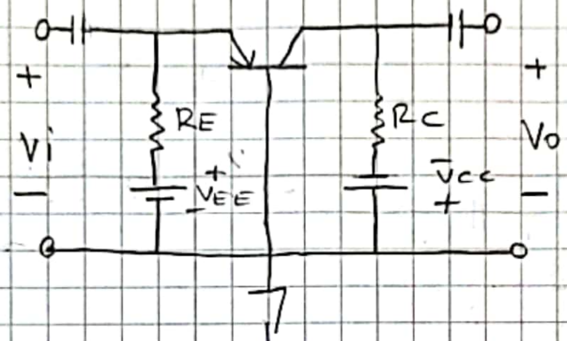
$$\boxed{Z_o \cong 12{,}6}$$

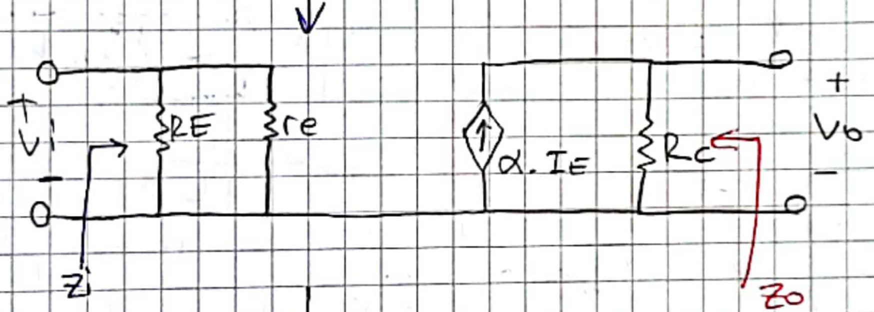
$$V_o = V_i . \frac{R_E}{r_e + R_E} \Rightarrow A_V = \frac{V_i}{V_o} = \frac{R_E}{r_e + R_E} = \frac{3{,}3k}{12{,}6\Omega + 3{,}3k} = 0{,}996 \cong 1$$

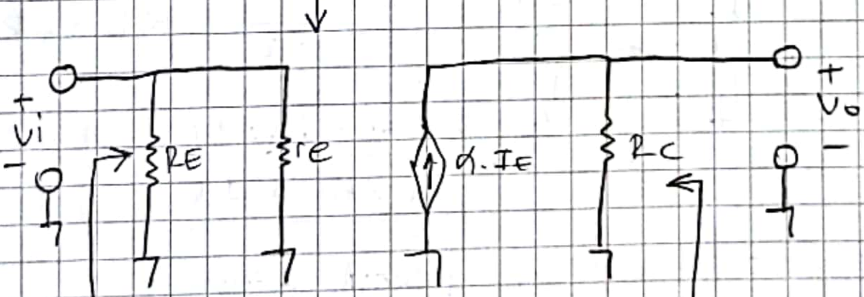
Ortak Kollektörde:

* Giriş direnci büyük.
* Çıkış direnci küçük
* Av pozitif ve yaklaşık "1" dir.

Ortak Baseli Devre:







$$\boxed{Z_i = R_E // r_e}$$

$$\boxed{Z_o = R_C}$$

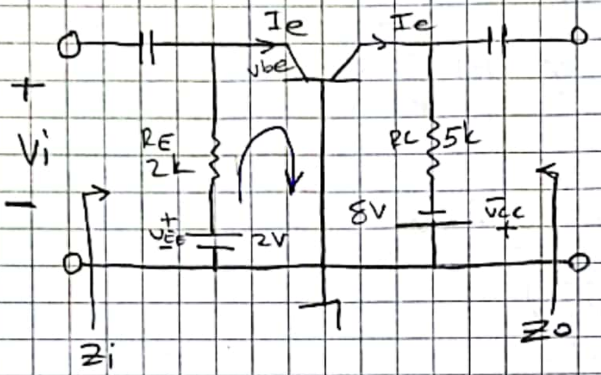
$$V_o = \alpha \cdot I_E \cdot R_C$$

$$V_o = \alpha \cdot \frac{V_i}{r_e} \cdot R_C$$

$$A_v = \frac{V_o}{V_i} = \alpha \cdot \frac{R_C}{r_e} \qquad \alpha \cong 1$$

$$\boxed{A_v \cong \frac{R_C}{r_e}}$$

Example:



kendisi veriyor.

$\boxed{\alpha = 0{,}98}$

DC analizden: $2V = 1k \times I_e + \underbrace{0{,}7V}_{V_{BE}} \Rightarrow \boxed{I_E = \frac{1{,}3V}{1k} = 1{,}3\,mA}$

$r_e = \frac{V_T}{I_E} = \frac{26mV}{1{,}3mA} = 20\,\Omega$

$Z_i = R_E \parallel r_e \Rightarrow \boxed{Z_i = 1k \parallel 20\,\Omega \cong 20\,\Omega}$

$Z_o = R_C \Rightarrow \boxed{Z_o = 5k}$

$\boxed{A_v = \alpha \cdot \frac{R_C}{r_e}}$

$\boxed{A_v = 0{,}98 \times \frac{5k}{20\Omega} = 245}$

α ihmal edilirse

$A_v \cong \frac{R_C \rightarrow 5k}{r_e \rightarrow 20\Omega} \Rightarrow \boxed{A_v \cong 250}$

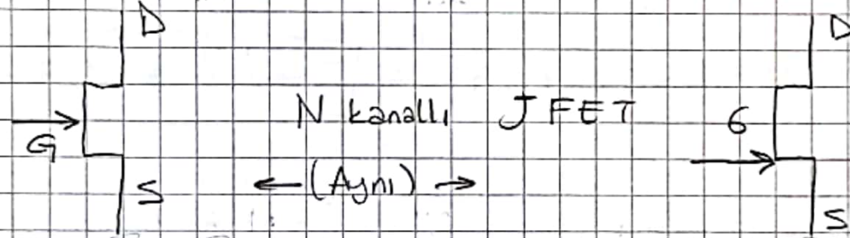
FET'lerin DC Kutuplanması

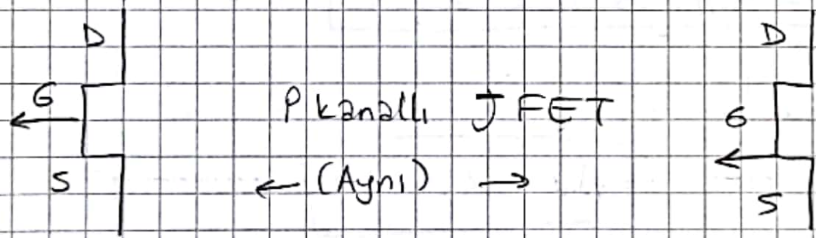
(Field effect transistor)

★BJT'ler akım kontrollü, FET'ler voltaj kontrollü yapılardır.

BJT için: $I_C = \beta \cdot I_B$

JFET için: $I_D = I_{DSS}\left(1-\frac{V_{GS}}{V_P}\right)^2$





→ D=Drain, G=Gate, S=Source.

★ FET'ler sıcaklık değişimine göre BJT'lerden daha kararlıdırlar.

$r_e = \frac{V_T}{I_E}$ → Termal sıcaklık (26mV)

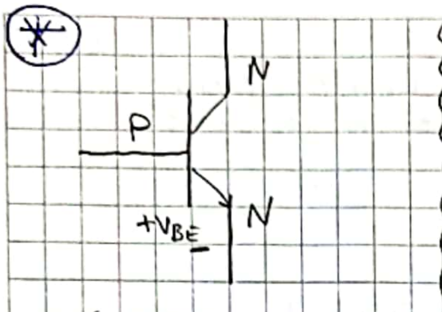
→ BJT'ler sıcaklıktan etkilenir.

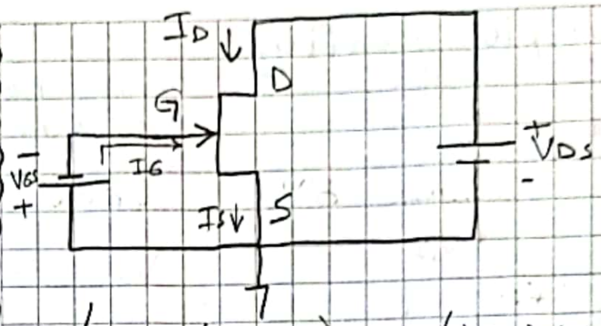
★FET'lerin giriş dirençleri BJT'lerden daha yüksektir.

→ $\boxed{I_G=0}$ FET $\boxed{I_B = \ldots mA}$ BJT.

★ FET'ler fiziksel olarak daha küçüktür.

★ BJT'lerin kazançları daha yüksektir.





$-(V_D > V_S > V_G)-$

Kontrol parametresi: V_{GS}

$\boxed{I_D = I_S}$ $\boxed{I_G = 0}$

Sabitler: I_{DSS}, V_P

Example:

Örneğin $V_{GS} = 0{,}5V_P \Rightarrow I_D = I_{DSS}\left(1 - \frac{0{,}5V_P}{V_P}\right)^2 = \boxed{0{,}25\, I_{DSS}}$

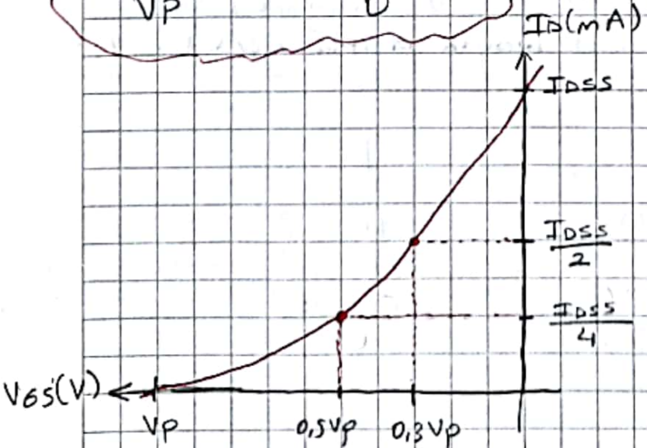
$V_{GS} = 0{,}3V_P \Rightarrow I_D = I_{DSS}\left(1 - \frac{0{,}3V_P}{V_P}\right)^2 \cong \boxed{0{,}5\, I_{DSS}}$

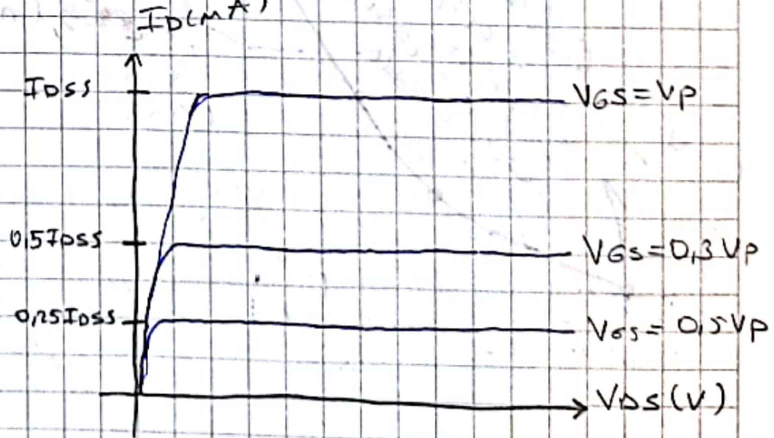
$V_{GS} = 0 \Rightarrow I_D = I_{DSS}$ (I_D MAX)

$V_{GS} = V_P \Rightarrow I_D = 0$ (I_D MIN.)

V_{GS}	I_D
0	I_{DSS}
$0{,}3V_P$	$0{,}5 I_{DSS}$
$0{,}5V_P$	$0{,}25 I_{DSS}$
V_P	0

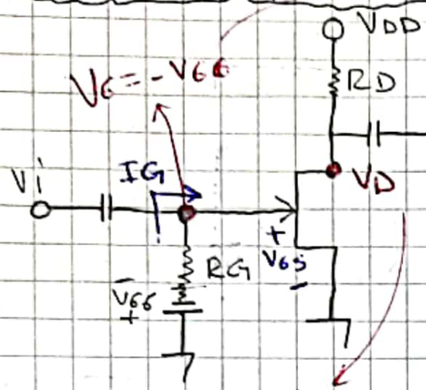
! Her soruda bu tabloyu kullanacaz.





* V_P'nin değeri (−) olduğu için sola çizildi. (V_{GS}'de (−))

Sabit Kutuplu Config.



$V_G = -V_{GG}$

Çünkü RG üzerine gerilim düşmez. V_{GG}'nin hepsi V_G'ye yansır.

$I_G = 0$

$V_{GS} = -V_{GG}$

$$I_D = I_{DSS}\left(1 - \frac{V_{GS}}{V_P}\right)^2$$

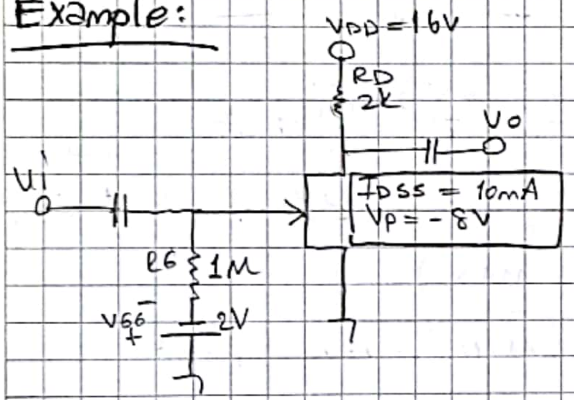
$$\Downarrow$$

$$I_D = I_{DSS}\left(1 - \frac{-V_{GG}}{V_P}\right)^2$$

$V_D = V_{DD} - I_D \cdot R_D$

$V_{DS} = V_D$

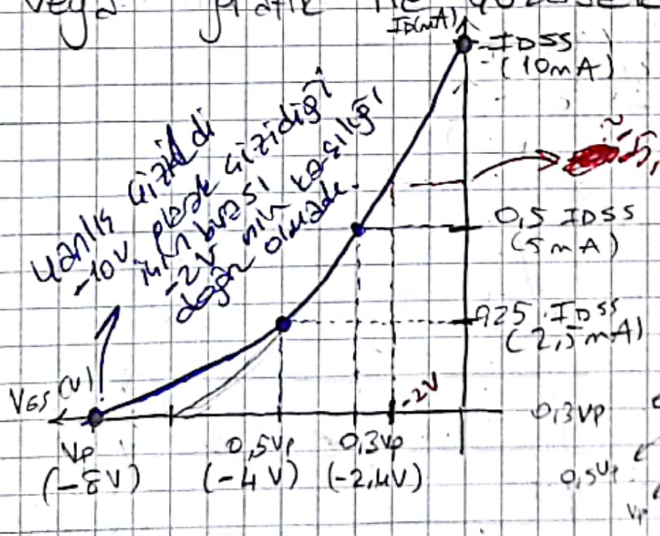
Example:



$V_{GG} = -V_{GS} \Rightarrow \boxed{V_{GS} = -2V}$

$I_D = 10mA\left(1 - \frac{-2V}{-8V}\right)^2 \Rightarrow \boxed{I_D = 5{,}625\ mA}$

veya grafik ile çözersek,



$I_{DSS} = 10mA$
$V_P = -8V$ alıyoruz ve tabloyu dolduruyoruz.

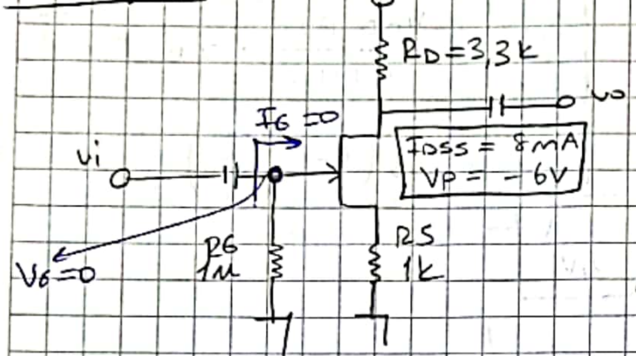
V_{GS}	I_D
0	10 mA → I_{DSS}
0,3Vp ← −2,4V	5 mA → $0{,}5 I_{DSS}$
0,5Vp ← −4V	2,5 mA → $0{,}25 I_{DSS}$
Vp ← −8V	0

★ V_{GS}'yi −2V bulmuştuk.

I_D = Tablodaki karşılığı tahmini olarak $\boxed{\cong 5{,}6mA}$

Sınavda kereli alan verilecek. Grafik ortaya çizilecek.

Example:



$V_{GS} = V_G - V_S \Rightarrow V_{GS} = 0 - \underbrace{I_D \cdot R_S}_{=I_S}$

$\boxed{V_{GS} = -I_D \cdot R_S}$

$I_D = I_{DSS}\left(1 - \frac{V_{GS}}{V_P}\right)^2 \Rightarrow$

$\boxed{I_D = I_{DSS}\left(1 - \frac{-I_D \cdot R_S}{V_P}\right)^2}$

$\boxed{V_{GS} = -I_D \cdot 1k}$, $I_D = 8mA\left(1 - \frac{1k \cdot I_D}{-6V}\right)^2 \Rightarrow \boxed{I_D = I_{DSS}\left(1 - \frac{10^3 \cdot I_D}{6V}\right)}$

$\Rightarrow \underbrace{10^6}_{a} \cdot I_D^2 \underbrace{-16500}_{b} \cdot I_D \underbrace{+36}_{c} = 0 \Rightarrow x_{1,2} = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$

$\Rightarrow x_1 = 13,9mA$, $\boxed{x_2 = 2,59mA}$ $\Rightarrow \boxed{I_D = 2,59mA}$

Bu olamaz çünkü I_D'nin max değeri olan (I_{DSS})'den büyük

$\Rightarrow V_{GS} = -I_D \cdot R_S \Rightarrow \boxed{-2,59V}$

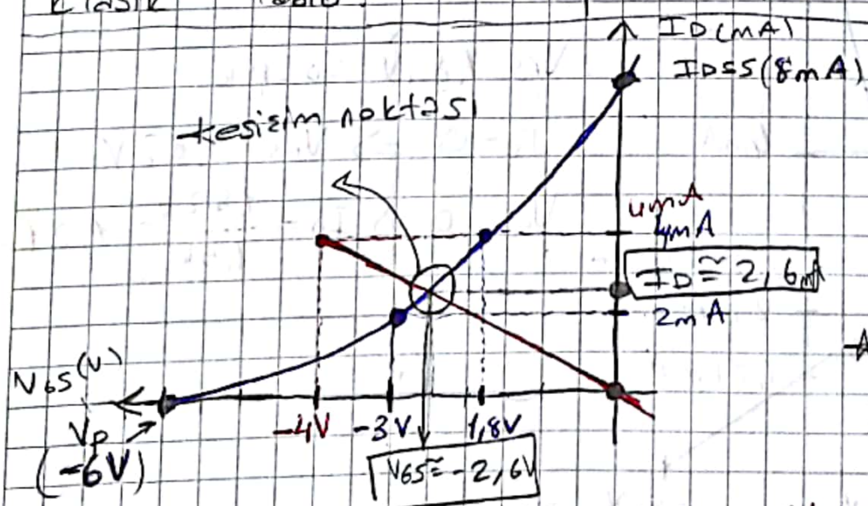
Görüldüğü gibi bu yöntem(↑) çok uzun. Onun için:

V_{GS}	I_D
0	I_{DSS}
$0,3V_P$	$0,5I_{DSS}$
$0,5V_P$	$0,25I_{DSS}$
V_P	0

Klasik Tablo

V_{GS}	I_D
0	8mA
-1,8V	4mA
-3V	2mA
-6V	0

İşimize yarayacak olan tablo.



- $I_D = I_{DSS}\left(1 - \frac{V_{GS}}{V_P}\right)$
- $V_{GS} = -I_D \cdot R_S$

$V_{GS} = -I_D \cdot 1k$

Yukarıdaki iki formül çizilip kesişimleri alınmalı.

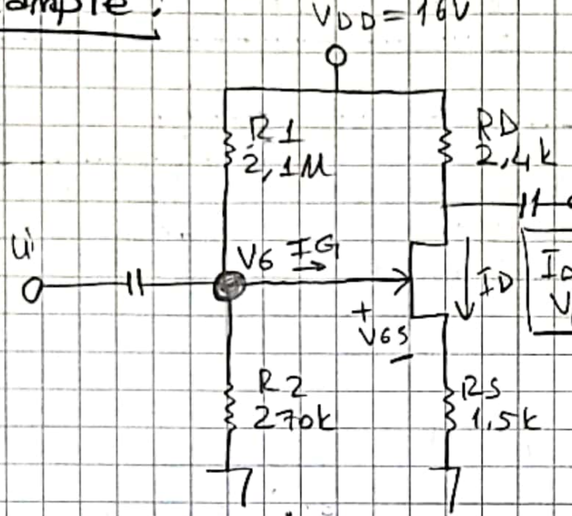
★ 2. formülde 2 değer lazım çizmek için. bunu sağlamak için $V_{GS} = 0$ ve $I_D = 0$ yapılmalı.

$V_{GS} = 0 \Rightarrow I_D = 4mA$

$I_D = 0 \Rightarrow V_{GS} = -4V$

(-4 V), (4mA) ve (0V, 0 mA) olmak üzere 2 nokta belirlendi

Example:



IDSS = 8mA
Vp = −4V

$V_{GS} = V_G - V_S$

$$\boxed{V_{GS} = \frac{V_{DD} \cdot R_2}{R_1 + R_2} - I_D \cdot R_S}$$

$$\boxed{I_D = I_{DSS}\left(1 - \frac{V_{GS}}{V_P}\right)^2}$$ ortak çöz.

$$V_{GS} = \frac{16V \cdot 270k}{270k + 2.1M} - I_D \cdot R_S = (1{,}82 - I_D \cdot \underbrace{R_S}_{1{,}5k})$$

$$I_D = 8mA\left(1 - \frac{V_{GS}}{-4V}\right)^2$$

V_{GS}	I_D
0	I_{DSS}
$0{,}3V_p$	$0{,}5 I_{DSS}$
$0{,}5V_p$	$0{,}25 I_{DSS}$
V_p	0

Klasik Tablo.

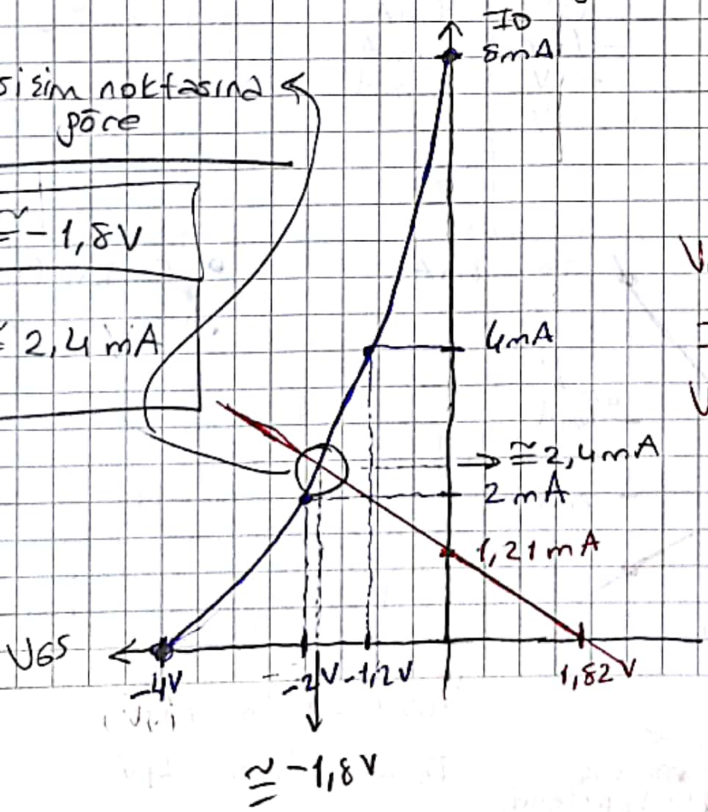
V_{GS}	I_D
0	8mA
−1,2V	4mA
−2V	2mA
−4V	0

Bu değerlere göre ve $V_{GS} = 1{,}82 - I_D \cdot 1{,}5k$ ya göre grafik çiz.

Kesişim noktasına göre

$$\boxed{V_{GS} \cong -1{,}8V}$$

$$\boxed{I_D \cong 2{,}4\ mA}$$



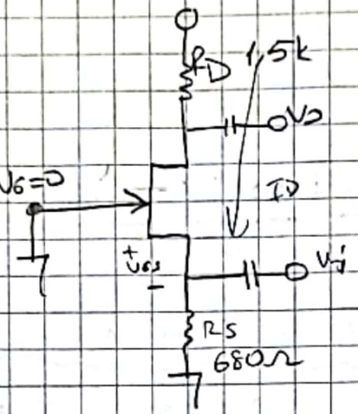
- $I_D = I_{DSS}\left(1 - \frac{V_{GS}}{V_p}\right)^2$
- $V_{GS} = 1{,}82 - I_D \cdot 1{,}5k$

$V_{GS} = 1{,}82V - I_D \cdot 1{,}5k$

$I_D = 0 \Rightarrow V_{GS} = 1{,}82V$

$V_{GS} = 0 \Rightarrow I_D = \frac{1{,}82V}{1{,}5k} = 1{,}21mA$

Example :



Sorudaverilıyor.

$I_{DSS} = 12mA$
$V_P = -6V$

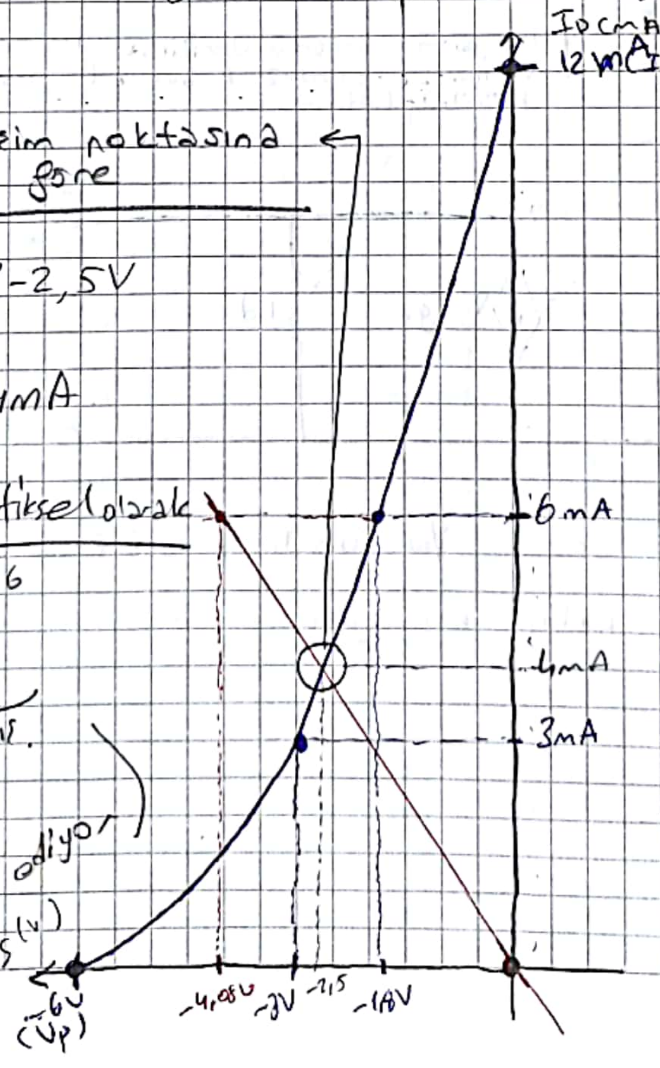
$V_{GS} = V_G - V_S \Rightarrow \boxed{V_{GS} = -I_D . R_S}$ ($V_G \to 0$, $V_S = I_D . R_S$)

$\boxed{I_D = I_{DSS}\left(1 - \frac{V_{GS}}{V_P}\right)^2}$ ortak çöz.

$V_{GS} = -680\Omega . I_D$, $I_D = 12mA\left(1 - \frac{V_{GS}}{-6V}\right)^2$

V_{GS}	I_D
0	I_{DSS}
$0,3V_P$	$0,5 I_{DSS}$
$0,5V_P$	$0,25 I_{DSS}$
V_P	0

V_{GS}	I_D
0	12mA
−1,8V	6mA
−3V	3mA
−6V	0



Kesişim noktasına göre

$V_{GS_Q} \cong -2,5V$

$I_{D_Q} \cong 4mA$

Matematiksel olarak

$V_{GS_Q} = 2,6$

$I_D = 3,8$

Hesaplanmış.

Ama yakın değerler bulursak da oluyor hoca kabul

• $I_D = I_{DSS}\left(1 - \frac{V_{GS}}{V_P}\right)^2$

• $V_{GS} = -680\Omega . I_D$

$V_{GS} = 0 \Rightarrow I_D = 0$

$I_D = 6mA \Rightarrow V_{GS} = -4,08V$

CamScanner ile tarandı

FET'lerin AC Analizi:

Transkondüktans (Geçiş iletkenliği)

$$g_m = \frac{\Delta I_D}{\Delta V_{GS}} \Rightarrow g_m = \frac{d.I_D}{d.V_{GS}} = \frac{d.I_{DSS}.\left(1-\frac{V_{GS}}{V_P}\right)^2}{d\,V_{GS}}$$

↳ *Q çalışma noktasındaki eğim.

$$\Rightarrow \boxed{g_m = \frac{2I_{DSS}}{|V_P|}\cdot\left[1-\frac{V_{GSQ}}{V_P}\right]} \qquad \boxed{g_m = \frac{2\,I_{DSS}}{|V_P|}\cdot\sqrt{\frac{I_{DQ}}{I_{DSS}}}}$$

★ 2 tane formül vardır.

AC eşdeğer devresi:

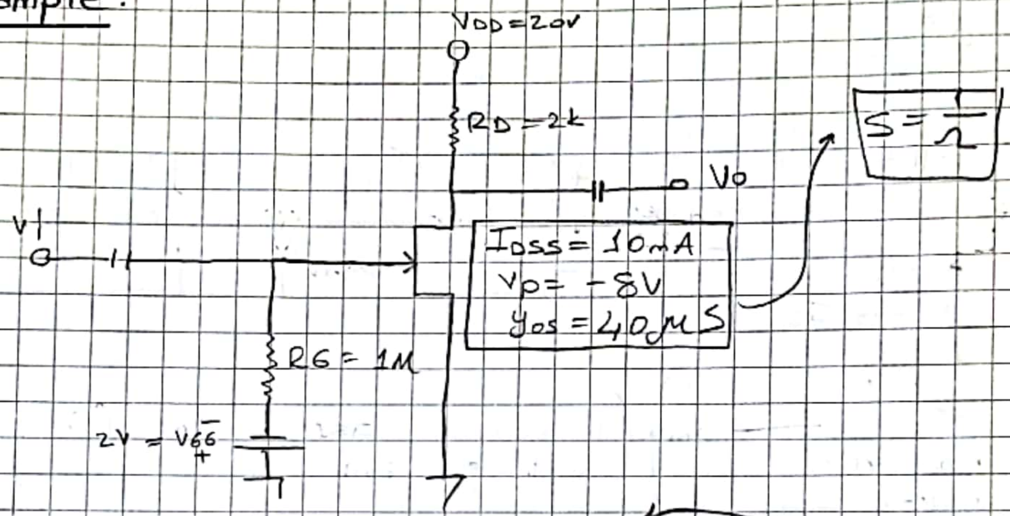
! Bu direnç soruda verilirse hesapla verilmezse sonsuz kabul et yani hesaba katma.

$$\boxed{y_{os} = \frac{1}{r_d}}$$

Genelde soruda y_{os} verilir. Ama biz rd'yi bulup buna göre işlem yapacağız.

↓ Çıkış iletkenliği

Example:



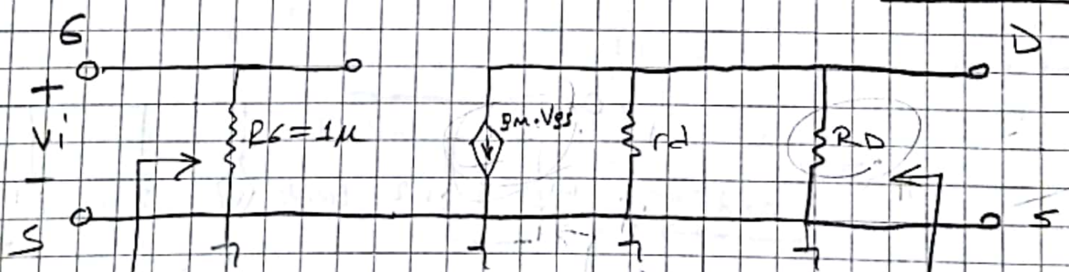
$$\boxed{g_m = \frac{2 I_{DSS}}{|V_p|} \cdot \left(1 - \frac{V_{GSQ}}{V_p}\right)}$$

DC Analizden: $\boxed{V_{GSQ} = -2V}$

$$g_m = \frac{2 \cdot 10mA}{|-8V|} \cdot \left(1 - \frac{-2V}{-8V}\right) = \boxed{1{,}88\ mS}$$

$$r_d = \frac{1}{y_{os}} \Rightarrow r_d = \frac{1}{40\mu S}$$

$$\boxed{\Rightarrow r_d = 25k}$$



$\boxed{Z_i = 1M}$

$\boxed{V_i = V_{gs}}$

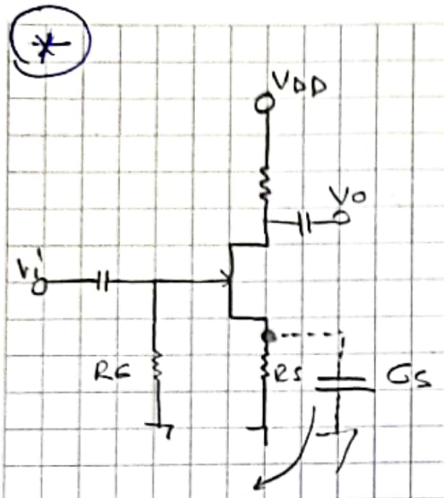
$Z_o = (r_d // R_D)$

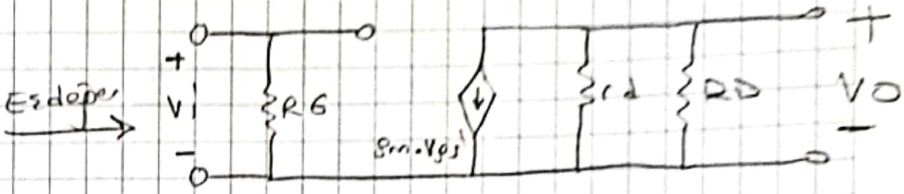
$\boxed{Z_o = 1{,}85k}$

$$A_v = \frac{V_o}{V_i} = -g_m \cdot (r_d // R_D) \Rightarrow \boxed{A_v = -3{,}478}$$

CamScanner ile tarandı

(*)

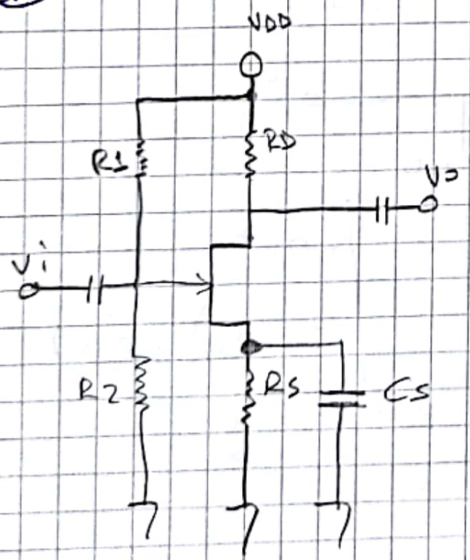


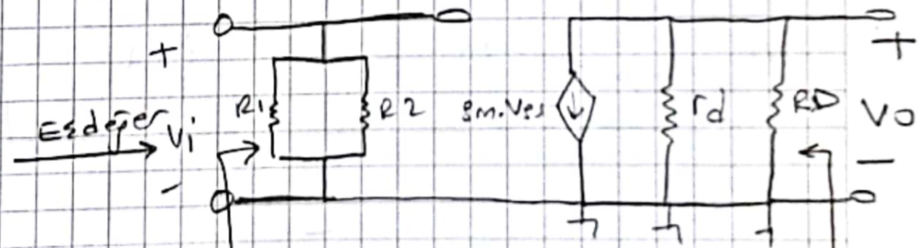


! AC analizde kapasitörler kısa devre olarak işlem görür.

(Bir önceki devre ile AC analizleri aynı)

(*)

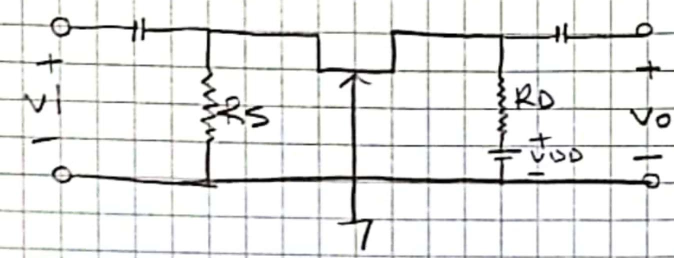




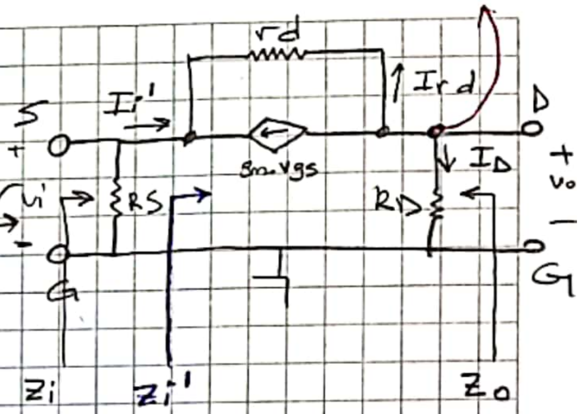
$\boxed{Z_i = R_1 // R_2}$

$\boxed{Z_o = r_d // R_D}$

(1)



Eşdeğer

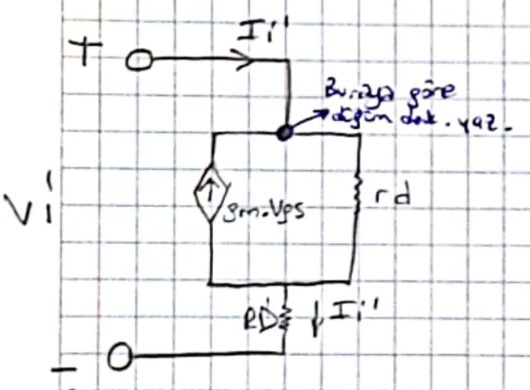


$\boxed{V_i'' = -V_{gs}}$

(*) Zi yi bulmak için Zi' yi bul.

$$\boxed{Z_i' = \frac{V_i''}{I_i''}}$$

(*) Devreyi 2 parçaya ayırıp öyle incele.
(Giriş ve çıkış direncini bulmak için)



(Giriş direncini bulmak için)

$V_{gs} = -V_i'$

$$V_i' = V_{rd} + V_{RD}$$

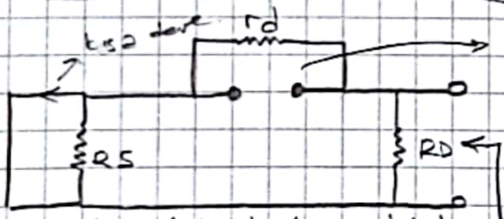
$$V_i' = r_d\,(g_m \cdot V_{gs} + I_i') + R_D \cdot I_i'$$

$$V_i' = r_d\,(-g_m \cdot V_i' + I_i') + R_D \cdot I_i'$$

$$V_i' = -r_d \cdot g_m \cdot V_i' + r_d \cdot I_i' + R_D \cdot I_i'$$

$$V_i' = (1 + r_d \cdot g_m) = I_i' \cdot (r_d + R_D)$$

$$\boxed{Z_i = \frac{V_i'}{I_i'} = \frac{r_d + R_D}{1 + r_d \cdot g_m}}$$



(Çıkış direncini bulmak için)

Girişi toprak kabul ettiğimizde.

$V_i = -V_{gs}$ olduğundan $g_m \cdot V_{gs} = 0$ olur

dolayısıyla akım kaynağından akım akmaz

$\boxed{Z_o = R_D // r_d}$

$$V_i = -V_{gs}$$

$$V_o = I_D \cdot R_D$$

$$V_{rd} = V_o - V_i$$

$$I_{rd} = \frac{V_{rd}}{r_d} = \frac{V_o - V_i}{r_d}$$

(1) noktasına göre düğüm denk yazarsak

$$I_D + g_m \cdot V_{gs} + I_{rd} = 0$$

$$\frac{V_o}{r_d} - g_m \cdot V_i' + \frac{V_o - V_i}{r_d} = 0 \quad \text{(Yanda bulduk)}$$

$$\boxed{A_V = \frac{V_o}{V_i} = \frac{g_m + \frac{1}{r_d}}{\frac{1}{R_D} + \frac{1}{r_d}}}$$

– DÖNEM SONU –