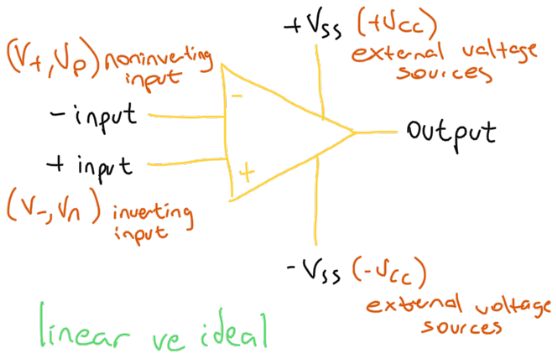
opamp(işlemsel yükselticiler)

opamp=operational amplifiers



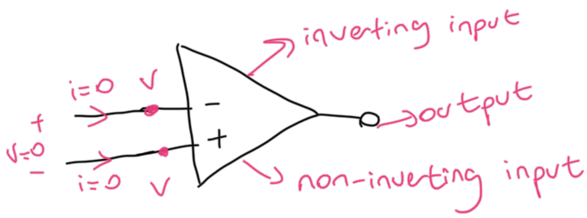
* normalde non-linear ama biz ideal linear modeli kullanacağız
elektrik devrelerinde;
- matematiksel işlemler
- karşılaştırma işlemleri (kontrol uygulamaları)
- analog bilgisayarlar
- analog aktif filtreler olarak kullanılırlar

linear ve ideal

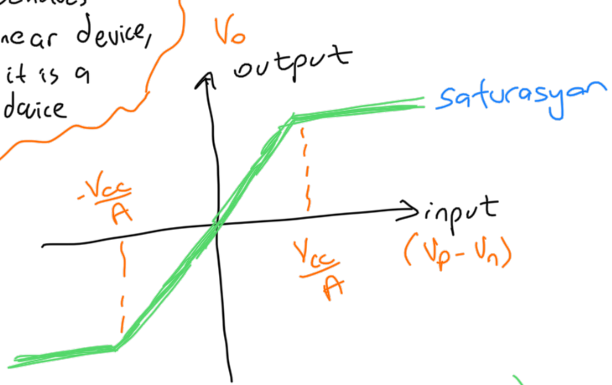
- inputlardan akım almaz
- inputları arasında gerilim farkı yoktur

Opamp uygulamaları

* çalışmak için harici bir güç kaynağına ihtiyaç duydukları için aktif element olarak değerlendirilirler.
- sinyal yükseltirken bir yerden enerji gerekir. bu nedenle sınırlıdırlar. (saturasyon noktaları)

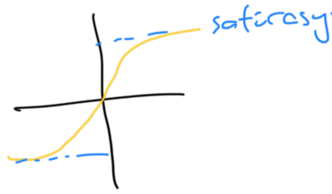


- if $|V_p - V_n| < \frac{V_{cc}}{A}$
opamp behaves like a linear device, otherwise it is a nonlinear device



(voltage yükseltme grafiği)

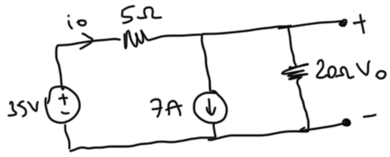
linear



(linear olmayan)

Common reference circuit diagrams

- all connections are not shown explicitly (all voltages are mesured relative to a comm reference)



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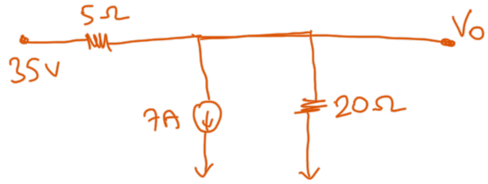
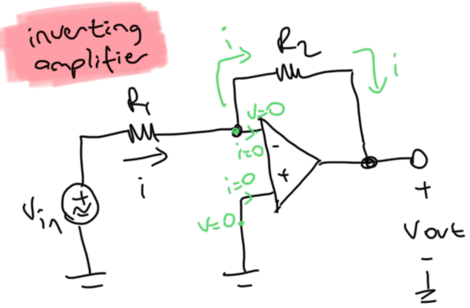


inverting amplifier



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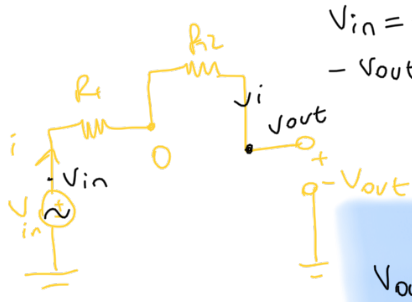


$V_{in} = R_1 \cdot i$

$-V_{out} = R_2 i$

$\frac{V_{in}}{R_1} = \frac{-V}{R}$

$V_{out} = -V_{in} \frac{R_2}{R_1}$

* iki tanesi arka arkaya bağlayarak etki yok edilebilir.

ooo

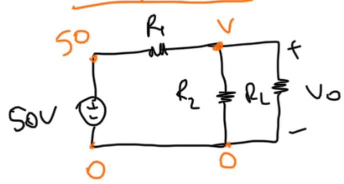
$R_2 > R_1$ çarpma ⟵

$R_1 > R_2$ böler

$R_1 = R_2$ $V_{out} = -V_{in}$

$V_{gain} = \frac{V_o}{V_{in}} =$

voltage divider



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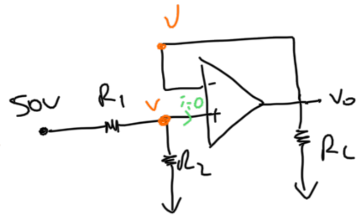

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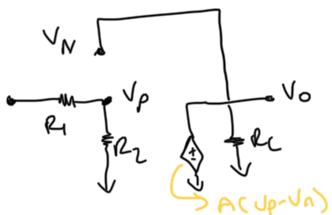


$V_o = V$

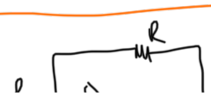
$(V_N = V_p = V_o)$

$$\frac{V_o - 50}{R_1} + \frac{V_o}{R_2} + \frac{V_o}{R_L} = 0$$

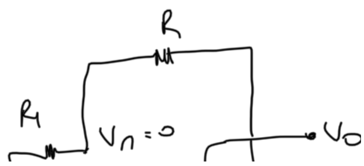
$$\frac{V_o - 50}{R_1} + \frac{V_o}{R_2} = 0$$

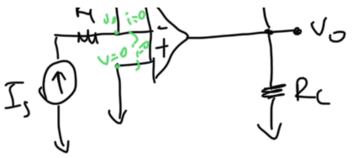
$$V_o = \frac{R_2}{R_1 + R_2} 50$$ (independent of R_L)

Current to voltage divider



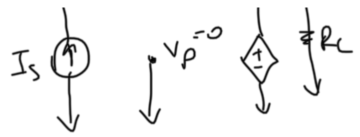
$$-I_o + \frac{-V_o}{R} = 0$$



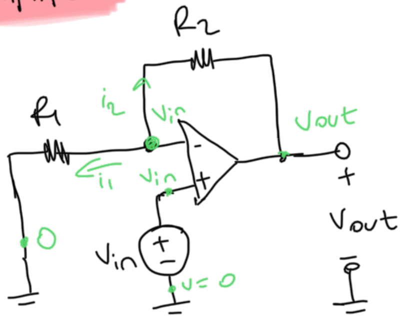


$$I_o = -\frac{V_o}{R}$$

$=$



non inverting amplifier



$$i_1 + i_2 = 0$$

$$\frac{V_{in}}{R_1} + \frac{V_{in} - V_{out}}{R_2} = 0$$

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

$$V_{in}\left(\frac{R_1 + R_2}{R_1 \cancel{R_2}}\right) = \frac{V_{out}}{\cancel{R_2}}$$

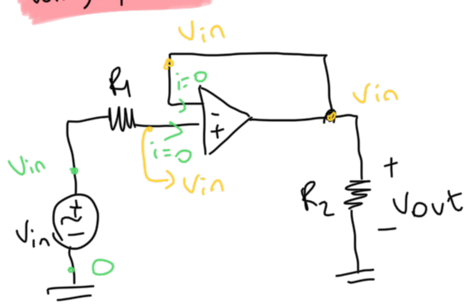
$$\frac{V_{out}}{V_{in}} = \text{gain}$$

$$= \frac{R_1 + R_2}{R_1} = 1 + \frac{R_2}{R_1}$$

buffer = tampon / korumak

(current buffer)

buffer, voltage follower (unity gain amplifier) (ideal)



$$V_{in} = V_{out}$$

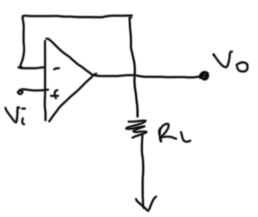
$$\lim_{\substack{R_i \to \infty \\ R_o \to 0 \\ A \to \infty}} V_i \frac{1 + \cancel{\frac{R_o}{A \cdot R_i}}}{\cancel{\frac{1}{A}} + 1 + \cancel{\frac{R_o}{A R_L}} + \cancel{\frac{R_o}{A \cdot R_i}}} = V_o$$

$\Rightarrow V_i = V_o$

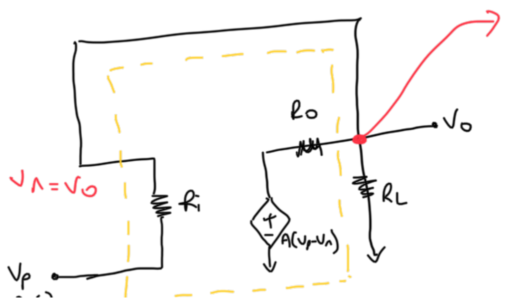
* Sinyal düşük olan kaynaktan yararlanmak için

(akım çekilen noktanın gerilimi düşer bununla voltage kaybı olmadan iletebiliyoruz)

real opamp voltage follower (not ideal)



$\Rightarrow$



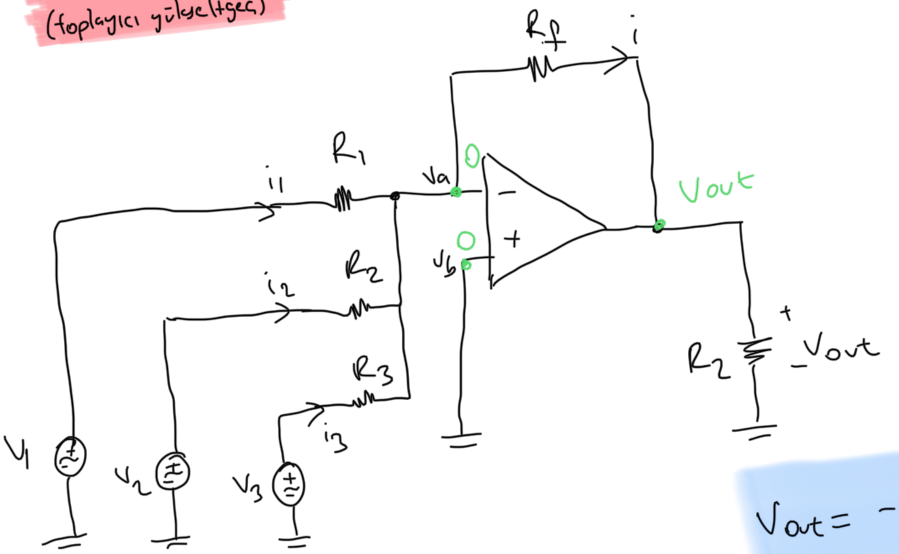
$$\frac{V_o - A(V_i - V_o)}{R_o} + \frac{V_o}{R_L} + \frac{V_o - V_i}{R_i} = 0$$

$$V_o = V_i \frac{1 + \frac{R_o}{A \cdot R_i}}{\frac{1}{A} + 1 + \frac{R_o}{A R_L} + \frac{R_o}{A \cdot R_i}}$$

(vi)
$V_p = V_i$ "real" model of opamp

* problem must state which model to use

summing amplifier
(toplayıcı yükseltgeç)

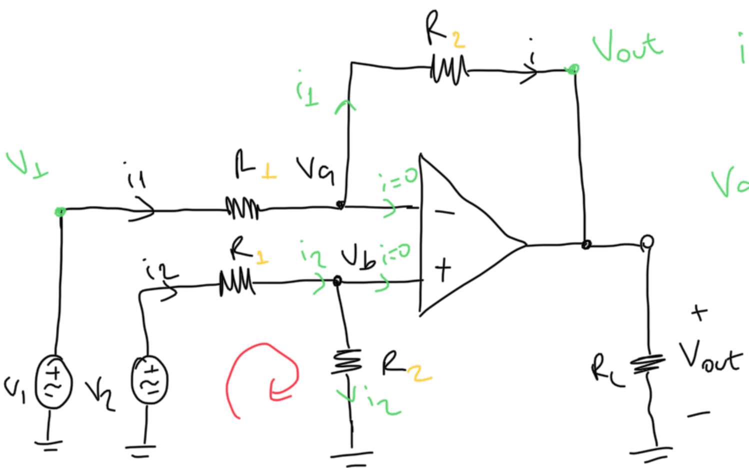


$$i_1 + i_2 + i_3 = i$$

$$\frac{V_1}{R_1} + \frac{V_2}{R_2} + \frac{V_3}{R_3} = \frac{-V_o}{R_{\cdot}}$$

$$\boxed{V_{out} = -R_f\left(\frac{V_1}{R_1} + \frac{V_2}{R_2} + \frac{V_3}{R_3}\right)}$$

difference amplifier
(fark yükseltici)



$$i_2 = \frac{V_2}{R_1 + R_2} \qquad V_b = \frac{R_2 \cdot V_2}{(R_1 + R_2)}$$

$$V_a = V_b = \frac{R_2 V_2}{(R_1 + R_2)} \qquad i = i_1$$

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

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

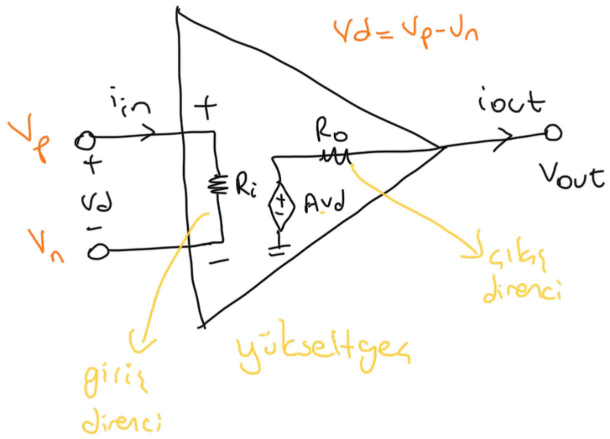
$$\boxed{V_o = V_2 - V_1}$$

birden fazla opamp içeren sistemlerde

* analiz etmeye sondan başla

* opampların çıkışlarında kcl uygulanma çünkü çıkış akımı bilinmez.

ideal olmayan opamp modeli



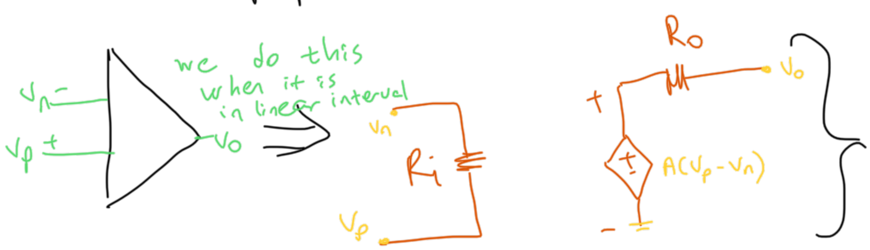
* verilen Vd gerilimini A (yüksek) (100k) katı kadar yükseltiyor
* Ro direncinden dolayı ideal değil

Ri çok büyük ama sonsuz değil (idealde ∞) (5MΩ)
(sonsuz ise $i_p \cong i_n \cong 0$)

Ro çok küçük ama sıfır değil (idealde 0) (75Ω)

	real opamp	ideal opamp	
R_i	very large	∞	→ $i_- \equiv i_+ = 0$
R_o	very small	0	→ output is not affected by what is connected to
A	very large	∞	→ $V_p = V_n$

- Opamps are nonlinear devices, but we operate them in a linear range

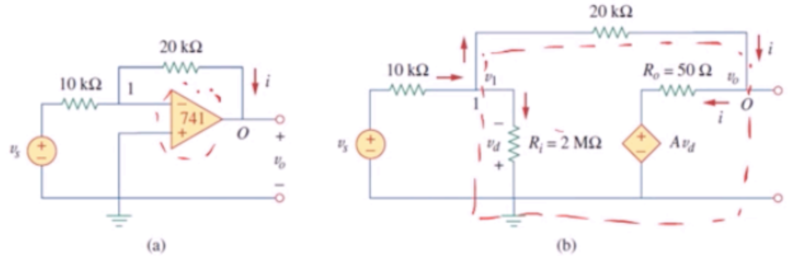


şekline dönüştürülebi

$$kazanç = \frac{AV_d}{V_d} = A$$

Example 5.1

A 741 op amp has an open-loop voltage gain of 2×10^5, input resistance of 2 MΩ, and output resistance of 50 Ω. The op amp is used in the circuit of Fig. 5.6(a). Find the closed-loop gain v_o/v_s. Determine current i when $v_s = 2$ V.



(a) (b)

$A = 2 \times 10^5$

$R_i = 2M\Omega$

$R_o = 50\Omega$

$\underline{V_1}$

$$\frac{V_S - V_1}{10k} = \frac{V_1}{2M} + \frac{V_1 - V_o}{20k}$$

$$3V_1 - 2V_S - V_o = 0$$

$$V_1 = \frac{2V_S + V_o}{3}$$

$$= \frac{V_o}{V_S} \approx -2$$

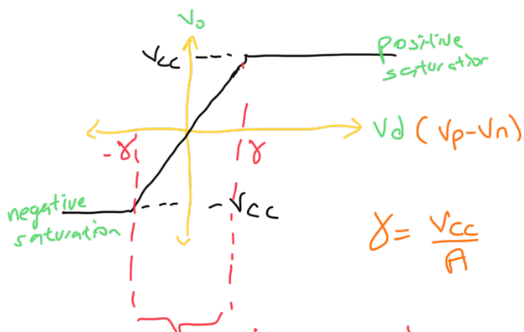
$\underline{V_o}$

$V_1 = -1$

$$\frac{V_1 - V_o}{20k} = \frac{V_o - AV_o}{50}$$

$$\frac{V_1 - V_o}{20k} = \frac{V_o + AV_1}{50}$$

$$V_1 - V_o = 400(V_o + AV_1)$$

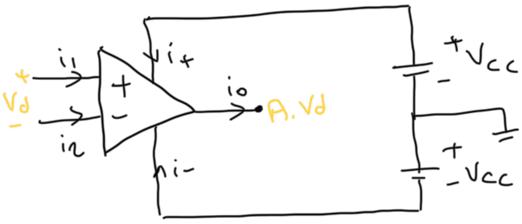


$\gamma = \frac{V_{cc}}{A}$

giriş gerilimi bunların arasındaysa opamp linear yükseltme işlemi yapar

- giriş gerilimini aşınca ($V_d > \gamma$) opamp satürasyona giriyor, her zaman Vcc gerilimini veriyor. $(V_p - V_n) > \frac{V_{cc}}{A}$

Karşılaştırıcı opamp



example

$V_a > V_b \Rightarrow 15V$

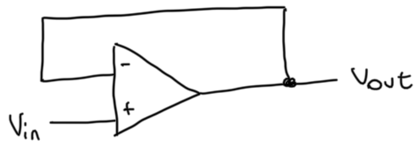
$V_b > V_a \Rightarrow -15V$

$V_d = 5V - 3V = 2V$

A çok küçük olduğundan 2V'yi sonsuza kadar yükseltemez
(A=200.000 gibi bir şey.
A.2V = 400.000 V sağlayamaz
en fazla 15V'a kadar yükseltir)

feedbacks

negative



output of the op-amp is connected to the negative terminal

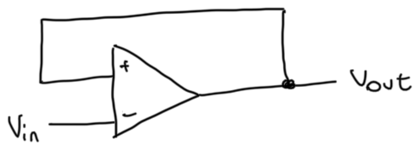
assume error: $\varepsilon = V_{in} - V_{out}$

if $\varepsilon > 0$ ($V_{in} > V_{out}$) → V_{out} will increase by $A\varepsilon$. $V_{in} > V_{out} + A\varepsilon$ will get closer.
error becomes smaller

if $\varepsilon < 0$ ($V_{in} < V_{out}$) → V_{out} will decrease by $A\varepsilon$ $V_{in} < V_{out} - A\varepsilon$ will get close
error becomes smaller

the output is fed back to the input, it minimaze the error.

pozitive



output of the op-amp is connected to the pozitive terminal

assume error: $\varepsilon = V_{in} - V_{out}$

if $\varepsilon > 0$ ($V_{in} > V_{out}$) → V_{out} will decrease by $A\varepsilon$. $V_{in} > V_{out} - A\varepsilon$ the gap will become grater.
error becomes larger

if $\varepsilon < 0$ ($V_{in} < V_{out}$) → V_{out} will increase by $A\varepsilon$ $V_{in} < V_{out} + A\varepsilon$ the gap will become greater
error becomes larger

in both cases op-amp will quickly saturate

negative feedback is essential, otherwise op-amp will be unstable and saturate
↳ with negative feedback ⇒ $V_{in} = V_{out}$