# Elektronik II

## BJT fark yükselteci ve fark çifti problemleri

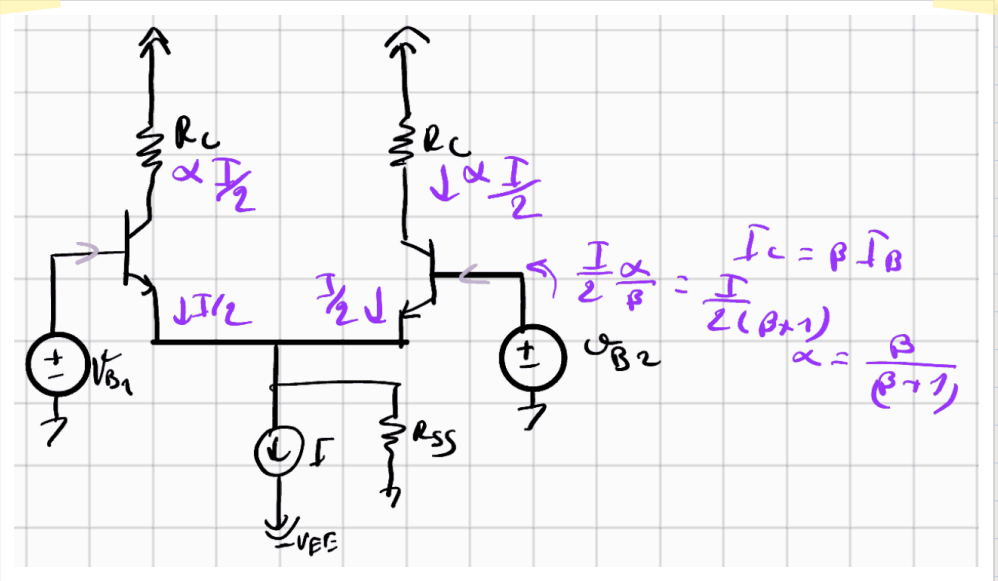
Orijinal not: Ders6.pdf

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

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

orj. s. 1

## BJT Differential Amplifier




orijinal çizim, s. 1

$$I_C = \beta I_B$$

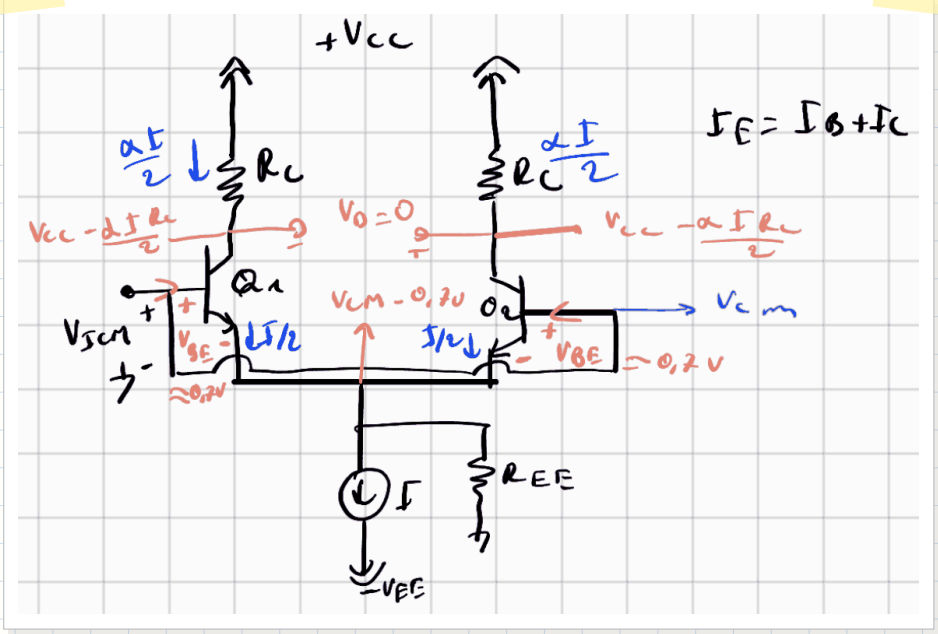
$$\frac{I}{2}\frac{\alpha}{\beta} = \frac{I}{2(\beta+1)} \qquad \alpha = \frac{\beta}{\beta+1}$$

$I_B \neq 0$

$g_m = \dfrac{I_C}{V_T}$ $\quad V_T \rightarrow 25{,}8\,\text{mV}$ at room temp

$r_\pi = (\beta+1)\, r_e$

$r_e \simeq 1/g_m = \dfrac{V_T}{I_E}$



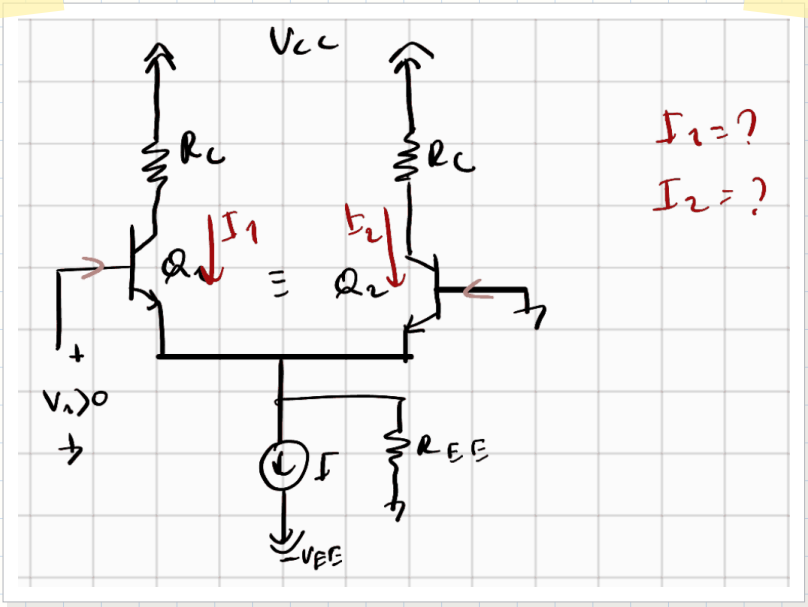

orijinal çizim, s. 1

$$I_E = I_B + I_C$$

$Q_1 \equiv Q_2$ (EBJ Area$_1$ = EBJ Area$_2$)

$$I_C = I_S e^{V_{BE}/V_T}$$

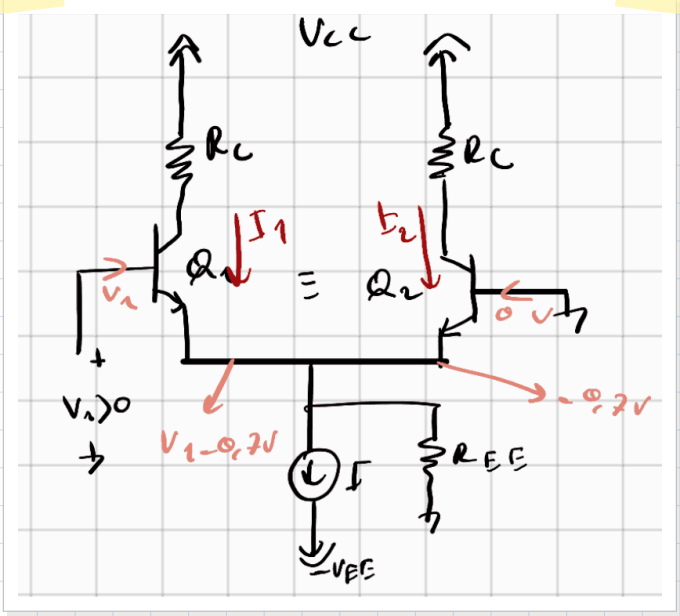
orj. s. 2




orijinal çizim, s. 2

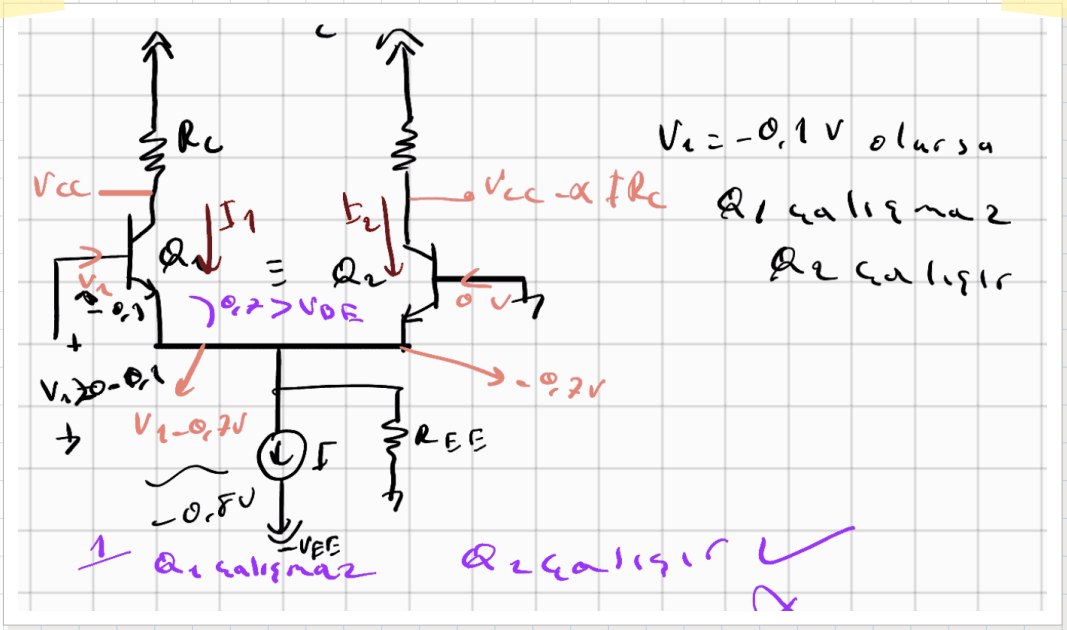
$I_1 = ?$ $I_2 = ?$

İki transistörün çalıştığını varsayalım




orijinal çizim, s. 2

$V_1 - 0{,}7 \neq -0{,}7$ (?birinciden kaynaklı)
(ikinciden kaynaklı)




orijinal çizim, s. 2

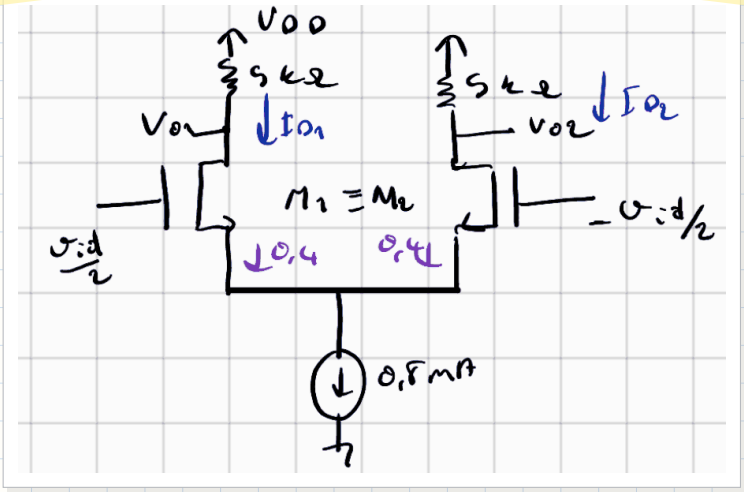
$V_1 = -0{,}1\,V$ olursa
$Q_1$ çalışmaz
$Q_2$ çalışır

1 $Q_1$ çalışmaz $Q_2$ çalışır ✓ α

orj. s. 3

**Örnek 4**

A MOS differential pair is operated at a bias current of 0,8 mA. Find $V_{ov}$, $g_m$, $r_o$, and $A_{diff}$ using transistors with a $\frac{W}{L}$ ratio of 100, $\mu_n C_{ox} = 0{,}2\,mA/V^2$, $V_A = 20\,V$ and $R_D = 5\,k\Omega$




orijinal çizim, s. 3

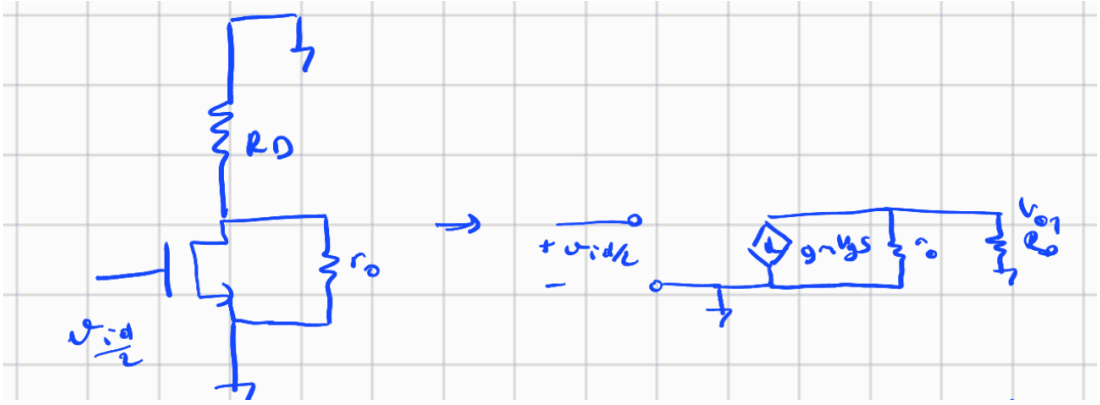
$I_{D1} + I_{D2} = 0{,}8\ \text{mA}$
since $M_1 \equiv M_2$
$2I_{D1} = 2I_{D2} = 0{,}8\ \text{mA}$
$I_{D1} = I_{D2} = I/2 = 0{,}4\ \text{mA}$

$$0{,}4\ \text{mA} = \frac{1}{2} \cdot 0{,}2 \cdot 100\,(V_{ov})^{2}{}^{1}$$

$$V_{ov} = \begin{cases} \boxed{+0{,}2} \\ -0{,}2 \quad \times \text{ eksi olmaz} \end{cases}$$

$$\boxed{g_m = \frac{2I_D}{V_{ov}} = \frac{2 \cdot 0{,}4}{0{,}2} = 4\ \text{mS}^{2}}$$

$$r_o = \frac{V_A}{I_D} = \frac{20}{0{,}4} = 50\ \text{k}\Omega$$




orijinal çizim, s. 3

[1] Çarpımın üzerine 0,1 ve 10 yazılmış (ara sonuçlar).
[5] Pay ve paydadaki sayılar çizilmiş; 0,4'ün üzerine 2 yazılmış.

$$\frac{v_{o1}}{v_{id}/2} = -g_m (r_o \parallel R_D)$$

$$= -4\,\text{mS}\ \underbrace{(50\,\text{k}\Omega \parallel 5\,\text{k}\Omega)}_{4{,}54}$$

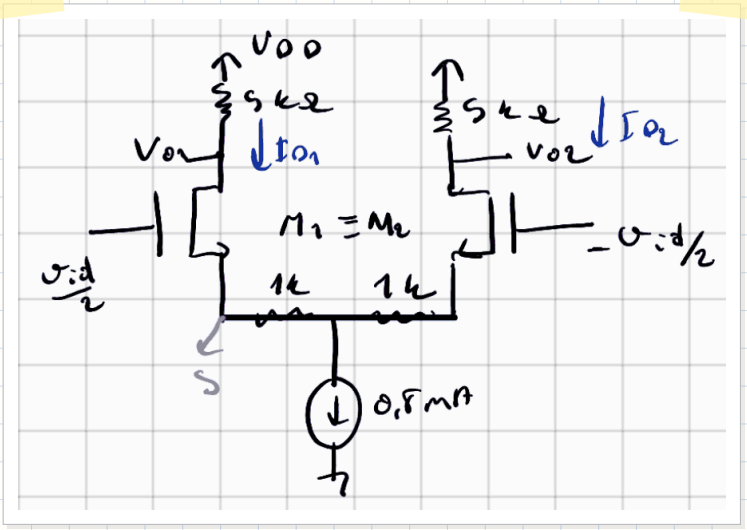
$$\frac{v_{o2}}{v_{id}} = 9{,}08\ [\text{V/V}] \quad \Longleftarrow \quad \frac{v_{o1}}{v_{id}} = -9{,}08\ [\text{V/V}]$$

orj. s. 4

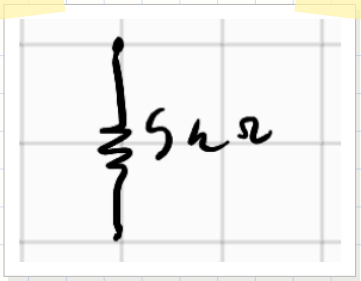
$$A_{diff} = \frac{v_{diff}}{v_{id}} = \frac{v_{o2} - v_{o1}}{v_{id}} = 18{,}16\ [\text{V/V}]$$

$$= 20\log(18{,}16)\ \text{dB}$$

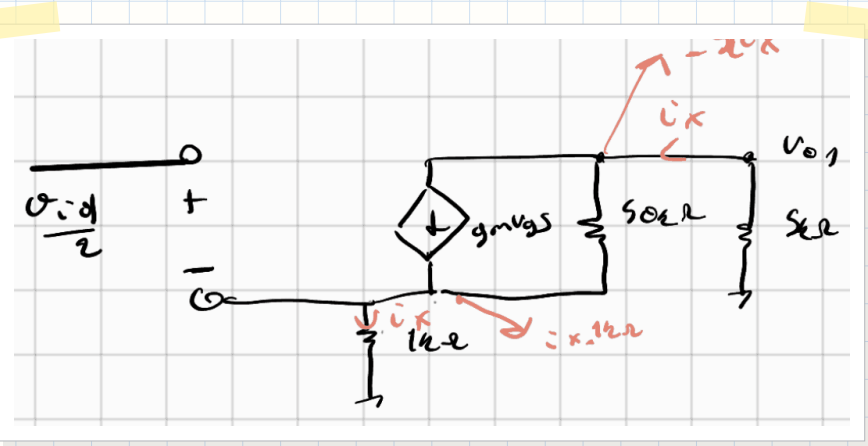
$$A_{diff} = 25{,}18\ \text{dB}$$




orijinal çizim, s. 4




orijinal çizim, s. 4




orijinal çizim, s. 4

$$\frac{v_{o1}}{v_{id}/2} = \frac{v_{o1}}{v_{gs}} \;??$$

$$v_{id}/2 \;??\; v_{gs}$$

$$v_{o1} = -5k\, i_x$$

$$g_m v_{gs} + \frac{-5\,i_x - i_x}{50} = i_x$$

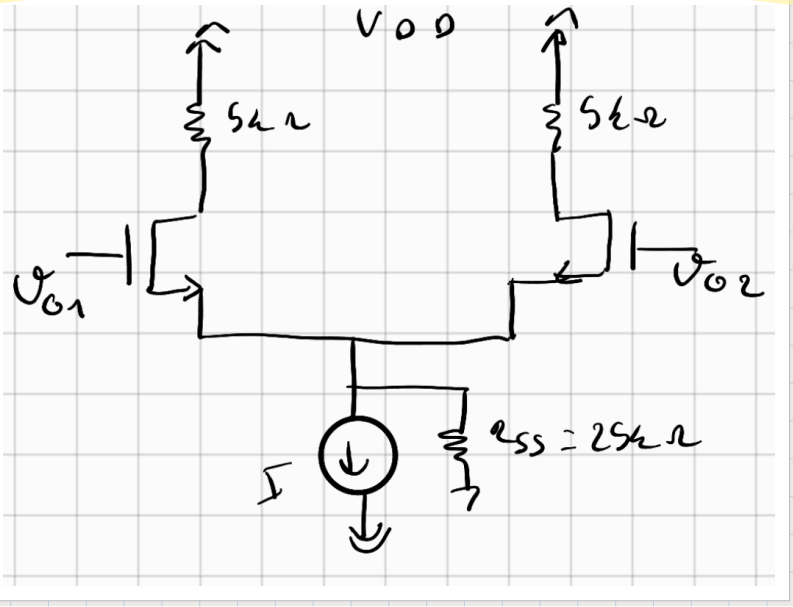
$$g_m v_{gs} = \frac{56\,i_x}{50}$$

orj. s. 5

$$v_{gs} = \frac{1}{g_m} \cdot \frac{56\,i_x}{50}$$

$$\frac{v_{o1}}{v_{gs}} = \frac{-5\,i_x}{\frac{56\,i_x}{200}} = -17{,}86\ [V/V]$$

$V_A = \infty$ $\qquad |A_{single}| = \frac{v_{o1}}{v_{id}}$




orijinal çizim, s. 5

**Örnek**

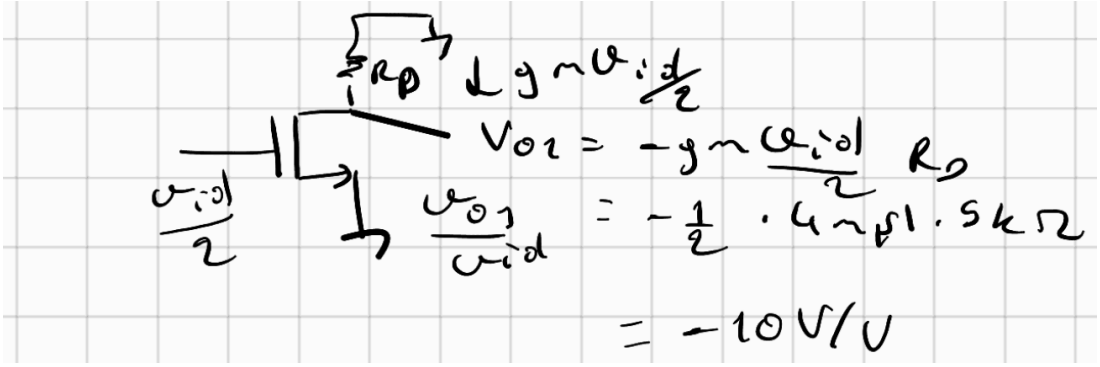
a) Find the differential gain, the common mode gain, and the common-mode rejection ratio if the output is taken single endedly. Assume devices are perfectly matched.

b) Repeat a for differential output.

c) Repeat b when the resistances have a mismatch of 1%.

orj. s. 6

## Diff mode half-circuit model




orijinal çizim, s. 6

$$v_{o1} = -g_m \frac{v_{id}}{2} R_D$$

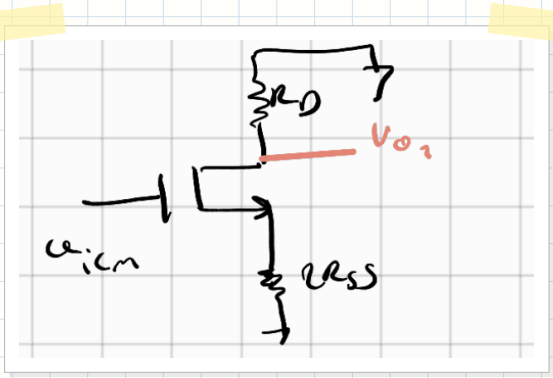
$$\frac{v_{o1}}{v_{id}} = -\frac{1}{2} \cdot 4\,\text{mS} \cdot 5\,\text{k}\Omega$$

$$= -10\ \text{V/V}$$

$$|A_{single}| = 10\ [\text{V/V}] = 20\ \text{dB}$$

$$|A_{diff}| = 40 \text{ dB}^{6}$$

## Common mode half-circuit model




orijinal çizim, s. 6

$$\frac{v_{o1}}{v_{icm}} \simeq -\frac{R_D}{2R_{SS}} = -\frac{5}{50\,k}$$
$$= -0{,}1 \text{ [V/V]}$$

$$|A_{cm}| = +0{,}1 \text{ [V/V]} = -20 \text{ dB}$$

$$|A_{cm\,diff}| = 0$$

$$\text{CMRR} = \frac{A_{single}\text{ [V/V]}}{A_{cm}\text{ [V/V]}} = A_{single}\text{ [dB]} - A_{cm}\text{ [dB]} = 40 \text{ dB}$$

$$\text{CMRR} = \infty$$

$$|A_{cm\,diff}| = |A_{cm}|_{single} \times \frac{1}{100}$$
$$= 1 \times 10^{-3} \text{ [V/V]}$$
$$|A_{cm}|_{diff} = -60 \text{ dB}$$

$$\text{CMRR}_{\text{? with mismatch}} = 40 - (-60) = 100 \text{ dB}$$

[6] Claude notu: muhtemelen $|A_{diff}| = 2 \cdot 10 = 20$ V/V ≈ 26 dB olmalı (aşağıdaki 100 dB sonucu da bu değere dayanıyor).