EHB222E INTRODUCTION TO ELECTRONICS (22985, 22982, 22986, 22984)

Midterm Exam #2 16 May 2022 09:00-11:00

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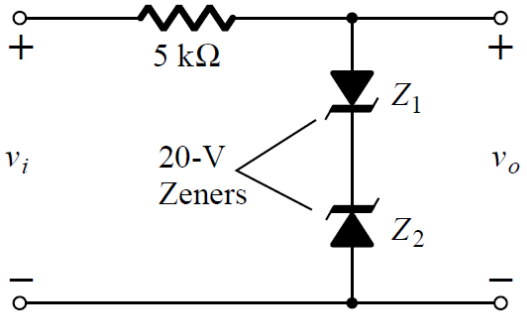
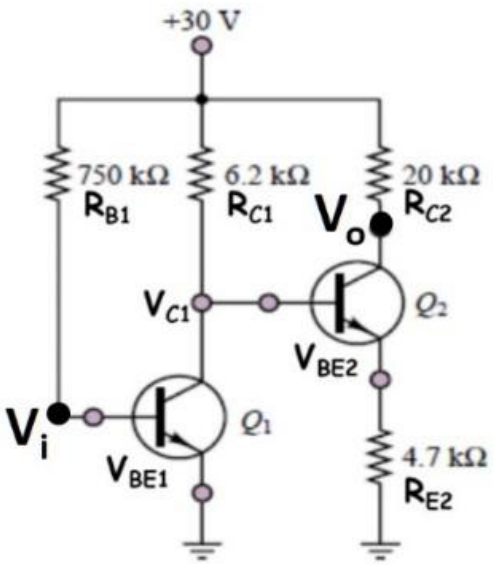
1. Calculate the peak voltage values for both half cycles of the output waveform. V_1=20 sin (2π.200.t). Use modified ideal diode model (V_d=0.7V) for diodes. (5 points)

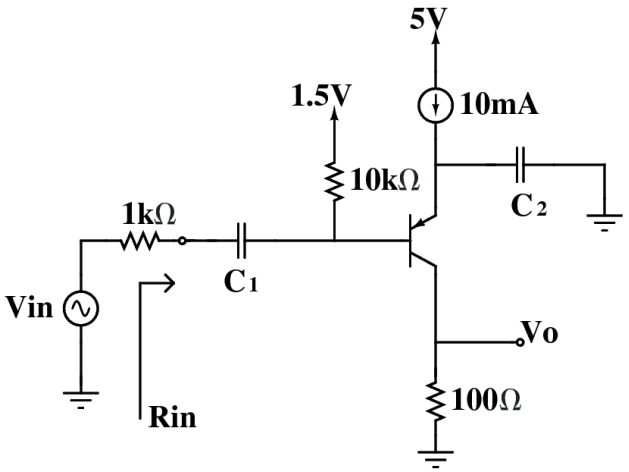


2. Consider the circuit shown below. Use the following transistor parameters for your calculations: h_{FE}=β=100, $|V_{BE}|$=0.7V, V_T=25mV, V_A=∞. Calculate the input impedance of the circuit. (10 points)

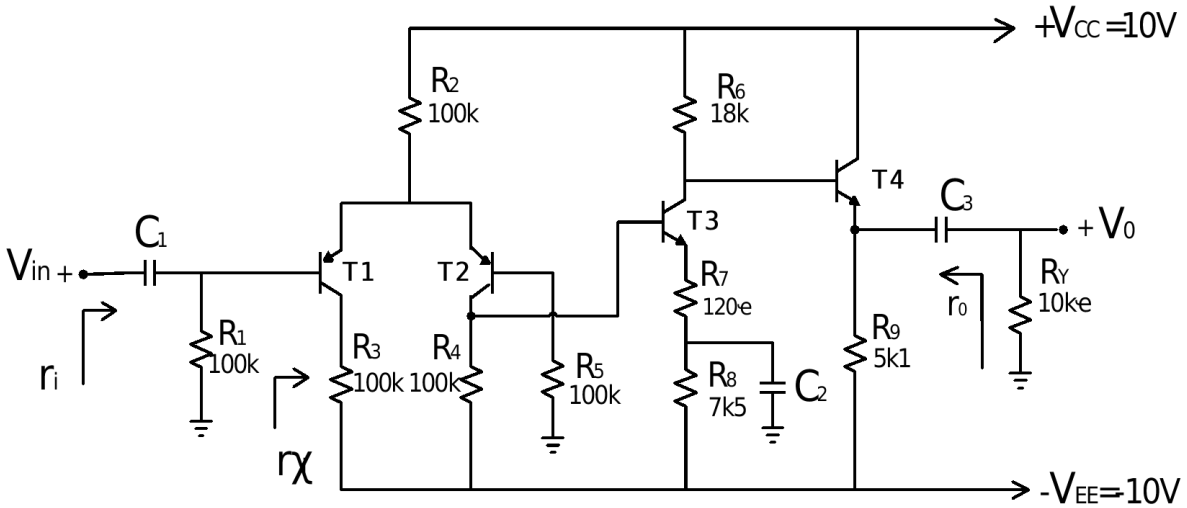


GOOD LUCK EVERYONE

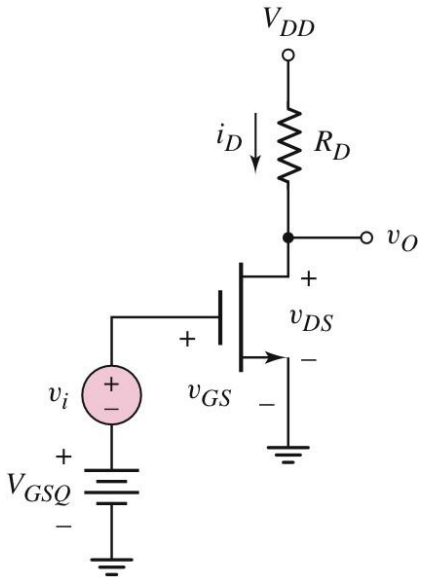
3. (20 points) Assuming ideal capacitors and a current gain of 200 ($V_A = \infty$, V_T = 25mV)
   a. Find DC voltages at C, B and E terminals.
   b. Draw small signal circuit and find input resistance of the circuit.
   c. Find AC voltage gain (Vo/V_{in}, for a sinusoidal AC signal with ±0.4 V (Vo) what should the value of input (Vin) be?



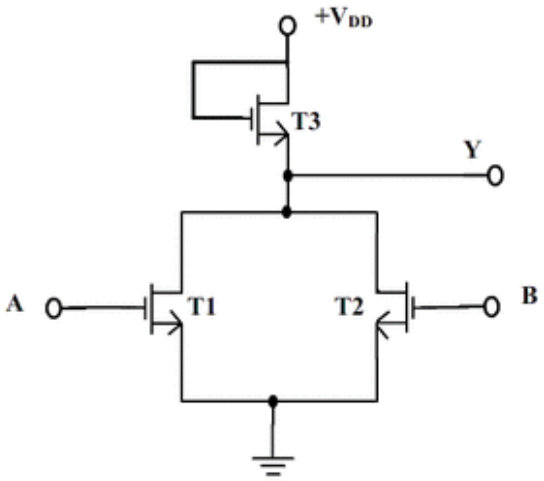
4. (35 points) Analyze the 3-stage amplifier circuit above. For all transistors $h_{FE}=h_{fe}$=200, $|V_{BE}| = 0{,}6V$, $h_{re}\cong 0$, $h_{oe}\cong 0$ and V_T=25mV.
   a. Find the collector currents of all 4 transistors.
   b. Calculate the total voltage gain.
   c. Calculate input resistance (r_i) and output resistance (r_0).
   d. Calculate CMRR of the first stage.

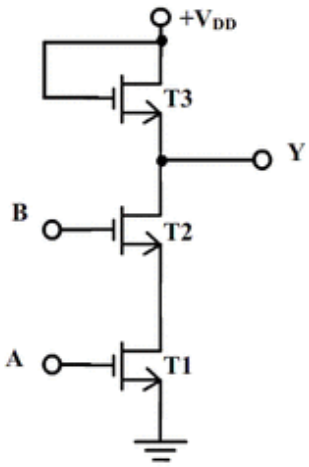


5. Calculate the value of the RD resistance so that the MOSFET transistor works in the saturation region. v_i is a small signal AC voltage source. V_{DD}=10V, V_{GSQ}=4V, V_t =2V, and ID=1mA. (10 points)



6. Consider the MOS digital gates shown below. Complete a truth table for each circuit and determine their function. (20 points)





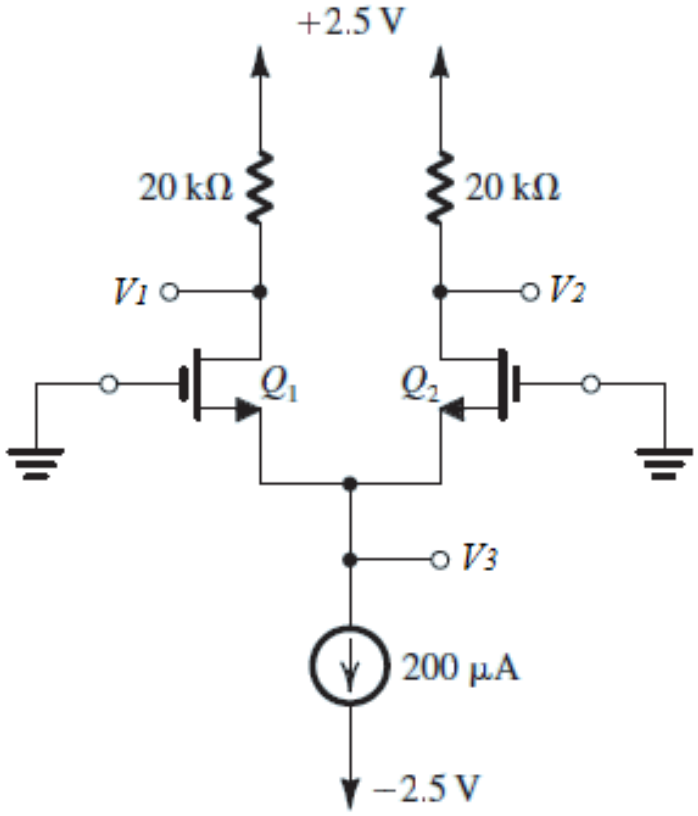
7. (20 points) For the figure given below MOS parameters are
V_{TH} = 0.7V, $k_n{}' = \mu_n C_{ox} = 125(\frac{\mu A}{V^2})$. Find **$V_1$**, **$V_2$** and **$V_3$** for (W/L) values given below.

   a. $(W/L)_1 = (W/L)_2 = 20$

V_1, V_2 ve V_3

   b. $(W/L)_1 = 1.5(W/L)_2 = 20$

V_1, V_2 ve V_3



Q1) +-20V

Q2)

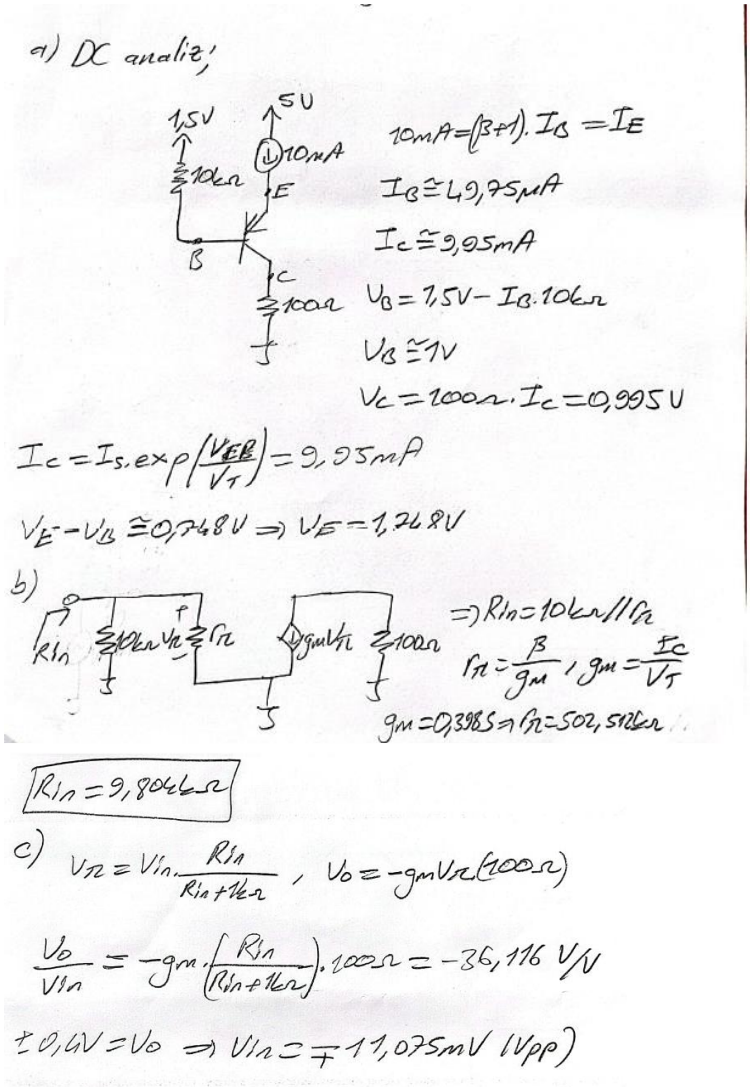
$$-30 + I_{B1} * R_{B1} + V_{BE1} = 0$$

$$I_{B1} = \frac{30 - 0.7}{750 * 10^3} = 39.07 \mu A$$

$$I_{C1} = \beta * I_{B1} = 3.907 mA$$

$R_i = r_\pi = {V_t}/{I_B} = 639.87\Omega$

Q3:



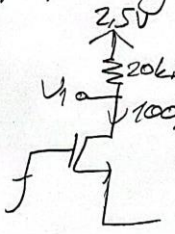
Q5) ANSWER: $R_D < (V_{DD} - (V_{GSQ} - V_T)) / I_D$

Q6) Answer the first is NOR the second NAND

Q7)

a) Mosfetlerin $\left(\frac{W}{L}\right)$ oranları, savak terminallerindeki dirençler ve diğer terminallerindeki gerilimler eşit olduğuna göre, çalıştıkları bölge farketmeksizin 200μA akımı eşit bölüşeceklerdir.

Buna göre sadece bir mosfet üzerinden hesaplamalar yapılıp, hangi bölgede çalışıldığı bulunabilir.



Saturasyon;

$I_{D1} = 100\mu A = (125\mu A/V^2)(-V_3 - 0,7V)^2 \cdot 20 \cdot \frac{1}{2}$

① $V_3 + 0,7V \cong 0,28V \Rightarrow V_3 = -0,42V$

② $V_3 + 0,7V = -0,28V \Rightarrow V_3 = -0,98V$ ✓

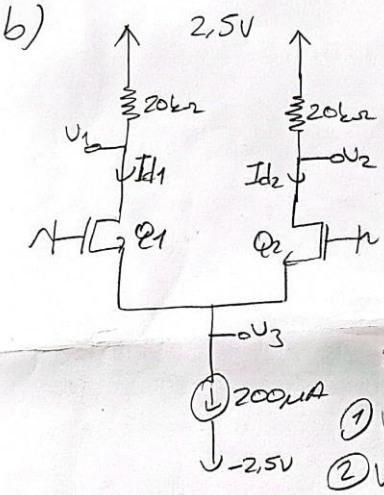
$V_3 = -0,98V$ için $V_{GS} - V_{th} > 0V$

$V_1 = 2,5V - (20k\Omega)\cdot(100\mu A) = 0,5V$

$V_{DS} > (V_{GS} - V_{th}) > 0V \Rightarrow$ Mosfetlerin saturasyonda çalıştığı doğrulandı.

$V_1 = V_2 = 0,5V$, $V_3 = -0,98V$

b)



Saturasyon için;

$I_{d1} = \frac{1}{2}(125\mu A/V^2)\cdot 20\cdot(-V_3 - 0,7V)^2$

$I_{d2} = \frac{1}{2}(125\mu A/V^2)\cdot\frac{40}{3}(-V_3 - 0,7V)^2$

$I_{d1} + I_{d2} = \frac{1}{2}125\mu A/V^2\cdot(-V_3 - 0,7V)^2\cdot\frac{100}{3}$

$200\mu A = \frac{1}{2}125(\mu A/V^2)(-V_3 - 0,7V)^2\cdot\frac{100}{3}$

① $V_3 \cong -0,30V$ ×

② $V_3 \cong -1,01V$ ✓

$V_3 = -1,01V$ için $V_{GS} - V_{th} > 0$

$V_1 = 2,5V - (20k\Omega)\cdot I_{D1} \Rightarrow I_{D1} = \frac{1}{2}(125\mu A/V^2)\cdot 20\cdot(1,01V - 0,9V)^2$

$I_{D1} = 120\mu A$

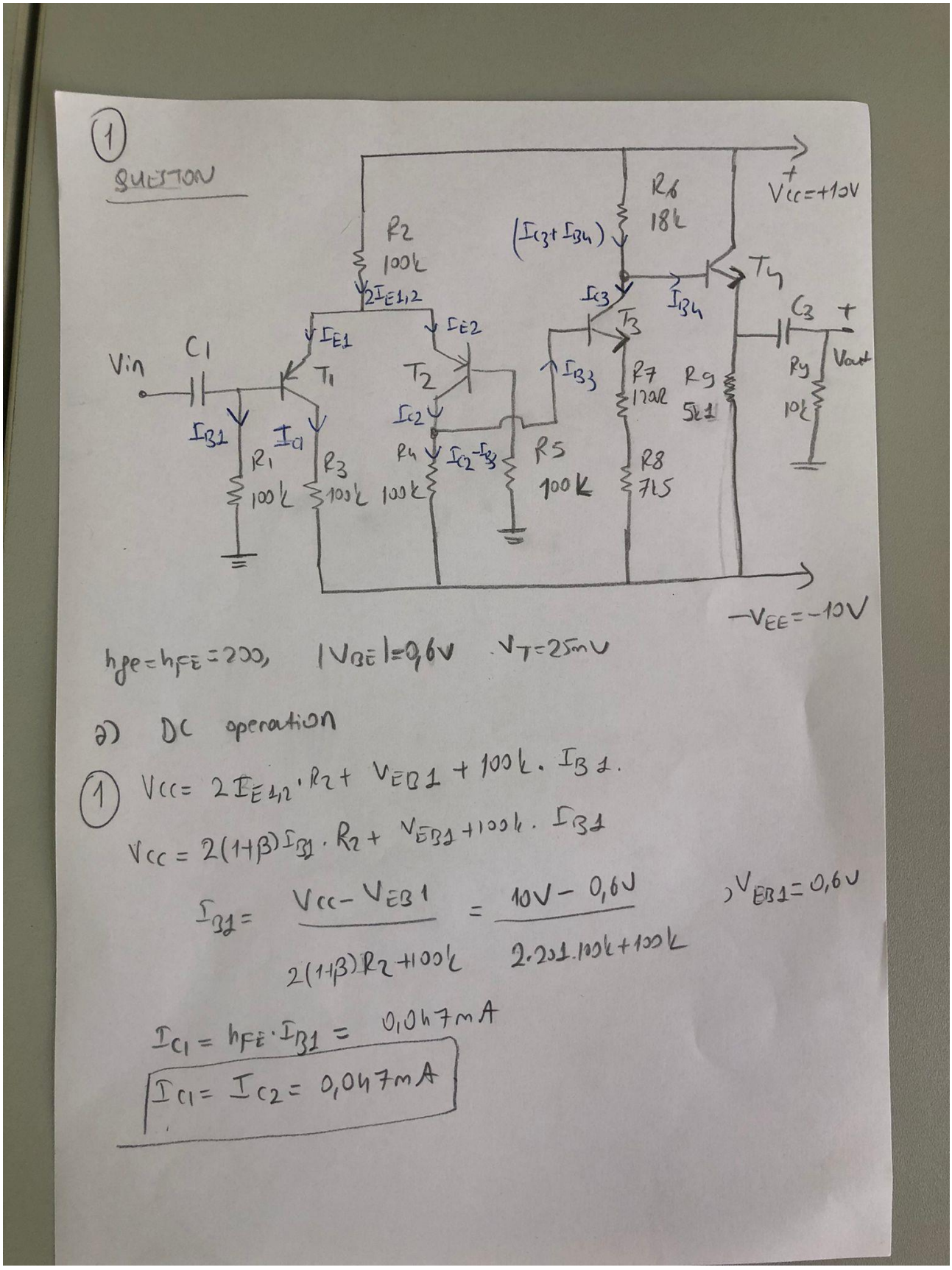
$V_1 = 0,1V \Rightarrow V_{DS1} = 0,1V - (-1,01V) = 1,11V > (1,01V - 0,7V)$

Q_1'in saturasyonda olduğu ispatlandı.

$V_2 = 2,5V - (20k\Omega)\cdot(200\mu A - I_{D1}) = 0,9V \Rightarrow V_{DS2} = 0,9V - (-1,01V) = 1,91V$

Q_2'de saturasyondadır. $V_3 = -1,01V$, $V_1 = 0,1V$, $V_2 = 0,9V$

Q4)



$h_{ie} = h_{FE} = 200$, $|V_{BE}| = 0{,}6V$ $V_T = 25mV$

a) DC operation

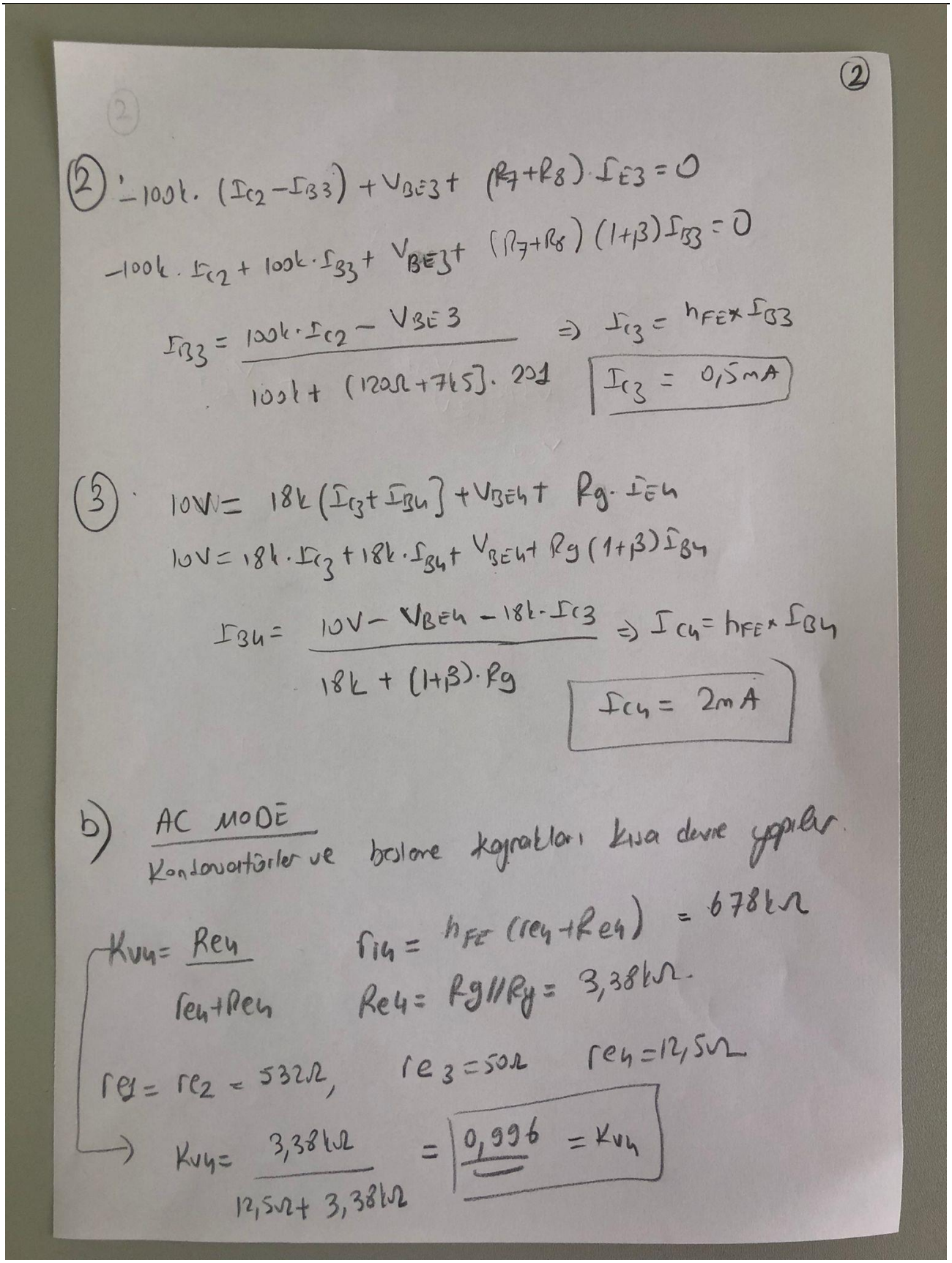
(1) $V_{CC} = 2I_{E1,2} \cdot R_2 + V_{EB1} + 100k \cdot I_{B1}$

$V_{CC} = 2(1+\beta) I_{B1} \cdot R_2 + V_{EB1} + 100k \cdot I_{B1}$

$$I_{B1} = \frac{V_{CC} - V_{EB1}}{2(1+\beta)R_2 + 100k} = \frac{10V - 0{,}6V}{2 \cdot 201 \cdot 100k + 100k}, \quad V_{EB1} = 0{,}6V$$

$I_{C1} = h_{FE} \cdot I_{B1} = 0{,}047mA$

$\boxed{I_{C1} = I_{C2} = 0{,}047mA}$



② $-100k \cdot (I_{C2} - I_{B3}) + V_{BE3} + (R_7 + R_8) \cdot I_{E3} = 0$

$-100k \cdot I_{C2} + 100k \cdot I_{B3} + V_{BE3} + (R_7 + R_8)(1+\beta) I_{B3} = 0$

$I_{B3} = \dfrac{100k \cdot I_{C2} - V_{BE3}}{100k + (120\Omega + 765) \cdot 201} \Rightarrow I_{C3} = h_{FE} \times I_{B3}$

$\boxed{I_{C3} = 0{,}5mA}$

③ $10V = 18k(I_{C3} + I_{B4}) + V_{BE4} + R_g \cdot I_{E4}$

$10V = 18k \cdot I_{C3} + 18k \cdot I_{B4} + V_{BE4} + R_g(1+\beta) I_{B4}$

$I_{B4} = \dfrac{10V - V_{BE4} - 18k \cdot I_{C3}}{18k + (1+\beta) \cdot R_g} \Rightarrow I_{C4} = h_{FE} \times I_{B4}$

$\boxed{I_{C4} = 2mA}$

b) AC MODE

Kondansatörler ve boşlare kısa devre yapılır.

$K_{V4} = \dfrac{R_{e4}}{r_{e4} + R_{e4}}$ $\quad r_{i4} = h_{FE}(r_{e4} + R_{e4}) = 678k\Omega$

$R_{e4} = R_g // R_y = 3{,}38k\Omega$.

$r_{e1} = r_{e2} = 532\Omega$, $\quad r_{e3} = 50\Omega$ $\quad r_{e4} = 12{,}5\Omega$

$K_{V4} = \dfrac{3{,}38k\Omega}{12{,}5\Omega + 3{,}38k\Omega} = \boxed{0{,}996 = K_{V4}}$

T_3 'den oluşan kuvvetlendirici için (3)

$$K_{v3} = -\frac{R_6 // r_{i4}}{r_{e3} + R_7} = -\frac{18k // 678k\Omega}{50\Omega + 120\Omega} = \frac{17,5k\Omega}{170\Omega}$$

$$K_{v3} = -103$$

$$r_{i3} = h_{fe3}(r_{e3} + R_{e3}) = 34k\Omega$$

Diffantial kat için $R_4 // r_{i3} = 25,4\ k\Omega$

$$K_{v2} = \frac{R_4 // r_{i3}}{2r_{e2} + \frac{R_5}{h_{fe2}}} = 16,2$$

$$K_{v2} = 16,2$$

$$K_v = K_{v2} \cdot K_{v3} \cdot K_{v4} = -1662$$

c) $r_i = R_1 // r_i' \Rightarrow r_i' = 2h_{fe} \cdot r_{e1} + R_5 = 312,8k\Omega$

$$r_i = 100k // 312,8k\Omega = 75,8\ k\Omega.$$

$$r_o = R_g // \left(r_{e4} + \frac{R_6}{h_{fe}}\right) = 100,5\Omega.$$

d) $$CMRR = 20\log\left|\frac{2R_E + r_e}{r_e}\right| = 20\log\left|\frac{2 \cdot 100k + 532\Omega}{532\Omega}\right|$$

$$CMRR = 51,5\ dB$$