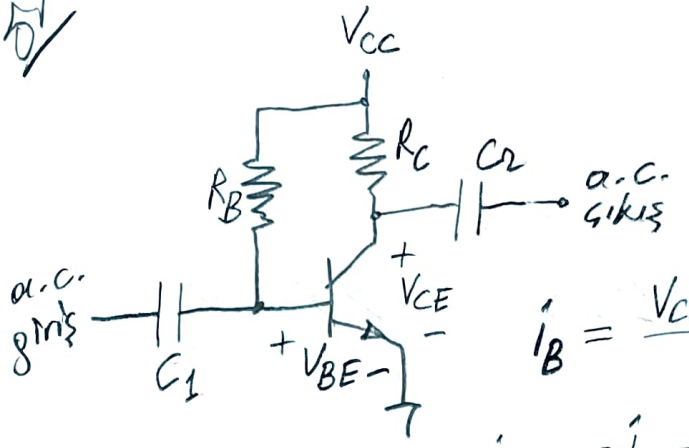
5/



$V_{CC} = 12V$, $R_C = 2.2K$, $R_B = 240K$

$\beta = 50$, $V_T = 0.7V$

Transistörün çalışma noktasını bulunuz.

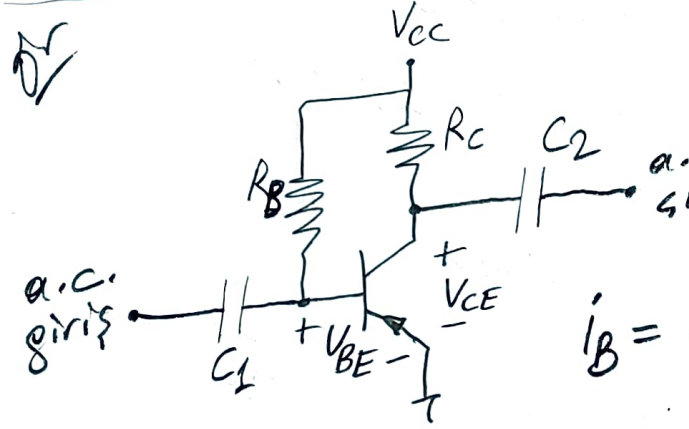
$$i_B = \frac{V_{CC} - V_{BE}}{R_B} = \frac{12V - 0.7V}{240K} = \frac{11.3V}{240K} = 47.08\mu A$$

$$i_C = \beta i_B = 50 \times 40.08\mu A = 2.35mA$$

$$V_{CE} = V_{CC} - R_C i_C = 12V - 2.2K \times 2.35mA = 6.83V$$

Çalışma Noktası $= (i_{CEQ}, V_{CEQ}) = (2.35mA, 6.83V)$

6/



$V_{CC} = -22V$, $R_C = 3.3K$, $R_B = 680K$

$\beta = 120$, $V_T = 0.7V$

Transistörün çalışma noktasını bulunuz.

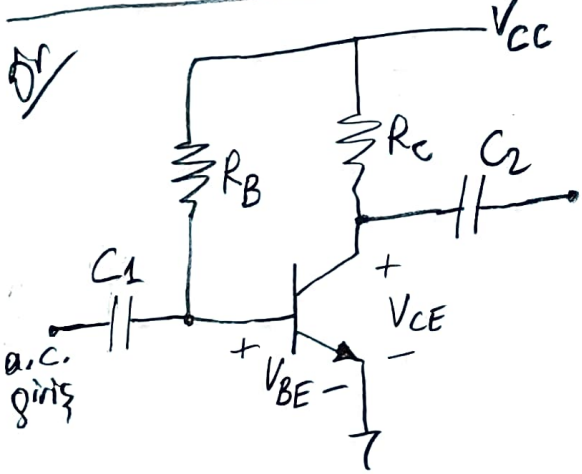
$$i_B = \frac{V_{BE} - V_{CC}}{R_B} = \frac{-0.7V - (-22V)}{680K} = \frac{21.3V}{680K} = 31.32\mu A$$

$$i_C = \beta i_B = 120 \times 31.32\mu A = 3.76mA$$

$$V_{CE} = V_{CC} + R_C i_C = -22V + 3.3K \times 3.76mA = -9.6V$$

Çalışma Noktası $= (i_{CEQ}, V_{CEQ}) = (3.76mA, -9.6V)$

7/



$V_{CC} = 20V$, $R_C = 1.2K$, $R_B = 97K$

$V_T = 0.6V$

a) $\beta = 50$ için transistörü incele

b) $\beta = 100$ için transistörü incele

diğer sayfa

a) $i_B = \frac{V_{CC} - V_{BE}}{R_B} = \frac{20V - 0.6V}{97K} = \frac{19.4V}{97V} = 0.2mA$

$i_C = \beta i_B = 50 \times 0.2mA = 10mA > 0$

$V_{CE} = V_{CC} - R_C i_C = 20V - 1.2K \times 10mA = 8V > 0$

Transistör çalışma noktasında

Çalışma Noktası $= (i_{CQ}, V_{CEQ}) = (10mA, 8V)$

b) $i_B = \frac{V_{CE} - V_{BE}}{R_B} = \frac{20V - 0.6V}{97K} = \frac{19.4V}{97K} = 0.2mA$

$i_C = \beta i_B = 100 \times 0.2mA = 20mA > 0$

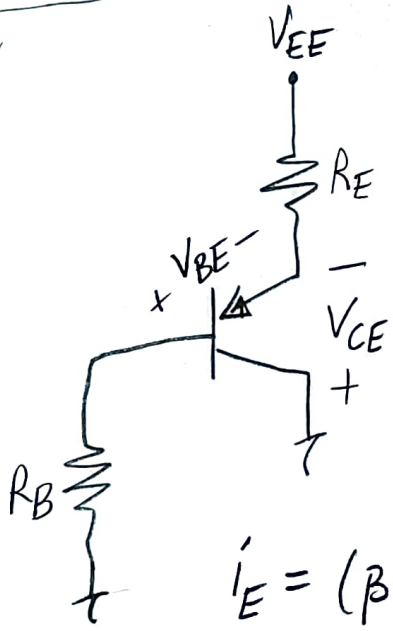
$V_{CE} = V_{CC} - R_C i_C = 20V - 1.2K \times 20mA = -4V < 0$

Transistör doyum noktasında

$i_{Cmax} = \frac{V_{CC}}{R_C} = \frac{20V}{1.2K} \approx 16.67mA$

---

b/



$V_{EE} = 18V$, $R_E = 0.5K$, $R_B = 47K$

$V_T = 0.6V$, $\beta = 79$

Çalışma noktası varsa bul.

$i_B = \frac{V_{EE} + V_{BE}}{R_B + (\beta+1)R_E} = \frac{18V - 0.6V}{47K + 80 \times 0.5K}$

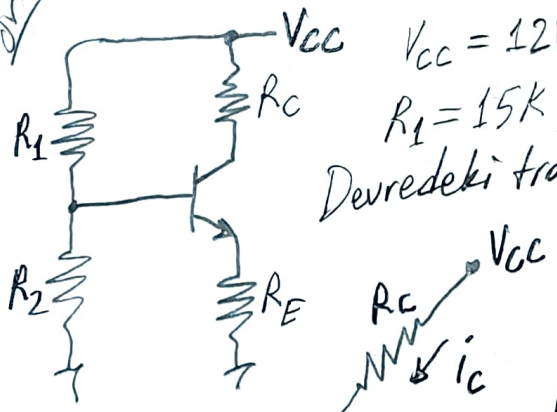
$= \frac{17.4V}{87K} = 0.2mA$

$i_E = (\beta+1) i_B = 80 \times 0.2mA = 16mA \approx i_C > 0$

$V_{CE} = R_E i_E - V_{EE} = 0.5K \times 16mA - 18V = -10V < 0$

Çalışma Noktası $= (i_{CQ}, V_{CEQ}) = (16mA, -10V)$

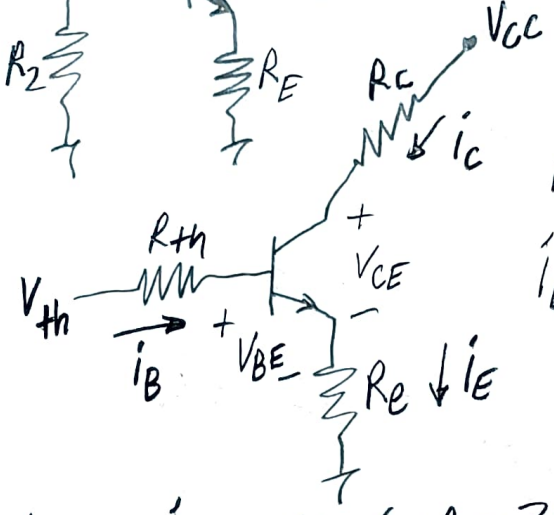
8V



$V_{CC} = 12V$, $V_T = 0.6V$, $\beta = 50$

$R_1 = 15K$, $R_2 = 30K$, $R_C = 1K$, $R_E = 24K$

Devredeki transistörün çalışma noktasını (i_{CQ}, V_{CEQ}) bul.



$$V_{th} = \frac{R_2 V_{CC}}{R_1 + R_2} = \frac{30K \times 12V}{15K + 30K} = 8V$$

$$R_{th} = R_1 // R_2 = \frac{R_1 R_2}{R_1 + R_2} = \frac{15K \times 30K}{15K + 30K} = 10K$$

$$i_B = \frac{V_{th} - V_{BE}}{R_{th} + (\beta+1) R_E} = \frac{8V - 0.6V}{10K + 51 \times 24K}$$

$$= \frac{7.4V}{1234K} \approx 6\,\mu A$$

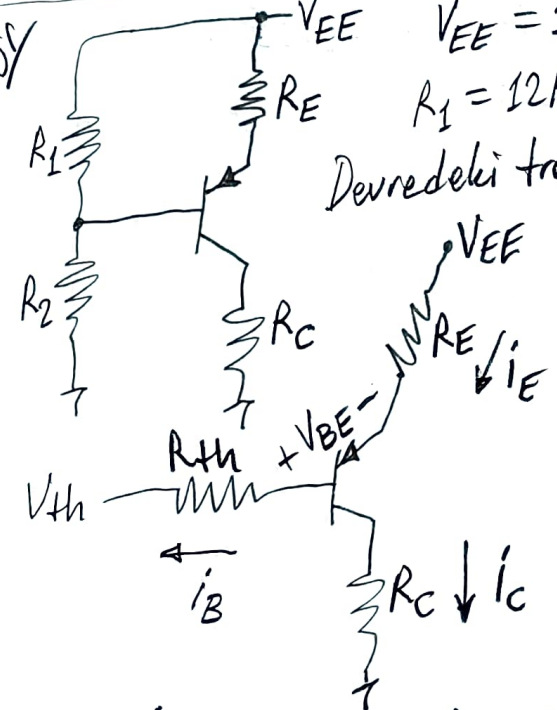
$$i_C = \beta i_B = 50 \times 6\,\mu A = 300\,\mu A = 0.3mA \approx i_{EQ} > 0$$

$$V_{CE} = V_{CC} - R_C i_C - R_E i_E \approx V_{CC} - (R_C + R_E) i_C$$

$$= 12V - (1K + 24K) \times 0.3mA = 12V - 7.5V = 4.5V > 0$$

Çalışma Noktası $= (i_{CQ}, V_{CEQ}) = (0.3mA, 4.5V)$

8V



$V_{EE} = 15V$, $V_T = 0.7V$, $\beta = 100$

$R_1 = 12K$, $R_2 = 24K$, $R_E = 6K$, $R_C = 4K$

Devredeki transistörün çalışma noktasını (i_{CQ}, V_{CEQ}) bul.

$$V_{th} = \frac{R_2 V_{EE}}{R_1 + R_2} = \frac{24K \times 15V}{12K + 24K} = 10V$$

$$R_{th} = R_1 // R_2 = \frac{R_1 R_2}{R_1 + R_2} = \frac{12K \times 24K}{12K + 24K} = 8K$$

$$i_B = \frac{V_{EE} + V_{BE} - V_{th}}{R_{th} + (\beta+1) R_E} = \frac{15V - 0.7V - 10V}{8K + 101 \times 6K}$$

$$= \frac{4.3V}{614K} \approx 7\,\mu A$$

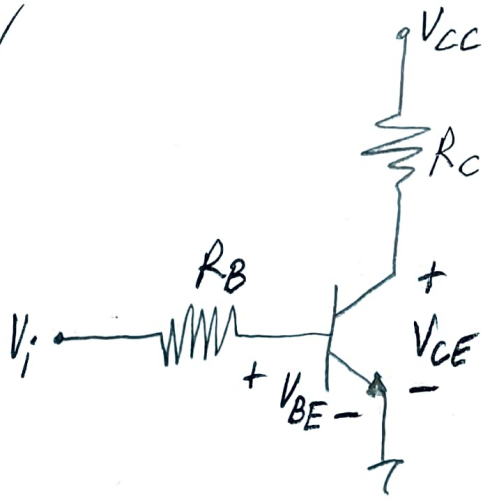
$$i_C = \beta i_B = 100 \times 7\,\mu A = 700\,\mu A = 0.7mA \approx i_E > 0$$

$$V_{CE} = R_C i_C + R_E i_E - V_{EE} \approx (R_C + R_E) i_C - V_{EE}$$

$$= (6K + 4K) \times 0.7mA - 15V = 7V - 15V = -8V < 0$$

Çalışma Noktası $= (i_{CQ}, V_{CEQ}) = (0.7mA, -8V)$

Ör 8/



$V_{CC} = 15V$, $R_B = 54K$, $R_C = 0.5K$

$\beta = 80$, $V_T = 0.6V$

$R_{BB} = 3K$ (V_{BE}'nin iç direnci)

a) $V_i = 12V$ için transistörü incele.

b) $V_i = -8V$ için transistörü incele.

c) $V_i = 24V$ için transistörü incele.

a) $$i_B = \frac{V_i - V_{BE}}{R_B + R_{BB}} = \frac{12V - 0.6V}{54K + 3K} = \frac{11.4V}{57K} = 0.2\,mA$$

$$i_C = \beta i_B = 80 \times 0.2mA = 16mA > 0$$

$$V_{CE} = V_{CC} - R_C i_C = 15V - 0.5K \times 16mA = 7V > 0$$

Çalışma Noktası $= (i_{CQ}, V_{CEQ}) = (16mA, 7V)$

b) $$i_B = \frac{V_i - V_{BE}}{R_B + R_{BB}} = \frac{-8V - 0.6V}{54K + 3K} = -\frac{8.6V}{57K} \approx -0.15\,mA < 0$$

Transistör Kapalıdır.

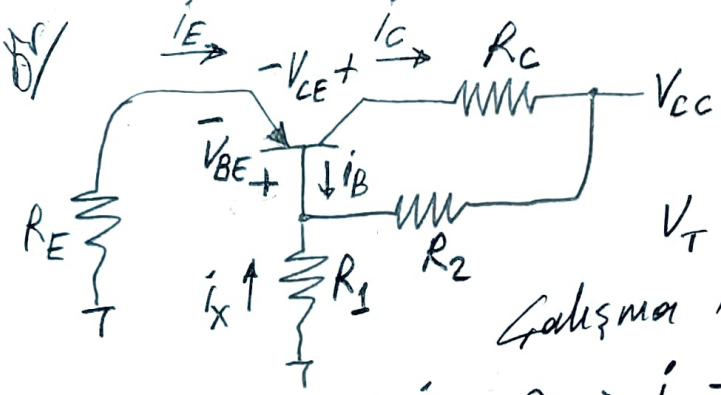
c) $$i_B = \frac{V_i - V_{BE}}{R_B + R_{BB}} = \frac{24V - 0.6V}{54K + 3K} = \frac{23.4V}{57K} \approx 0.44\,mA$$

$$i_{Cmax} = \frac{V_{CC}}{R_C} = \frac{15V}{0.5K} = 30\,mA$$

$$i_C = \beta i_B = 80 \times 0.44mA \approx 35.2mA > i_{Cmax}$$

Transistör doyum bölgesinde

8/



$R_E = 4.7K$, $R_E = 2.3K$

$R_1 = R_2 = 20K$, $\beta = 100$

$V_T = 0.6V$, $V_{CE} = -20V$

Çalışma noktasını bul.

$$-R_E i_E + V_{BE} + R_1 i_x = 0 \Rightarrow i_x = \frac{R_E i_E - V_{BE}}{R_1} = \frac{4.7 i_E + 0.6}{20}$$

$$V_{CC} + R_2(i_x + i_B) + R_1 i_x = 0$$

$$\hookrightarrow i_x = \frac{-V_{CC} - R_2 i_B}{R_1 + R_2} = \frac{20 - 20 i_B}{40} = \frac{1 - i_B}{2} = \frac{101 - i_E}{202}$$

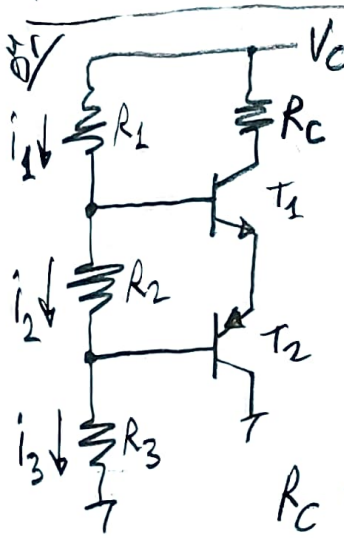
$$i_x = i_x \Rightarrow \frac{4.7 i_E + 0.6}{20} = \frac{101 - i_E}{202} \Rightarrow i_E \approx 2mA \approx i_C > 0$$

$$V_{CE} = V_{CC} + R_C i_C + R_E i_E \approx V_{CC} + (R_C + R_E) i_C = -20V + (4.7K + 2.3K) \times 2mA$$

$$= -20V + 14V = -6V < 0$$

Çalışma Noktası $= (i_{CQ}, V_{CEQ}) = (2mA, -6V)$

9/



$V_{CE1} = 8V$, $V_{CE2} = -10V$

$i_{C1} = i_{C2} = 2mA$, $\beta_1 = \beta_2 = 50$, $V_{T1} = V_{T2} = 0.6V$

$i_1 = 31 i_{B1}$, $R_1 = R_3$

R_1, R_2, R_3, R_C dirençlerini bul.

$$V_{CC} - R_C i_{C1} - V_{CE1} + V_{CE2} = 0$$

$$R_C = \frac{V_{CC} - V_{CE1} + V_{CE2}}{i_{C1}} = \frac{30V - 8V - 10V}{2mA} = \frac{12V}{2mA} = 6K$$

$$i_{B1} = \frac{i_{C1}}{\beta_1} = \frac{2mA}{50} = 40\mu A, \quad i_{B2} = \frac{i_{C2}}{\beta_2} = \frac{2mA}{50} = 40\mu A$$

$$i_1 = 31 i_{B1} = 31 \times 40\mu A = 1.24mA$$

$$i_2 = i_1 - i_{B1} = 1.24mA - 40\mu A = 1.2mA$$

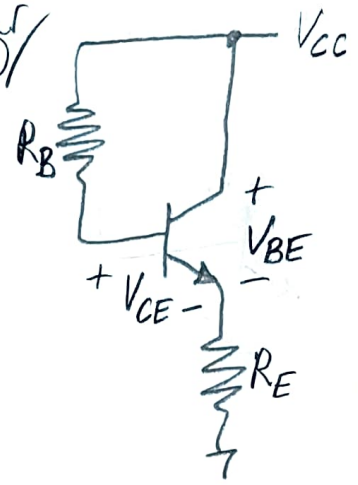
$$i_3 = i_2 + i_{B2} = 1.2mA + 40\mu A = 1.24mA$$

$$R_2 = \frac{V_{BE1} - V_{BE2}}{i_2} = \frac{1.2V}{1.2mA} = 1K$$

$$R_1 i_1 + R_2 i_2 + R_3 i_3 = V_{CC} \Rightarrow 1.24R_1 + 1.2 + 1.24R_1 = 30$$

$$R_1 = R_3 = \frac{30 - 1.2}{2.48} V = 11.6K$$

5/



$V_{CC} = 12V$, $R_B = 250K$, $R_E = 3.5K$

$\beta = 100$, $V_T = 0.7V$

Devrede verilen npn tipi BJT transistörün çalışma noktasını (i_{CQ}, V_{CEQ}) bulunuz.

$$i_B = \frac{V_{CC} - V_{BE}}{R_B + (\beta+1)R_E} = \frac{12V - 0.7V}{250K + 101 \times 3.5K}$$

$$= \frac{11.3V}{603.5K} \approx 18.724\,\mu A$$

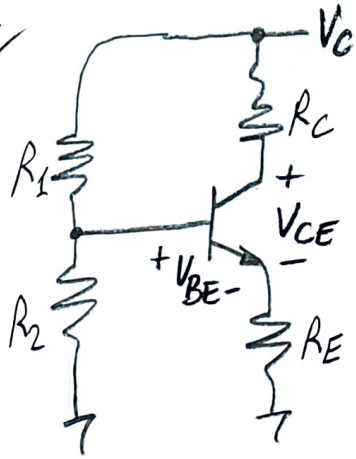
$$i_C = \beta i_B = 100 \times 18.724\,\mu A = 1.8724\,mA$$

$$i_E = (\beta+1) i_B = 101 \times 18.724\,\mu A = 1.89\,mA$$

$$V_{CE} = V_{CC} - R_E i_C = 12V - 3.5K \times 1.89\,mA = 5.385V$$

Çalışma Noktası $= (i_{CQ}, V_{CEQ}) = (1.89\,mA, 5.385V)$

6/



Yanda verilen elektronik devrede

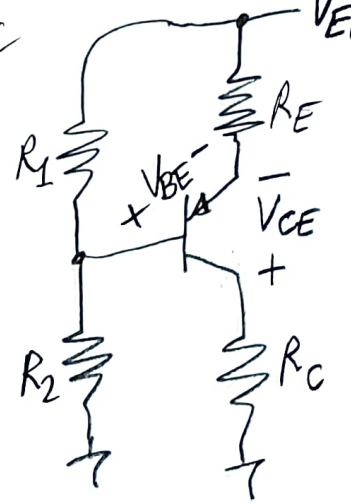
$V_{CC} = 15V$, $R_1 = 12K$, $R_2 = 24K$

$R_C = 4.7K$, $R_E = 15.3K$

$V_T = 0.6V$, $\beta = 100$ olarak veriliyor.

Transistörün çalışma noktasını bul

7/



Yanda verilen elektronik devrede

$V_{EE} = 15V$, $R_1 = 12K$, $R_2 = 24K$

$R_E = 6K$, $R_C = 4K$

$V_T = 0.7V$, $\beta = 100$ olarak veriliyor.

Transistörün çalışma noktasını bul.

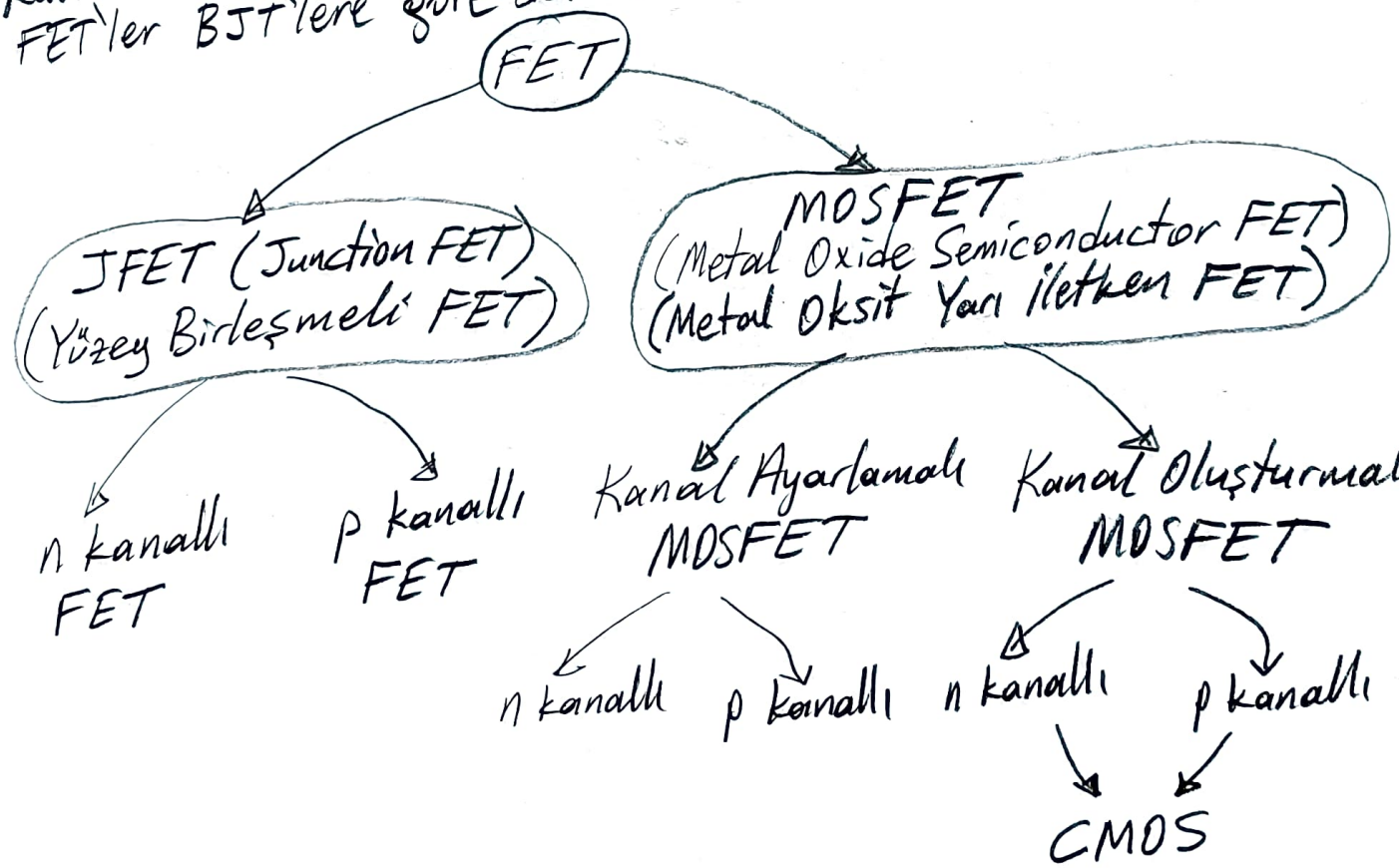
Field Effect Transistor - Alan Etkili Transistör

FET'ler gerilim kontrollü tek kutuplu transistörlerdir. n kanallı ve p kanallı olmak üzere iki tipte üretilirler. n kanallı FET'ler elektron akımıyla, p kanallı FET'ler oyuk akımıyla çalışır. Çalışma mantıkları temelde aynıdır. Aralarındaki tek fark kutuplama yönlerinin birbirlerine ters olmasıdır.

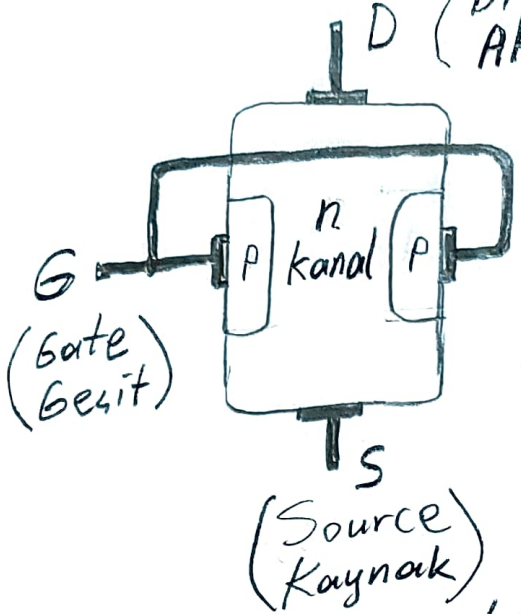
FET'ler gerilim kontrollü, BJT'ler akım kontrollüdür. FET'lerin giriş empedansı çok yüksektir. (100 MΩ gibi). FET'ler de BJT'ler gibi anahtarlama ve yükseltme amacıyla kullanılan üç uçlu yarı iletken devre elemanlarıdır. Ortak görevleri, kontrol ucu vasıtasıyla diğer iki uç arasındaki akımı ayarlamaktır.

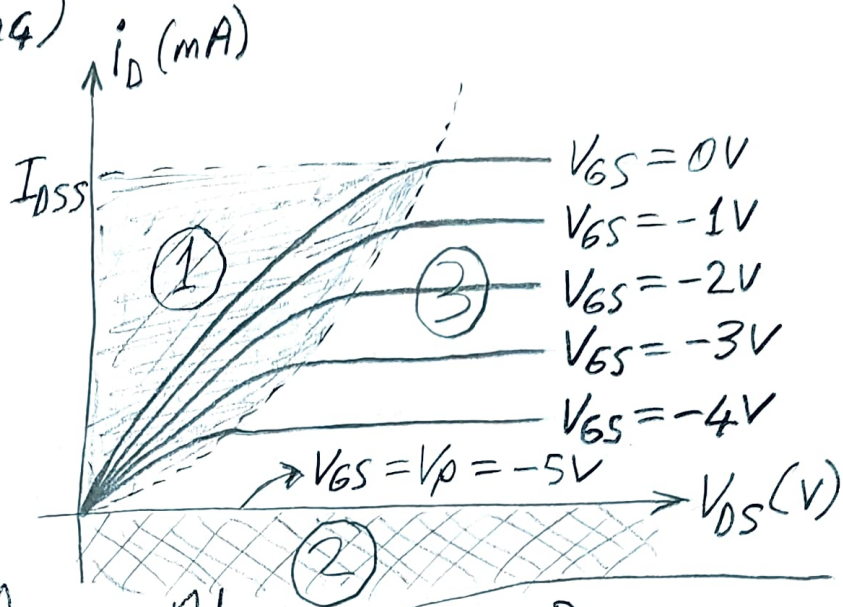
FET'lerin sıcaklığa karşı kararlılıkları BJT'lerden daha iyidir. BJT yükselteçlerin tipik AC kazancı FET'lerinkinden oldukça yüksektir.

FET'ler BJT'lerden çoğunlukla daha küçük tasarlanırlar. Bu yüzden FET'ler entegre devrelerde daha yaygın olarak kullanılırlar. FET'lerin gürültü oranları daha düşüktür. FET'ler BJT'lere göre daha kolay hasar görebilirler.



n kanallı JFET





I_{DSS} : Akaç-Kaynak Doyum Akımı

V_p : Kısılma Gerilimi

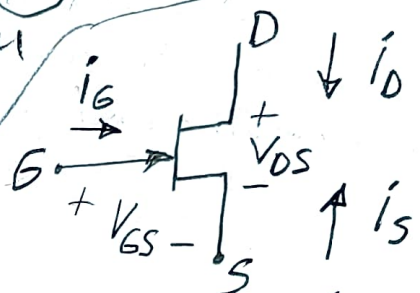
① Direnç Bölgesi $V_{DS} < V_{GS} - V_p$

② Kapalı Bölge $V_{GS} \leq V_p < 0$

③ Sabit Akım Bölgesi

$V_{DS} \geq V_{GS} - V_p > 0$

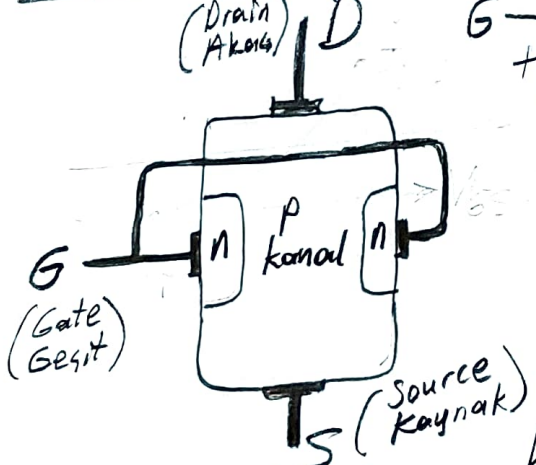
$$i_D = I_{DSS}\left(1 - \frac{V_{GS}}{V_p}\right)^2$$

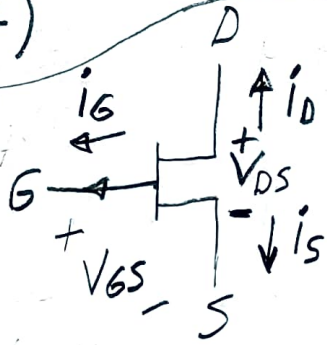


$i_G = 0$, $i_D = -i_S > 0$

$V_{DS} > 0$, $V_p < V_{GS} \leq 0$

p kanallı JFET

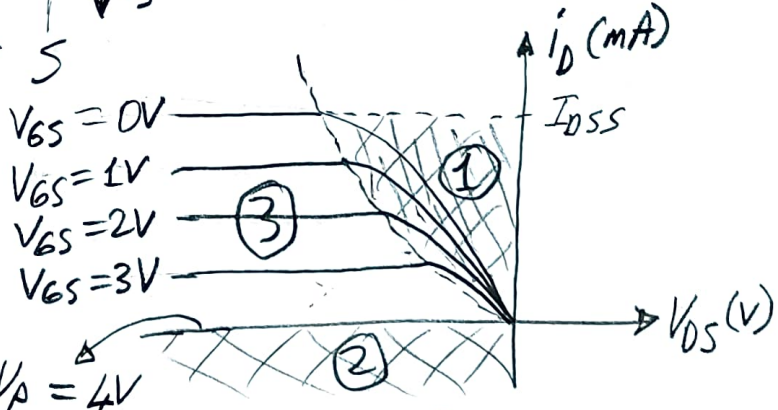




$i_G = 0$

$i_D = -i_S > 0$

$V_{DS} < 0$, $0 \leq V_{GS} < V_p$



① Direnç Bölgesi

$V_{DS} > V_{GS} - V_p$

② Kapalı Bölge

$V_{GS} \geq V_p > 0$

③ Sabit Akım Bölgesi

$V_{DS} \leq V_{GS} - V_p < 0$

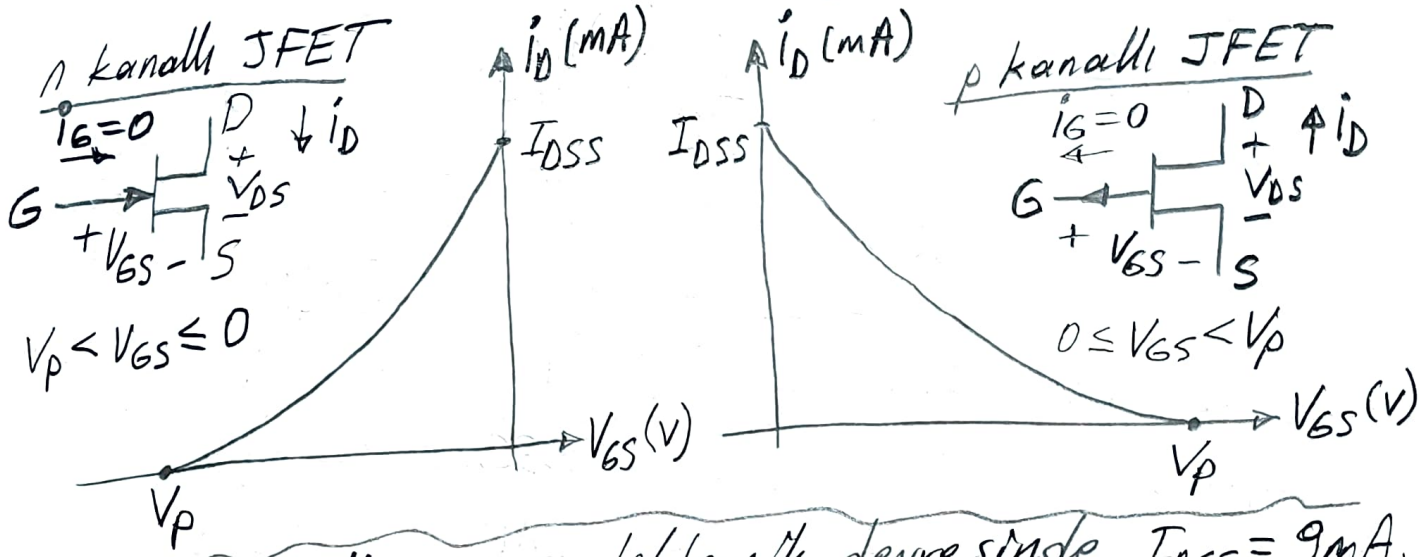
$$i_D = I_{DSS}\left(1 - \frac{V_{GS}}{V_p}\right)^2$$

Sabit Akım Bölgesi

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

→ $V_{DS} \geq V_{GS} - V_p > 0$, n kanallı

→ $V_{DS} \leq V_{GS} - V_p < 0$, p kanallı



Ör Bir n kanallı JFET elektronik devresinde $I_{DSS} = 9mA$, $V_p = -6V$ alınıyor.

a) $V_{GS} = 0V$ b) $V_{GS} = -2V$ c) $V_{GS} = -3V$ d) $V_{GS} = -6V$

e) $V_{GS} = -7V$ f) $V_{GS} = 2V$ durumları için $i_D = ?$, $V_{DS} = ?$

a) $i_D = I_{DSS}\left(1 - \frac{V_{GS}}{V_p}\right)^2 = 9mA\left(1 - \frac{0V}{-6V}\right) = 9mA$

$V_{DS} \geq V_{GS} - V_p = 0V - (-6V) = 6V$

b) $i_D = I_{DSS}\left(1 - \frac{V_{GS}}{V_p}\right)^2 = 9mA\left(1 - \frac{-2V}{-6V}\right)^2 = 4mA$

$V_{DS} \geq V_{GS} - V_p = -2V - (-6V) = 4V$

c) $i_D = I_{DSS}\left(1 - \frac{V_{GS}}{V_p}\right)^2 = 9mA\left(1 - \frac{-3V}{-6V}\right)^2 = 2.25mA$

$V_{DS} \geq V_{GS} - V_p = -3V - (-6V) = 3V$

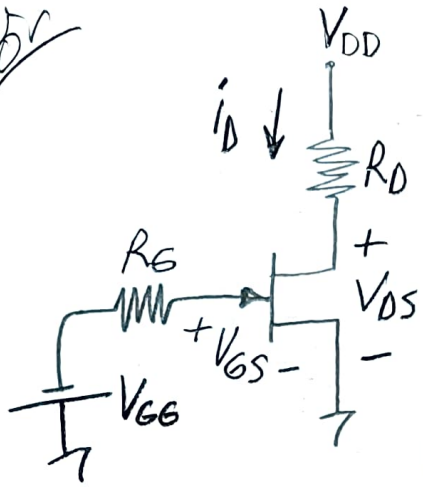
d) $i_D = I_{DSS}\left(1 - \frac{V_{GS}}{V_p}\right)^2 = 9mA\left(1 - \frac{-6V}{-6V}\right)^2 = 0mA$

$V_{DS} \geq V_{GS} - V_p = -6V - (-6V) = 0V$

e) $V_{GS} = -7V$ için JFET kapalı bölgede çünkü $V_{GS} < V_p$ olamaz.

f) $V_{GS} = 2V$ için uygunsuz durum çünkü $V_p < V_{GS} \leq 0$ arasında olmalı.

Ör



$V_{DD} = 15V$, $V_{GG} = 2V$, $R_G = 1M\Omega$

$R_D = 2K\Omega$, $I_{DSS} = 12mA$, $V_p = -5V$

n kanallı JFET transistörünün çalışma noktasını bul.

$V_{GS} = -V_{GG} = -2V$

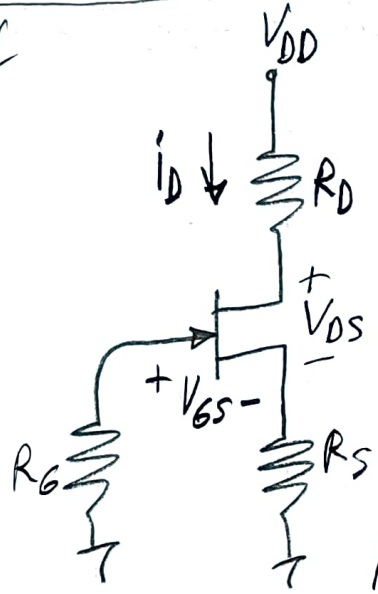
$$i_D = I_{DSS}\left(1 - \frac{V_{GS}}{V_p}\right)^2 = 12mA\left(1 - \frac{-2V}{-5V}\right)^2$$

$$= 12mA \times \left(\frac{3}{5}\right)^2 = 4.32\,mA$$

$V_{DS} = V_{DD} - R_D i_D = 15V - 2K \times 4.32mA = 6.36V > V_{GS} - V_p = 3V$

Çalışma Noktası $= (i_{DQ}, V_{DSQ}) = (4.32mA, 6.36V)$

Ör



$V_{DD} = 15V$, $R_G = 1M$, $R_D = 5K$, $R_S = 2K$

$I_{DSS} = 8mA$, $V_p = -4V$

Devredeki n kanallı JFET transistörün çalışma noktasını bul.

$V_G = 0$, $V_S = R_S i_D = 2i_D$

$V_{GS} = V_G - V_S = -2i_D$

$$i_D = I_{DSS}\left(1 - \frac{V_{GS}}{V_p}\right)^2 = 8mA\left(1 - \frac{-2i_D}{-4}\right)^2$$

$$= 8\left(1 - \frac{i_D}{2}\right)^2 = 2(i_D - 2)^2$$

$2i_D^2 - 9i_D + 8 = 0 \rightarrow i_D = 3.28\,mA$ veya $i_D = 1.22\,mA$

$i_D = 3.28mA$ için $V_{GS} = -2i_D = -6.56V < V_p$ ✗

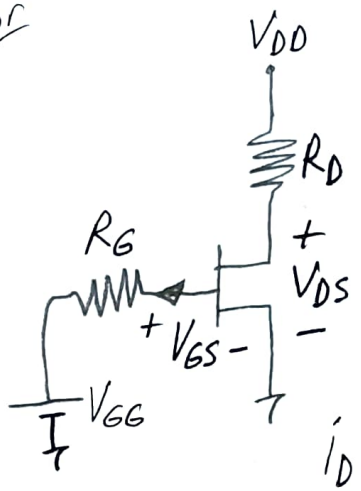
$i_D = 1.22mA$ için $V_{GS} = -2i_D = -2.44V > V_p$ ✓

$V_{DS} = V_{DD} - (R_D + R_S) i_D = 15V - (5K + 2K) \times 1.22mA$

$= 15V - 7K \times 1.22mA = 6.46V > V_{GS} - V_p = 1.56V$ ✓

Çalışma Noktası $= (i_{DQ}, V_{DSQ}) = (1.22mA, 6.46V)$

b/



$V_{DD} = -15V$, $V_{GG} = 2V$, $R_G = 1M$

$R_D = 2K$, $I_{DSS} = 12mA$, $V_p = 5V$

p kanallı JFET transistörün çalışma noktasını bul.

$V_{GS} = V_{GG} = 2V$

$$i_D = I_{DSS}\left(1 - \frac{V_{GS}}{V_p}\right)^2 = 12mA\left(1 - \frac{2V}{5V}\right)^2$$

$$= 12mA \times \left(\frac{3}{5}\right)^2 = 4.32\,mA$$

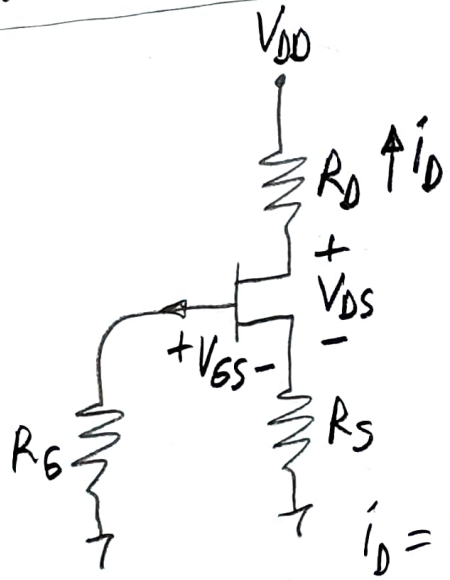
$$V_{DS} = V_{DD} + R_D i_D = -15V + 2K \times 4.32mA$$

$$= -6.36V < V_{GS} - V_p = -3V$$

Çalışma Noktası $= (i_{DQ}, V_{DSQ}) = (4.32mA, -6.36V)$

---

d/



$V_{DD} = -15V$, $R_G = 1M$, $R_D = 5K$

$R_S = 2K$, $I_{DSS} = 8mA$, $V_p = 4V$

p kanallı JFET transistörün çalışma noktasını bul.

$V_G = 0$, $V_S = -R_S i_D = -2i_D$

$V_{GS} = V_G - V_S = 2i_D$

$$i_D = I_{DSS}\left(1 - \frac{V_{GS}}{V_p}\right)^2 = 8mA\left(1 - \frac{2i_D}{4}\right)^2$$

$$= 8\left(1 - \frac{i_D}{2}\right)^2 = 2(i_D - 2)^2$$

$$2i_D^2 - 9i_D + 8 = 0 \rightarrow i_D = 3.28\,mA$$

$$\searrow i_D = 1.22\,mA$$

$i_D = 3.28mA$ için $V_{GS} = 2i_D = 6.56V > V_p$ ✗

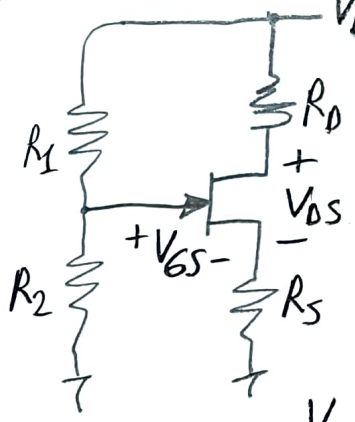
$i_D = 1.22mA$ için $V_{GS} = 2i_D = 2.44V < V_p$ ✓

$$V_{DS} = V_{DD} + (R_D + R_S) i_D = -15V + 7K \times 1.22mA$$

$$= -6.46V < V_{GS} - V_p = -1.56V$$

Çalışma Noktası $= (i_{DQ}, V_{DSQ}) = (1.22mA, -6.46V)$

Ör



$V_{DD} = 20V$, $R_1 = 3M$, $R_2 = 1M$

$R_D = 1.5K$, $R_S = 1K$ Çalışma noktası

$V_p = -4V$, $I_{DSS} = 10mA$

$$V_G = \frac{R_2 V_{DD}}{R_1 + R_2} = \frac{1M \times 20V}{3M + 1M} = \frac{1M \times 20V}{4M} = 5V$$

$$V_S = R_S i_D = i_D \,, \quad V_{GS} = V_G - V_S = 5 - i_D$$

$$i_D = I_{DSS}\left(1 - \frac{V_{GS}}{V_p}\right)^2 = 10mA\left(1 - \frac{5 - i_D}{-4}\right)^2 = \frac{10}{16}(i_D - 9)^2$$

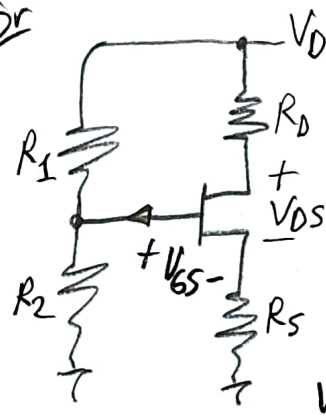
$$i_D^2 - 19.6 i_D + 81 = 0 \begin{cases} \rightarrow i_D \approx 13.68mA > I_{DSS} \ \times \\ \rightarrow i_D \approx 5.92mA < I_{DSS} \ \checkmark \end{cases}$$

$i_D = 5.92mA$ için $V_{GS} = 5 - i_D = -0.92V > V_p = -4V$

$V_{DS} = V_{DD} - (R_D + R_S) i_D = 20V - 2.5k \times 5.92mA = 5.2V > V_{GS} - V_p = 3.08V$

Çalışma Noktası $= (i_{DQ}, V_{DSQ}) = (5.92mA, 5.2V)$

Ör



$V_{DD} = -25V$, $R_1 = 4M$, $R_2 = 1M$, $R_D = 2K$

$R_S = 1K$, $V_p = 5V$, $I_{DSS} = 10mA$

Çalışma Noktasını Bul.

$$V_G = \frac{R_2 V_{DD}}{R_1 + R_2} = \frac{1M \times (-25V)}{4M + 1M} = \frac{1M \times (-25V)}{5M} = -5V$$

$$V_S = -R_S i_D = -i_D \,, \quad V_{GS} = V_G - V_S = i_D - 5$$

$$i_D = I_{DSS}\left(1 - \frac{V_{GS}}{V_p}\right)^2 = 10mA\left(1 - \frac{i_D - 5}{5}\right)^2 = \frac{10}{25}(i_D - 10)^2$$

$$i_D^2 - 22.5 i_D + 100 = 0 \begin{cases} \rightarrow i_D = 16.4mA > I_{DSS} \ \times \\ \rightarrow i_D = 6.1mA < I_{DSS} \ \checkmark \end{cases}$$

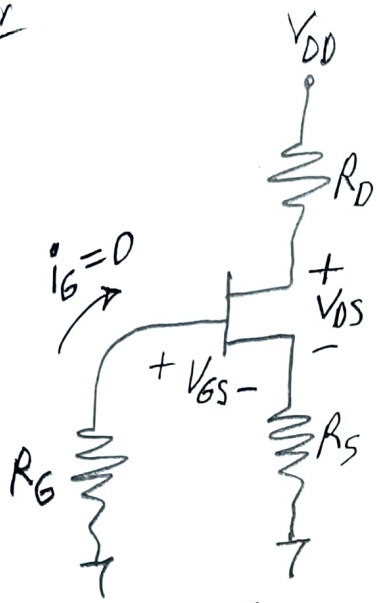
$i_D = 6.1mA$ için $V_{GS} = i_D - 5 = 1.1V < V_p = 5V$

$V_{DS} = V_D + (R_D + R_S) i_D = -25V + 3K \times 6.1mA$

$= -6.7V < V_{GS} - V_p = -3.9V \ \checkmark$

Çalışma Noktası $= (i_{DQ}, V_{DSQ}) = (6.1mA, -6.7V)$

Ör



$V_{DD}=20V$, $R_D=4K$, $R_S=2.5K$

$R_G=1M$, $I_{DSS}=9mA$, $V_p=-6V$

n kanallı JFET transistörün çalışma noktasını bul.

$V_G=0$, $V_S=R_S i_D=2.5 i_D$

$V_{GS}=V_G-V_S=-2.5 i_D$

$$i_D=I_{DSS}\left(1-\frac{V_{GS}}{V_p}\right)^2=9mA\left(1-\frac{-2.5i_D}{-6}\right)^2=9\left(1-\frac{5i_D}{12}\right)^2$$

$$=9\frac{25}{144}\left(\frac{12}{5}-i_D\right)^2=\frac{25}{16}(i_D-2.4)^2$$

$$0.64 i_D=(i_D-2.4)^2=i_D^2-4.8 i_D+5.76$$

$$i_D^2-5.44 i_D+5.76=0$$

$i_D=4mA$

$V_{GS}=-2.5 i_D=-10V<V_p$

Çözüm Değil.

$i_D=1.44\ mA$

$V_{GS}=-2.5 i_D=-3.6V>V_p$

$V_{DS}=V_{DD}-(R_D+R_S)i_D$

$=20V-(4K+2.5K)\times 1.44mA$

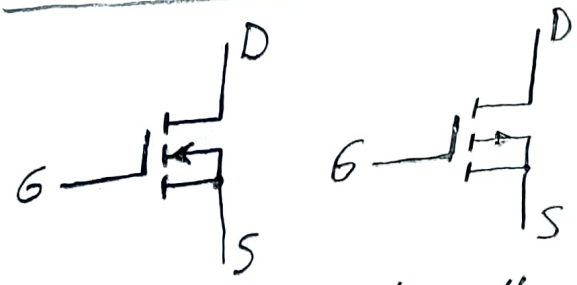
$=20V-7.5K\times 1.44mA$

$=10.64V>V_{GS}-V_p=2.4V$

Çalışma Noktası $=(i_{DQ}, V_{DSQ})$

$=(1.44\ mA, 10.64V)$

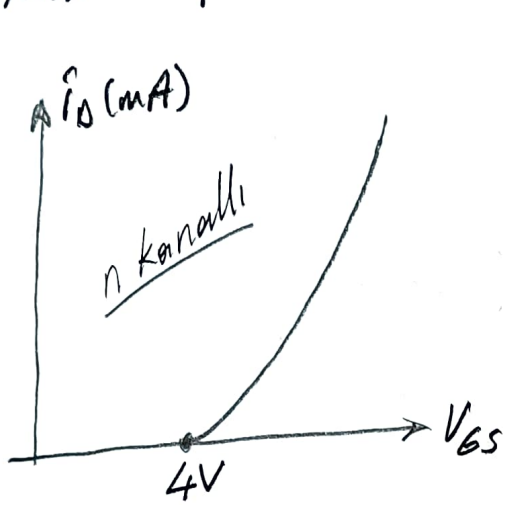
Kanal Oluşturmalı MOSFET

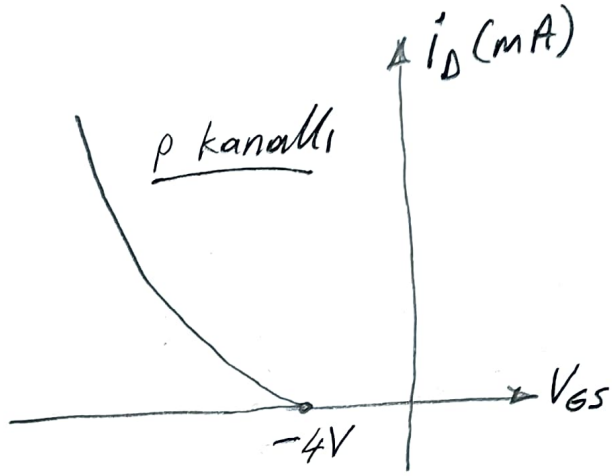


n kanallı p kanallı

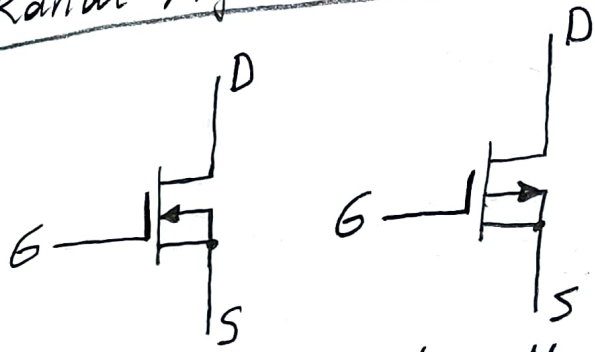
$$i_D = k\,(V_{GS} - V_T)^2$$

$$k = \frac{i_{D(on)}}{(V_{GS(on)} - V_T)^2}$$



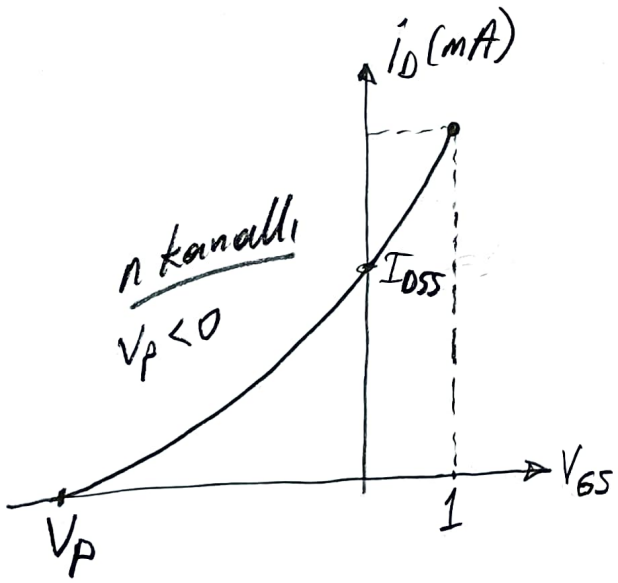


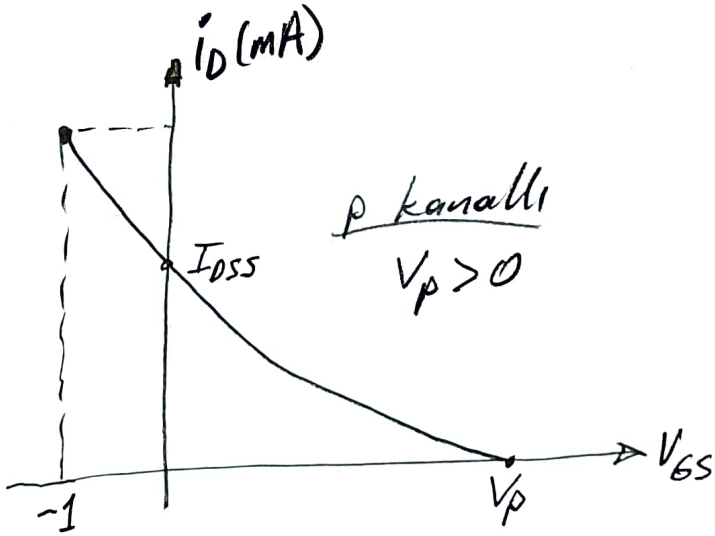
Kanal Ayarlamalı MOSFET



n kanallı p kanallı

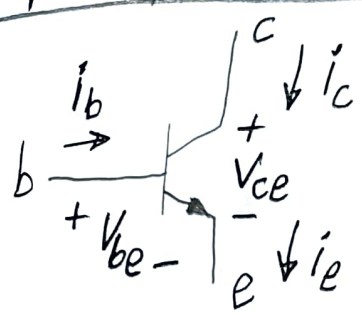
$$i_D = I_{DSS}\left(1 - \frac{V_{GS}}{V_P}\right)^2$$

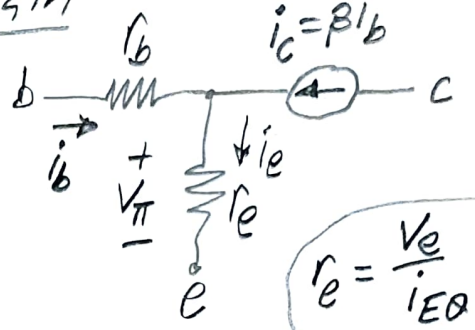


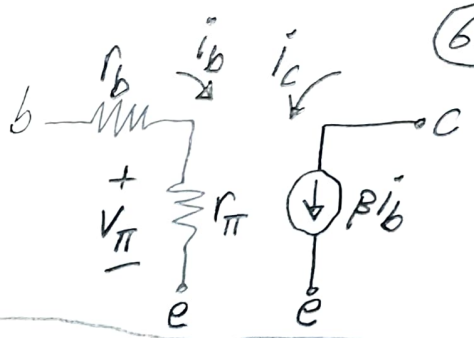


Küçük Sinyal Analizi

npn tipi BJT için



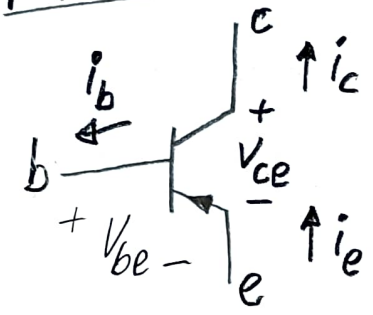


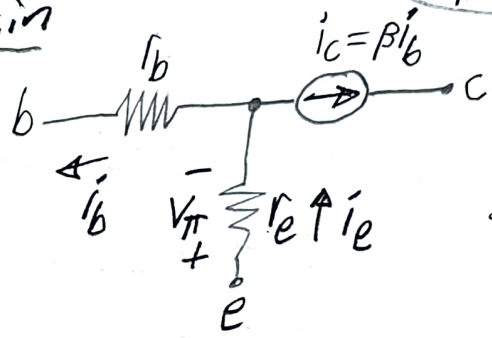


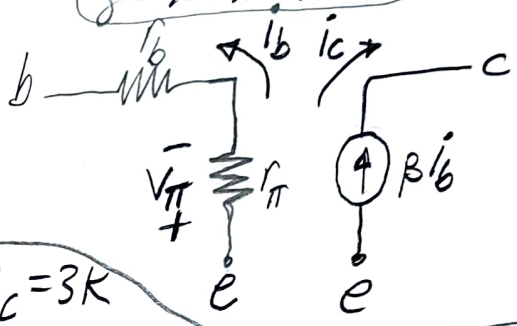
$$r_e = \frac{V_e}{i_{EQ}}, \quad r_\pi = (\beta+1) r_e$$

$$V_\pi = r_e i_e = r_\pi i_b$$

pnp tipi BJT için

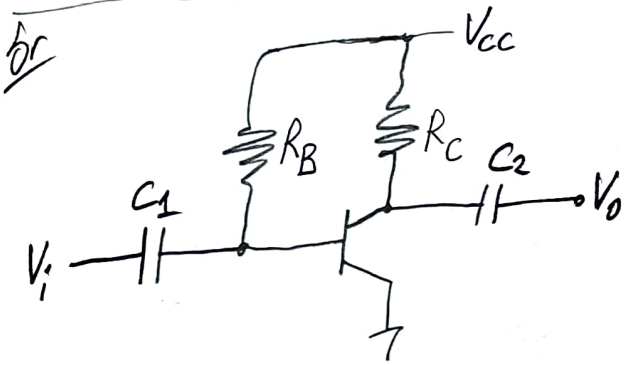






Aynı formüller geçerlidir.

Ör



$R_B = 560K$, $R_C = 3K$

$V_{cc} = 12V$, $V_T = 0.7V$

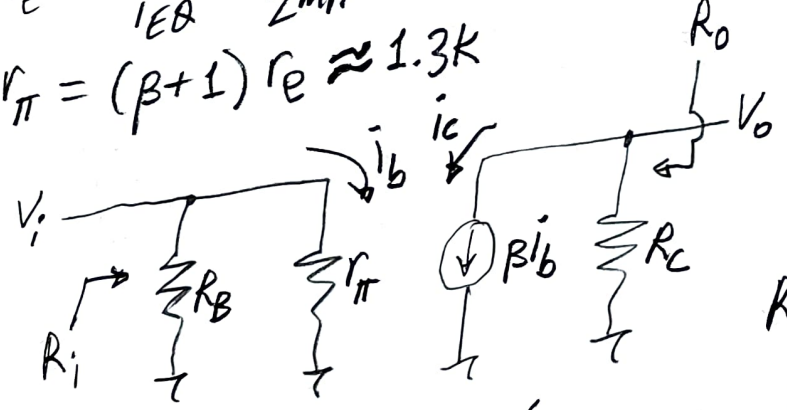
$\beta = 100$, $r_b = 0$ ise R_i, R_o, A_v bul.

$$i_{BQ} = \frac{V_{cc} - V_{BE}}{R_B} = \frac{12V - 0.7V}{560K} \approx 20\,\mu A$$

$$i_{CQ} = \beta i_{BQ} = 100 \times 20\mu A = 2mA = i_{EQ}$$

$$r_e = \frac{26mV}{i_{EQ}} = \frac{26mV}{2mA} = 13\Omega$$

$$r_\pi = (\beta+1) r_e \approx 1.3K$$

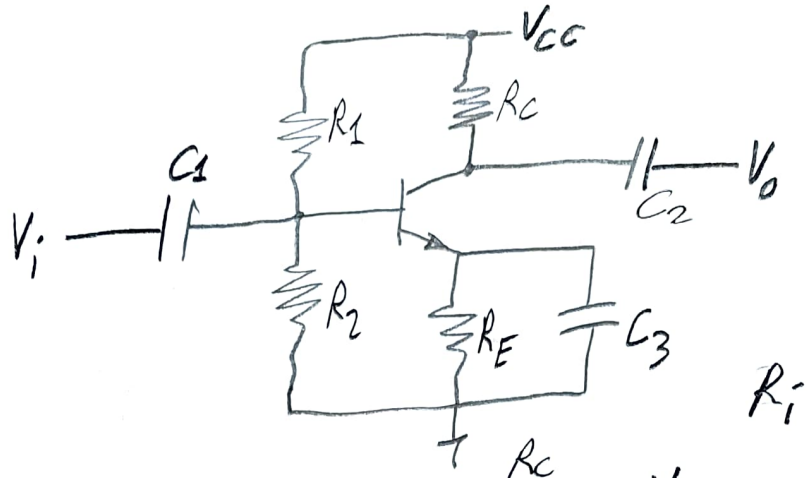


$$R_i = R_B \,//\, r_\pi \approx r_\pi = 1.3K, \quad R_B >> r_\pi$$

$$R_o = R_C = 3K$$

$$V_o = -R_C i_c = -R_C \beta i_b = -R_C \beta \frac{V_i}{r_\pi}$$

$$A_V = \frac{V_o}{V_i} = -R_C \beta / r_\pi = -3K \times 100 / 1.3K \approx -230.77$$



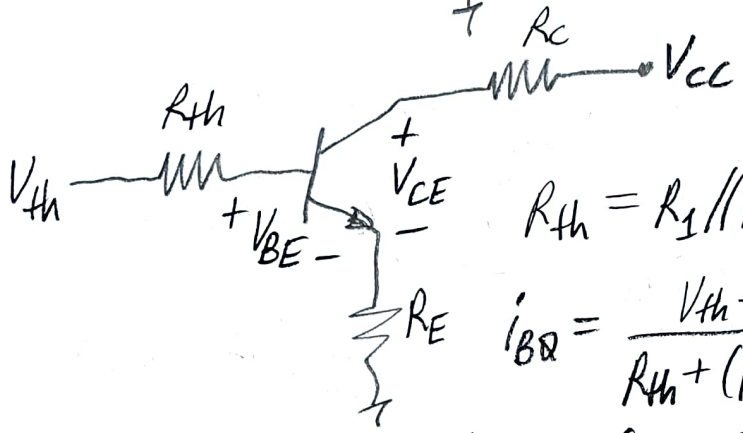
$V_{CC} = 22V$, $\beta = 90$

$R_1 = 56k$, $R_2 = 5.6k$

$R_C = 10k$, $R_E = 1.5k$

$r_b = 0$ ise

$R_i, R_o, A_v = ?$



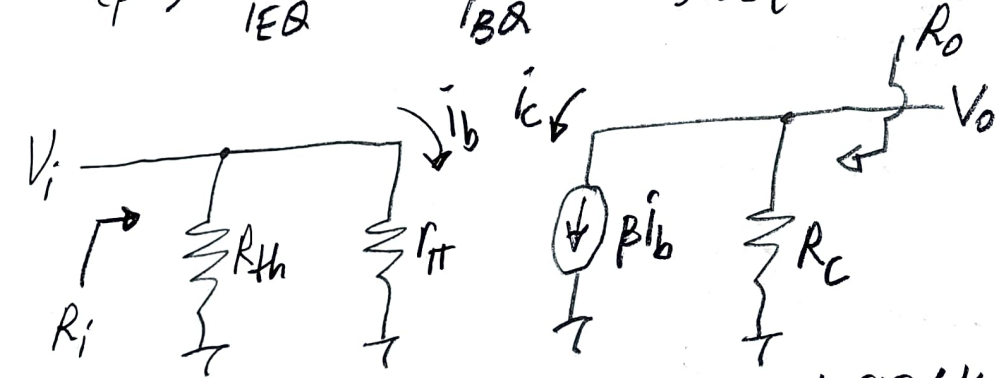
$$V_{th} = \frac{R_2 V_{CC}}{R_1 + R_2} = \frac{5.6k \times 22V}{56k + 5.6k} = 2V$$

$$R_{th} = R_1 // R_2 = 56k // 5.6k \approx 5.09k$$

$$i_{BQ} = \frac{V_{th} - V_{BE}}{R_{th} + (\beta+1) R_E} = \frac{2V - 0.7V}{5.09k + 91 \times 1.5k} = 9.18\mu A$$

$$i_{CQ} = \beta i_{BQ} = 90 \times 9.18\mu A = 0.826mA \approx i_{EQ}$$

$$r_\pi = (\beta+1) r_d = (\beta+1) \frac{26mV}{i_{EQ}} = \frac{26mV}{i_{BQ}} = \frac{26mV}{9.18\mu A} = 2.835K$$



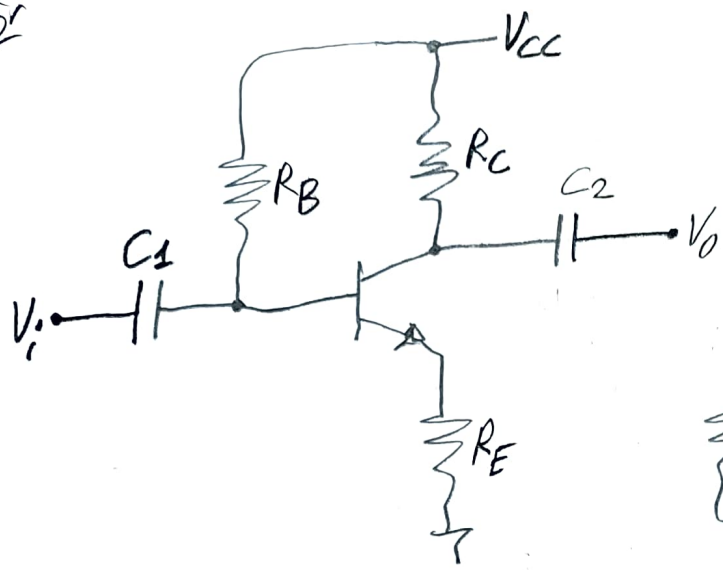
$$R_i = R_{th} // r_\pi = 5.09k // 2.835k = 1.821K$$

$$R_o = R_C = 10K$$

$$V_o = -R_C i_c = -R_C \beta i_b = -R_C \beta \frac{V_i}{r_\pi}$$

$$A_v = \frac{V_o}{V_i} = -R_C \beta / r_\pi = -10k \times 90 / 2.835k = -317.5$$

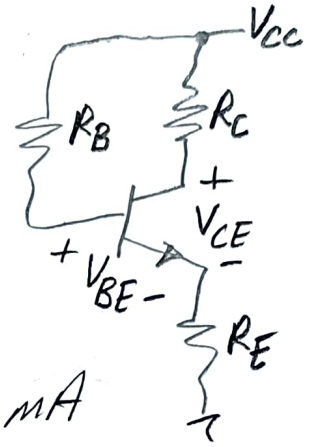
5/



$V_{CC} = 20V$, $\beta = 120$, $V_T = 0.2V$

$R_B = 270k$, $R_C = 5.6k$, $R_E = 1.2k$

R_i, R_o, A_v = ? $\quad r_b = 0$



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

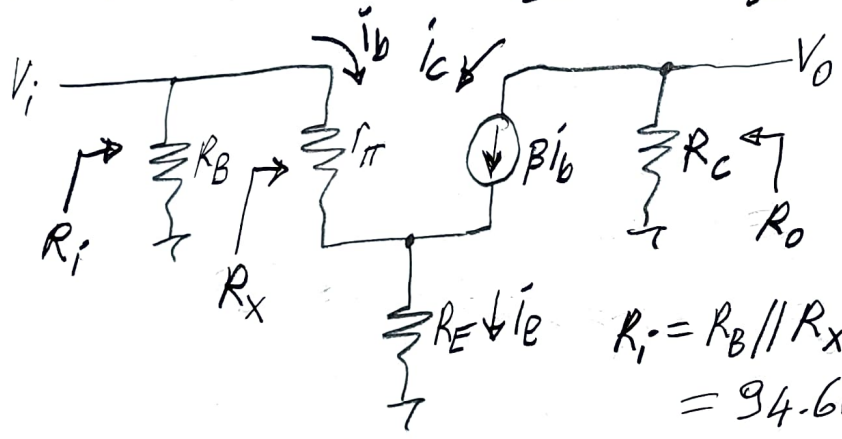
$$= \frac{20V - 0.7V}{270K + 121 \times 1.2K}$$

$$= \frac{19.3V}{415.2K} = 46.48\mu A$$

$$I_{EQ} = I_{CQ} = (\beta+1) I_{BQ}$$

$$= 121 \times 46.48\mu A = 5.624\ mA$$

$$r_\pi = (\beta+1) r_e = (\beta+1) \frac{26mV}{I_{EQ}} = \frac{26mV}{I_{BQ}} = \frac{26mV}{46.48\mu A} = 0.56K$$



$$R_x = r_\pi + (\beta+1) R_E$$

$$= 0.56K + 121 \times 1.2K$$

$$= 145.76K$$

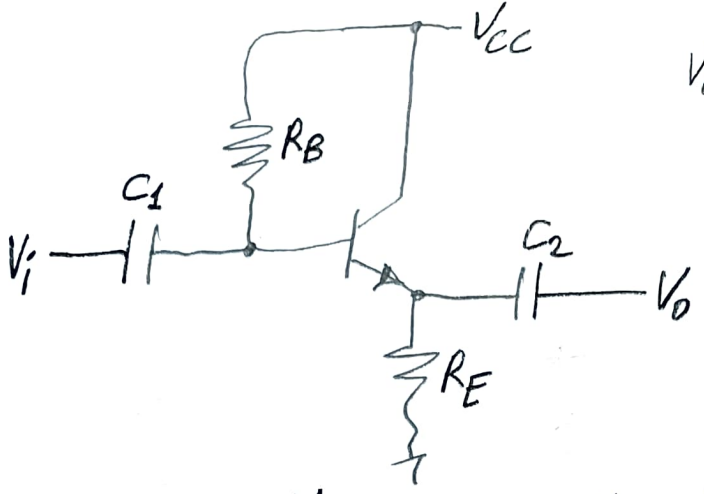
$$R_i = R_B // R_x = 270K // 145.76k$$

$$= 94.66K$$

$$R_o = R_C = 5.6K$$

$$V_o = -R_C i_c = -R_C \beta i_b = -R_C \beta \frac{V_i}{R_x}$$

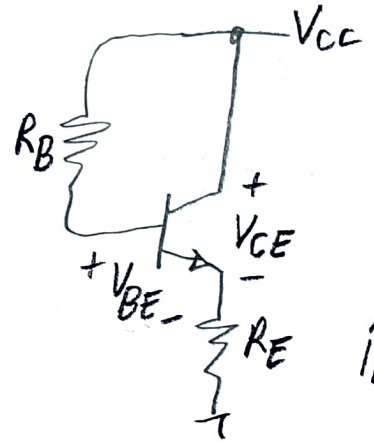
$$A_v = \frac{V_o}{V_i} = -R_C \beta / R_x = -5.6K \times 120 / 145.76k = -4.61$$



$V_{CC} = 12V$, $V_T = 0.7V$, $\beta = 98$

$R_B = 220K$, $R_E = 3.3K$, $r_b = 0$

R_i, R_o, $A_v = ?$

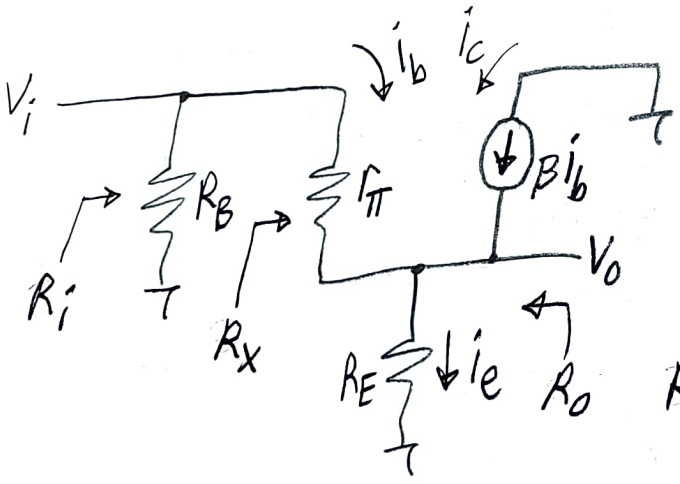


$$I_{BQ} = \frac{V_{CC} - V_T}{R_B + (\beta+1)R_E} = \frac{12V - 0.7V}{220K + 99 \times 3.3K}$$

$$= \frac{11.3V}{546.7K} = 20.67\,\mu A$$

$$I_{EQ} = I_{CQ} = (\beta+1) I_{BQ} = 99 \times 20.67\mu A = 2.05\,mA$$

$$r_\pi = (\beta+1) r_e = (\beta+1)\frac{26mV}{I_{EQ}} = \frac{26mV}{I_{BQ}} = \frac{26mV}{20.67\mu A} = 1.26K$$



$$R_x = r_\pi + (\beta+1)R_E$$

$$= 1.26K + 99 \times 3.3K$$

$$= 327.96K$$

$$R_i = R_B // R_x = 220K // 327.96K$$

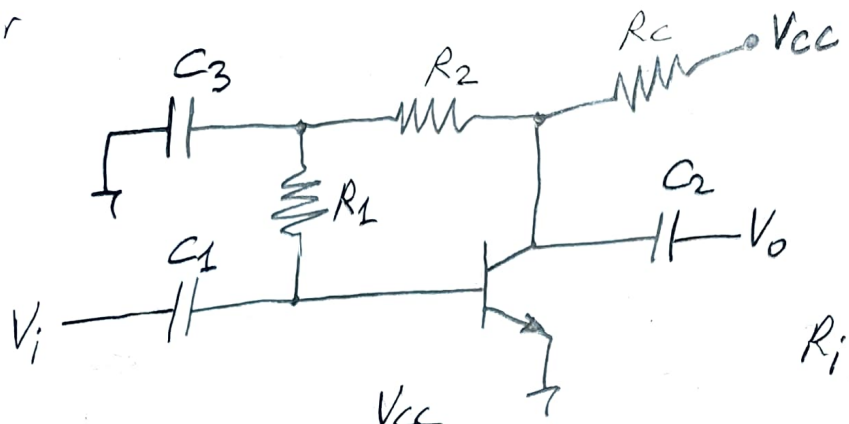
$$= 131.67K$$

R_o'i bulmak için $V_i = 0$ yapılırsa

$$R_o = R_E // \left(\frac{r_\pi}{\beta+1}\right) = (3.3K) // \left(\frac{1.26K}{99}\right) = 3.3K // 12.7\Omega \approx 12.7\Omega$$

$$V_o = R_E i_e = R_E(\beta+1) i_b = R_E(\beta+1) V_i / R_x$$

$$A_V = \frac{V_o}{V_i} = (\beta+1)\frac{R_E}{R_x} = 99 \times \frac{3.3K}{327.96K} \approx 1$$

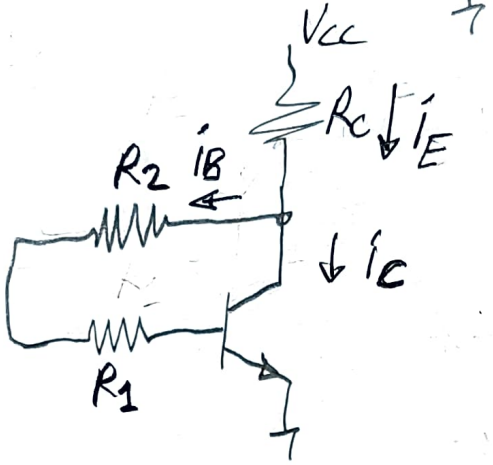


$V_{CC} = 12V$, $V_T = 0.7V$

$R_1 = 120K$, $R_2 = 68K$

$R_C = 3K$, $\beta = 140$

$R_i, R_o, A_V = ?$ $\quad r_b = 0$

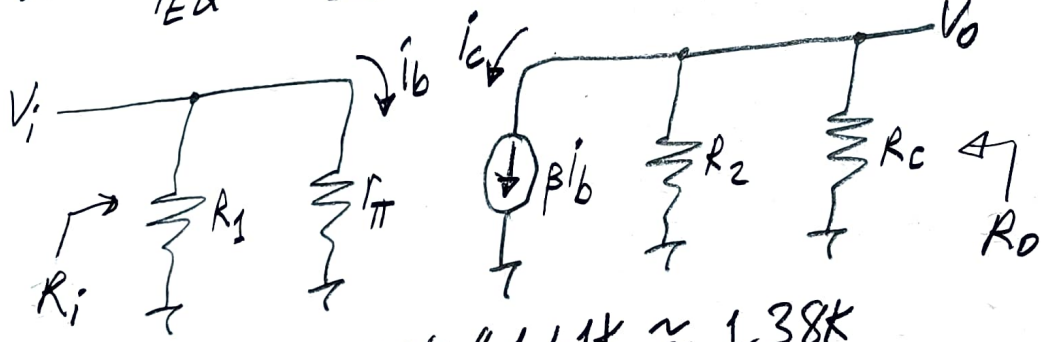


$$I_{BQ} = \frac{V_{CC} - V_{BE}}{R_1 + R_2 + (\beta+1)R_C} = \frac{12V - 0.7V}{120K + 68K + 141 \times 3K} = \frac{11.3V}{611K}$$

$$= 18.5\,\mu A$$

$$I_{EQ} = (\beta+1) I_{BQ} = 141 \times 18.5\mu A = 2.6\,mA \approx I_{CQ}$$

$$r_e = \frac{26mV}{I_{EQ}} = \frac{26mV}{2.6mA} = 10\,\Omega, \quad r_\pi = (\beta+1) r_e = 1.41K$$

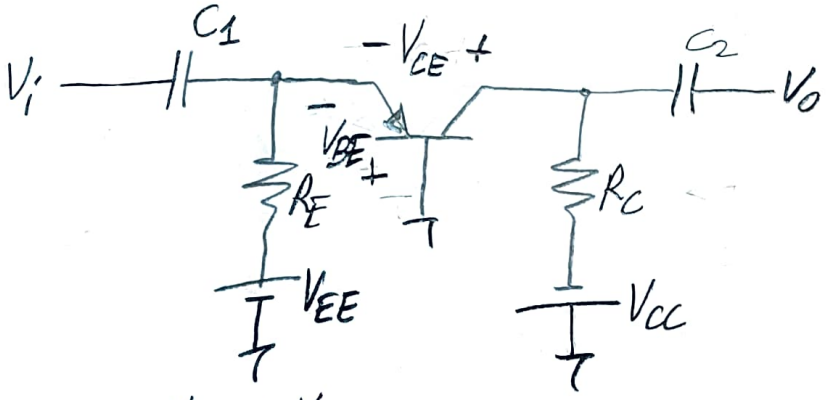


$$R_i = R_1 // r_\pi = 120K // 1.41K \approx 1.38K$$

$$R_o = R_C // R_2 = 3K // 68K \approx 2.87K$$

$$V_o = -(R_2 // R_C) i_c = -R_o i_c = -R_o \beta i_b = -R_o \beta \frac{V_i}{r_\pi}$$

$$A_V = \frac{V_o}{V_i} = -\beta \frac{R_o}{r_\pi} = -140 \frac{2.87K}{1.41K} \approx -285$$



$R_E = 1k$, $R_C = 5k$

$V_{EE} = 2V$, $V_{CC} = 8V$

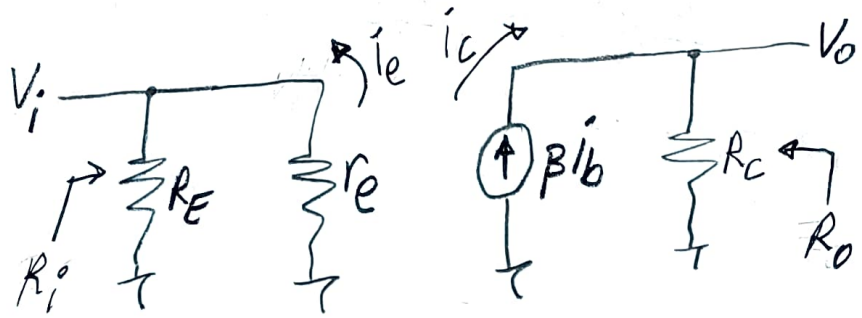
$V_\gamma = 0.7V$, $\beta = 100$

$r_b = 0$ ise

$R_i, R_o, A_V = ?$

$$i_{EQ} = \frac{V_{EE} + V_{BE}}{R_E} = \frac{2V - 0.7V}{1K} = 1.3mA$$

$$r_e = \frac{26mV}{i_{EQ}} = \frac{26mV}{1.3mA} = 20\Omega$$



$$\alpha = \frac{\beta}{\beta+1} \approx 1$$

$$R_i = R_E // r_e = 1K // 20\Omega = 19.6\Omega$$

$$R_o = R_C = 5K$$

$$V_o = R_C i_c = R_C \beta i_b = R_C \beta \frac{i_e}{\beta+1} = \frac{\beta}{\beta+1} R_C i_e$$

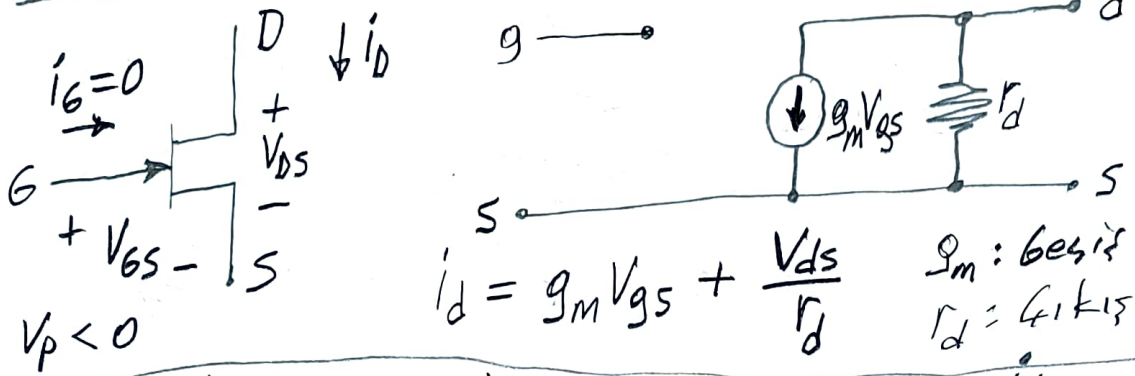
$$= \alpha R_C \left(-\frac{V_i}{r_e}\right)$$

$$A_V = \frac{V_o}{V_i} = -\alpha \frac{R_C}{r_e} = -\frac{5K}{20\Omega} = -250$$

JFET'ler için Küçük Sinyal Analizi

$$i_D = I_{DSS}\left(1 - \frac{V_{GS}}{V_p}\right)^2 \quad \begin{cases} \rightarrow V_{DS} \geq V_{GS} - V_p > 0 & \text{n kanallı} \\ \rightarrow V_{DS} \leq V_{GS} - V_p < 0 & \text{p kanallı} \end{cases}$$

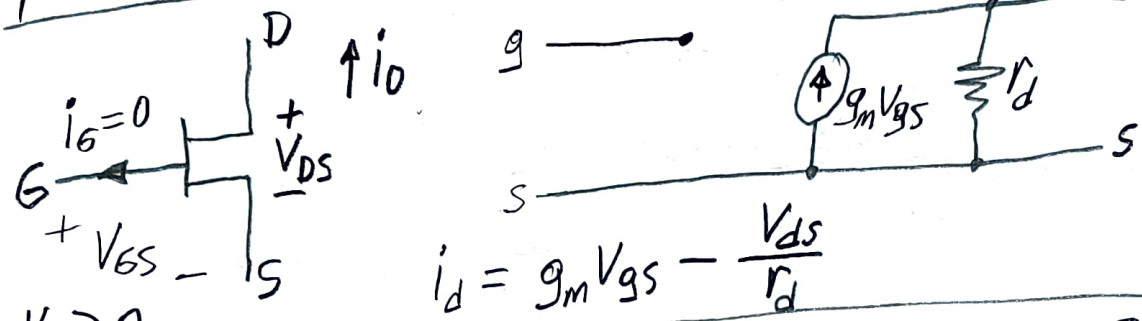
n kanallı JFET için



$$i_d = g_m V_{gs} + \frac{V_{ds}}{r_d}$$

g_m : Geçiş iletkenliği
r_d : Çıkış direnci

p kanallı JFET için



$$i_d = g_m V_{gs} - \frac{V_{ds}}{r_d}$$

$$g_m = \left.\frac{\partial i_D}{\partial V_{GS}}\right|_Q = g_{mo}\cdot\left(1 - \frac{V_{GS}}{V_p}\right), \quad g_{mo} = \frac{2I_{DSS}}{|V_p|}$$

$$r_d = \left.\frac{\partial V_{DS}}{\partial i_D}\right|_Q = r_{ds} \quad (10K \text{ ile } 100K \text{ arası})$$

n kanallı JFET için $I_{DSS} = 12mA$, $V_p = -5V$, $V_{GS} = -2V$ ise

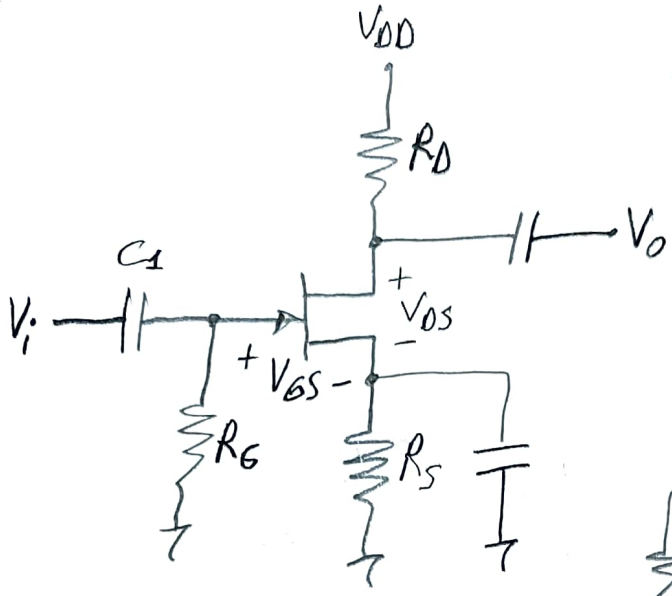
$$g_{mo} = \frac{2I_{DSS}}{|V_p|} = \frac{2\times 12mA}{5V} = 4.8mS$$

$$g_m = g_{mo}\left(1 - \frac{V_{GS}}{V_p}\right) = 4.8mS \times \left(1 - \frac{-2V}{-5V}\right) = 4.8mS \times \frac{3}{5} = 2.88mS$$

p kanallı JFET için $I_{DSS} = 8mA$, $V_p = 4V$, $V_{GS} = 2.5V$ ise

$$g_{mo} = \frac{2I_{DSS}}{|V_p|} = \frac{2\times 8mA}{4V} = 4mS$$

$$g_m = g_{mo}\left(1 - \frac{V_{GS}}{V_p}\right) = 4mS\left(1 - \frac{2.5V}{4V}\right) = 4mS \times \frac{3}{8} = 1.5mS$$

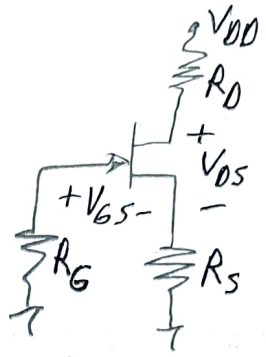


$I_{DSS} = 10mA$, $V_p = -4V$

$r_d = 50K$ $R_G = 1M$, $R_D = 6.2K$

$R_S = 1.5K$, $V_{DD} = 24V$

R_i, R_o, A_V = ?



$V_G = 0$, $V_S = R_S i_D = 1.5 i_D$

$V_{GS} = V_G - V_S = -1.5 i_D$

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

$$= 10\left(1 - \frac{-1.5 i_D}{-4}\right)^2$$

$$= \frac{10}{64}(3 i_D - 8)^2$$

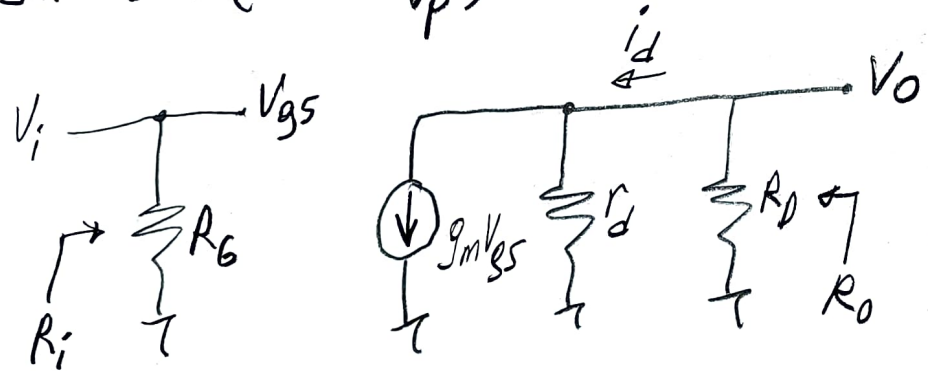
$$9 i_D^2 - 54.4 i_D + 64 = 0$$

$\rightarrow i_D = 1.6mA \rightarrow V_{GS} = -1.5 i_D = -2.4V > V_p$ ✓

$\rightarrow i_D = 4.44mA \rightarrow V_{GS} = -1.5 i_D = -6.66V < V_p$ ✗

$$g_{mo} = \frac{2 I_{DSS}}{|V_p|} = \frac{2 \times 10mA}{4V} = 5mS$$

$$g_m = g_{mo}\left(1 - \frac{V_{GS}}{V_p}\right) = 5mS \times \left(1 - \frac{-2.4V}{-4V}\right) = 2mS$$



$R_i = R_G = 1M\Omega$

$R_o = r_d \,//\, R_D$

$= 50k \,//\, 6.2k$

$= 5.52k$

$$i_d = g_m V_{gs} + \frac{V_{ds}}{r_d} = 2V_i + \frac{V_o}{50}$$

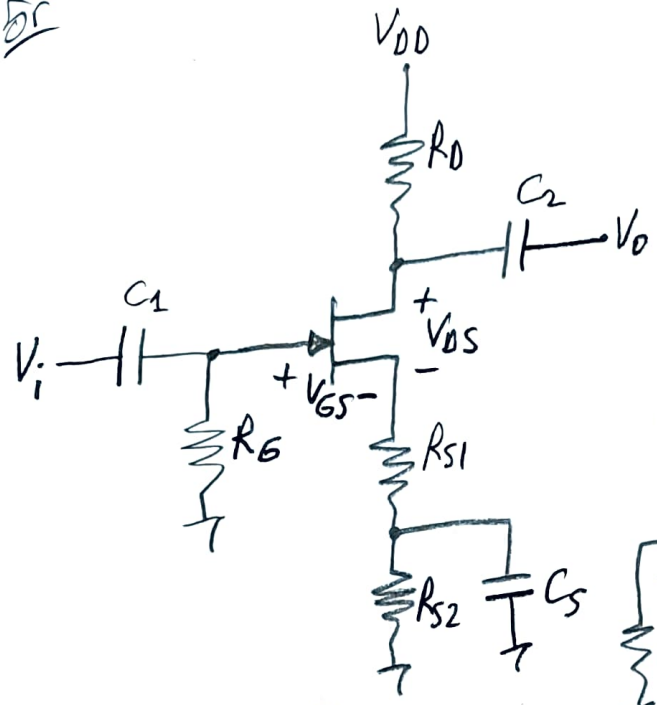
$$V_o = -R_D i_d = -6.2\left(2V_i + \frac{V_o}{50}\right)$$

$$\left(\frac{1}{50} + \frac{1}{6.2}\right) V_o = -2V_i \rightarrow A_V = \frac{V_o}{V_i} = \frac{-2 \times 6.2 \times 50}{6.2 + 50}$$

(6.2) (50)

$$A_V = -\frac{620}{56.2} = -11.03$$

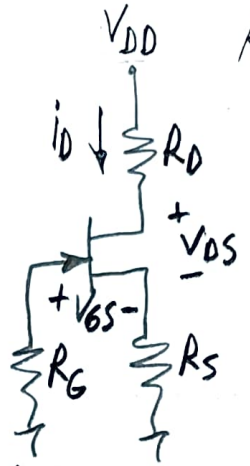
6r



$I_{DSS} = 10mA$, $V_p = -6V$, $r_d = 50k$

$V_{DD} = 24V$, $R_D = 4.3k$, $R_{S1} = 0.25k$

$R_{S2} = 1.75k$ ise $A_V = ?$



$R_S = R_{S1} + R_{S2} = 2K$

$V_G = 0$, $V_S = R_S i_D = 2 i_D$

$V_{GS} = V_G - V_S = -2 i_D$

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

$= 10\left(1 - \frac{-2i_D}{-6}\right)^2$

$i_D = \frac{10}{9}(i_D - 3)^2 \Rightarrow i_D^2 - 6.9 i_D + 9 = 0 \longrightarrow i_D = 5.155\,mA$

$\searrow\ i_D = 1.745\,mA$

$V_{DS} = V_{DD} - (R_D + R_S) i_D = 24 - 6.3 i_D$

$i_D = 5.155mA \Rightarrow V_{DS} = 24 - 6.3 \times 5.155 = -8.48V < 0$ ✗

$i_D = 1.745mA \Rightarrow V_{DS} = 24 - 6.3 \times 1.745 = 13V > 0$ ✓

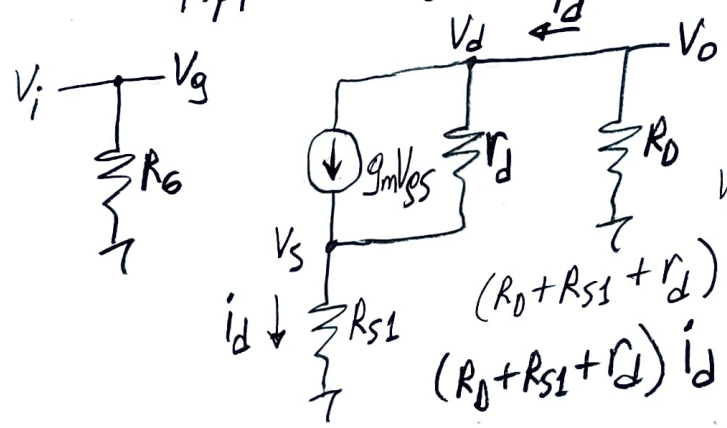
Çalışma Noktası $= (i_{DQ}, V_{DSQ}) = (1.745mA, 13V)$

$V_{GSQ} = -2 i_{DQ} = -3.49V$

$g_{mo} = \frac{2 I_{DSS}}{|V_p|} = \frac{2 \times 10mA}{6V} = \frac{10}{3}\,mS$

$g_m = g_{mo}\left(1 - \frac{V_{GSQ}}{V_p}\right)$

$= \frac{10}{3}ms \cdot \left(1 - \frac{-3.49V}{-6V}\right) = 5.27\,mS$



$V_{gs} = V_g - V_S = V_i - R_{S1} i_d$

$V_o = -R_D i_D = R_{S1} i_d + r_d (i_d - g_m V_{gs})$

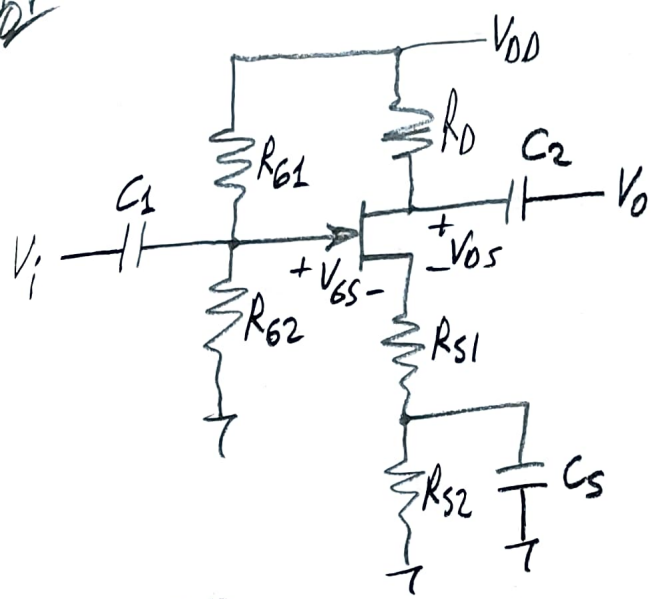
$(R_D + R_{S1} + r_d) i_d - r_d g_m V_{gs} = 0$

$(R_D + R_{S1} + r_d) i_d - r_d g_m (V_i - R_{S1} i_d) = 0$

$i_d = \frac{r_d g_m V_i}{R_D + R_{S1} + r_d(1 + g_m R_{S1})} = -\frac{V_o}{R_D} \Rightarrow A_V = \frac{-r_d R_D g_m}{R_D + R_{S1} + r_d(1 + g_m R_{S1})}$

$A_V = -\frac{50 \times 4.3 \times 5.27}{4.3 + 0.25 + 50(1 + 5.27 \times 0.25)} = -\frac{1133.05}{120.425} = -9.41$

$= \frac{V_o}{V_i}$



$R_{G1} = 3M$, $R_{G2} = 1M$, $R_D = 1.5k$

$R_{S1} = 0.25k$, $R_{S2} = 0.75k$

$V_{DD} = 20V$, $I_{DSS} = 8mA$

$V_p = -5V$, $r_d = 50k$

$A_v = ?$

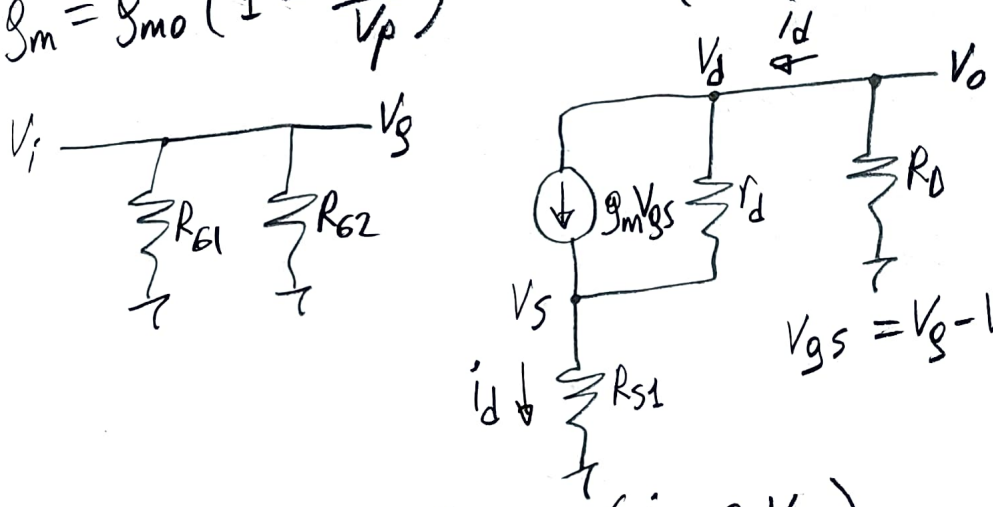
Çalışma noktasını çözersek.

$I_{DQ} = 5.76\,mA$, $V_{DSQ} = 5.6V$

$V_{GS} = -0.76V$ buluruz.

$$g_{mo} = \frac{2I_{DSS}}{|V_p|} = \frac{2 \times 8mA}{5V} = 3.2\,mS$$

$$g_m = g_{mo}\left(1 - \frac{V_{GS}}{V_p}\right) = 3.2mS \times \left(1 - \frac{-0.76V}{-5V}\right) = 2.71\,mS$$



$$V_{gs} = V_g - V_s = V_i - R_{S1} i_d$$

$$V_o = -R_D i_d = R_{S1} i_d + r_d (i_d - g_m V_{gs})$$

$$(R_D + R_{S1} + r_d)\, i_d - r_d g_m V_{gs} = 0$$

$$(R_D + R_{S1} + r_d)\, i_d - r_d g_m (V_i - R_{S1} i_d) = 0$$

$$\left((R_D + R_{S1} + r_d(1 + g_m R_{S1})\right) i_d = r_d g_m V_i$$

$$i_d = \frac{r_d g_m V_i}{R_D + R_{S1} + r_d(1 + g_m R_{S1})} = -\frac{V_o}{R_D}$$

$$A_v = \frac{V_o}{V_i} = \frac{-r_d R_D g_m}{R_D + R_{S1} + r_d(1 + g_m R_{S1})} = \frac{-50 \times 1.5 \times 2.71}{1.5 + 0.25 + 50 \times (1 + 2.71 \times 0.25)}$$

$$= -\frac{203.25}{85.625} = -2.37$$

Hasan Temurtaş