**3.**

$$v_I = \begin{cases} -\frac{V_D}{2}, v_U > -\frac{V_D}{2} \\ v_U, v_U \le -\frac{V_D}{2} \end{cases}$$

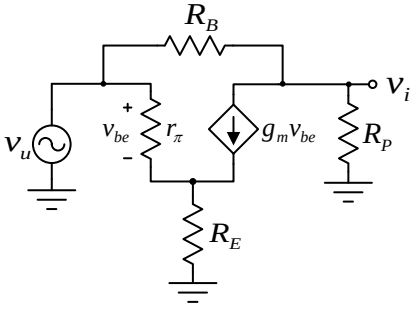
$$i_u = \begin{cases} 0, v_U > -\frac{V_D}{2} \\ i_U = \frac{-2v_U - V_D}{R}, v_U \le -\frac{V_D}{2} \end{cases}$$

**4.**

a) Ako pretpostavimo da transistor radi u direktnom aktivnom režimu, napon na bazi tranzistora je jednak $V_B = -V_{CC} + R_E(1+\beta)I_B + V_{BE} = V_I - I_B R_B = -I_B R_B$. Na osnovu toga se dobija vrednost struje $I_B$: $I_B = \frac{V_{CC} - V_{BE}}{R_E(1+\beta) + R_B} = 1\,\text{mA}$. Iz Kirhofovog zakona za struje za čvor kolektora tranzistora dobija se sledeća jednačina iz koje se dobija tražena otpornost $R_P$:

$$(1+\beta)I_B = I_0 + \frac{V_{CC} - V_I}{R_P},\ R_P = \frac{V_{CC}}{(1+\beta)I_B - I_0} = 500\,\Omega.$$

b) Ekvivalentna šema za male signale je prikazana na sledećoj slici:




Parametri u modelu za male signale iznose:

$$g_m = \frac{I_C}{V_T} = 1{,}96\,\text{S},\ r_\pi = \frac{\beta}{g_m} = 25\,\Omega,\ r_i \to \infty.$$

Za napon na otpornosti $r_\pi$ važi: $v_u - \left( g_m v_{be} + \frac{v_{be}}{r_\pi} \right) R_E = v_{be}$, odakle je $v_{be} = v_u \frac{1}{1 + g_m R_E + \frac{R_E}{r_\pi}}$. Iz Kirhofovog zakona za struje za izlazni čvor dobija se: $\frac{v_i}{R_P} + g_m v_{be} + \frac{v_i - v_u}{R_B} = 0$. Uvrštavanjem izaza za $v_{be}$ u poslednju jednačinu dobija se sledeća jednačina: $v_i \left( \frac{1}{R_P} + \frac{1}{R_B} \right) = v_u \frac{1 + g_m (R_E - R_B) + \frac{R_E}{r_\pi}}{R_B \left( 1 + g_m R_E + \frac{R_E}{r_\pi} \right)}$, odakle se dobija naposnko pojačanje:

$$A_v = \frac{v_i}{v_u} = \frac{\left( 1 + g_m (R_E - R_B) + \frac{R_E}{r_\pi} \right) R_P}{(R_P + R_B) \left( 1 + g_m R_E + \frac{R_E}{r_\pi} \right)} = -0{,}393.$$

c) Ulazna otpornost jednaka je odnosu ulaznog napona i ulazne struje:

$$R_{ul} = \frac{v_u}{i_u} = \frac{v_u}{\frac{v_{be}}{r_\pi} + \frac{v_u - v_i}{R_B}} = \frac{v_u}{\frac{v_u}{r_\pi \left( 1 + g_m R_E + \frac{R_E}{r_\pi} \right)} + \frac{v_u - A_v v_u}{R_B}} = 210\,\Omega.$$

**6.**

a)

$$v_{OUT} = \frac{R_2 + R_3 + R_4}{R_2 + (1-k)R_3} V_Z$$

$$v_{OUT\,\max} = \left(1 + \frac{R_3 + R_4}{R_2}\right) V_Z = V_{CC}$$

$$R_2 = \frac{R_3 + R_4}{\frac{V_{CC}}{V_Z} - 1} = 5\ \text{k}\Omega$$

$$v_{OUT\,\min} = \left(1 + \frac{R_4}{R_2 + R_3}\right) V_Z = 5\ \text{V}$$

b)

$$i_Z = \frac{R_4 + kR_3}{R_2 + R_3 + R_4} v_{OUT} \frac{1}{R_1} = \frac{R_4 + kR_3}{R_2 + (1-k)R_3} \frac{V_Z}{R_1} \geq i_{Z\,\min}$$

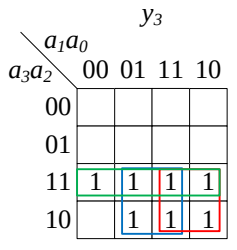
$$R_1 \leq \frac{R_4}{R_2 + R_3} \frac{V_Z}{i_{Z\,\min}} = 2\ \text{k}\Omega$$

**7.**

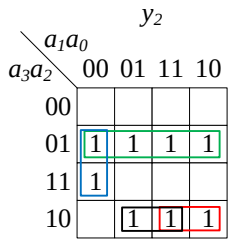
a)

| $a_3$ | $a_2$ | $a_1$ | $a_0$ | $y_3$ | $y_2$ | $y_1$ | $y_0$ |
|---|---|---|---|---|---|---|---|
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 |
| 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 |
| 0 | 0 | 1 | 1 | 0 | 0 | 1 | 1 |
| 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 |
| 0 | 1 | 0 | 1 | 0 | 1 | 0 | 1 |
| 0 | 1 | 1 | 0 | 0 | 1 | 1 | 0 |
| 0 | 1 | 1 | 1 | 0 | 1 | 1 | 1 |
| 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1 | 0 | 0 | 1 | 1 | 1 | 1 | 1 |
| 1 | 0 | 1 | 0 | 1 | 1 | 1 | 0 |
| 1 | 0 | 1 | 1 | 1 | 1 | 0 | 1 |
| 1 | 1 | 0 | 0 | 1 | 1 | 0 | 0 |
| 1 | 1 | 0 | 1 | 1 | 0 | 1 | 1 |
| 1 | 1 | 1 | 0 | 1 | 0 | 1 | 0 |
| 1 | 1 | 1 | 1 | 1 | 0 | 0 | 1 |

b)




$$y_3 = a_3a_1 + a_3a_0 + a_3a_2$$




$$y_2 = \overline{a_3}a_2 + a_2\overline{a_1}\,\overline{a_0} + a_3\overline{a_2}a_0 + a_3\overline{a_2}a_1$$

$y_1$

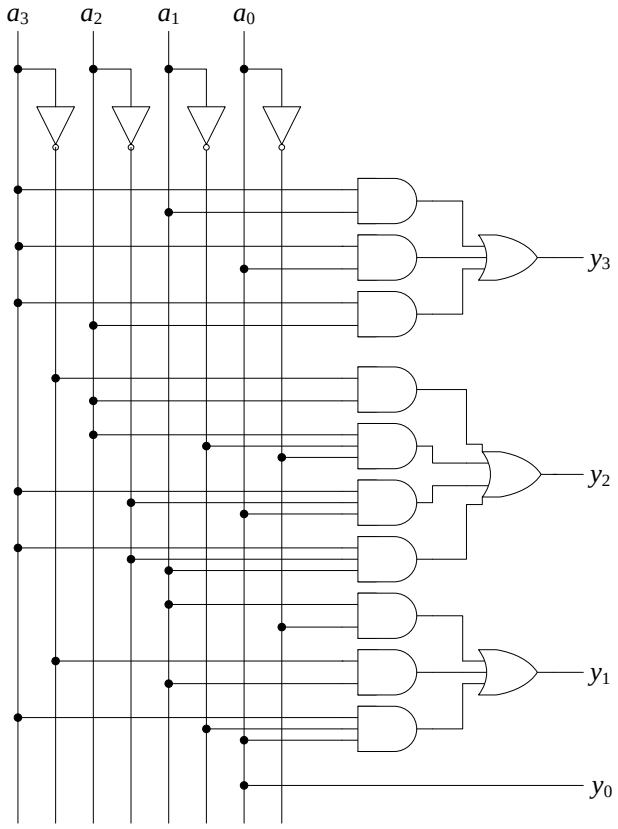
| $a_3a_2$ \ $a_1a_0$ | 00 | 01 | 11 | 10 |
|---|---|---|---|---|
| 00 | | | 1 | 1 |
| 01 | | | 1 | 1 |
| 11 | | 1 | | 1 |
| 10 | | 1 | | 1 |

$$y_1 = a_1\overline{a_0} + \overline{a_3}a_1 + a_3\overline{a_1}a_0$$

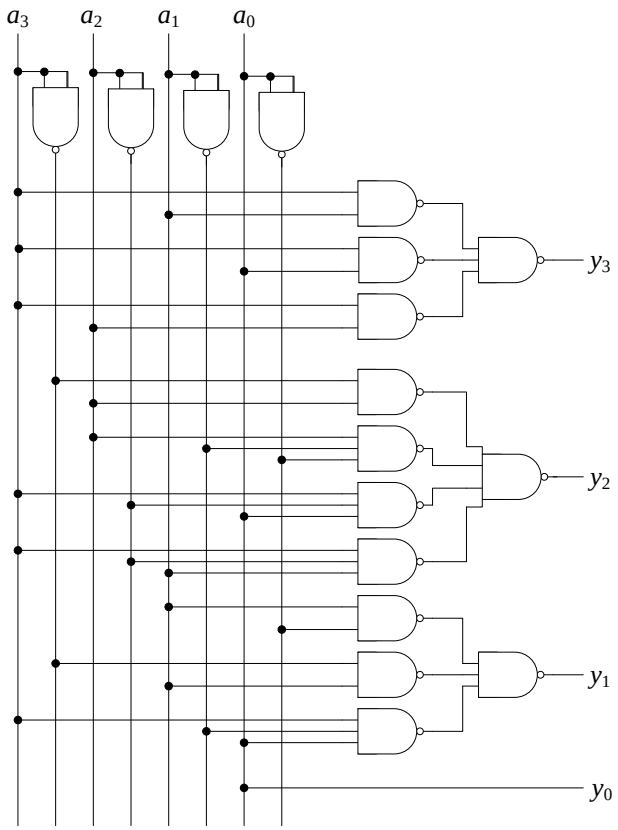
$y_0$

| $a_3a_2$ \ $a_1a_0$ | 00 | 01 | 11 | 10 |
|---|---|---|---|---|
| 00 | | 1 | 1 | |
| 01 | | 1 | 1 | |
| 11 | | 1 | 1 | |
| 10 | | 1 | 1 | |

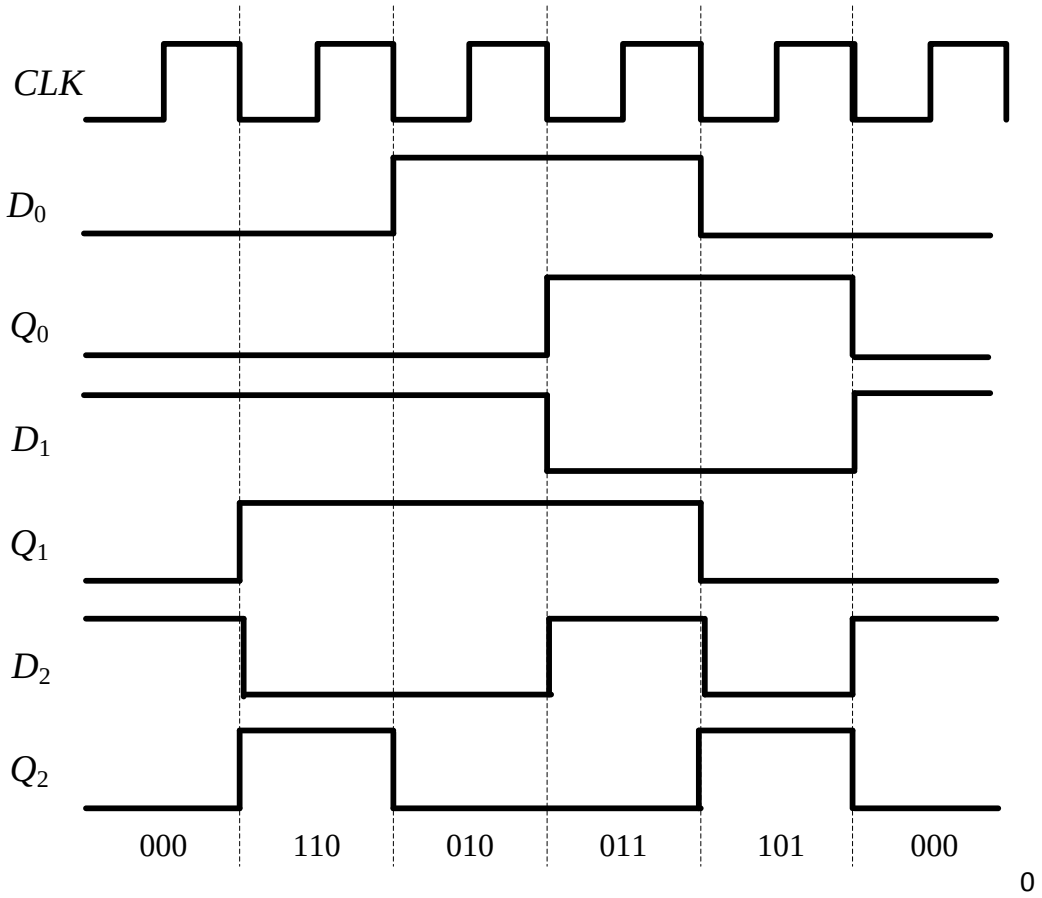
$$y_0 = a_0$$



c)



**8.**




Sekvenca brojanja brojača je 0 – 6 – 2 – 3 – 5.
Moduo brojanja brojača je 5.