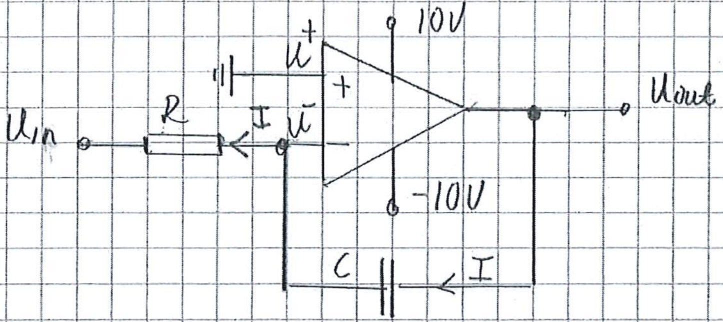
1



• Ideal OpAmp + Negative feedback $\rightarrow u^+ \approx u^-$

1a) Answer: $|u_{out}| < 10$ [V]

1b)

$$\begin{cases} u_{in} + RI = 0 \\ u_{out} - \frac{1}{C}\int_{s=0}^{t} I(s)\,ds \end{cases}$$

$$u_{out} = \frac{-1}{RC}\int_{s=0}^{t} u_{in}(s)\,ds = \left| u_{in}(s) = \alpha,\ s > 0 \right| =$$

$$= -\frac{\alpha t}{RC}\ [V],\quad t \geq 0$$

1c) Answer: Integration

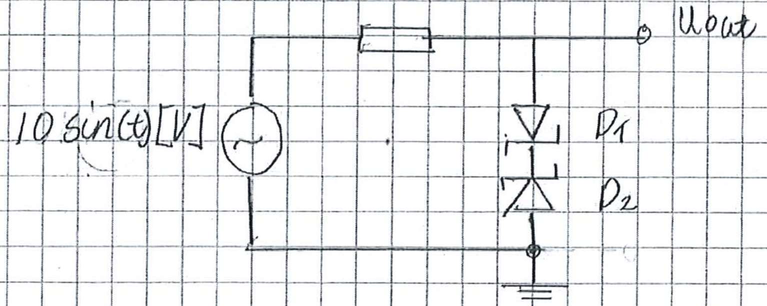
1d)

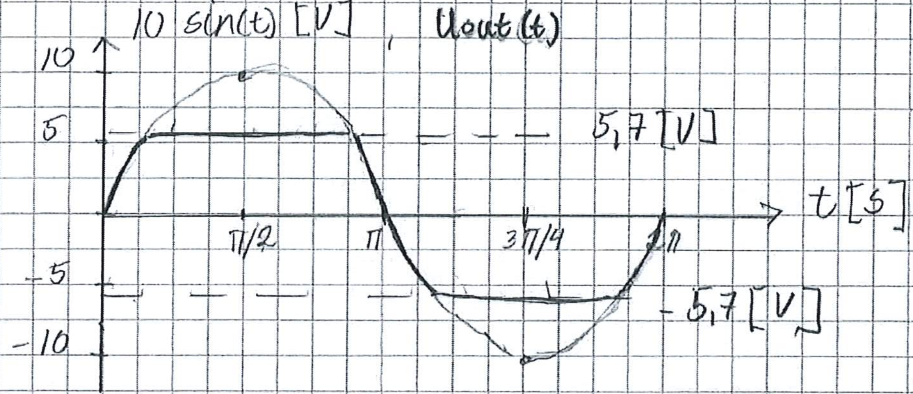
$$\alpha = -t \longrightarrow u_{out}(t) = \frac{-1}{RC}\int_{s=0}^{t} -s\,ds = \frac{t^2}{2RC}$$

$$u_{out}(2) = \frac{4}{2RC} = 4 \longrightarrow RC = \frac{1}{2} \rightarrow C = \frac{1}{2}\mu F.$$

Answer: $C = \frac{1}{2}$ [μF]

2a





Positive part of cycle: D_1 - forward biased

D_2 - backword biased

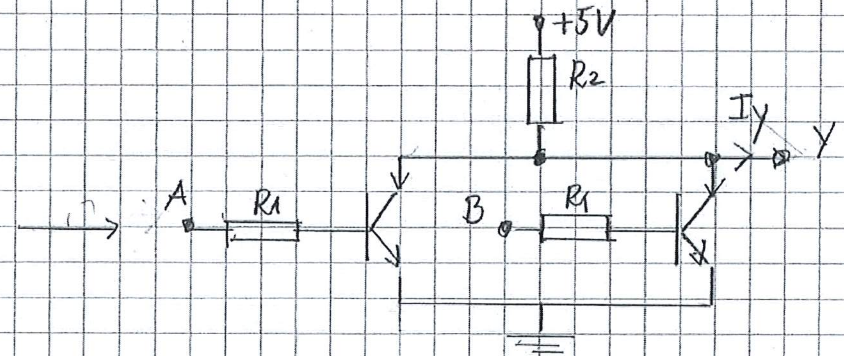
Negative part of cycle: D_2 - forward biased

D_1 - backward biased

2b

NOR - gate

A	B	Y
0	0	1
0	1	0
1	0	0
1	1	0



$h_{FE} = 100$

$V_{BE} = 0,7$ [V]

$V_{CEsat} = 0,1$ [V]

$I_{cmax} = 10$ [mA]

Logical 1 ⇒ ≥ 4 [V]

Logical 0 ⇒ ≤ 1 [V]

Max input & output current of gate: 1 [mA]

Selection of R_2.

$$Y = 1 \longrightarrow U_Y = 5 - I_Y^{max} \cdot R_2 > 4 \longrightarrow R_2 < \frac{5-4}{1 \cdot 10^{-3}} = 1\,[k\Omega]$$

$$Y = 0 \longrightarrow U_Y = 5 - (I_C + \underbrace{I_Y^{min}}_{=0})R_2 < 1 \longrightarrow R_2 = \frac{4}{10^{-2}} > 400\,[\Omega]$$

$$\Longrightarrow \text{Select: } R_2 = 820\,[\Omega]$$

Selection of R_1

$$R_2 = 820\,[\Omega] \longrightarrow I_C < \frac{5 - V_{CEsat}}{R_2} = 6\,[mA]$$

$$\longrightarrow I_B > I_C / h_{FE} = 6 \cdot 10^{-3} / 10^{2} = 60\,[\mu A]$$

$$\longrightarrow R_1 < \frac{\overset{4V}{U_A^{min}} - V_{BE}}{I_B} = \frac{4 - 0{,}7}{60 \cdot 10^{-6}} = \overset{55}{\cancel{5{,}5}}\,[k\Omega]$$

$$I_B = \frac{U_A^{MAX} - V_{BE}}{R_1} < 1\,[mA] \longrightarrow R_1 > 4{,}3\,[k\Omega]$$

$$\Longrightarrow \text{Select: } R_1 = 4{,}7\,[k\Omega]$$

3

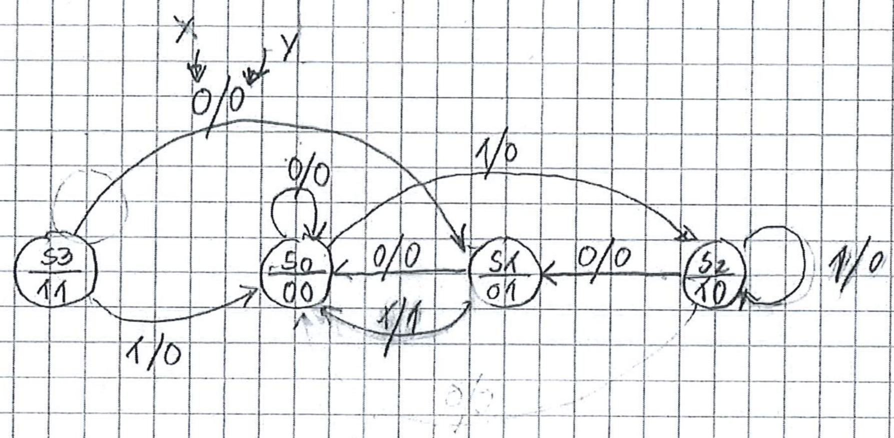
a) Answer: Mealy machine. The output depends both on the state & current input.

b) Answer: 4 states, Nr. of. states $\leq 2^n$, where n is the number of bits in the memory.

c)

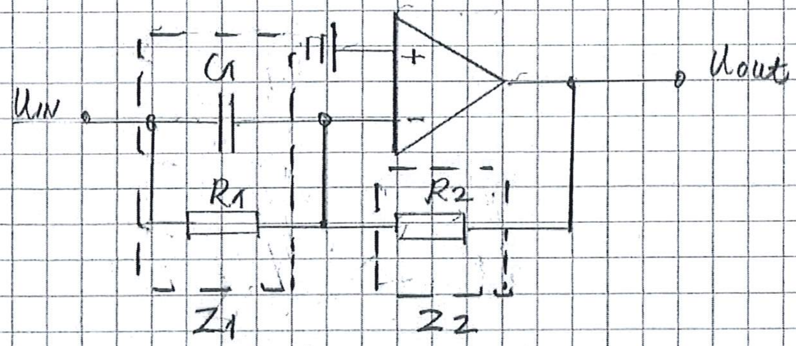
S (state)	X	Q_1	Q_2	Q_1^+	Q_2^+	S^+	Y
0	0	0	0	0	0	0	0
1	0	0	1	0	0	0	0
2	0	1	0	0	1	1	0
3	0	1	1	0	1	1	0
0	1	0	0	1	0	2	0
1	1	0	1	0	0	0	1
2	1	1	0	1	0	2	0
3	1	1	1	0	0	0	1

d)



e) Answer: 101.

4 a)



$H(j\omega) = -Z_2/Z_1$, Z_i – complex impedance

$Z_2 = R_2$

$$Z_1 = \frac{(1/j\omega C_1 \cdot R_1}{\frac{1}{j\omega C} + R_1} = \frac{R_1}{1 + j\omega R_1 C_1}$$

$$\longrightarrow \underline{\underline{H(j\omega) = -\frac{R_2}{R_1} \cdot (1 + j\omega R_1 C_1)}}$$

b) $R_1 = 10\ [k\Omega]$, $R_2 = 1\ [k\Omega]$, $C_1 = 1\ [\mu F]$

$\longrightarrow H(j\omega) = -0{,}1\ (1 + 0{,}01\, j\omega)$

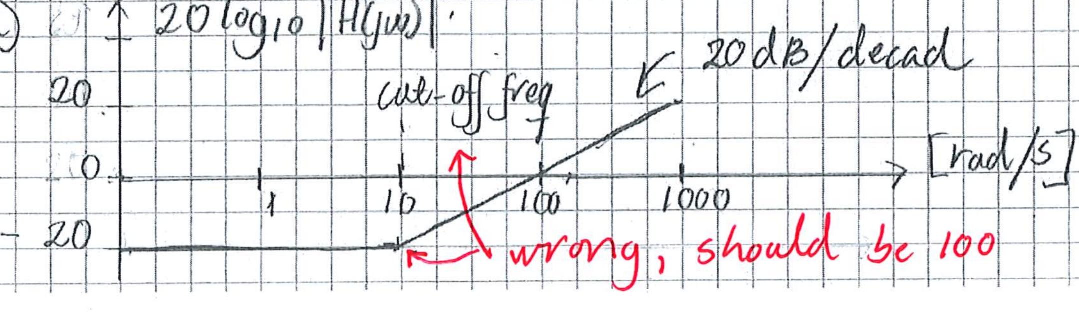
$|H(0)| = 0{,}1$

$\lim_{\omega \to \infty} |H(j\omega)| = \infty$

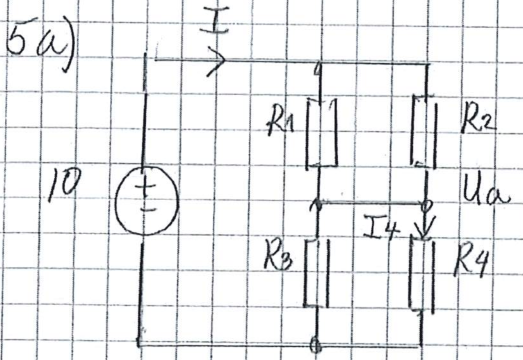
Answer: HP-filter

c) Answer: Cut-off freq: $1/R_1C_1 = \cancel{10}$ 100 [rad/s]

d)



5a)



$I_4 = U_a / R_4$

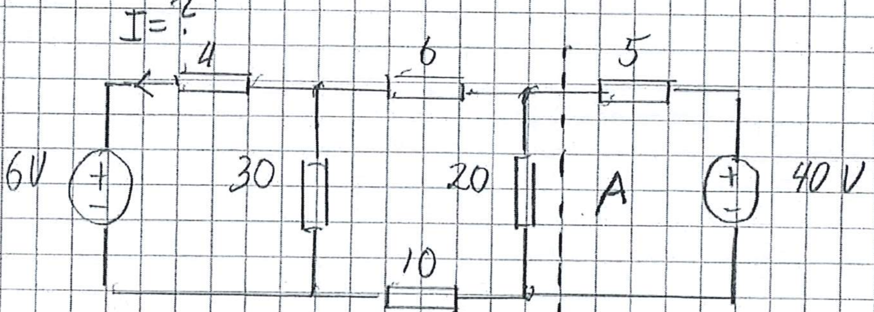
$$U_a = \frac{R_3 // R_4}{R_1 // R_2 + R_3 // R_4} \cdot 10$$

$$\rightarrow I_4 = \frac{10}{R_4} \cdot \frac{\frac{R_3 \cdot R_4}{R_3 + R_4}}{\frac{R_1 \cdot R_2}{R_1 + R_2} + \frac{R_3 \cdot R_4}{R_3 + R_4}} =$$

$$= \frac{10}{4 \cdot 10^3} \cdot \frac{4/3 \cdot 10^3}{2/3 \cdot 10^3 + 4/3 \cdot 10^3} = \frac{10}{4 \cdot 10^3} \cdot \frac{2}{3} = \frac{5}{3} \cdot 10^{-3} \; [A]$$

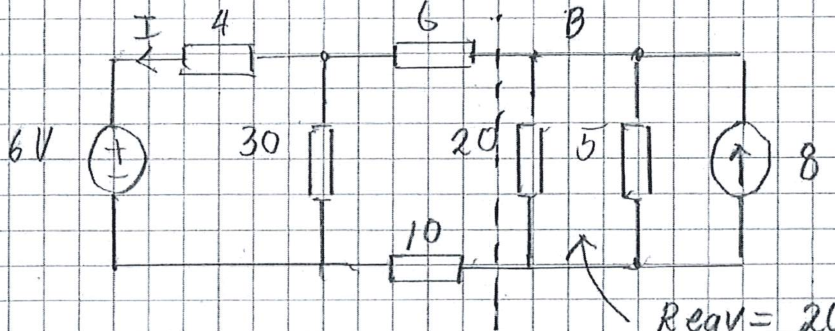
Answer: 5/3 [mA]

5b)



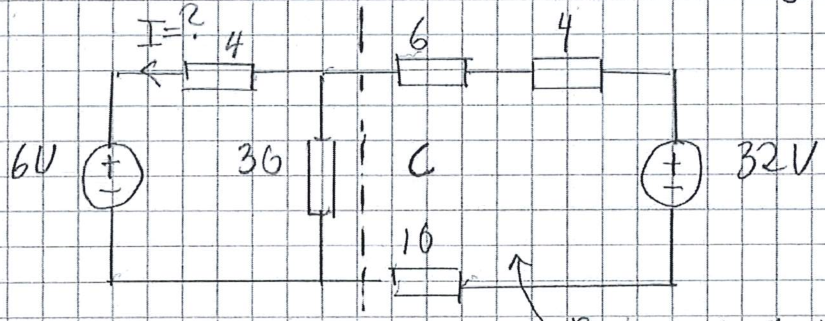
The current I can be found in multiple ways. Here source transformation is used.

Step 1: Convert A to current source



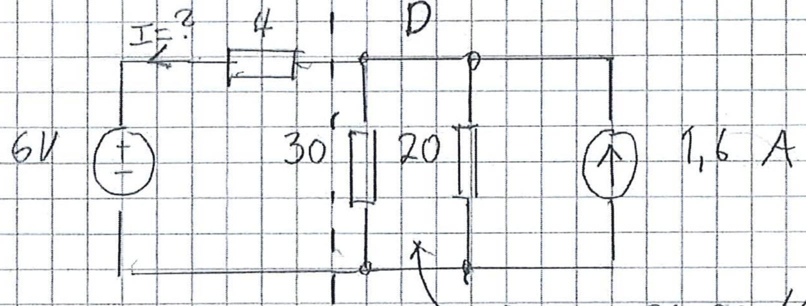
$R_{eqv} = 20 \cdot 5/(20+5) = 4\ \Omega$

Step 2: Convert B to voltage source



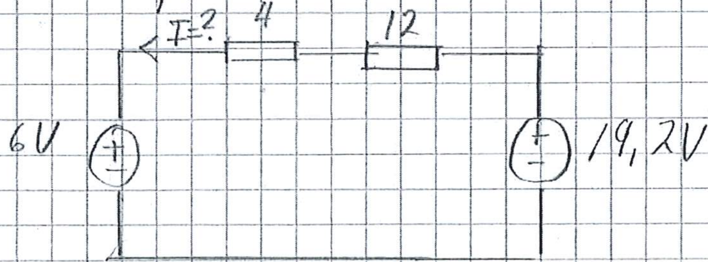
$R_{eqv} = 6+4 \cdot 10 = 20\ \Omega$

Step 3: Convert C to current source



$R_{eqv} = 30 \cdot 20/(30+20) = 12\ \Omega$

Step 4: Convert D to volage source



Answer: $I = (19{,}2 - 6)/(4+12) = 0{,}825$ [A]