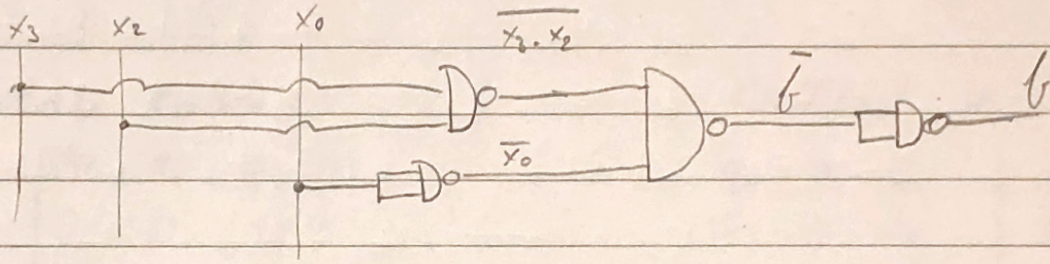
A_1

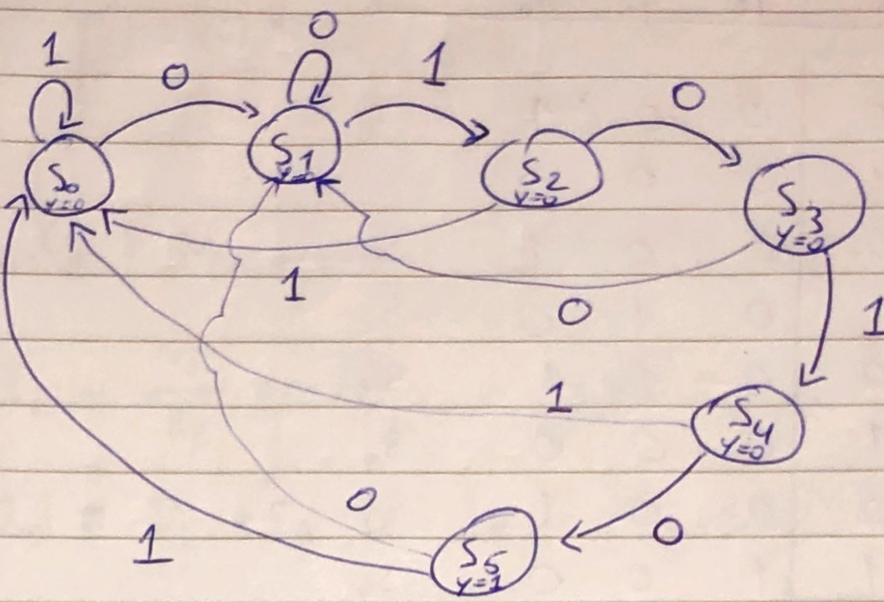
x_3x_2 \ x_1x_0	00	01	11	10
00	1	-		1
01	1			-
11		-		-
10	1			1

$$f = \overline{x_3} \cdot \overline{x_0} + \overline{x_2} \cdot \overline{x_0} = \left(\overline{x_3} + \overline{x_2}\right) \cdot \overline{x_0}$$

$$= \overline{x_3 \cdot x_2} \cdot \overline{x_0}$$



A_2



State coding:

	q_2	q_1	q_0
S_0	0	0	0
S_1	0	0	1
S_2	0	1	0
S_3	0	1	1
S_4	1	0	0
S_5	1	0	1

Output y

q_2	q_1	q_0	y
0	0	0	0
0	0	1	0
0	1	0	0
0	1	1	0
1	0	0	0
1	0	1	1

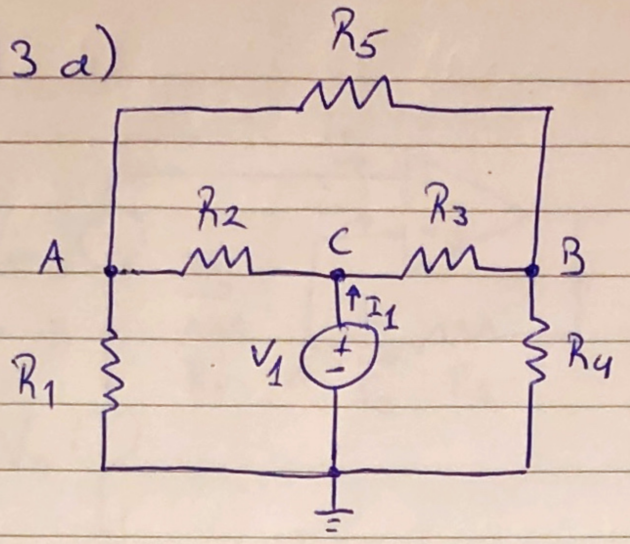
(missing rows are treated as "don't care

State transitions

q_2	q_1	q_0	x	q_2^+	q_1^+	q_0^+	
0	0	0	0	0	0	1	S_1
0	0	0	1	0	0	0	S_0
0	0	1	0	0	0	1	S_1
0	0	1	1	0	1	0	S_2
0	1	0	0	0	1	1	S_3
0	1	0	1	0	0	0	S_0
0	1	1	0	0	0	1	S_1
0	1	1	1	1	0	0	S_4
1	0	0	0	1	0	1	S_5
1	0	0	1	0	0	0	S_0
1	0	1	0	0	0	1	S_1
1	0	1	1	0	0	0	S_0

Moore Type, because output y only depends on the states.
3 memory bits are used, so 3 flip-flops are needed.

A3 a)



Using the method of potentials, we label each node as A, B, C, and each volt[age] with respect to ground is V_A, V_B, V_C.

- $V_C = V_1$, $V_A = ?$, $V_B = ?$

KCL at each node with unknown voltage

$$\begin{cases} A: & -\dfrac{V_A}{R_1} - \dfrac{V_A - V_C}{R_2} - \dfrac{V_A - V_B}{R_5} = 0 \\ B: & -\dfrac{V_B}{R_4} - \dfrac{V_B - V_C}{R_3} - \dfrac{V_B - V_A}{R_5} = 0 \end{cases}$$

$$(\Leftrightarrow) \begin{cases} -\left(\dfrac{1}{R_1} + \dfrac{1}{R_2} + \dfrac{1}{R_5}\right) V_A + \dfrac{1}{R_5} V_B = -\dfrac{V_1}{R_2} \\ \dfrac{1}{R_5} V_A - \left(\dfrac{1}{R_3} + \dfrac{1}{R_4} + \dfrac{1}{R_5}\right) V_B = -\dfrac{V_1}{R_3} \end{cases}$$

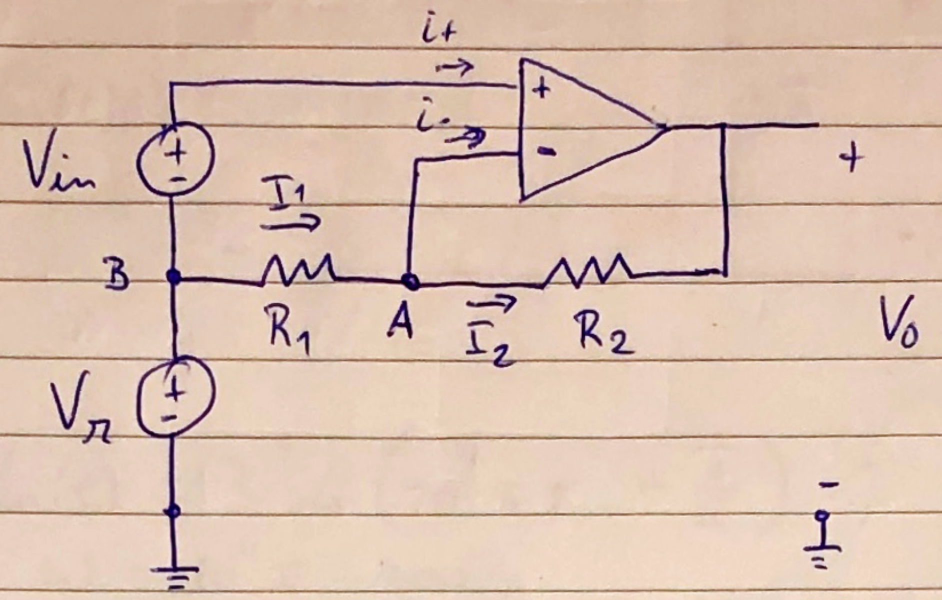
(inserting the values for R's and V_1, we get:)

$$V_A = V_B = \frac{R_4}{R_3 + R_4} V_1 = \frac{5}{4} \text{ V}$$

KCL on C:

$$I_1 = \frac{V_1 - V_A}{R_2} + \frac{V_1 - V_B}{R_3} = 250 \text{ mA}$$

A3.b)



OP AMP with negative feedback:

i) $i_+ = i_- = 0$; ii) $V_+ = V_-$

$$V_A = V_- = V_+ = V_{in} + V_r \; ; \; V_B = V_r$$

KCL at node A: $\underbrace{\frac{V_B - V_A}{R_1}}_{= I_1} - \underbrace{\cancel{i_-}}_{=0} - \underbrace{\frac{V_A - V_0}{R_2}}_{= I_2} = 0$

$$\Leftrightarrow \frac{\cancel{V_r} - V_{in} - \cancel{V_r}}{R_1} - \frac{V_{in} + V_r - V_0}{R_2} = 0 \Leftrightarrow$$

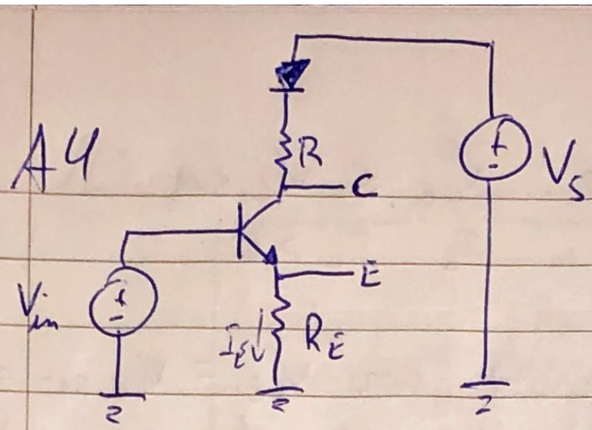
$$\frac{V_0}{R_2} = \frac{V_{in}}{R_1} + \frac{V_{in}}{R_2} + \frac{V_r}{R_2} \Leftrightarrow V_0 = \left(1 + \frac{R_2}{R_1}\right) V_{in} + V_r$$

$$V_0 = 3 V_{in} + V_r = 11 \text{ V}$$

$$I_2 = \frac{V_A - V_0}{R_2} = \frac{V_{in} + V_r - V_0}{R_2} = \frac{V_{in} + \cancel{V_r} - 3 V_{in} - \cancel{V_r}}{R_2} = -\frac{2 V_{in}}{R_2} =$$

$$= - \frac{6}{\;} A = - 30 \text{ mA}$$

A4



a)

$V_{in} - V_E = V_{BE,SAT} \iff V_E = V_{in} - V_{BE,SAT} = 5V$

$I_E = \frac{V_E}{R_E} = \frac{5}{50} = 100\ mA$

$I_C = I_E - I_B \simeq I_E = 100\ mA$

K.V.L : $V_S - V_D - R I_C - V_{CE} - V_E = 0$

$\iff V_{CE} = V_S - V_D - V_E - \frac{R}{RE} V_E$

$= 24 - 2 - 5 - \frac{100}{50} \times 5 = 24 - 17 = 7V$

$I_B = \frac{1}{\beta} I_C = \frac{100\ mA}{300} = \frac{1}{3}\ mA = 333\ \mu A$

$\therefore I_B > 0, \ I_C > 0, \ V_{CE} > V_{CE,SAT} \Rightarrow$ Active regio

$R_E = ?$

A4.b) Saturation mode: $V_{CE} \leq V_{CE,SAT}$

$I_B, I_C > 0$.

Let us analyze the circuit for $V_{CE} = V_{CE,SAT} = 0.2\,V$ (border between the saturation and active regions)

From A4.a): $I_C \simeq I_E = \frac{5}{R_E}$

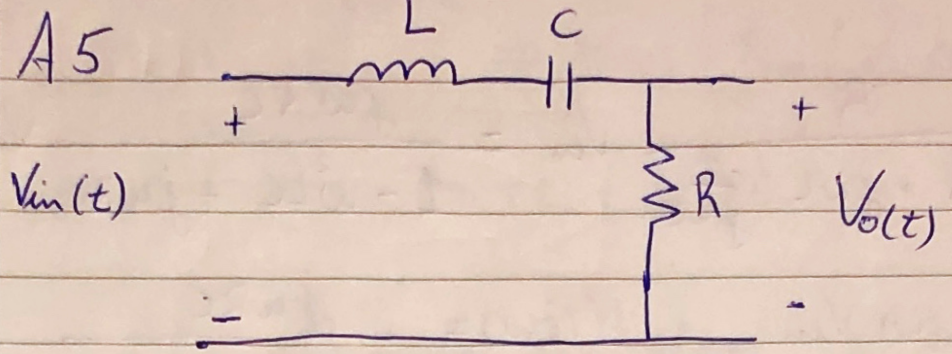
KVL: $V_S - V_D - R I_C - V_{CE} - V_E = 0 \Leftrightarrow$

$$\frac{5R}{R_E} = 24 - 2 - 0.2 - 5 \Leftrightarrow R_E = \frac{500}{16.8} \simeq 29.7\,\Omega$$

$R_E = 29.7\,\Omega$ is the largest value for which the BJT is in saturation.

- A larger R_E than $29.7\,\Omega$ will decrease $I_E = \frac{5}{R_E}$, decrease $I_C \simeq I_E$, which will make V_{CE} increase above $V_{CE,SAT}$ so that the KVL holds (note that, in the KVL, V_S, V_D, and V_E are constant, so only I_C and V_{CE} can vary).

A5



$$V_{in}(t) = 3\sin\left(10^4\pi t + \frac{\pi}{2}\right) \; ; \quad V_o(t) = ?$$

$$\omega = 10^4\pi \text{ rad/s}$$

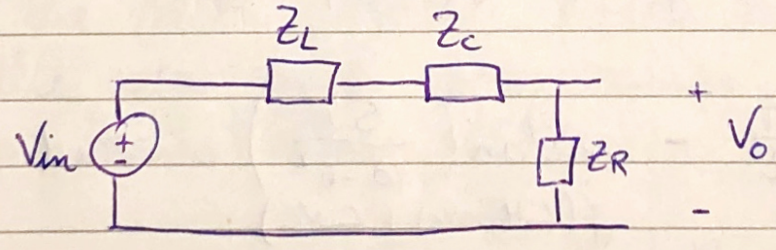
i) Associate $V_{in}(t)$ to a varying complex voltag

$V_{in}(t) = \mathrm{Im}(V_{c\,in}(t))$; $V_{c\,in}(t) = 3\cos(10^4\pi t + \frac{\pi}{2}) + j3\sin(10^4\pi$

In polar form: $V_{c\,in}(t) = 3e^{j(10^4\pi t + \frac{\pi}{2})}$

$$= \underbrace{3e^{j\frac{\pi}{2}}}_{=V_{in}} \times e^{j\omega t} = V_{in} \times e^{j\omega t}$$

For AC analysis, we convert the AC circuit to a DC circuit with constant complex-valu voltages and complesc impedances:



Where $V_{in} = 3e^{j\frac{\pi}{2}}$, $V_o = ?$, $Z_R = R$, $Z_L = j\omega L$, $Z_c = \frac{1}{j\omega C}$

From KVL, we get:

$$V_o = \frac{Z_R}{Z_R + Z_L + Z_c} V_{in}$$

A5 (cont.)

$$V_o = \frac{R}{R + jwL + \frac{1}{jwC}} V_{in} = \frac{jwRC}{1 - w^2LC + jwRC} V_{in}$$

$$V_o = H(jw) V_{in} \quad ; \quad H(jw) = \frac{jwRC}{1 - w^2LC + jwRC}$$

$w = 10^4 \pi$ rad/s

$R = 50\Omega$, $C = 10^{-6}$ F , $L = 10^{-3}$ H

$$H(j10^4\pi) = \frac{j\,10^4 . \pi . 50 . 10^{-6}}{1 - 10^8 . \pi^2 . 10^{-9} + j\,10^4 . \pi . 50 . 10^{-6}} =$$

$$= \frac{j5\pi \times 10^{-1}}{1 - 10^{-1}\pi^2 + j5\pi \times 10^{-1}} = \frac{j5\pi}{10 - \pi^2 + j5\pi}$$

To solve $V_o = H(jw) V_{in}$, we need to convert $H(jw)$ into polar form: $H(jw) = |H(jw)| \times e^{j\angle H(jw)}$

$$|H(j10^4\pi)| = \frac{|j5\pi|}{|10 - \pi^2 + j5\pi|} = \frac{5\pi}{\sqrt{(10-\pi^2)^2 + (5\pi)^2}}$$

$$\angle H(j10^4\pi) = \frac{\pi}{2} - \arctan\left(\frac{5\pi}{10-\pi^2}\right) \text{ rad}$$

$$V_o = |H(j10^4\pi)| . |V_{in}| \times e^{j(\angle H(j10^4\pi) + \angle V_{in})}$$

$$= \frac{15\pi}{\sqrt{(10-\pi^2)^2 + 25\pi^2}} \times e^{j\left(\pi - \arctan\left(\frac{5\pi}{10-\pi^2}\right)\right)}$$

(A5 cont. 2)

$$V_{co}(t) = V_o \times e^{j10^4\pi t} \Rightarrow V_o(t) = \mathrm{Im}(V_{co}(t))$$

$$V_o(t) = |V_o| \sin(10^4\pi t + \angle V_o)$$

$$= \frac{15\pi}{\sqrt{(10-\pi^2)^2 + 25\pi^2}} \sin\left(10^4\pi t + \pi - \arctan\left(\frac{5\pi}{10-\pi^2}\right)\right)$$

To determine the type of filter, we look at $H(j\omega)$ and how it varies with ω.

$$|H(j0)| = \frac{0}{1} = 0$$

$$\lim_{\omega\to\infty} |H(j\omega)| = \lim_{\omega\to\infty} \left|\frac{j\omega RC}{1-\omega^2LC + j\omega RC}\right| =$$

$$\simeq \lim_{\omega\to\infty} \left|\frac{j\cancel{\omega}R\cancel{C}}{-\omega^{\cancel{2}}L\cancel{C}}\right| = \lim_{\omega\to\infty} \frac{|jR|}{|-\omega L|} = 0$$

The filter blocks both the very low and the very high frequencies, so it is a Band-Pass filter.