UPPSALA
UNIVERSITET

2974058

Försättsblad tentamen/ Examination cover

Teknisk- naturvetenskapliga fakulteten /
Faculty of Science and Technology

Kursnamn / Course name

Digitalteknik och elektronik

Kurskod / Course code	Provkod / Test code
1TE717	1000

Tentamensdatum / Examination date	Anonymkod / Anonymous code
Y/Y/Y/Y M/M D/D	
2019 - 10 - 31	BO - 0061 - NXX

2974058

Utskriven 2019-11-22 kl. 14:20:44

Exam: 1TE717 Digital Technologies and Electronics
Date: October 31, 2019

Name / Code: BO-0061-NXX

Part A.

	A1	A2	A3	A4	A5		Total		
MAX Pts	4	5	9	6	6		30		
Score	3.5	4.5	9	5.5	6		28.5		

Total A: 28.5

Part B.

	B1	B2	B3			Total		
MAX Pts	8	6	6			20		
Score	8	5	—			13		
Bonus Pts								

Total B: 13

Exam Grade: 5

BO-0061-NXX

DTE-1TE717, 2019-10-31

A.1

$$f(x_3,x_2,x_1,x_0) = \sum(0,2,4,8,10) + d(1,6,13,14)$$

x_3	x_2	x_1	x_0		$f(\vec{x})$
0	0	0	0	0	1
0	0	0	1	1	x
0	0	1	0	2	1
0	0	1	1		0
0	1	0	0	4	1
0	1	0	1		0
0	1	1	0	6	x
0	1	1	1		0
1	0	0	0	8	1
1	0	0	1		0
1	0	1	0	10	1
1	0	1	1		0
1	1	0	0		0
1	1	0	1	13	x
1	1	1	0	14	x
1	1	1	1		0

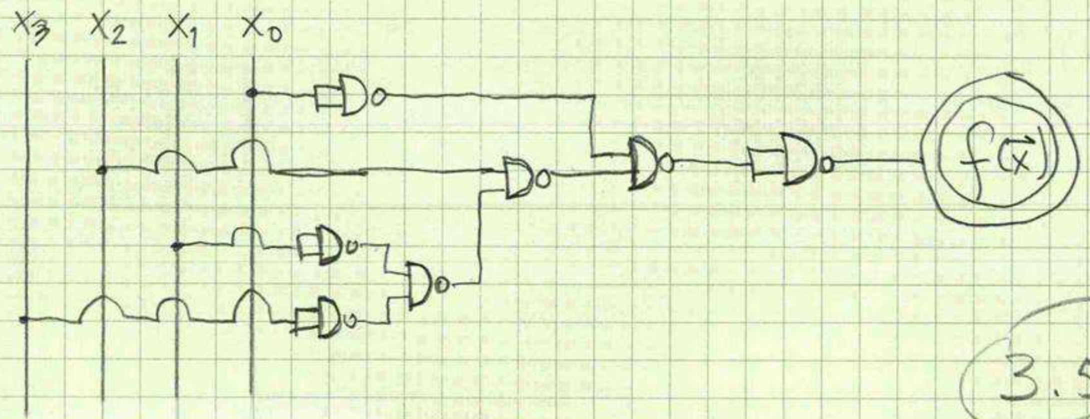
Karnaugh:

x_3x_2 \ x_1x_0	00	01	11	10
00	1	x	0	1
01	1	0	0	x
11	0	x	0	x
10	1	0	0	1

$$f(\vec{x}) = \overline{x_2}\cdot\overline{x_0} + \overline{x_3}\cdot\overline{x_1}\cdot\overline{x_0}$$ (Minimal Sum of Products)

$$\underbrace{\left(\overline{x_2} + \overline{\overline{\left(\overline{x_3}\cdot\overline{x_1}\right)}}\right)\cdot\overline{x_0} = \left(\overline{x_2\cdot\overline{\left(\overline{x_3}\cdot\overline{x_1}\right)}}\right)\cdot\overline{x_0}}_{\text{De Morgan: } \overline{A}+\overline{B}=\overline{A\cdot B},\ A = x_2,\ B = \overline{(\overline{x_3}\cdot\overline{x_1})}}$$

$$= \overline{\overline{\left(\overline{x_2\cdot\overline{\left(\overline{x_3}\cdot\overline{x_1}\right)}}\cdot\overline{x_0}\right)}} = \overline{\overline{\left(\overline{x_0}\cdot\overline{\left(x_2\cdot\overline{\left(\overline{x_1}\cdot\overline{x_3}\right)}\right)}\right)}}$$



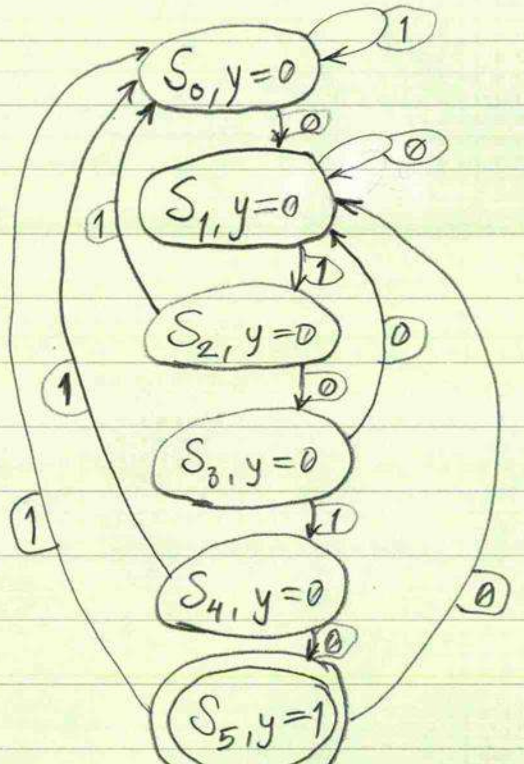
3.5

1TE717, 2019-10-31

BO-0061-NXX

A.2

1. A state diagram:



2&3. State coding and truth table:

State	q_5	q_4	q_3	q_2	q_1	x	q_5^+	q_4^+	q_3^+	q_2^+	q_1^+	y
S_0	0	0	0	0	0	0	0	0	0	0	1	0
	0	0	0	0	0	1	0	0	0	0	0	0
S_1	0	0	0	0	1	0	0	0	0	0	1	0
	0	0	0	0	1	1	0	0	0	1	0	0
S_2	0	0	0	1	0	0	0	0	1	0	0	0
	0	0	0	1	0	1	0	0	0	0	0	0
S_3	0	0	1	0	0	0	0	0	0	0	1	0
	0	0	1	0	0	1	0	1	0	0	0	0
S_4	0	1	0	0	0	0	1	0	0	0	0	0
	0	1	0	0	0	1	0	0	0	0	0	0
S_5	1	0	0	0	0	0	0	0	0	0	1	1
	1	0	0	0	0	1	0	0	0	0	0	1

This is a Moore machine. It needs 5 flip-flops, one for each state varible.

why?

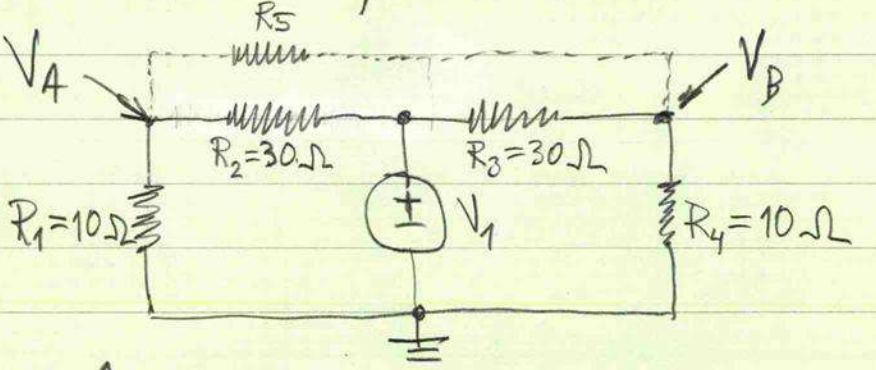
All other lines in the truth table will have don't care for q_i^+, $i=1,\dots,5$

4.5

BO-0061-NXX

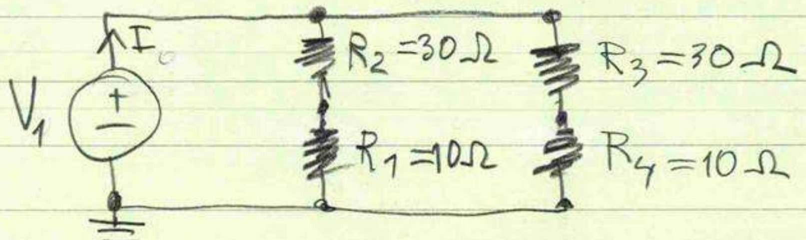
1TE717, 2019-10-31

A.3 a) Since there is only one voltage source, and since $R_2 = R_3$ and $R_1 = R_4$, the circuit is completely symmetric. Because of this, the potential between R_1 and R_2 will be the same as the potential between R_3 and R_4:

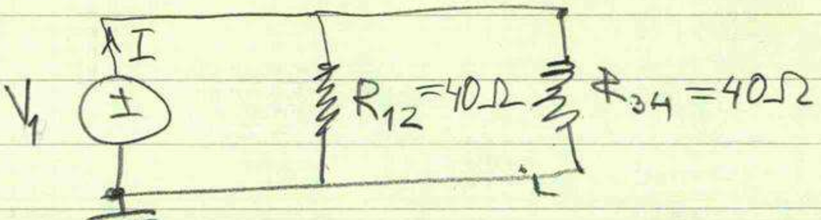


Because of symmetry, V_A will equal V_B.
As a result, no current will flow through R_5.

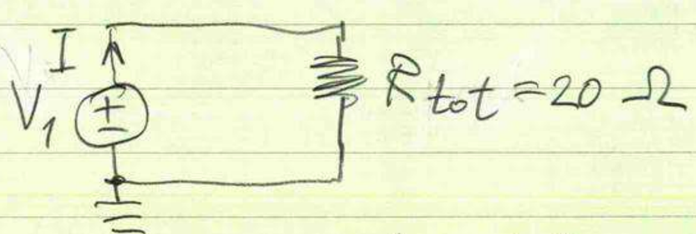
The whole circuit may now be replaced by one looking as:



Or



Or



} This answers B.1a) as well.

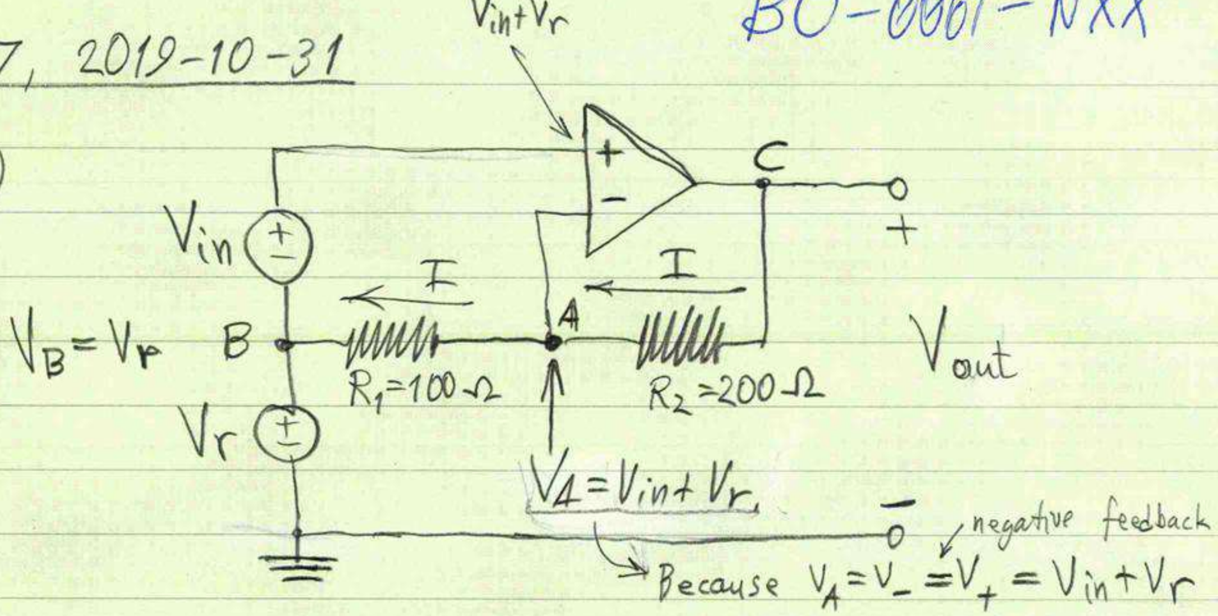
5p

Answer: the current passing through the voltage source goes upwards and is $5V/20\Omega = \underline{0,25 A}$

1TE717, 2019-10-31

BO-0061-NXX

A.3b)



Since the OpAmp is ideal, and since it gets negative feedback (through R_2), the voltage drop from C to A is $\frac{R_2}{R_1}$ times the voltage drop from A to B:

Also $I_+ = I_- = 0$ (because the OpAmp is ideal and has negative feedback)

Hence the currency flowing (leftwards) through R_1 is the same as the currency flowing (also leftwards) through R_2:

$$\frac{V_{in}}{R_1} = \frac{V_{out} - V_{in} - V_r}{R_2} \Leftrightarrow \frac{V_{out}}{R_2} = \frac{V_{in}}{R_1} + \frac{V_{in}}{R_2} + \frac{V_r}{R_2}$$

Or, $$V_{out} = \left(1 + \frac{R_2}{R_1}\right) V_{in} + V_r \underset{\frac{R_2}{R_1} = 2,\ V_{in} = 3V,\ V_r = 2V}{=} (1+2) \cdot 3V + 2V = \underline{\underline{11\,V.}}$$

The current is $\frac{3V}{100\,\Omega} = 30\,mA$

<u>Answer</u>: The expression for the output voltage V_o is

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

The current passing through R_2 is $(11-5)V / 200\,\Omega = 30\,mA$ <u>leftwards</u>.

4p

BO-0061-NXX

1TE717, 2019-10-31

A.4 a) $R_E = 50\,\Omega \Rightarrow I_E = (V_{in} - V_{BE})/R_E = (5{,}6 - 0.6)\,V/50\,\Omega$
$= 5V/50\,\Omega = 0.1A = 100\ mA$ ✓

Since (by definition of β) $I_C = \beta I_B$, and since $I_E = I_B + I_C$ it follows that $I_E = I_B + \beta I_B = (1+\beta)\,I_B$ and hence that
$I_B = (\beta+1)^{-1} I_E = 301^{-1} \cdot 100\,mA = 332\,\mu A$ ✓

And since $I_C = I_E - I_B = 100\,mA - 0{,}33\,mA = 99{,}67\,mA$ ✓

The voltage drop over the resistor R is $RI_C = 0.1\,k\Omega \cdot 99.7\,mA$
$= 9.97\,V$

The V_{CE} becomes the residual voltage drop over the transistor: $V_{CE} = V_S - V_D - RI_C - R_E I_E$ ✓
$= (24 - 2 - 9.97 - 5.0)\,V = 7{,}03\,V$.

Answer: $V_{CE} = 7{,}03V$; $I_E = 100\,mA$; $I_C = 99{,}7\,mA$; $I_B = 332\,\mu A$ ✓
and the BJT is in its cut-off region, meaning the transistor is (partly) off. ✗ ✗

2.5

A.4b) Saturation mode $\Rightarrow V_{CE} = 0{,}2V$ so the voltage drop over R must be $(24 - 5 - 2 - 0.2)\,V = 16.8V$ which means the currency flowing through R must be big enough, $I_C = (16.8V)/0.1k\Omega = 168\ mA$
$\Rightarrow I_{B,min} = 168\,mA/300 = 560\,\mu A$. Since $I_E = (\beta+1)\,I_B$ it follows that $I_{E,min} = 301 \cdot 560\,\mu A = 168.56\ mA$

Finally, for I_E not to be too small, R_E must not be too large, $R_{E,max} = 5V/168.56\,mA = 29{,}66\ \Omega$ ✓

Answer: for the transistor to be in saturation mode, the resistor R_E must be no larger than $29\,\Omega$. ✓

3

UU 2018

BO-0061-NXX

1TE717, 2019-10-31

A.5 $V_{in}(t) = 3\sin\left(10\,000\pi t + \frac{\pi}{2}\right) = Im\left(\Phi_{in} e^{j\omega t}\right)$

where $\Phi_{in} = A_{in} e^{j\varphi}$, $A_{in} = 3V$, $\varphi = \arg(\Phi_{in}) = \frac{\pi}{2}$, $\omega = 10\pi$ krad/sec

$\Phi_{out} = H(j\omega)\Phi_{in}(j\omega)$, where Φ_{in} is as above and

$$H(j\omega) = \frac{R}{R + j\omega L + \frac{1}{j\omega C}} \cdot \frac{j\omega C}{j\omega C} = \frac{j\omega RC}{1-\omega^2 LC + j\omega RC} \cdot \frac{1-\omega^2 LC - j\omega RC}{1-\omega^2 LC - j\omega RC}$$

$$H(j\omega) = \frac{(\omega RC)^2 + j\omega RC(1-\omega^2 LC)}{(1-\omega^2 LC)^2 + (\omega RC)^2} = a + jb$$

where

$$a = \frac{(\omega RC)^2}{(1-\omega^2 LC)^2 + (\omega RC)^2}$$

$$b = \frac{\omega RC(1-\omega^2 LC)}{(1-\omega^2 LC)^2 + (\omega RC)^2}$$

$$\arg(H(j\omega)) = \arctan\frac{b}{a}$$

(*)

$C = 1\mu F$
$L = 1mH$
$R = 0{,}05\,k\Omega$
$\omega = 10\pi$ krad/sec

With numbers inserted into (*):

$a \approx 0.999931 \qquad b \approx 0.008301$

$|H(j\omega)| = \sqrt{a^2+b^2} \approx 0.999966$

$\arctan\frac{b}{a} \approx 0.008301$

$$\arg(\Phi_{out}(j\omega)) = \arg(H(j\omega)) + \arg(\Phi_{in}) = 0.008301 + \frac{\pi}{2} \approx 1.5791$$

$$|\Phi_{out}(j\omega)| = |H(j\omega)| \cdot A_{in} \approx 2.999897\,V$$

Recall that $V_{out}(t) = Im\left(\Phi_{out} e^{j\omega t}\right)$

<u>Answer:</u> $V_{out}(t) = 2.9999 \sin\left(10\,000\pi t + 1.5791\right)$

Low-pass? High-pass? Band-pass? Band-stop?

$$H(s) = H(j\omega) = \frac{(j\omega)RC}{1 + (j\omega)^2 LC + (j\omega)RC} \overset{s=j\omega}{=} \frac{sRC}{1 + sRC + s^2 LC} \Rightarrow H(0) = \frac{0 \cdot RC}{1+0+0} = 0$$

For $s \to \infty$, rewrite $H(s)$ as $H(s) = \dfrac{\frac{1}{s}RC}{\frac{1}{s^2} + \frac{1}{s}RC + LC}$

from which it is clear that $H(s) \to 0$ as $s \to \infty$

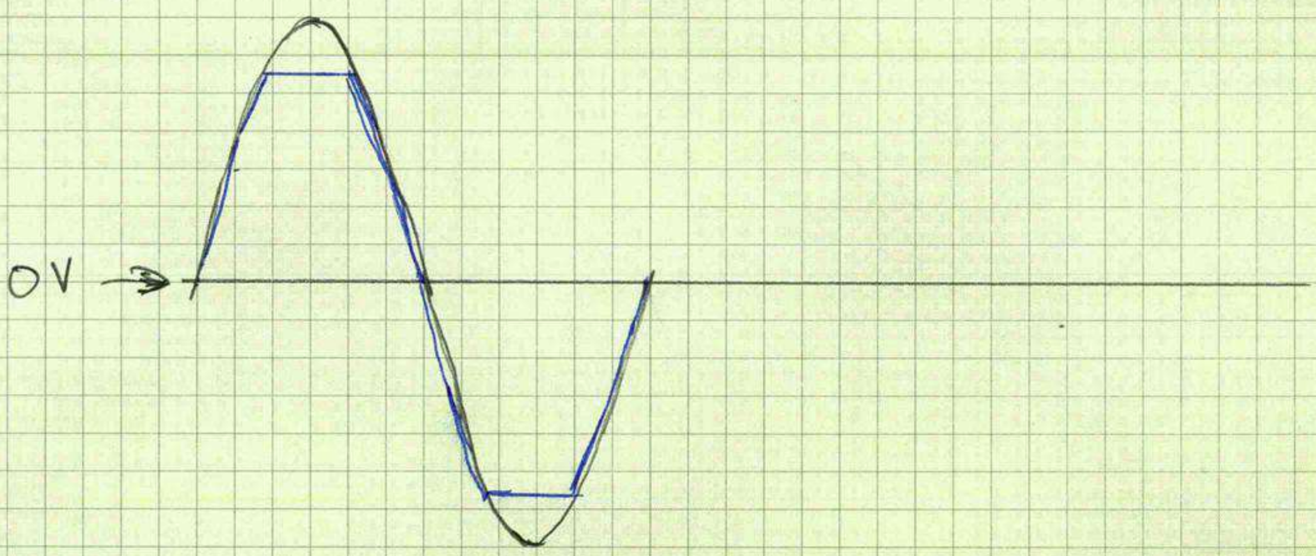
6p

$\therefore$ This is a <u>BAND-PASS</u> $\square$

BO-0061-NXX

B.1 a) See A.3 a)! ✓ 3p

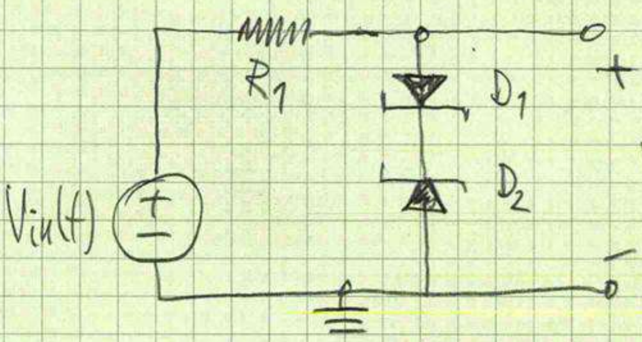
b)



- black: input signal
- blue: output signal

The diodes will cut the input signal at ± 5.5 V ✓

The reason is that the diodes will start conducting when... ✓

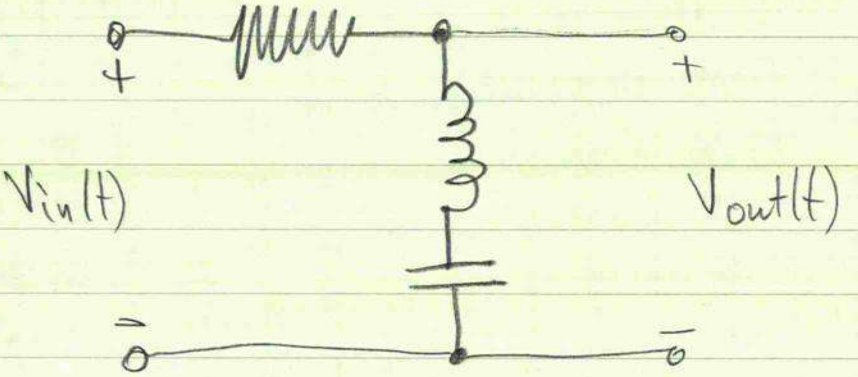


TIME IS OUT!

5p

BO-0061-NXX

B.2



This is a passive band-stop. I don't have time to explain why, but it is the inverse of the output signal in Figure 4. ✓
By doing similar calculations as in A.5 I could show that: for the transactional function $H(j\omega)$:

✓ $|H(0)| = 1$

✓ and $|H(\infty)| = 1$ } **AND** for some frequency ω^* in between, $|H(j\omega^*)| = 0$ ✓

5p