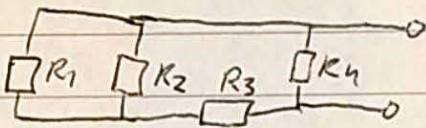


Problem 1C

a) [Like 1A (a)]

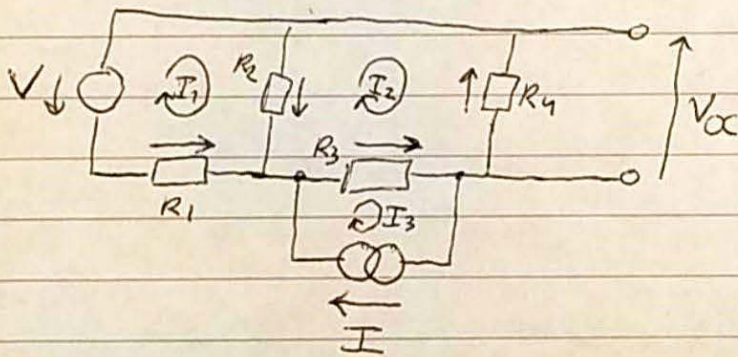
b) Replace the sources by their internal resistance:



So then $R_{Th} = R_4 // (R_3 + R_2 // R_1)$

$$= \frac{R_4 \left(R_3 + \frac{R_1 R_2}{R_1 + R_2} \right)}{R_4 + R_3 + \frac{R_1 R_2}{R_1 + R_2}} = \frac{R_4 \left((R_1 + R_2) R_3 + R_1 R_2 \right)}{(R_3 + R_4) (R_1 + R_2) + R_1 R_2}$$

c) Draw the arrow conventions and mesh currents.



Mesh 3: $I_3 = I$ (current source)

Mesh 1: $+V_{R_2} - V_{R_1} - V = 0$ (KVL)

$$\Rightarrow (I_2 - I_1)R_2 - I_1 R_1 - V = 0$$

$$\Rightarrow -V + I_2 R_2 - I_1 (R_1 + R_2) = 0 \quad \Rightarrow I_1 = (I_2 R_2 - V) \frac{1}{R_1 + R_2}$$

IK C (continued)

$$\text{Mesh 2: } -V_{R4} - \cancel{V_{R3}} V_{R3} - V_{R2} = 0 \quad (\text{KVL})$$

$$\Rightarrow I_2 R_4 + (I_2 - I_3) R_3 + (I_2 - I_1) R_2 = 0$$

$$\Rightarrow I_2 (R_2 + R_3 + R_4) - I R_3 - I_1 R_2 = 0 \quad (\text{using mesh 3 eq.})$$

$$\Rightarrow I_2 (R_2 + R_3 + R_4) - (I_2 R_2 - V) \frac{R_2}{R_1 + R_2} - I R_3 = 0$$

$$\Rightarrow I_2 \left(R_2 + R_3 + R_4 - \frac{R_2^2}{R_1 + R_2} \right) + V \frac{R_2}{R_1 + R_2} - I R_3 = 0 \quad (\text{using mesh 1 eq.})$$

$$\Rightarrow I_2 = \left(I R_3 - V \frac{R_2}{R_1 + R_2} \right) \frac{1}{R_2 + R_3 + R_4 - \frac{R_2^2}{R_1 + R_2}}$$

$$= \left(I \frac{R_3}{R_2} - V \frac{1}{R_1 + R_2} \right) \frac{1}{1 + \frac{R_3 + R_4}{R_2} - \frac{R_2}{R_1 + R_2}}$$

$$= \left(I \frac{R_3 (R_1 + R_2)}{R_2} - V \right) \frac{1}{R_1 + R_2 + \frac{R_1 + R_2}{R_2} (R_3 + R_4) - R_2}$$

$$= \left(I \frac{R_3 (R_1 + R_2)}{R_2} - V \right) \frac{1}{R_1 + \frac{R_1 + R_2}{R_2} (R_3 + R_4)}$$

$V_{Th} = V_{OC} = R_4 * I_2 = \dots$ (write it out) (simplifications not necessary!)

Problem

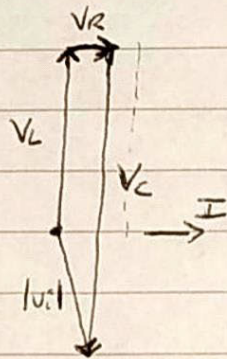
2C

a) The magnitudes of the voltages are:

$$V_L = X_L I, \quad V_C = I X_C, \quad V_R = RI.$$

$$\text{So, } V_C = 10V, \quad V_L = 6V, \quad V_R = 1V.$$

And the phasor diagram:



b) - The voltmeter impedance is more than an order of magnitude larger than that of the circuit, so loading effects will be relatively small and the measured voltages relatively correct.

or

c) The circuit acts as a band-pass filter or acceptor filter:

- the capacitor blocks low-f signals as
 - ~~the voltage cannot change~~ it acts as ~~an~~ circuit break for these
 - or - has a high reactance for low frequencies
 - or - acts as a high-pass filter
- the inductor is the other way around,
 - it blocks high-f signals as its current cannot change instantaneously
 - or - has a high reactance for high frequencies, preventing these from appearing in V_o .

2C

d) [like 2B d)]

e) Use the voltage divider:

$$V_o = V_i \frac{Z_R}{Z_C + Z_L + Z_R} \Rightarrow \frac{V_o}{V_i} = \frac{R}{1/j\omega C + j\omega L + R}$$

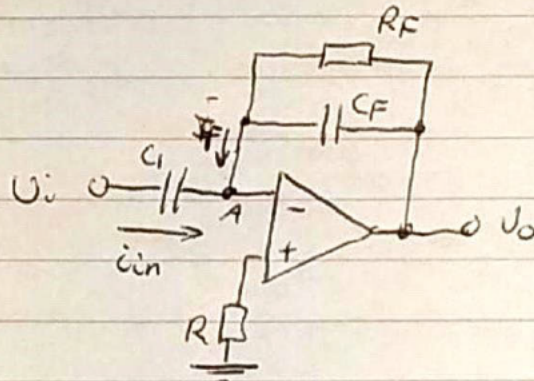
$$\text{So } \frac{V_o}{V_i} = \frac{1}{1 + j\omega \frac{L}{R} - j\omega \frac{1}{CR}}$$

and we have $D = G = 0$, $E = \frac{L}{R}$, $F = -\frac{1}{CR}$.

Problem 3C

a) en c) like 3A.

b) Method 1: KCL.



$U_+ = 0, U_- = U_+ \Rightarrow U_- = 0$ (virtual earth)

Apply KCL in node A: $i_{in} + i_F = 0$

$$\Rightarrow \frac{U_i}{Z_{C1}} + U_o / \left(\frac{1}{R_F} + \frac{1}{Z_{CF}} \right)^{-1} = 0$$

$$\Rightarrow \frac{U_o}{U_i} = - \frac{\left(\frac{1}{R_F} + \frac{1}{Z_{CF}} \right)^{-1}}{Z_{C1}} = -j\omega C_1 \frac{1}{1/R_F + j\omega C_F}$$

Method 2: superposition:

$$U_- = U_i \frac{\frac{R_F Z_{CF}}{R_F + Z_{CF}}}{Z_{C1} + \frac{R_F Z_{CF}}{R_F + Z_{CF}}} + U_o \frac{Z_{C1}}{Z_{C1} + \frac{R_F Z_{CF}}{R_F + Z_{CF}}}$$

$$\Rightarrow \frac{U_o}{U_i} = - \frac{R_F // Z_{CF}}{Z_{C1}} = - \frac{\left(\frac{1}{R_F} + \frac{1}{Z_{CF}} \right)^{-1}}{Z_{C1}} = -j\omega C_1 \frac{1}{R_F^{-1} + j\omega C_F}$$

Problem 4.1

A) a) E

		CD			
		00	01	11	10
AB	00	0	1	0	0
	01	0	0	X	0
	11	X	1	X	1
	10	1	0	X	X

$$E = \bar{A}\bar{B}\bar{C}D + AB + A\bar{D}$$

B) a) H

		CD			
		00	01	11	10
AB	00	X	1	X	X
	01	X	X	1	X
	11	0	0	X	0
	10	1	0	1	X

$$H = \bar{A} + CD + \bar{B}\bar{D}$$

C) a) V

		CD			
		00	01	11	10
AB	00	X	1	0	X
	01	1	X	1	0
	11	0	X	0	X
	10	1	0	0	X

$$V = \bar{A}\bar{C} + \bar{B}\bar{D} + \bar{A}BD$$

4.2C 0, 1, 4, 3, 5, 2

Digital	$Q_3 Q_2 Q_1$	$Q_3 Q_2 Q_1$	$J_3 K_3$	$J_2 K_2$	$J_1 K_1$
0	0 0 0	0 0 1	0 X	0 X	1 X
1	0 0 1	1 0 0	1 X	0 X	X 1
4	1 0 0	0 1 1	X 1	1 X	1 X
3	0 1 1	1 0 1	1 X	X 1	X 0
5	1 0 1	0 1 0	X 1	1 X	X 1
2	0 1 0	0 0 0	0 X	X 1	0 X
<u>6</u>	1 1 0	X X X	X X	X X	X X
7	1 1 1	X X X	X X	X X	X X

J_3

	$Q_2 Q_1$			
	00	01	11	10
Q_3 0	0	1	1	0
1	X	X	X	X

K_3

	00	01	11	10
0	X	X	X	X
1	1	1	X	X

$J_3 = Q_1$
 $K_3 = 1$
 $J_2 = Q_3$
 $K_2 = 1$
 $J_1 = \overline{Q_2}$
 $K_1 = \overline{Q_2}$

J_2

J_2	$Q_2 Q_1$			
	00	01	11	10
0	0	0	X	X
Q_3 1	1	1	1	X

K_2

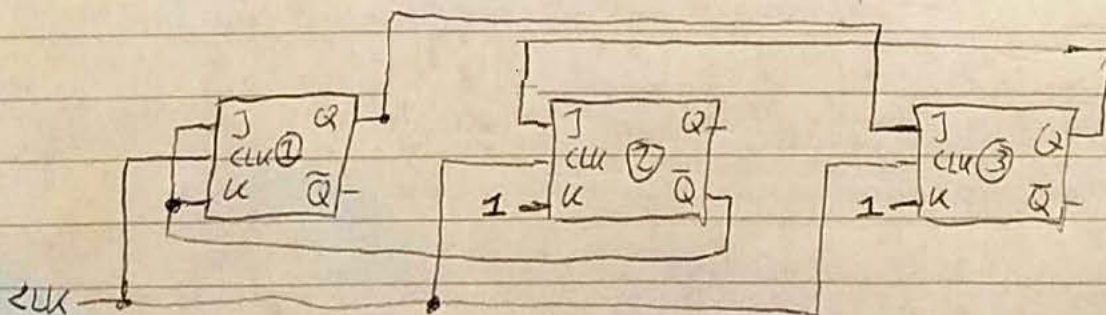
	00	01	11	10
0	X	X	1	1
1	X	X	X	X

J_1

	00	01	11	10
0	1	X	X	0
1	1	X	X	X

K_1

	00	01	11	10
0	X	1	0	X
1	X	1	X	X



Grading Rubric Electronics and Signal Processing 2019-2020 Exam April 7

Important: for any and all points given the line of reasoning should be there. Just the final answer does not yield any points.

Problem 1 2.5 point	Novice	Intermediate	Competent	Master
a)	0 point incorrect answer	-	-	0.5 point correct, complete explanation mentioning the series or parallel nature of the resistor involved with respect to the rest
b)	0 point more than 2 mistakes from "competent" level or , no resulting circuit drawn or explanation in words given (even if correct final answer)	0.25 point 2 mistakes from "competent" level or , multiple mistakes within one such level	0.5 point mistake in internal resistances or , mistake in parallel/series combination leading to final answer or , final answer with parallel operator "//"	0.75 point sources correctly replaced by internal resistance provides the resulting circuit, or explains this in words correct derivation of parallel/series combination leading to final answer final answer does not show parallel operator "//"
c) Circuit & definitions	0 point more than 1 mistake from "intermediate" level	0.25 point directions of loop currents missing or , direction of voltage arrow convention missing or , V_{Th} incorrectly defined	-	0.5 point defines all loop current directions defines all relevant voltage arrow conventions used defines $V_{Th} = V_{OC}$ in correct way
c) Loop equations & solving	0 point no answer or , mistakes in every "master" level point	0.25 point multiple mistakes from "master" level or , showing understanding of KCL and mesh, but missing complete answer	0.5 point correct signs of voltages going through loop, or 1 mistake or , correct loop currents (or subtractions thereof) used, or 1 mistake	0.75 point correctly sets loop current to I of current source (if present) correct signs of voltages going through loop correct loop currents (or subtractions thereof) used for these voltages combines loop equations to find loop current expression

Problem 2 2.5 point	Novice	Intermediate	Competent	Master
a)	0 point does not know how to calculate voltage magnitudes and how a phasor diagram is constructed	0.25 point mistake in phasor directions or magnitude or , phasor combination not drawn correctly	-	0.5 point correct calculation of voltage magnitudes correct drawing of phasors: direction and (approximate) length correct connection of phasors, including input voltage
b)	0 point does not correctly infer accuracy of the measurement. Does not compare circuit resistance to resistance of device	0.25 point only compares voltmeter impedance magnitude to that of the element it is connected across	-	0.5 point correctly compares voltmeter impedance magnitude with that of circuit and explains that this results in voltage drop, or that this results in significant loading of the circuit and therefore voltage drop
c)	0 point does not explain even partial functioning of filter correctly, from either C or L	0.25 point can only explain capacitor or inductor contribution to filter or , 1 mistake in the way capacitor or inductor contributes	-	0.5 point correct statement of type of filter explains contributions from both capacitor and inductor to this result
d)	0 point more than 1 mistake from "intermediate" level	0.25 point mistake in limit or , mistake in conversion to decibels or , sign error	-	0.5 point correctly takes the limit to high or low frequency, finding a quadratic dependence correctly converts this quadratic dependency to decibels/decade correct sign of answer
e)	0 point does not arrive at transfer function through voltage divider	0.25 point 1 or 2 mistakes in transfer function or constants D, E, F, G	-	0.5 point uses voltage divider to write transfer function correctly writes transfer function in terms of omega provides resulting constants D, E, F, G

Problem 3 2.5 point	Novice	Intermediate	Competent	Master
a)	0 point incorrect answer	0.25 point mentions that ideal opamp has no input bias current, or that opamp has infinite input resistance, but does not adequately explain mechanism		0.5 point correctly recalls that an ideal opamp has no input current, meaning that no voltage drops across R
b)	0 point more than 2 mistakes of "master" level	0.5 point 2 mistakes of "master" level	1 point uses KCL, but no clear definition of current directions or , mistake in rewriting or , final answer contains parallel operator "/"	1.5 point { uses KCL, defining the direction of the currents or , uses superposition theorem } invokes $v_+ = v_-$, ground potential arrives at v_o/v_i equation through rewriting no parallel operator "/" used in final answer
c)	0 point incorrect answer	0.25 point mentions that R can be used for correction of input bias current, but does not adequately explain mechanism		0.5 point states that non-ideal opamp has input bias current explains that this leads to a non-ground potential at v_- explains that R can be used to correct potential at v_+ to reduce effect of the input bias current on the output

Problem 4.1 1 point	Novice	Intermediate	Competent	Master
a)	0 point more than 2 mistakes in rectangles or simplified expressions given correctly, but no supporting evidence in K-map	0.3 point 2 mistakes in rectangles or all do-not-care conditions covered by rectangles as well or additional, superfluous rectangle drawn (covering the 1s)	0.6 point 1 mistake in rectangles leading to either one product term too large or an additional rectangle necessary	1 point correct, fully simplified sum-of-products expression supported by drawn rectangles
Problem 4.2 b) 1.5 point				
Excitation table	0 point entirely different counter from book or all mistakes from "competent" ->	0.25 point ordering of states is wrong or multiple mistakes from "competent" level ->	0.5 point minor "sloppy" mistakes present or not all states are present and correct or coherent mistakes in next states or coherent mistakes in J-K input conditions	0.75 point all states are present and correct (including unused states) next states are labelled and correct (including do not cares) J-K input conditions are correct (including do not cares)
Input Boolean expressions	0 point more than 2 mistakes or K-maps missing and Boolean expressions incorrect	0.25 point 1 or 2 mistakes in the simplified expressions (in the presence of K-maps)	-	0.5 point correct, simplified expressions (not necessarily using K-maps)
Diagram Drawing	0 point multiple mistakes from "intermediate" level ->	0.1 point Clock line not drawn or minor mistakes converting Booleans into drawing or no clear distinction between crossing lines and connecting lines	-	0.25 point Clock line present correct drawing of Boolean expressions clear distinction between crossing lines and connecting lines