Name: ______________________________ (please print)

Signature: ___________________________

ECE 3355 – Exam 1
March 6, 2021
Online

1. This quiz is open book, open notes. You may not consult another person, verbally or online, for help. You may not submit this exam to any online site to get help.
2. Show all work necessary to complete the problem on these pages. A solution without the work shown will receive no credit.
3. Do not use red ink or pencil to write your exam.
4. Show units in intermediate and final results, and in figures.
5. If your work is sloppy or difficult to follow, points will be subtracted.

Instructions

- The exam starts at 9 am. You will have 80 minutes to take the quiz, and 15 minutes to scan and upload it. Blackboard will stop accepting your work at 10:35 am.
- Please turn on your video.
- When you upload, make it a single .pdf document, and be sure it is legible and complete before uploading.
- I will be available for questions during the exam. If you need to ask a question, please use the chat option on Zoom.

__________________/35

__________________/40

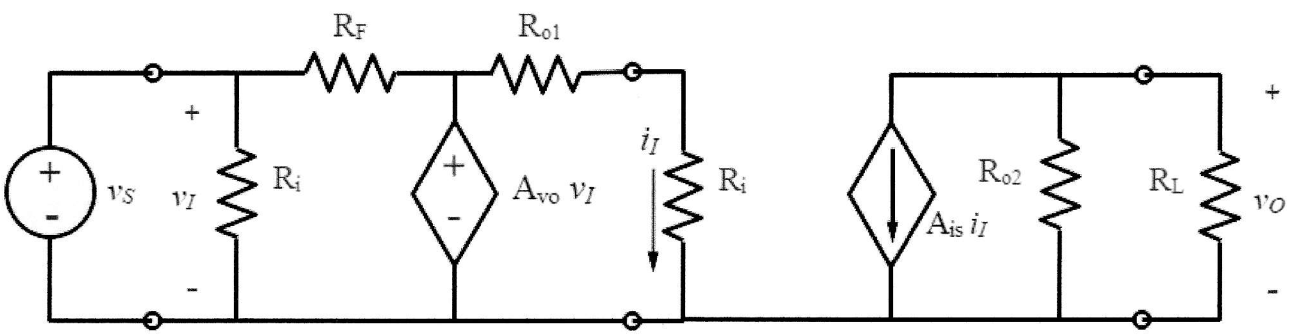
__________________/25

__________________/100

Room for extra work

1. (35 points) A clever *Electronics* student has cascaded a voltage amplifier and a current amplifier, and added a feedback resistor R_F to achieve a new amplifier with the properties she wants. The result is shown in the circuit diagram below. The source is v_S, and the load is $R_L = 2.2\ k\Omega$. The values of the other resistances are: $R_{o1} = 390\ \Omega$; $R_{o2} = 47\ k\Omega$; $R_i = 10\ k\Omega$. The gain parameters are $A_{vo} = 20$ V/V and $A_{is} = 15$ A/A.

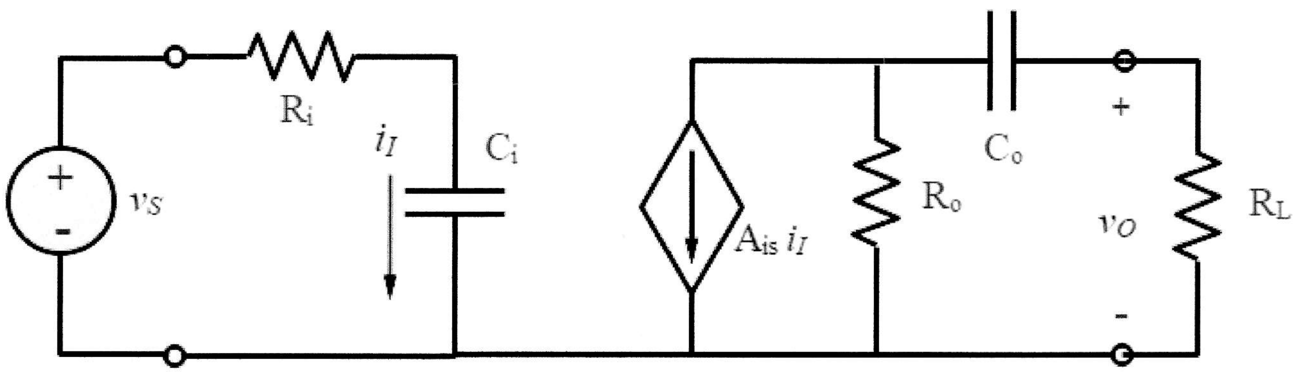
a) What value of R_F should be chosen so that the input resistance seen by the source v_S is 100 kΩ?
b) With the value of R_F you found in part a), and $v_S = 1$ mV, what output voltage v_O is delivered to R_L?
c) Draw a circuit model for an equivalent transconductance amplifier that has the same input resistance seen by v_S and output resistance seen by R_L, and delivers the same voltage output to R_L as you found in part b) with $v_S = 1$ mV.

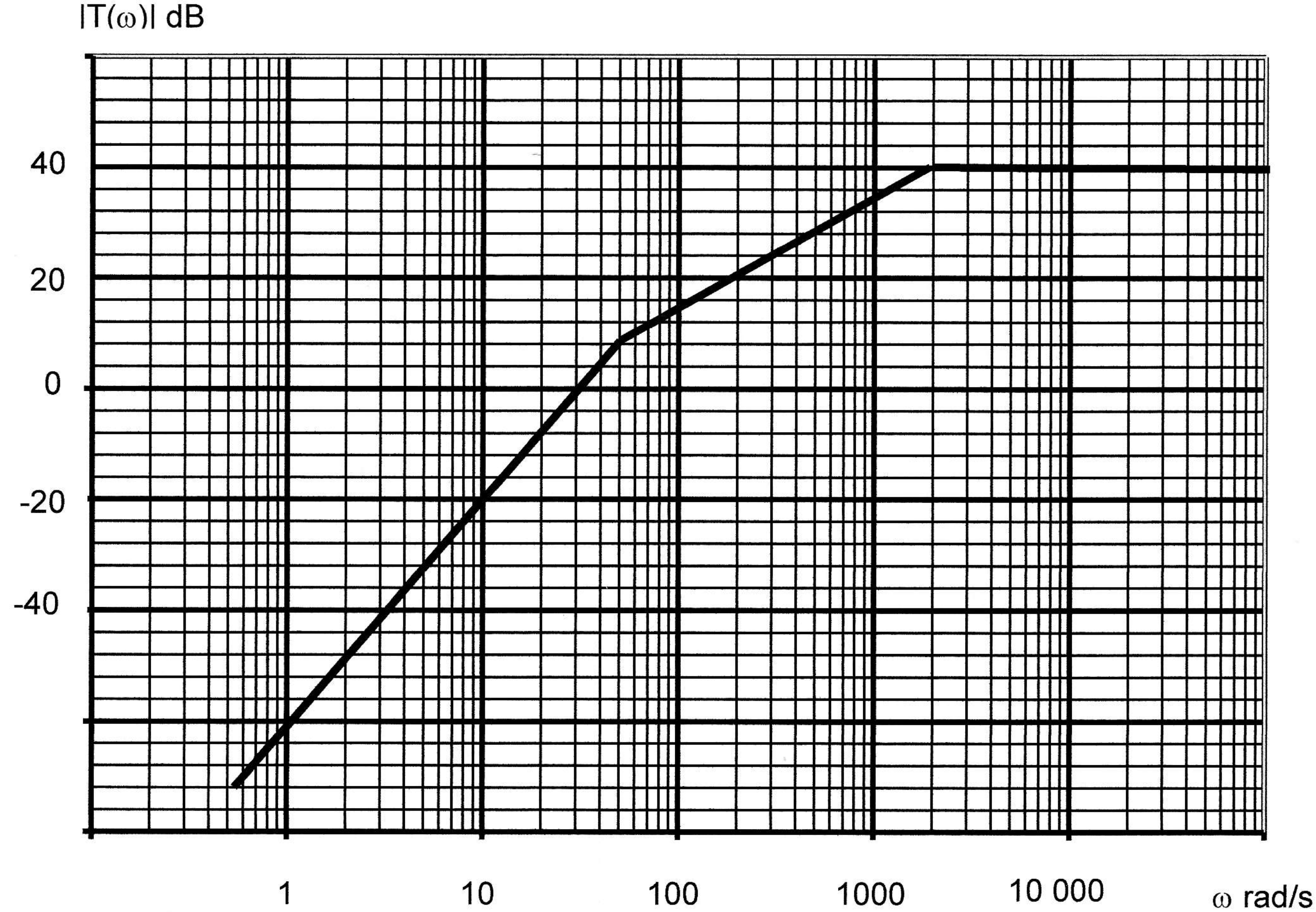


Room for extra work

2. (40 points) The circuit shown below has the magnitude Bode plot shown in the graph on the next page. The load is $R_L = 250\ \Omega$, and $A_{is} = 10$ A/A.

a) Find the transfer function $T(\omega) = $ **Vo/Vs** for the circuit. Express the transfer function algebraically. In other words, don't substitute numbers here.
b) Choose values for R_i, C_i, R_o, and C_o so that the transfer function results in the Bode plot shown. Make sure your values result in the correct magnitude as well as the correct breakpoints.



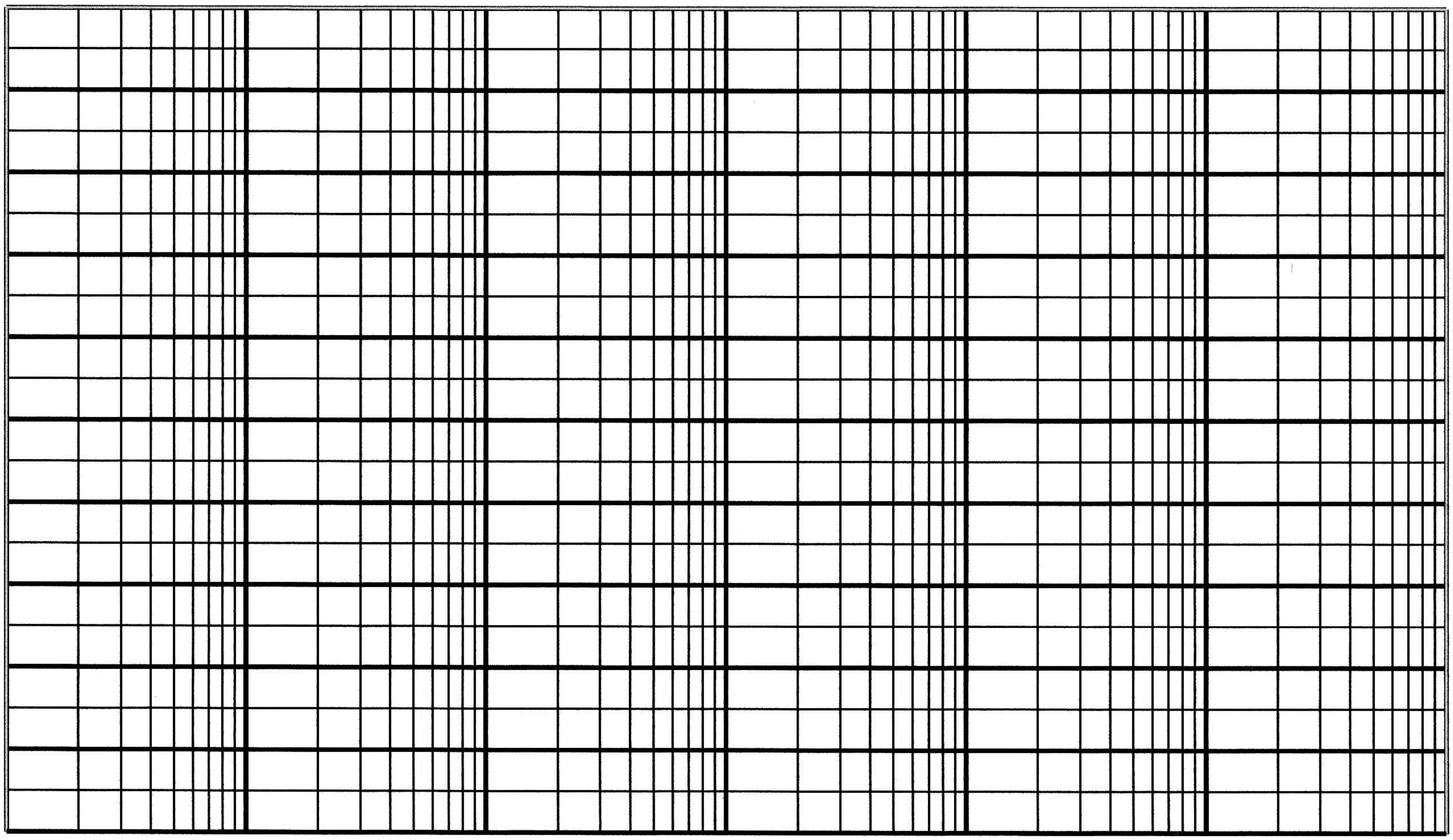


|T(ω)| dB
40
20
0
-20
-40
1
10
100
1000
10 000
ω rad/s

Room for extra work

3. (25 points) Using the graph paper on the next page, draw the phase Bode plot for the following transfer function T(ω).

$$T(\omega) = \frac{(j\omega 0.125)(j\omega 5\times 10^{-8})}{(2000 + j\omega)(50 + j\omega)}$$



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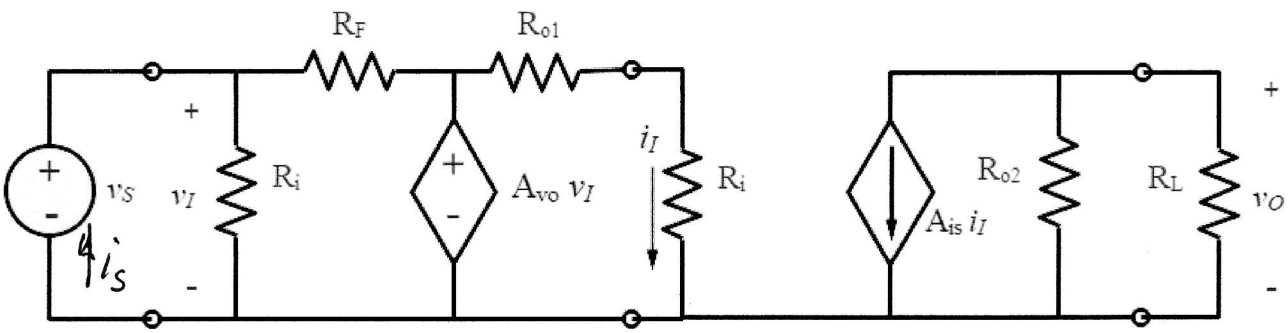
+15 a) What value of R_F should be chosen so that the input resistance seen by the source v_S is 100 kΩ?

+8 b) With the value of R_F you found in part a), and $v_S = 1$ mV, what output voltage v_O is delivered to R_L?

+12 c) Draw a circuit model for an equivalent transconductance amplifier that has the same input resistance seen by v_S and output resistance seen by R_L, and delivers the same voltage output to R_L as you found in part b) with $v_S = 1$ mV.



a) $i_s = \frac{v_I}{R_i} + \frac{(1-A_{vo})v_I}{R_F}$ $\quad v_I = v_s \Rightarrow i_s = v_s\left(\frac{1}{R_i} + \frac{1}{R_F} - \frac{A_{vo}}{R_F}\right)$

+6 $\therefore R_{in} = \frac{v_s}{i_s} = \frac{1}{\frac{1}{R_i} + \frac{1}{R_F} - \frac{A_{vo}}{R_F}} = 10^5$

$R_i = 10\,k\Omega$ so $\frac{1}{R_F}(1-A_{vo}) = 10^{-5} - 10^{-4}$

+9 $\Rightarrow R_F = \frac{1-A_{vo}}{-9\times10^{-5}} \approx 211\ k\Omega$

Room for extra work

b) $v_O = -A_{is}\, i_I \cdot \frac{R_{o2}}{R_{o2}+R_L} \cdot R_L \qquad i_I' = \frac{A_{vo} v_I}{R_{o1}+R_i} \qquad v_i = v_s$

1.925 uA

$$\therefore\ v_o = -A_{is} \cdot A_{vo} \cdot \frac{R_{o2}R_L}{R_{o2}+R_L} \cdot \frac{1}{R_{o1}+R_i}\, v_s$$

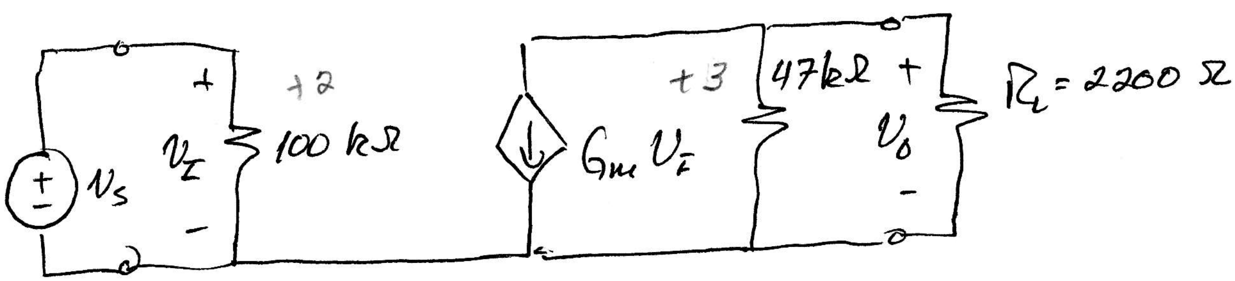
+10

$$v_o = -60.68\ mV$$

c) We have $R_{in} = 100\ k\Omega$ (given) and $R_o = R_{o2} = 47\ k\Omega$ (by inspection of the original circuit).

We draw the new transconductance amplifier:

+3 +2 +3



$$v_o = -G_m v_s \cdot \frac{47000}{47000+2200} \cdot 2200 = -60.68\ mV$$

if $v_s = 1\ mV$.

+4

Solving for G_m gives $G_m = 2.887 \times 10^{-4}\ \frac{A}{V}$

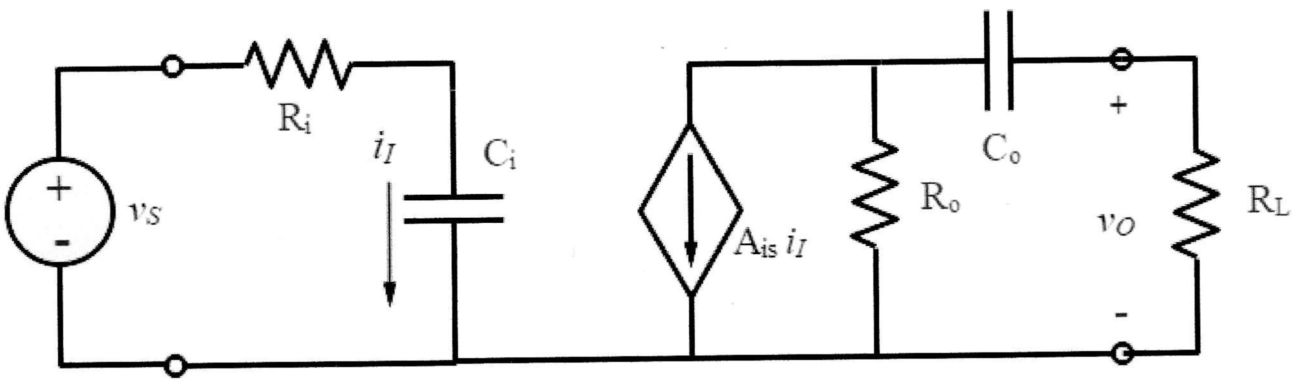
b), c) No R_L −3

Bad CDR sign −3

b) set $R_i = R_{in}$ −4

2. (40 points) The circuit shown below has the magnitude Bode plot shown in the graph on the next page. The load is $R_L = 250\ \Omega$, and $A_{is} = 10$ A/A.

a) Find the transfer function $T(\omega) = $ **Vo/Vs** for the circuit. Express the transfer function algebraically. In other words, don't substitute numbers here.
b) Choose values for R_i, C_i, R_o, and C_o so that the transfer function results in the Bode plot shown. Make sure your values result in the correct magnitude as well as the correct breakpoints.



a) $\bar{V}_o = -A_{is}\bar{I}_I \dfrac{R_o}{1/j\omega C_o + R_o + R_L} \cdot R_L = -A_{is}\bar{I}_I \dfrac{j\omega C_o R_o R_L}{1 + j\omega C_o(R_o + R_L)}$

$\bar{I}_I = \dfrac{\bar{V}_s}{R_i + 1/j\omega C_i} = \bar{V}_s \dfrac{j\omega C_i}{1 + j\omega C_i R_i}$

+15

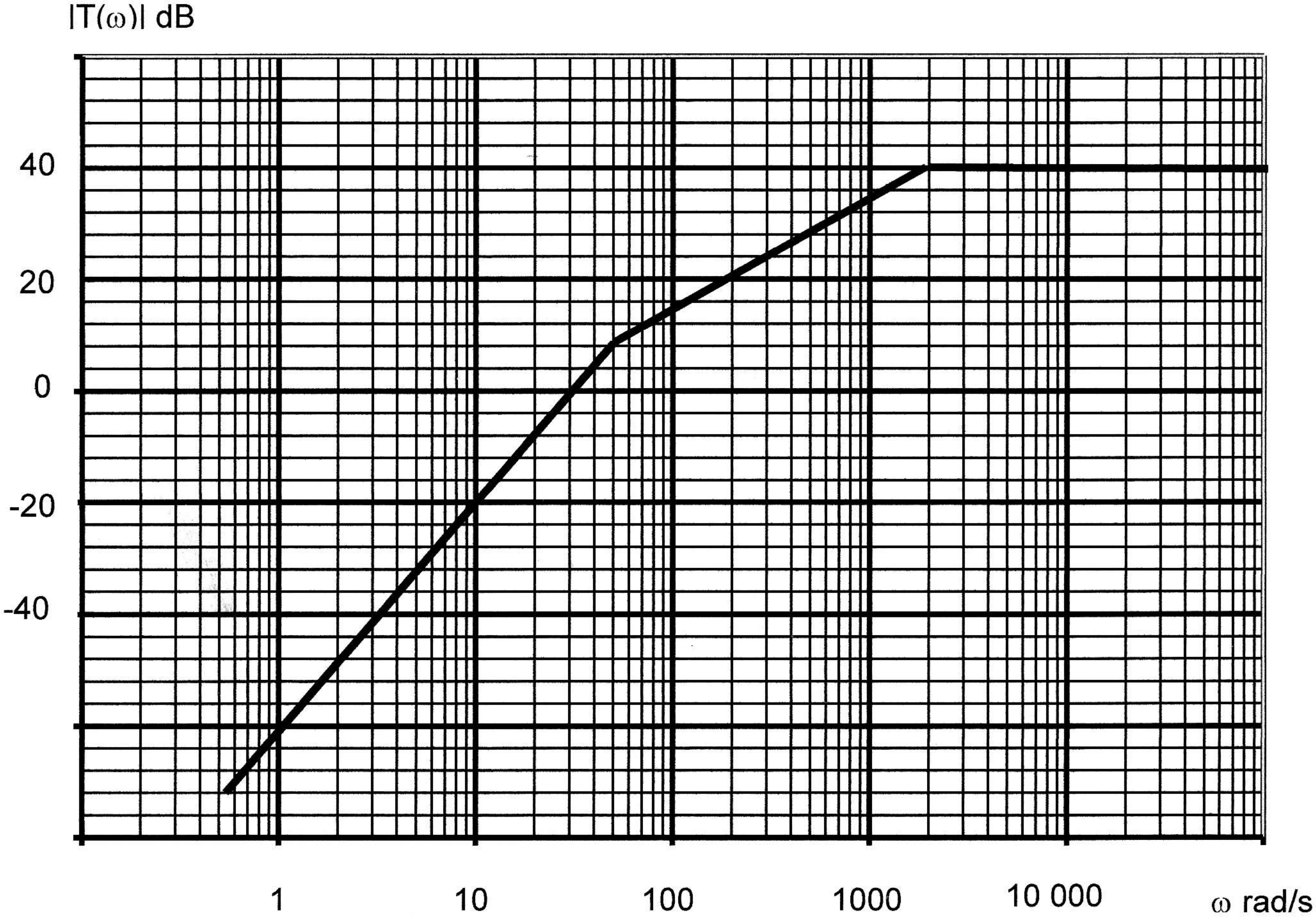
$\therefore \dfrac{\bar{V}_o}{\bar{V}_s} = -A_{is} \dfrac{j\omega C_i}{1 + j\omega C_i R_i} \cdot \dfrac{j\omega C_o R_o R_L}{1 + j\omega C_o(R_o + R_L)}$

b) We have poles at 50 rad/s and 2000 rad/s. There's no way to know which is which so we pick something:

$1/C_i R_i = 50$ rad/s $\qquad 1/C_o(R_o + R_L) = 2000$ rad/s

+4

+4



Before we go further, we note that $|T(\omega\to\infty)| = 40\,dB$.
This will put a constraint on our resistor values.

$$\omega \to \infty \Rightarrow T(\omega) \to -A_{is} \frac{j\omega C_i}{j\omega C_i R_i} \frac{j\omega C_o R_o R_L}{j\omega C_o (R_o + R_L)}$$

$$\Rightarrow |T(\omega)| \to A_{is} \frac{1}{R_i} \frac{R_o R_L}{R_o + R_L} = 40\,dB = 100\,\frac{V}{V}$$

$$A_{is} = 10\,\frac{A}{A} \Rightarrow \frac{1}{R_i} \frac{R_o R_L}{R_o + R_L} = 10.$$

+7

Choose $R_i = 1\,k\Omega \Rightarrow \frac{R_o R_L}{R_o + R_L} = 10\,k\Omega$

Room for extra work

Since R_L was given as $250\,\Omega$, we have...*

$$\frac{1}{R_i} \cdot \frac{250 R_o}{250 + R_o} = 10$$

choose $R_i = 5\,\Omega \Rightarrow R_o = 62.5\,\Omega$

Then $1/C_i \cdot R_i = 2000$ rad/s $\Rightarrow C_i = 100\,\mu F$

$1/C_o(R_o + R_L) = 50$ rad/s $\Rightarrow C_o = 64\,\mu F$

If we had made the other assignment for the poles:

$1/C_i R_i = 50$ rad/s $\Rightarrow C_i = 4\,mF$ (huge!)

$1/C_o(R_o + R_L) = 2000$ rad/s $\Rightarrow C_o = 1.6\,\mu F$

Here is a case, like many engineering design problems, where we do not have enough information to calculate all required parameters. In such cases, we must make choices - we want to make reasonable choices, but many correct solution are possible.

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* This is problematic, since depending on our choice of R_i or R_o, the remaining value can be negative. This is of course not realistic. On the exam, anyone making a good effort got full credit.

3. (25 points) Using the graph paper on the next page, draw the phase Bode plot for the following transfer function T(ω).

$$T(\omega)=\frac{(j\omega 0.125)(j\omega 5\times 10^{-8})}{(2000+j\omega)(50+j\omega)}$$

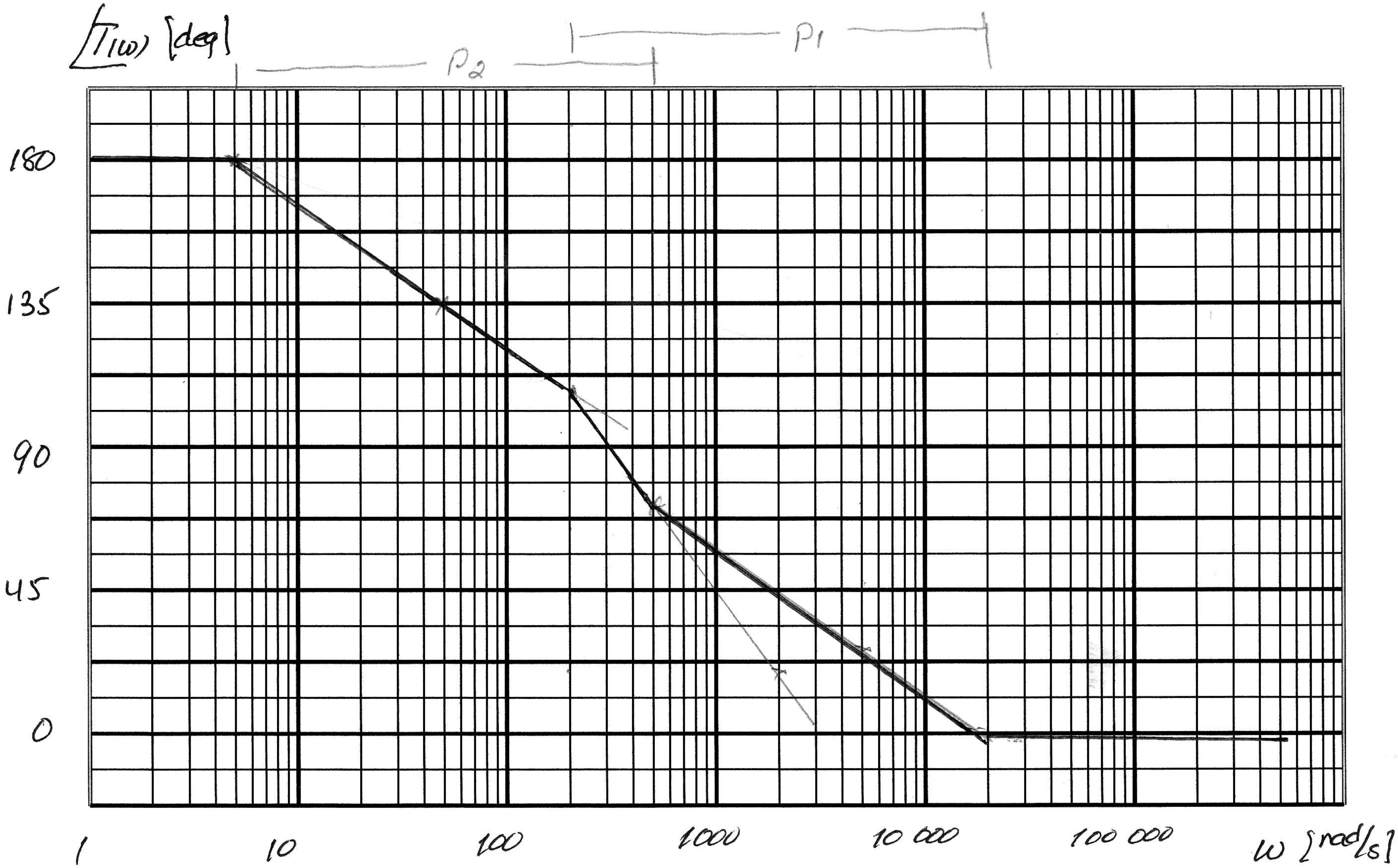
If this looks familiar, it's because it's the transfer function from problem 2.

we have two zeros at $\omega = 0$

$P_1 = 2000$ rad/s $\quad P_2 = 50$ rad/s

$\omega \to 0 \Rightarrow \angle T(\omega) \to 180^\circ$

$\omega \to \infty \Rightarrow \angle T(\omega) \to 0$


∠T(iω) [deg]
P2
P1
180
135
90
45
0
1
10
100
1000
10 000
100 000
ω [rad/s]