

i Front Page

UNIVERSITY OF OSLO

The Faculty of Mathematics and Natural Sciences

Written examination IN3170/4170

Spring 2022

Duaration: 9-Jun-2022 15:00 to 19:00

Permitted aids:

Everything on paper and approved calculator

It is important that you read this front page before you start.

Information about hand drawings(Scantron)

In this question set you have the opportunity to answer with hand drawings (question 4 'JK flipflop'). You use the handed out sketch sheets. It is possible to use several sheets per assignment. See instructions on how to fill in the sketch sheets in the link below the assignment overview.

You are not supposed to submit hand drawings for any other questions than question 4 'JK flipflop'. You will NOT be given extra time to fill in the information boxes on the sketch sheets (assignment codes, candidate number, etc.)

General information:

- All non-electronic sources of information are allowed, as well as an approved calculator. If you reproduce a text from books, articles, etc., a reference to these sources must be provided to avoid suspicions of plagiarism. This also applies if a text is translated from other languages.

Information on MATLAB functions and scripts:

Some tasks ask for MATLAB functions or MATLAB scripts. These are MATLAB executables stored in files with the ending '.m'. The file name is specified in the task. Do not name your file anything else! You will need to upload these files as your result. They need to be correctly written and executable in MATLAB! MATLAB is installed on your machine, so you can verify your code. Note the directory MATLAB is working in, indicated at the top underneath the tool bar: that is where any new files will be stored and where MATLAB will be looking for the m-files to execute them. You may change that directory to a convenient location before you start working. Use the 'New->function/script' button in the tool bar to make new m-files.

MATLAB functions have to start with a function header of syntax '[outputArg1 outputArg2]=function FunctionName(inputArg1, inputArg2)', where the number of output and input arguments can vary. The function header is specified in the task. Do not use any other function header! The function needs to contain a command that assigns a final expression to all the output arguments before it ends. For this exam functions will usually contain just a series of assignments where an mathematical expression is assigned to a variable. Functions shall be used in tasks where one needs to find a general expression assigning a value to variables in dependency of other variables.

Example in a file test1.m:

```
function [y]=test1(x)
y=2*x
end
```

MATLAB scripts do not have a function header and are just a series of MATLAB commands that are executed when the name of the file is typed into a MATLAB window. For this exam also scripts

will usually contain just a series of assignments where a mathematical expression or a value is assigned to a variable. Scripts shall be used in tasks with numerical endresults.

Example in a file test2.m where the final result shall be in 'y':

```
x=3
y=2*x
```

The syntax of some potentially useful functions: $\log(x)$ is $\ln(x)$, $\log_{10}(x)$ is $\log_{10}(x)$, $\exp(x)$ is e^x , ... The imaginary number i is 'j' in MATLAB. A line starting with '%' is a comment.

i Task Overview

Chapter 5

task 1: Current mirror properties

(text)

task 2: Diode connected nMOSFET

(MATLAB-function, file upload)

Chapter 15

task 3: Gate delay

(rank order)

Sequential Logic

task 4: JK-flipflop

(hand drawing)

Chapter 6/7

task 5: Intrinsic gain in different technologies

(MATLAB-script, file upload)

Chapter 8

task 6: Multistage Amplifier Offset

(MATLAB-script, file upload)

Chapter 9

task 7: Unity short circuit current gain

(MATLAB-script, file upload)

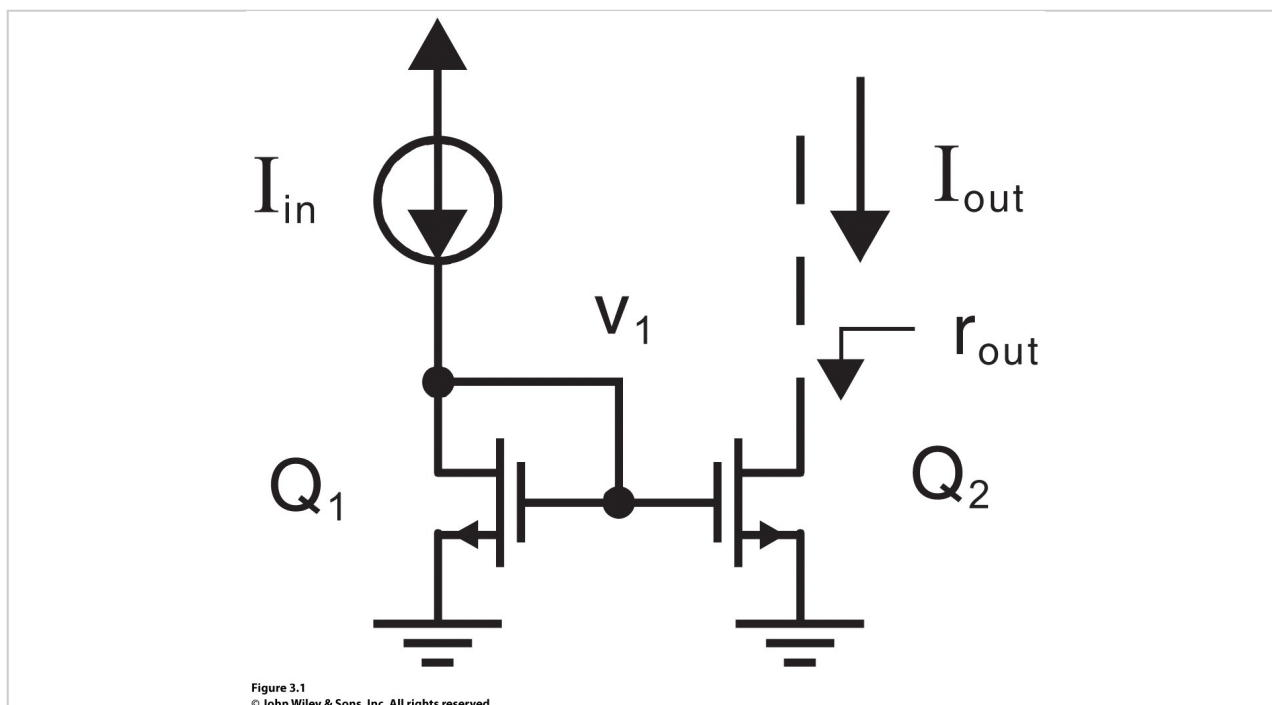
task 8: Transfer function from Bode Plot

(MATLAB-function, file upload)

task 9: Q Factor of source follower

(MATLAB-script, file upload)

1 Current mirror properties



Can you list effects/properties that will affect the output current of a current mirror and cause deviation of the output current from the input current (intentional or unintentional). Please make your answers a list of just 1-3 sentences per effect/property.

Fill in your answer here

Format



B

I

U

x_2

x^2

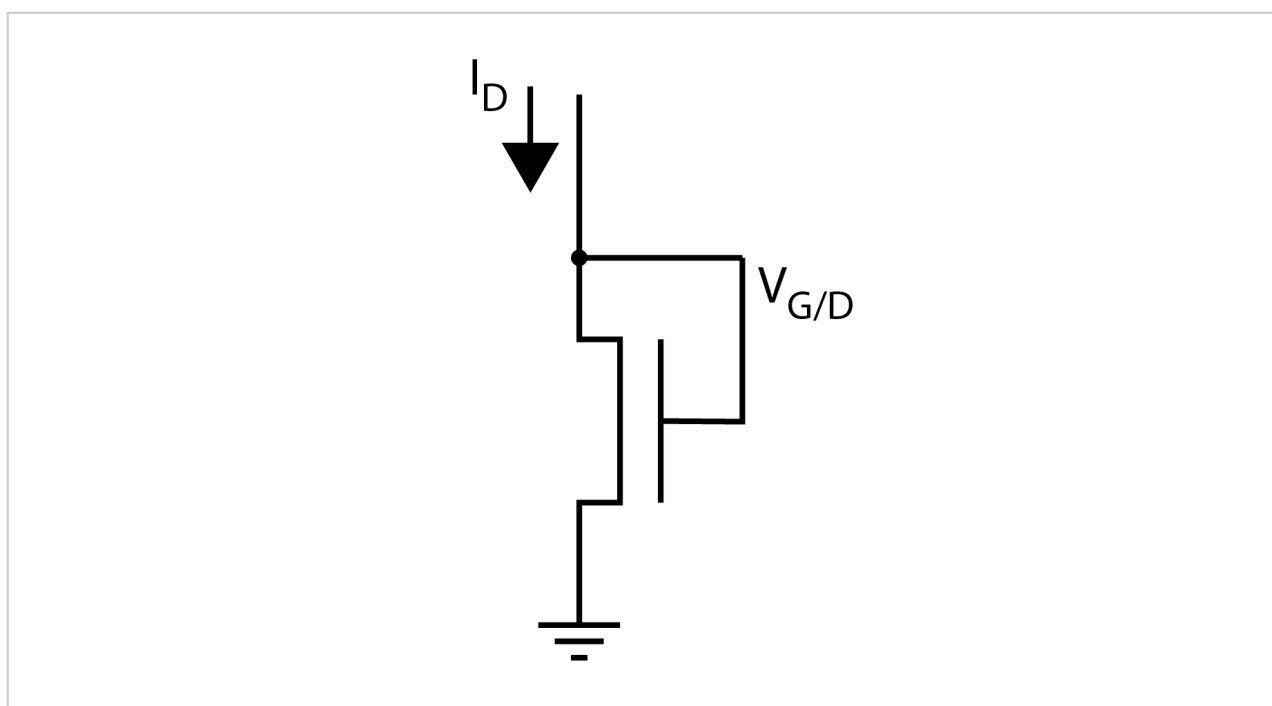
I_x



Words: 0

Maximum marks: 10

2 Diode connected nMOSFET voltage



Make a matlab function 'function '[Vd]=CMOSdiode(Id,kn,Vtn)' that computes the voltage V_d on a diode connected nMOSFET (i.e. drain and gate are shorted together) as a function of the input current I_d at the drain in **weak inversion (!!!)**, and given parameters k_n , V_{tn} (i.e. the MOSFET transconductance parameter and the threshold voltage). Ignore λ and V_a (the Early effect) and n (the slope factor from the EKV model). The thermal voltage V_T shall be 26mV. Assume the source voltage $V_s=0$.

Upload MATLAB function 'function '[Vd]=CMOSdiode(Id,kn,Vtn)' in file CMOSdiode.m



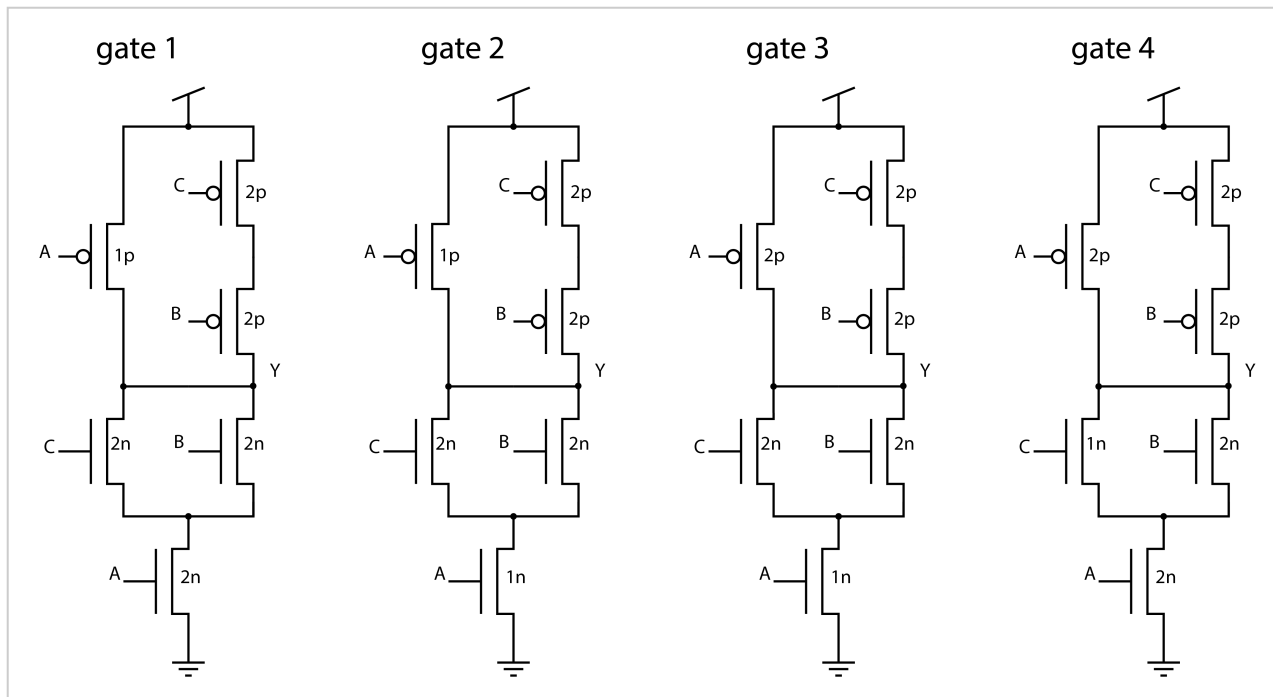
Upload your file here. Maximum one file.

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Maximum marks: 10

3 Gate Delay



Which of the following gates switches the fastest when all inputs (A;B;C) go from low to high, and which is second, third and slowest? Consider the 'internal' capacitors on the output node (!) only as listed in the book according to equation (15.59) and figure 15.32, as well as the equivalent resistances of the conducting transistors.

Note that the letters 'p' and 'n' indicate the W/L ratio of a balanced inverter, i.e. where both the PUN and PDN of that inverter have the same equivalent resistance when the transistor is conducting/switched on. So here, some of the transistors have double the W/L ratio of that inverter.

Here we do not consider any load capacitor, so only the parasitic capacitors of the transistors connected to the output node Y and all equivalent resistances of conducting transistors.

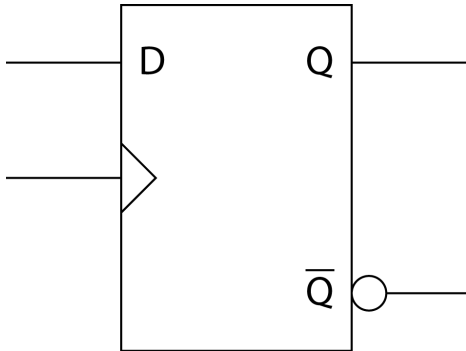
Important: Each gate has exactly one rank, i.e. do not assign several ranks to a single gate!
Please order by switching speed. Only one tick per row and per column allowed!

	gate 1	gate 2	gate 3	gate 4
fastest	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
2nd	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
3rd	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
slowest	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

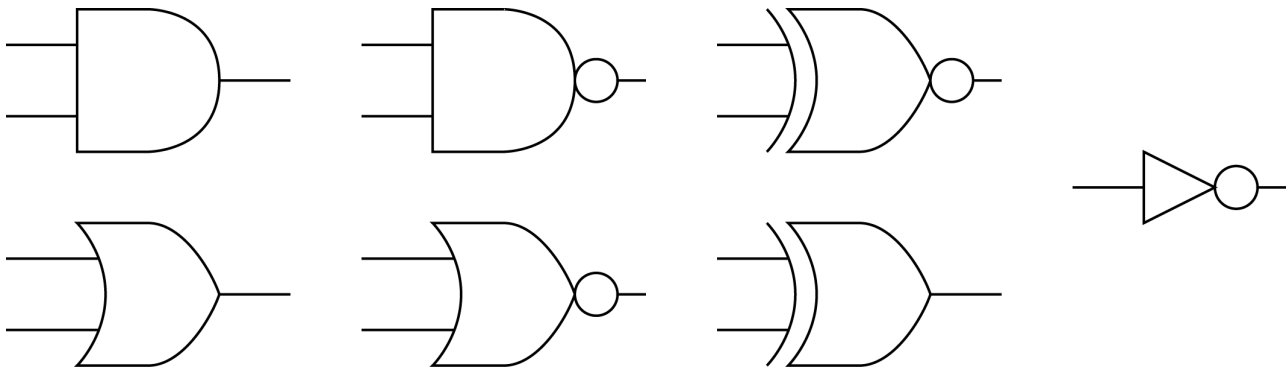
4 JK flipflop

Make a JK-flipflop using one D-flipflop and combinational logic gates. A JK-flipflop is a synchronous flip flop with two inputs J and K (as well as the clock signal CLK) and two outputs Q and its inverse notQ. If only J is high, Q will go high and not Q low at the next rising clock flank. If only K is high, Q will go low and notQ will go high at the next rising clock flank. If neither J nor K are high, the previous state is maintained. If both J and K are high the next state will be the inverse of the previous state, i.e. the state will 'toggle'. It is not important that you use a minimal number of gates.

Use this symbol for the D-flipflop:



And these for logic gates:



NAND, NOR, AND, and OR gates with more than two input ports are also allowed.

In this exercise you shall answer with digital hand drawing. Use your own sketch sheet (distributed). See instructions for filling in the sketch sheet in the link below the task bar. DO NOT use the text field below!

Fill in your answer here

Format | **B** | *I* | U | x_2 | x^2 | I_x | | | | | | | Ω | | | Σ |

Words: 0

Maximum marks: 10

5 Intrinsic gain in different technologies.

Table 1.5 MOSFET parameters representative of various CMOS technologies and used for rough hand calculations in this text.

Technology	0.8 μm		0.35 μm		0.18 μm		45 nm	
	NMOS	PMOS	NMOS	PMOS	NMOS	PMOS	NMOS	PMOS
μC_{ox} ($\mu\text{A}/\text{V}^2$)	92	30	190	55	270	70	280	70
V_{to} (V)	0.80	-0.90	0.57	-0.71	0.45	-0.45	0.45	-0.45
$\lambda \cdot L$ ($\mu\text{m}/\text{V}$)	0.12	0.08	0.16	0.16	0.08	0.08	0.10	0.15
C_{ox} (fF/ μm^2)	1.8	1.8	4.5	4.5	8.5	8.5	25	25
t_{ox} (nm)	18	18	8	8	5	5	1.2	1.2
n	1.5	1.5	1.8	1.7	1.6	1.7	1.85	1.85
θ (1/V)	0.06	0.135	1.5	1.0	1.7	1.0	2.3	2.0
m	1.0	1.0	1.8	1.8	1.6	2.4	3.0	3.0
$C_{ov}/W = L_{ov}C_{ox}$ (fF/ μm)	0.20	0.20	0.20	0.20	0.35	0.35	0.50	0.50
$C_{db}/W \approx C_{sb}/W$ (fF/ μm)	0.50	0.80	0.75	1.10	0.50	0.55	0.45	0.50

Table 1.5
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The table shows some typical process parameters. Consider the intrinsic gain of an nFET in 45nm and 180nm technology according to this table. What are the intrinsic gains A_{45} and A_{180} of a 45nm and 180nm nFET respectively, if both are biased at $40\mu\text{A}$ (assume strong inversion (!) and that this is the drain current without channel length modulation), have a length L_{45} and L_{180} that is two times their respective minimum length and are three times as wide as long.

Note in this table $\lambda * L$ is a process specific constant, the same as the inverse of $V'_A = \frac{1}{\lambda L}$ that the book prefers.

Be careful about using all units correctly: one option is to get rid of all the micro and kilo etc. in the units by writing *1e-6 and *1e3 respectively.

Submit the result as a MATLAB script in file IntrinsicGain.m. The final result after executing the script needs to be in variables A_{45} and A_{180} respectively. To make your file readable, use '45' and '65' in your variable names if they are process specific, e.g. W_{45} and W_{180} . Use variable names that are similar to the ones used in the equations in the book.

Please upload MATLAB script in file IntrinsicGain.m with the final result in variables A_{45} and A_{180} !



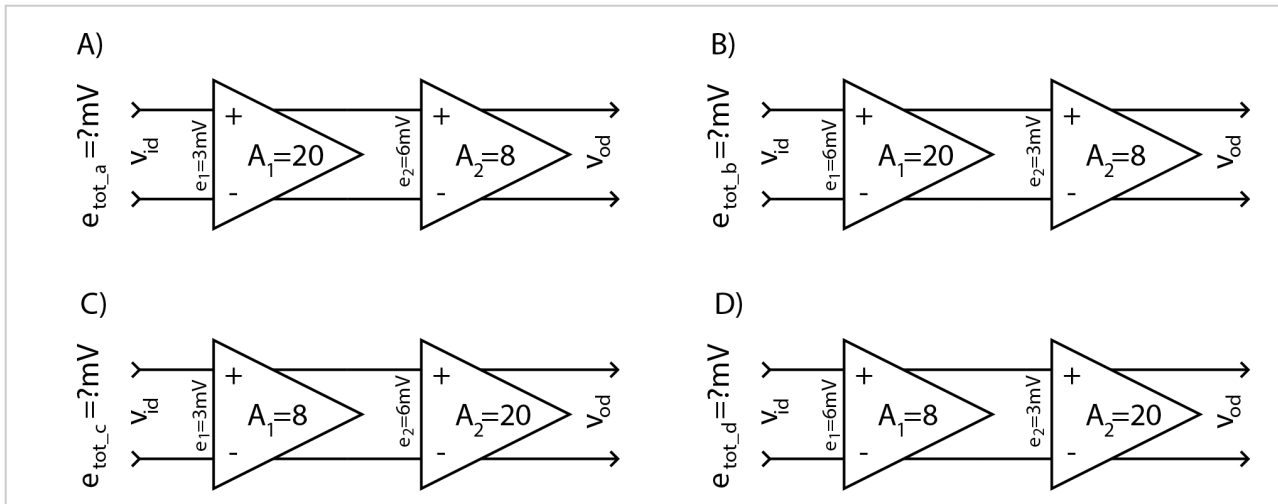
Upload your file here. Maximum one file.

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Maximum marks: 10

6 Multistage Amplifier Offset



Two differential amplifiers with gain A_1 and A_2 are used as two stages in series for getting a total gain A_{tot} that is the product of their individual gains $A_1 \cdot A_2$. However, both amplifiers have also an offset error e_1 and e_2 referred to their input, i.e. if the input difference to amplifier A_1 is $-e_1$, the output will be zero.

4 different combinations of gains and offset errors are depicted in the figure here. What is the total input referred (!) offset error for the combined amplifier stages in each case? Assign the results to variables e_{tot_a} , e_{tot_b} , e_{tot_c} , and e_{tot_d} , for subfigures A,B,C,D!

Upload a matlab script `OffsetError.m` assigning the results to variables e_{tot_a} , e_{tot_b} , e_{tot_c} , and e_{tot_d} .



Upload your file here. Maximum one file.

All file types are allowed. Maximum file size is **2 GB**

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Maximum marks: 10

7 Unity short circuit current gain

For a nFET with $k_n=400\frac{\mu\text{A}}{\text{V}^2}$ (pay attention to the 'micro' in the unit!) and threshold voltage $V_{tn}=0.5\text{V}$ biased at a current of $15\mu\text{A}$, and a $C_{gs}=10\text{fF}$ and $C_{gd}=1\text{fF}$, compute the short circuit current unity gain frequency f_T in the MATLAB script `fT.m`, i.e. it shall not be a matlab function with a function header but simply a series of matlab commands at the end of which the result shall be in variable `f_T`.

Upload MATLAB script `fT.m` which assigns final result to variable `f_T`!



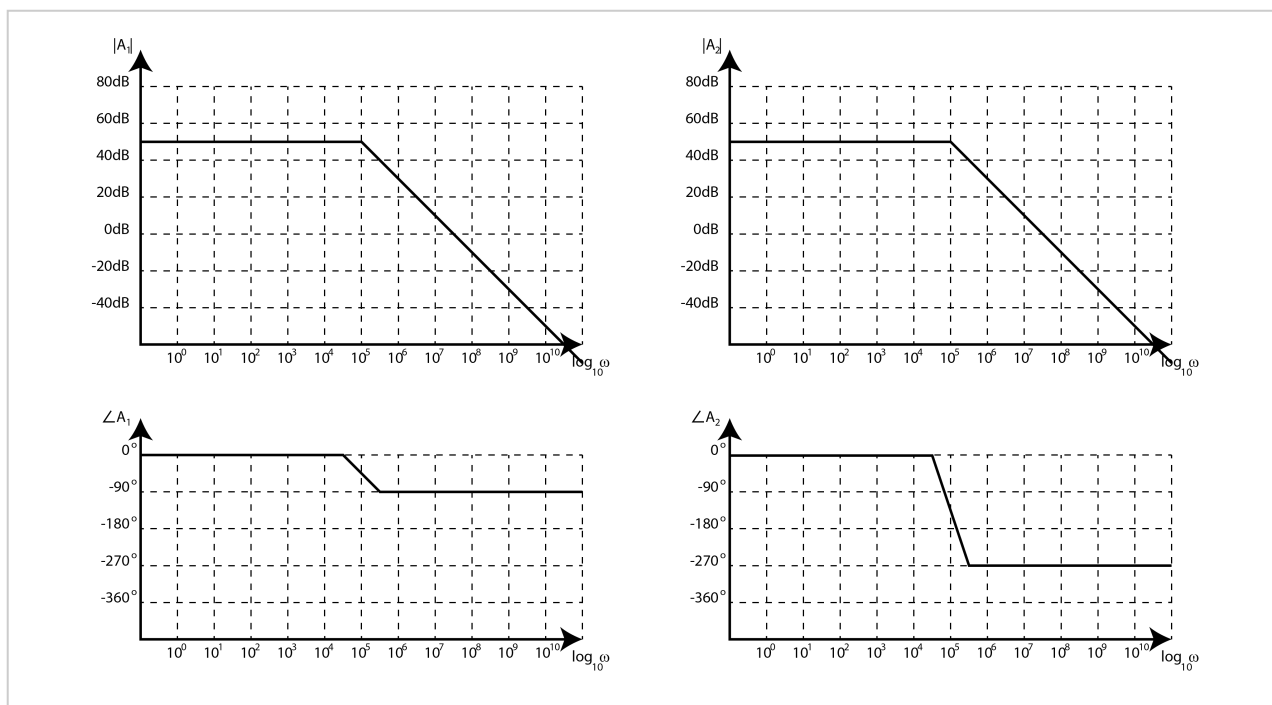
Upload your file here. Maximum one file.

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Maximum marks: 10

8 Transfer Function from Bode Plot



Consider the two Bode plots for transfer functions A_1 and A_2 . Find the corresponding transfer functions in root form and Implement the MATLAB function 'function [A1,A2]=transferF(s)' in file transferF.m which computes both transfer functions in dependency of s ($s = j * \omega$ but we shall just use the variable s here).

Upload the MATLAB function 'function [A1,A2]=transferF(s)' in file transferF.m!



Upload your file here. Maximum one file.

All file types are allowed. Maximum file size is **2 GB**

 Select file to upload

Maximum marks: 10

9 Q Factor of source follower

Find the Q-factor of a source follower as depicted in figure . Use

$$C_{gs} = 2\text{pF}, C_{gd} = 0.1\text{pF}, C_L = 1\text{pF}, g_m = 5\text{mA/V}, R'_L = 30\text{k}\Omega$$


Compute 5 results for 5 values of $R_{sig}=[200\ 500\ 5000\ 50000\ 125000]\ \Omega$ what is the Q-factor Q?

Upload MATLAB script Qfactor.m which assigns final result to variable Q where Q is a vector with 5 elements corresponding to $R_{sig}=[200\ 500\ 5000\ 50000\ 125000]!$



Upload your file here. Maximum one file.

All file types are allowed. Maximum file size is **2 GB**

 Select file to upload

Maximum marks: 10