Write your name at the top right corner of every page
(including this cover page).

Copy everything you want counted towards your grade onto the pages that I provided.

Write with a pen that cannot be erased!

No books are allowed!

Only the calculators I provided are allowed!

Write down all the steps that lead to your result.

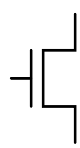
Identify new variables that you may introduce in the circuit diagrams that I provided.

Read all the problems before you start so that you can begin with those that seem easiest to you.

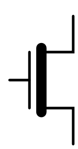
To get smooth calculations please use the following values for the magnitude forward voltage drop between base and emitter when calculating the large signal response of bias of a BJT: **0.7 V** if active, or **0.8 V** if in saturation. $V_T = 26$ mV.

MOSFET circuit symbols:

enhancement mode MOSFET



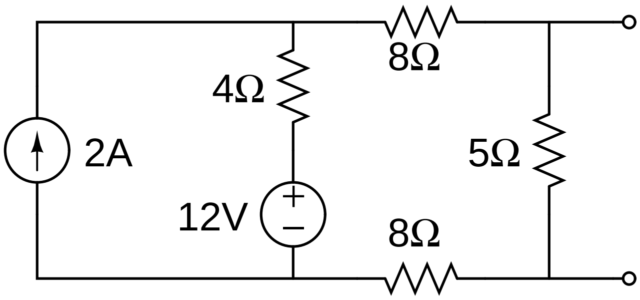
depletion mode MOSFET



Solutions

Problem 1 (6 pts):

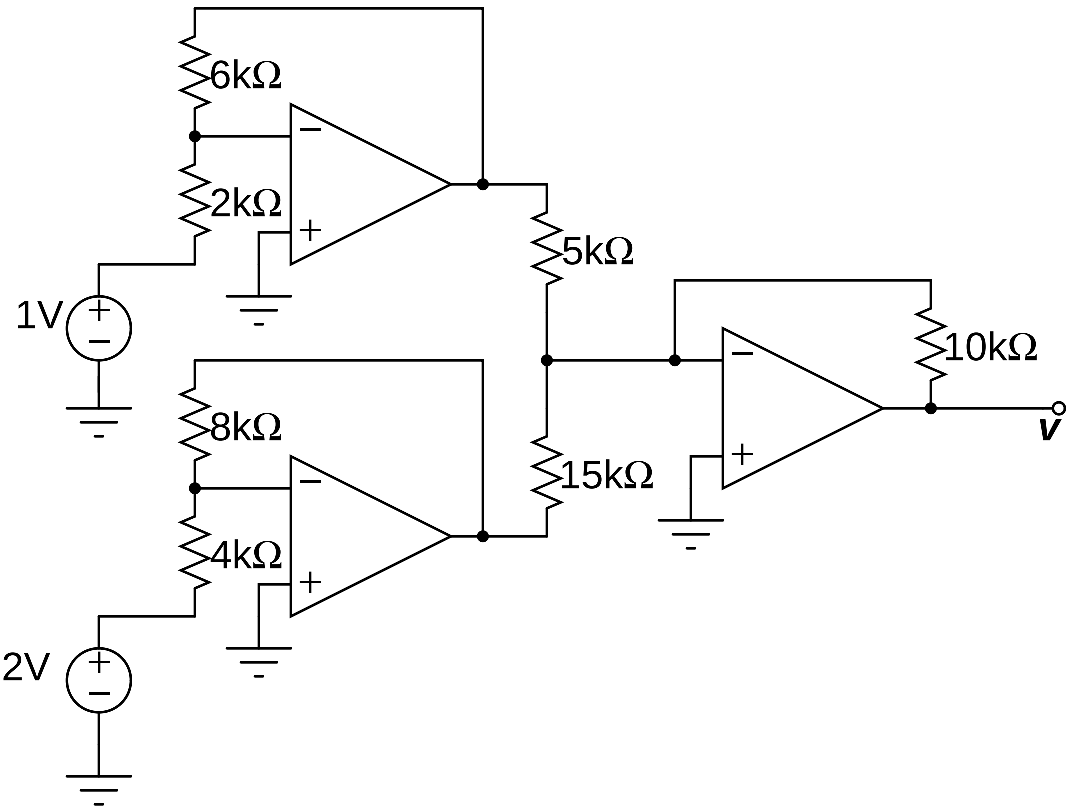
Find the Thevenin and the Norton Equivalents for the following circuit:



Solution: See review lecture: page 11ff: $R_{eq} = 4\Omega, U_T = 4V, I_N = 1A$

Problem 2 (8 pts):

What are the voltages at the three Op-Amp outputs?



Solution:

There are two inverters followed by an adding configuration. If we adopt the notation that v_1 is the upper Op-Amp's output voltage and v_2 the lower one's, the inverter outputs are:

$v_1 = -\frac{6k\Omega}{2k\Omega} 1V = -3V$

$v_2 = -\frac{8k\Omega}{4k\Omega} 2V = -4V$

With these inputs the adder will put out:

$v = -(\frac{10k\Omega}{5k\Omega} v_1 + \frac{10k\Omega}{15k\Omega} v_2) = 8\frac{2}{3}V$

Problem 3 (8 pts):

Write the Karnaugh map and analyze it to find an efficient(!) implementation for the following truth table:

A	B	C	D	F
0	0	0	0	1
0	0	0	1	0
0	0	1	0	1
0	0	1	1	0
0	1	0	0	1
0	1	0	1	1
0	1	1	0	0
0	1	1	1	0
1	0	0	0	1
1	0	0	1	0
1	0	1	0	1
1	0	1	1	0
1	1	0	0	1
1	1	0	1	1
1	1	1	0	0
1	1	1	1	0

Solution:

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

Be sure to get the order right: Only one bit changing between rows or columns!

$F = B\overline{C} + \overline{B}\,\overline{D}$

Problem 4 (7 pts):

Use only the straight-line asymptotes to sketch the Bode Plot (both, amplitude and phase!) for the transfer function:

$H(j\omega) = \frac{j\omega}{a+j\omega}$ with $a > 0$.

What type of filter is this?

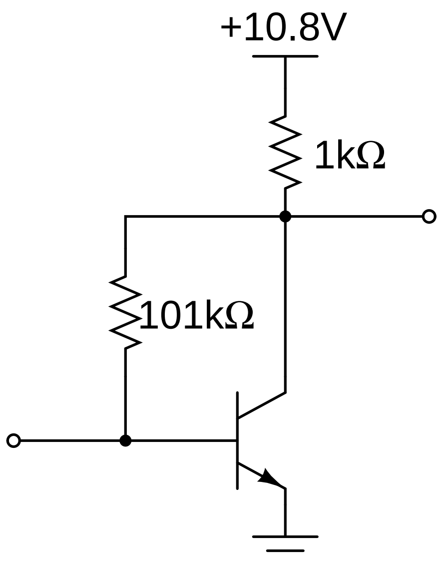
Solution: It is a high-pass filter. We express $H(j\omega)$ as the product:

$H(s) = \frac{1}{a} s \frac{a}{a+s}$

The resulting Bode Plots show a phase that drops from +90 degree up to $\omega = 0.1a$ to zero degree at $\omega = 10a$. Above $\omega = 10a$ the phase stays at zero degree. The resulting dB plot rises through -20dB at $\omega = 0.1a$ and hits 0dB at $\omega = a$. Above $\omega = a$ it stays at 0 dB.

Problem 5 (6 pts):

Below you find an example of collector feedback bias. Assuming that the transistor is operating in its active region and has $\beta = 100$, find i_B, i_C, and v_{CE}. Confirm that the transistor is in the active region.



Solution: Let us call the supply voltage V_{cc} and the two resistors R_1 and R_2, with R_1 being the resistor that is connected to V_{cc}. Then:

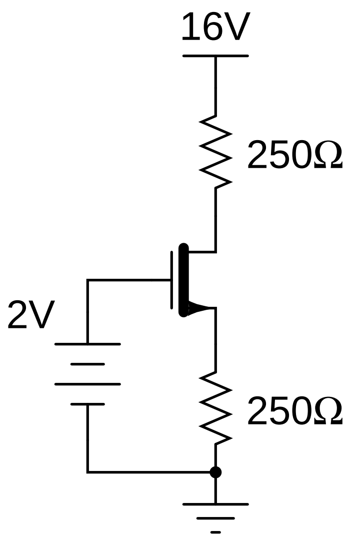
$V_{cc} = R_1(i_B + i_C) + R_2 i_B + V_{BE} = R_1(101 i_B) + R_2 i_B + 0.7\text{V}$

$\Rightarrow i_B = \frac{V_{cc} - 0.7\text{V}}{101 R_1 + R_2} = 50\mu\text{A} \Rightarrow i_C = 5\text{mA}$

$V_{CE} = V_{cc} - R_1(i_B + i_C)$ = 10.8V - 5.05V = 5.75V, which also proves that the transistor is in the active region.

Problem 6 (6 pts):

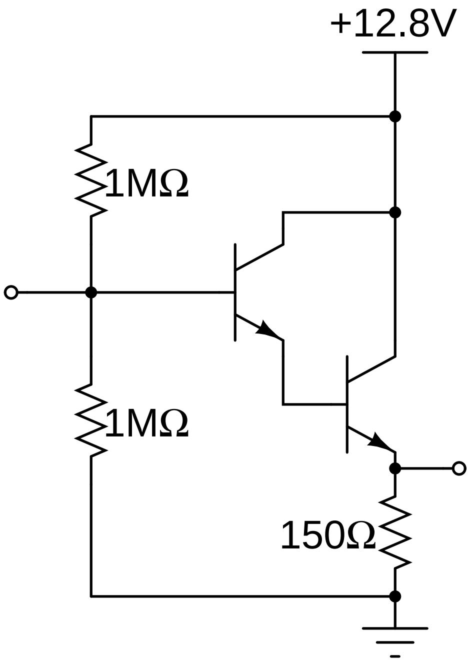
In the depletion-MOSFET circuit shown below the MOSFET has $I_{DSS} = 8mA$ and $V_p = -2V$. Find V_{GS}, i_D, V_{DS}, and confirm that the MOSFET is operated in the active region.



Solution: $i_D = (-V_{GS} + 2)/250 = 8m(1 + V_{GS}/2)^2 \Rightarrow V_{GS}^2 + 6V_{GS} = 0 \Rightarrow V_{GS} = 0(-6V < V_p)$
$V_{GS} = 0 \Rightarrow i_D = I_{DSS} = 8mA$
$V_{DS} = 16 - 2(250 i_D) = 12V \Rightarrow V_{DS} > V_{GS} - V_p = 2V$, i.e. active region okay.

Problem 7 ONLY 6610 students !!! (8 pts):

For the Darlington configuration below, find i_{B1}, if the transistors both have $\beta = 99$. i_{B1} is the base current into the first transistor. The first transistor is the one that has the second transistor's base connected to its emitter.



Solution: Let us call the two 1MΩ resistors R_1 and the 150Ω resistor R_2. The supply voltage shall be called V_{cc}. If i_1 is the current through the upper R_1 and i_2 the one through the lower R_1, then:

$i_1 = i_2 + i_{B1}$ and $V_{cc} = R_1(i_1 + i_2) = R_1(2i_1 - i_{B1}) \Rightarrow i_1 = \frac{1}{2}(\frac{V_{cc}}{R_1} + i_{B1})$

also: $i_{E2} = i_{B2} + i_{C2} = i_{B2} + \beta i_{B2} = (\beta + 1)(i_{B1} + i_{C2}) = (\beta + 1)^2 i_{B1}$

$V_{cc} = i_1 R_1 + 0.7\mathrm{V} + 0.7\mathrm{V} + \mathrm{R_2 i_{E2}}$
$\Rightarrow i_{B1}(R_1/2 + R_2(\beta + 1)^2) = V_{cc}/2 - 1.4\mathrm{V} \Rightarrow \mathrm{i_{B1}} = 2.5\mu\mathrm{A}$