University POLITEHNICA of Bucharest
Faculty of Electronics, Telecommunications and Information Technology

Project 1

Negative Voltage Regulator

Student: Vlad-Stefan Moreanu

Coordinators: Laurentiu Teodorescu
Cristina-Ioana Marghescu

Group: 431G

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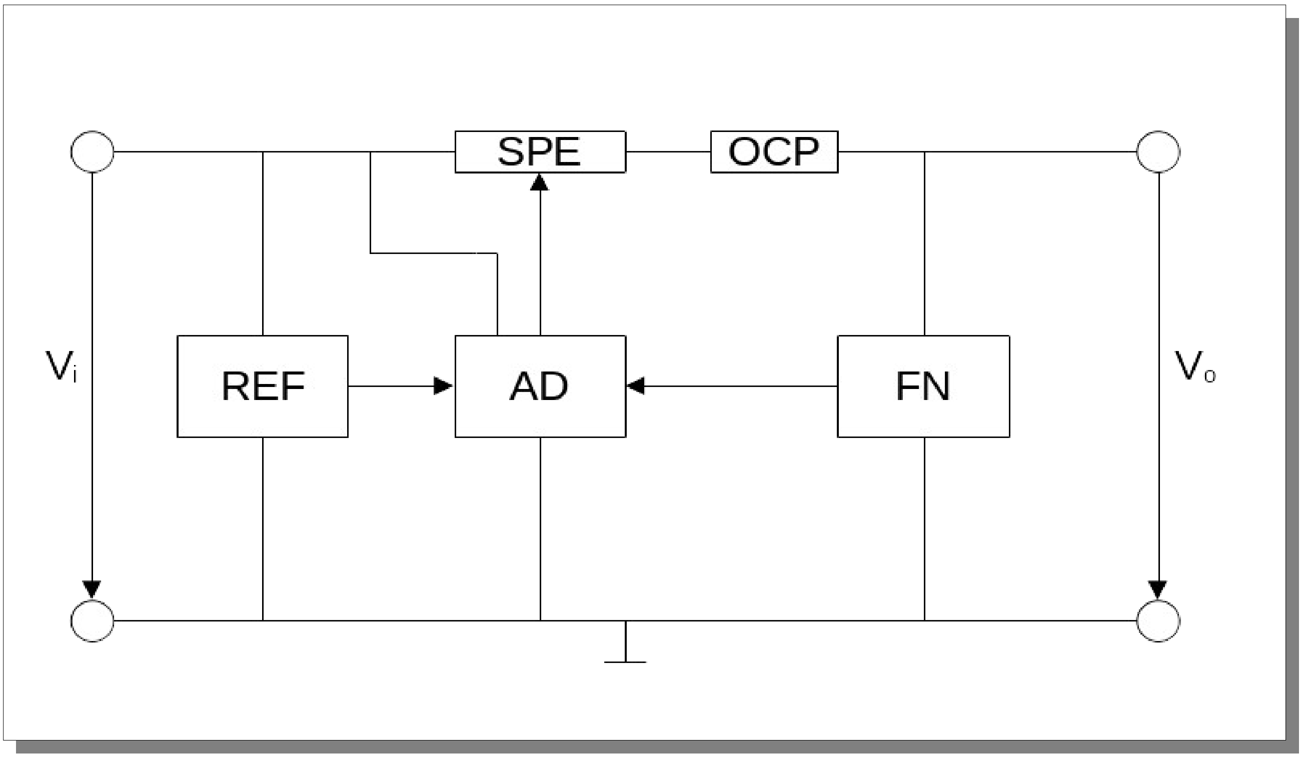
Project requirements

Design a negative linear voltage regulator with discrete components, with the following parameters:

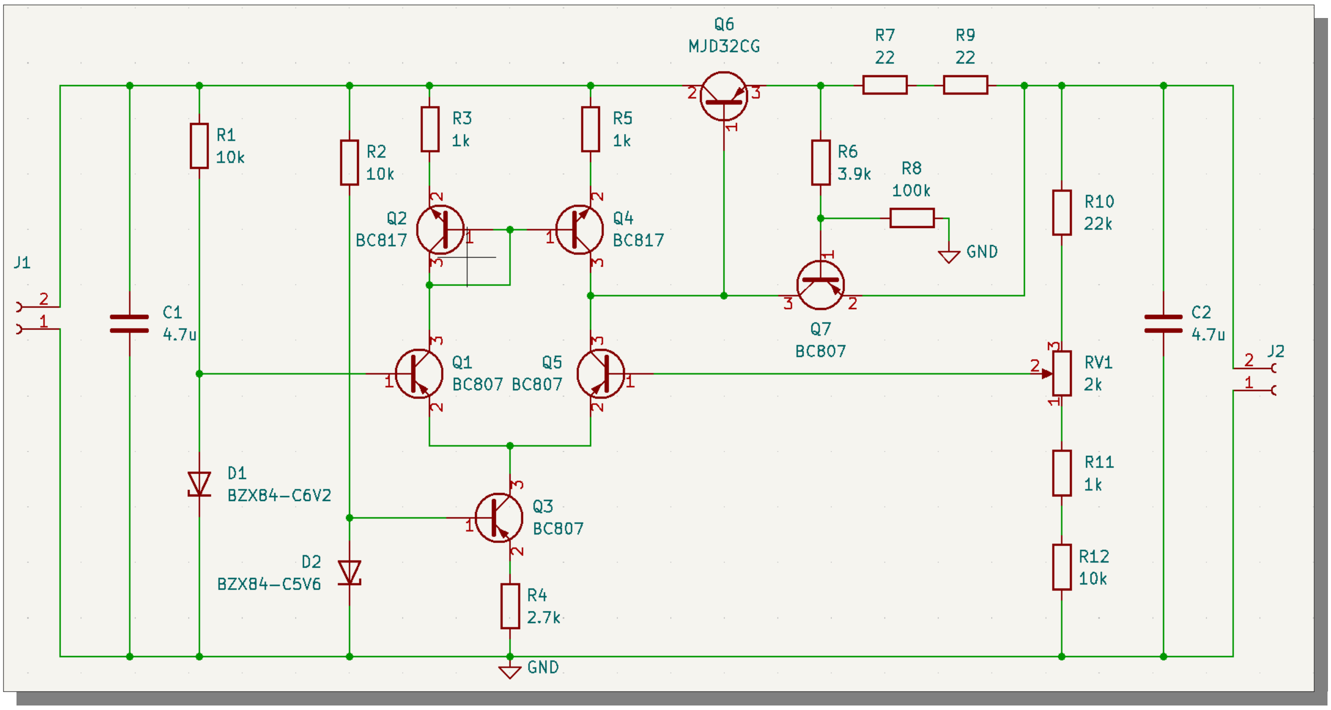
- Negative supply voltage between -27V and -23V
- Negative programmable output voltage between -19V and -17V
- The output current through the load between 0mA and 32mA
- Short circuit protection of the output terminals with foldback current limiting circuit
- $S = \frac{\Delta V_i}{\Delta V_o}\Big|_{RL} \geq 56$
- The output impedance of the regulator $R_o \leq 2\Omega$
- Minimum load value (with knee current set by OCP, see pg6): $R_L = \frac{max|Vout|}{max|Iout|} = \frac{19\,V}{31\,mA} \approx 613\,\Omega$

The block diagram of the circuit



SPE = Series Pass Element
REF = Voltage Reference
AD = Differential Amplifier/Error Amplifier
OCP = Overcurrent protection
FN = Resistive Feedback circuit

Project Schematic



The Voltage Reference

For the voltage reference we consider the current drawn by the amplifier to be negligable. The value R will be approximated to $10\,k\Omega$ and implemented using *SMD0805-10K-1%*

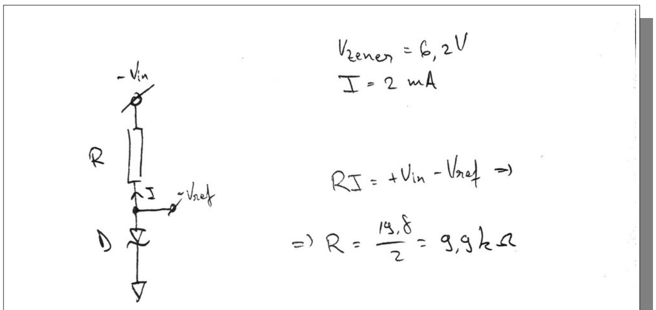


Fig. 1: Voltage Reference

The Overcurrent Protection

For the OCP, the value of R3 will be obtained using the series connection of two *SMD0805-22R-1%* resistors; R1 will be approximated with *SMD0805-3K9-1%*; and R2 will be *SMD0805-100K-1%*.

Recalculating the value of the knee current given the chosen values of R1, R2 and R3 we will obtain $I_K \approx 31\,mA$ which is less than the maximum required current, so the minimum value of the load for which the circuit functions normally is

$$R_L = \frac{19\,V}{31\,mA} \approx 613\,\Omega$$

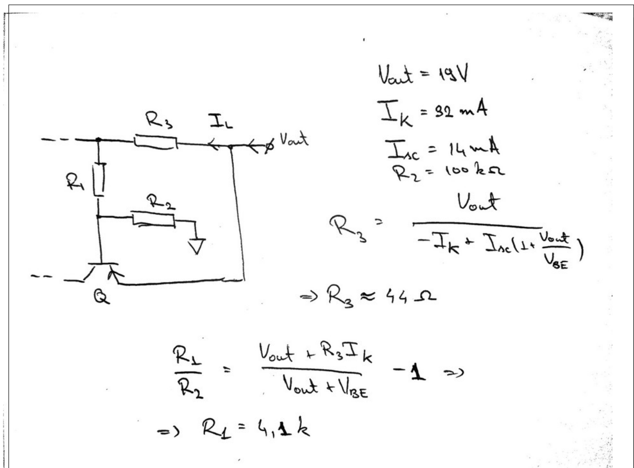


Fig. 2: Overcurrent Protection

The Feedback Network

The feedback network is created using a voltage divider consisting of resistors and a potentiometer. *Rp* is modelled in the LTSpice schematic using POT0 (modelling $p \cdot R_p$) and POT1 (modelling $(1-p) \cdot R_p$)

Rp is selected to be *TS53YL202MR10*; R1 will be approximated to $22\,k\Omega$ and *SMD0805-22K-1%* will be chosen; R2 will be made up of the series connection of resistors *SMD0805-10K-1%* and *SMD0805-1K-1%*.

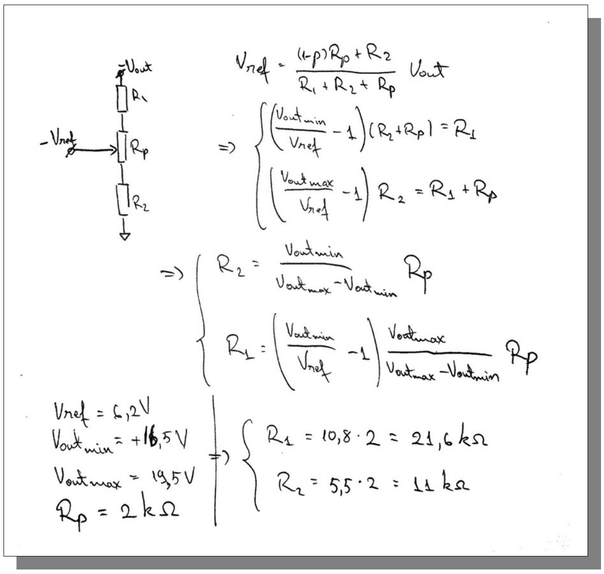


Fig. 3: Feedback Network

The Error Amplifier

The error amplifier is a basic differential amplifier. Q3 and Q4 for the differential pair, Q1 and Q2 form a current mirror and Q5 and D1 form a current source.

R1 will be approximately $10\,k\Omega$ and will be implemented using *SMD0805-10K-1%*; R2 will be approximated to $2.7\,k\Omega$ and implemented *SMD0805-2K7-1%* ; R3 and R4 will be two *SMD0805-1K-1%*.

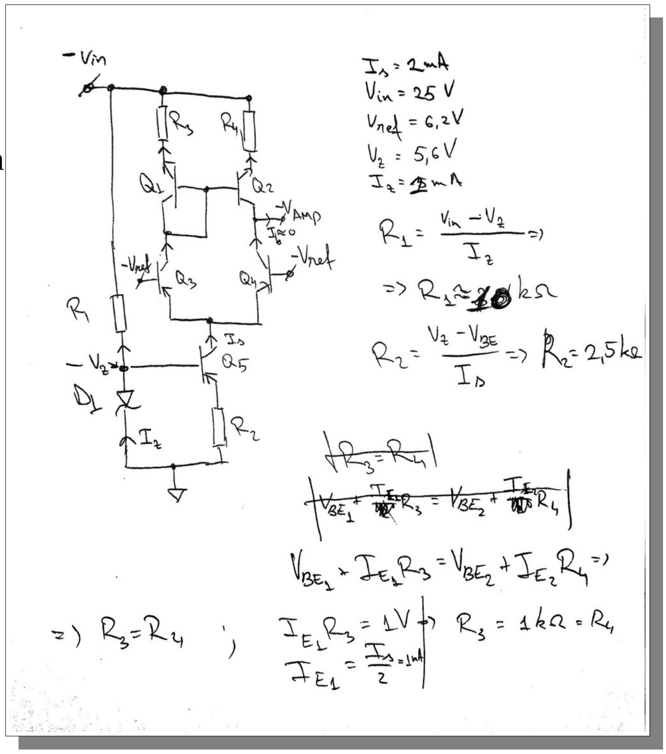
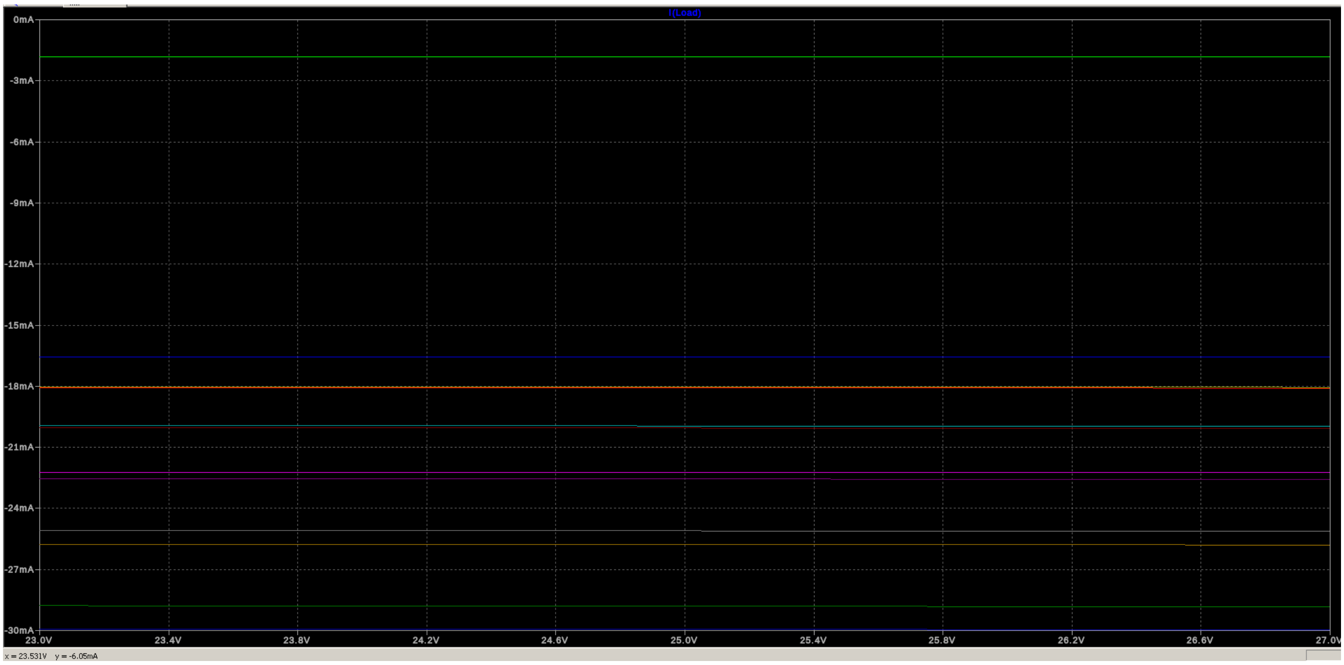


Fig. 4: Error Amplifier

SPICE simulations of the designed circuit

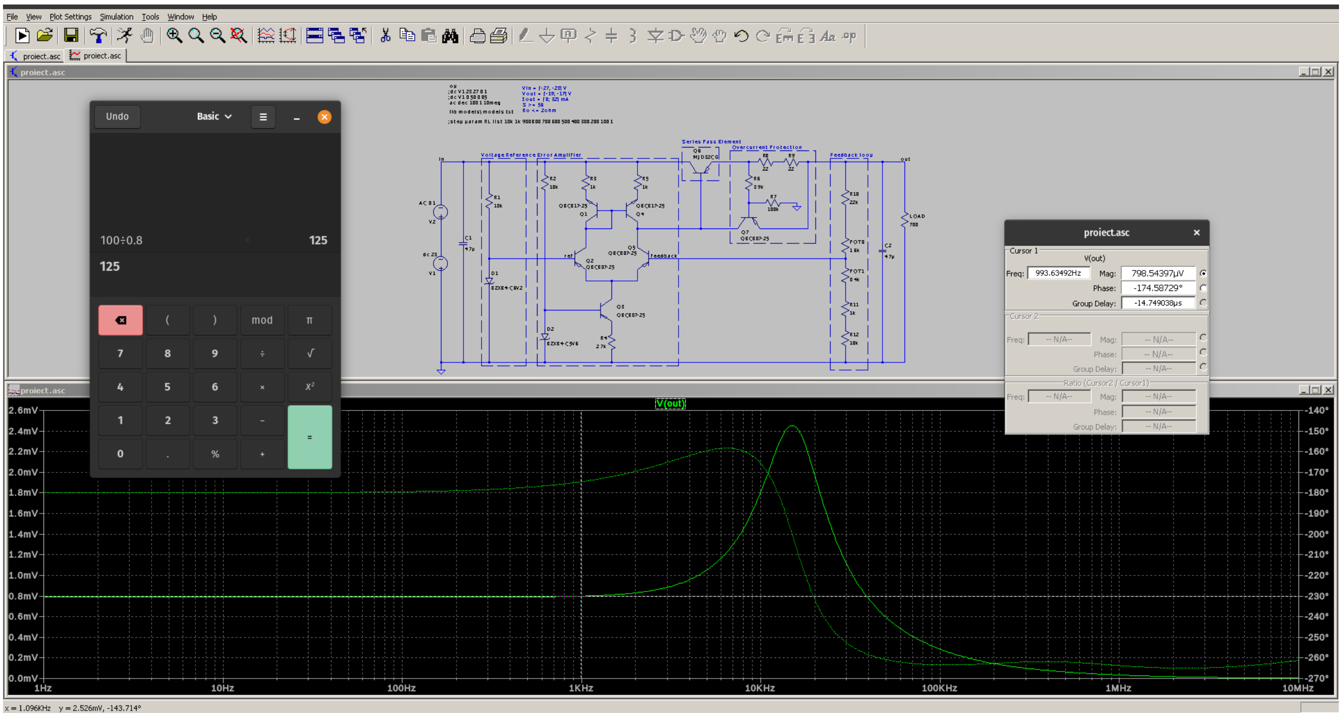
Overcurrent Protection

Running a DC sweep across the range of the supply voltage, using a parameter list for the value of the load, we obtain the following figure, representing the different possible currents flowing through the load. We can observe that they are all in the required range.



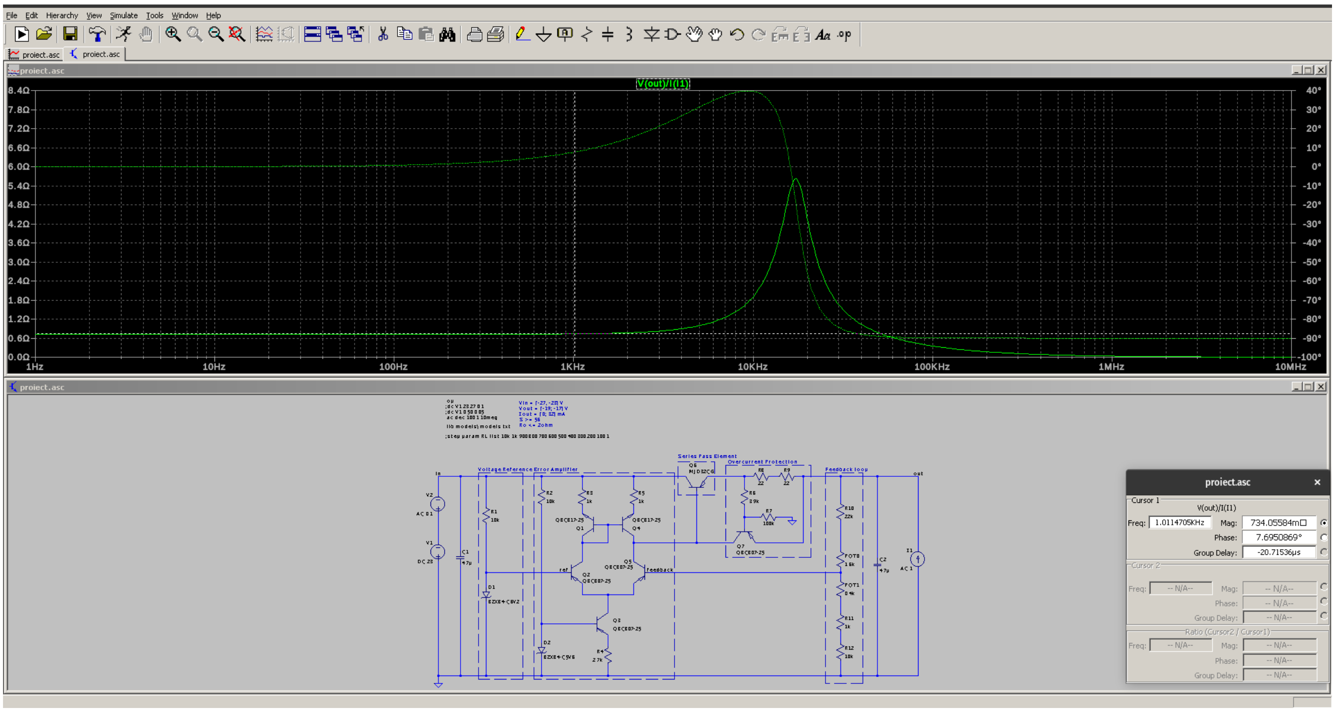
Simulation of S:

Using an AC voltage source set at 100mV we can simulate the noise of a DC voltage source. Measuring the output voltage at 1kHz then dividing the input variation by it, we can obtain a value for our circuits stability. We can observe that the simulated value for the worst case scenario is larger than the required value.

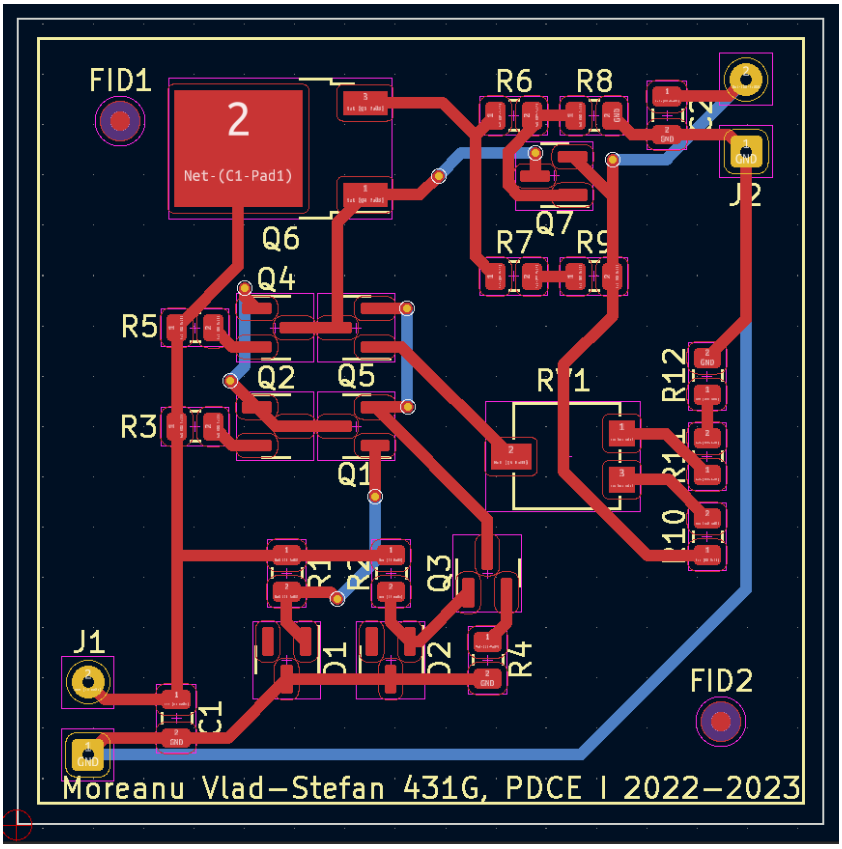


Simulation of Rout

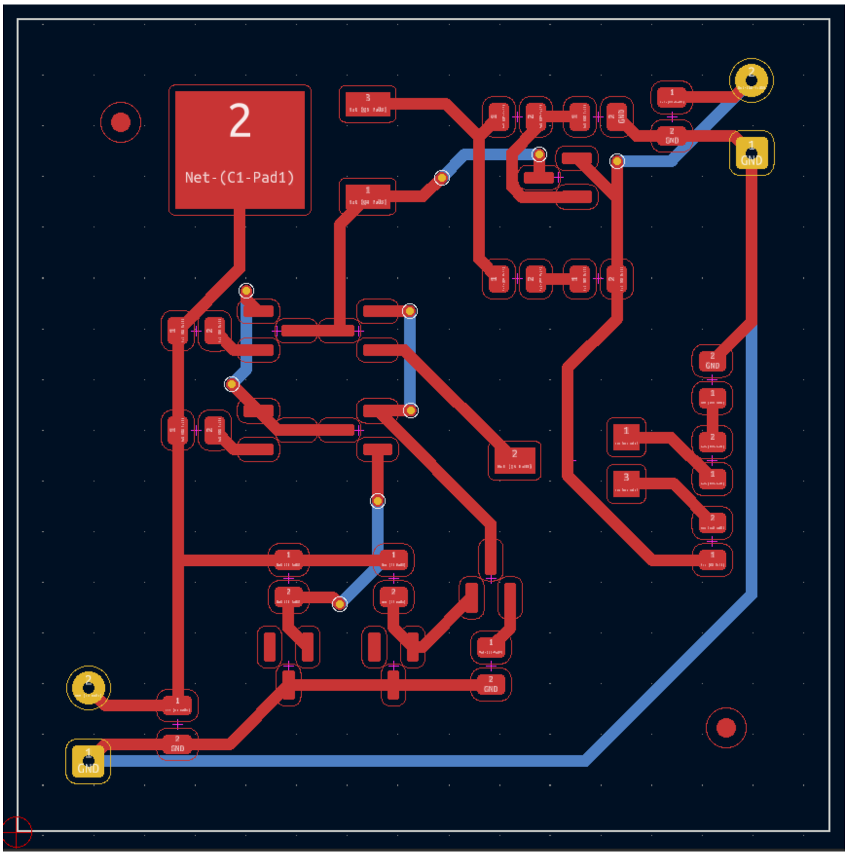
For this simulation we replace the load with an ideal current source. The output resistance of the circuit will be the output voltage divided by current given by the source. The resulting resistance value for the worst case scenario is approximately 735mOhms, less than the maximum required value.



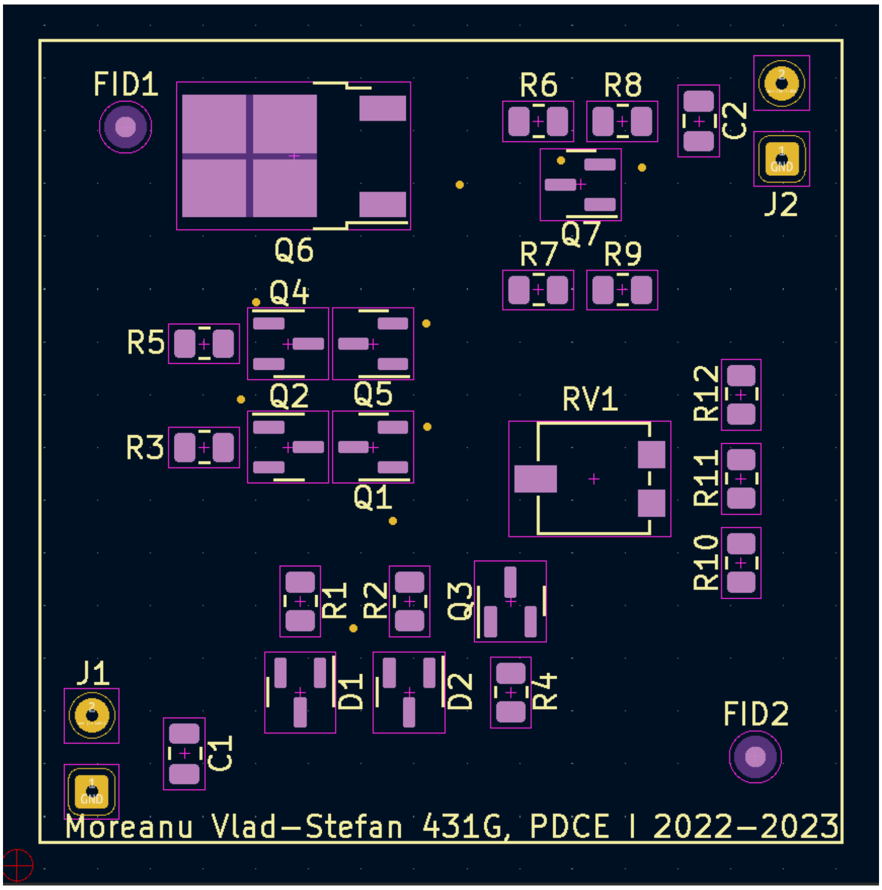
PCB Layout and tracks



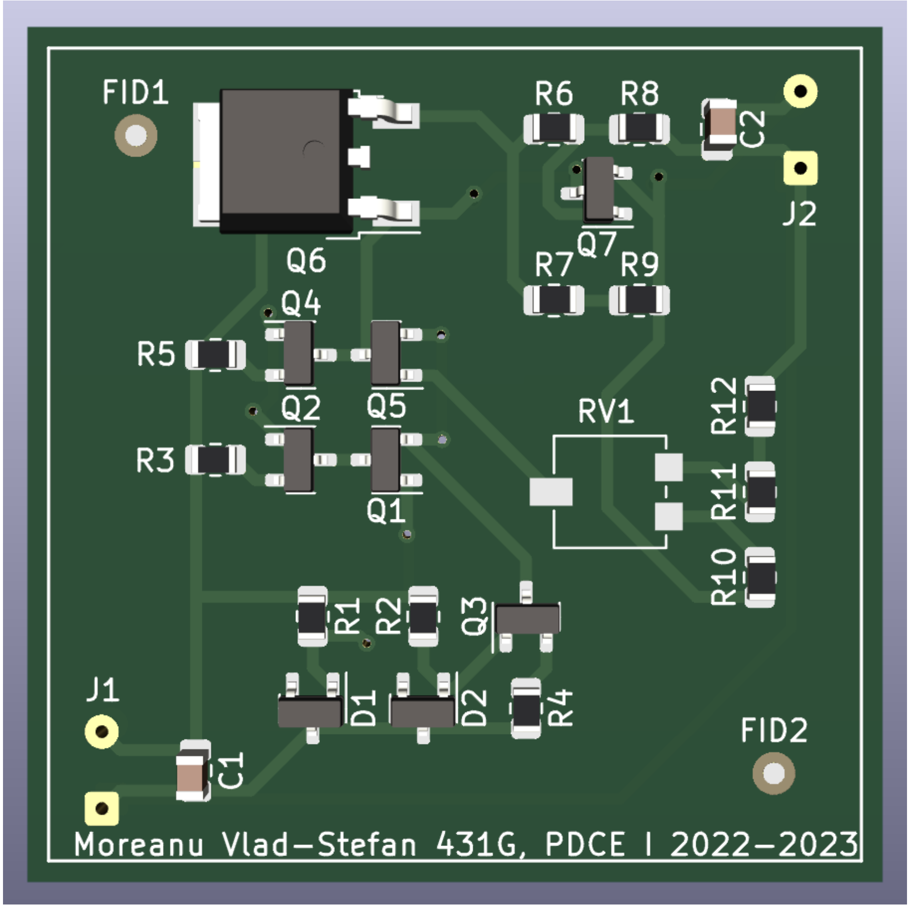
PCB Copper Layers



PCB Non-Copper Layers



3D Render of Circuit



Comments/Conclusions

It certainly was a project.

References

Datasheets:

https://www.tme.eu/Document/17496f94aed149a6280f8105698167e8/BZX84_SER.pdf
https://www.tme.eu/Document/a0b32af64c8f47be8306348e50e9ccfd/bc807.pdf
https://www.tme.eu/Document/14812c55f027a72a258137f891a70f6c/bc817.pdf
https://www.tme.eu/Document/4b521f5243f7531696a0dc4af2c14260/MJD31_MJD32.pdf

Course notes:

https://archive.curs.upb.ro/2021/course/view.php?id=8995#section-5

Seminar notes:

https://archive.curs.upb.ro/2021/pluginfile.php/185483/course/section/175623/LR12%2BSolution.pdf
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