Hardware design of MIMO low noise amplifier with variable gain

[700.608]INTERNET OF THINGS AND SMART BUILDINGS

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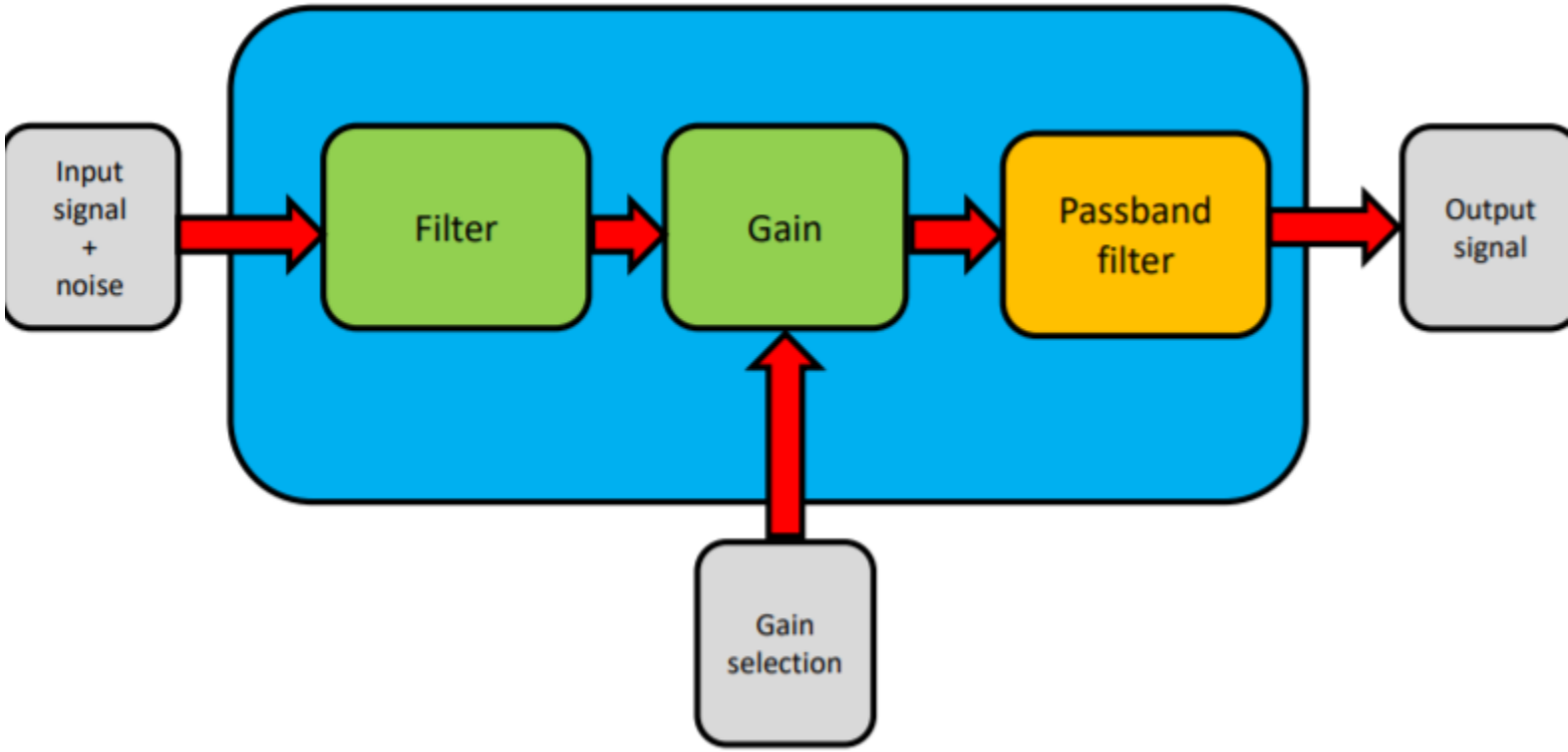
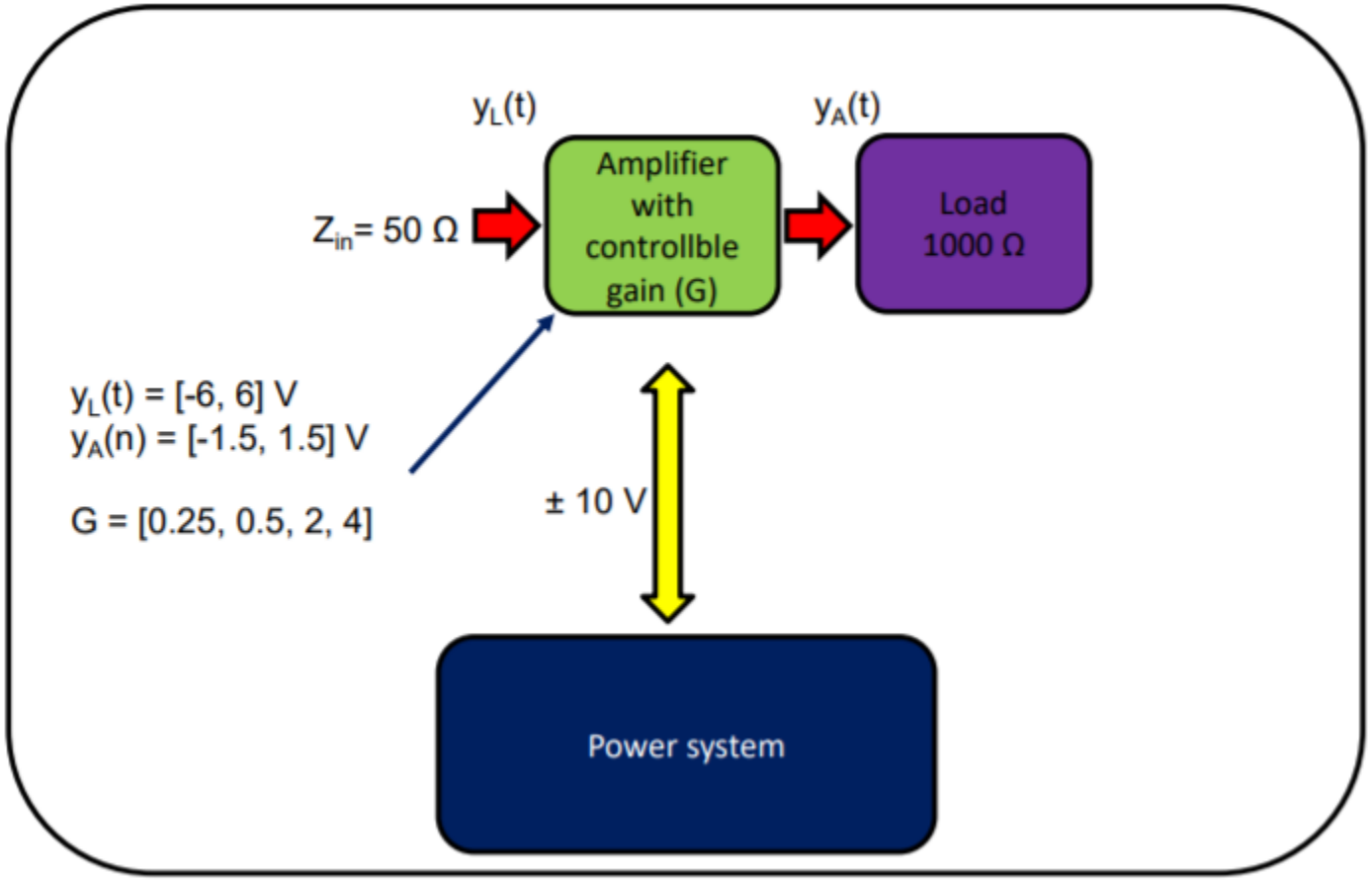
Project requirements

- Functions and characteristics of the circuit:
  - Signal acquired from antennas or other transmission medium may have very low voltage levels.
  - Amplifiers are needed to condition the signals to be read and digitalized.
  - MIMO low noise amplifier (LNA) 2x2 (2 inputs and 2 outputs).
  - Variable and programmable gain



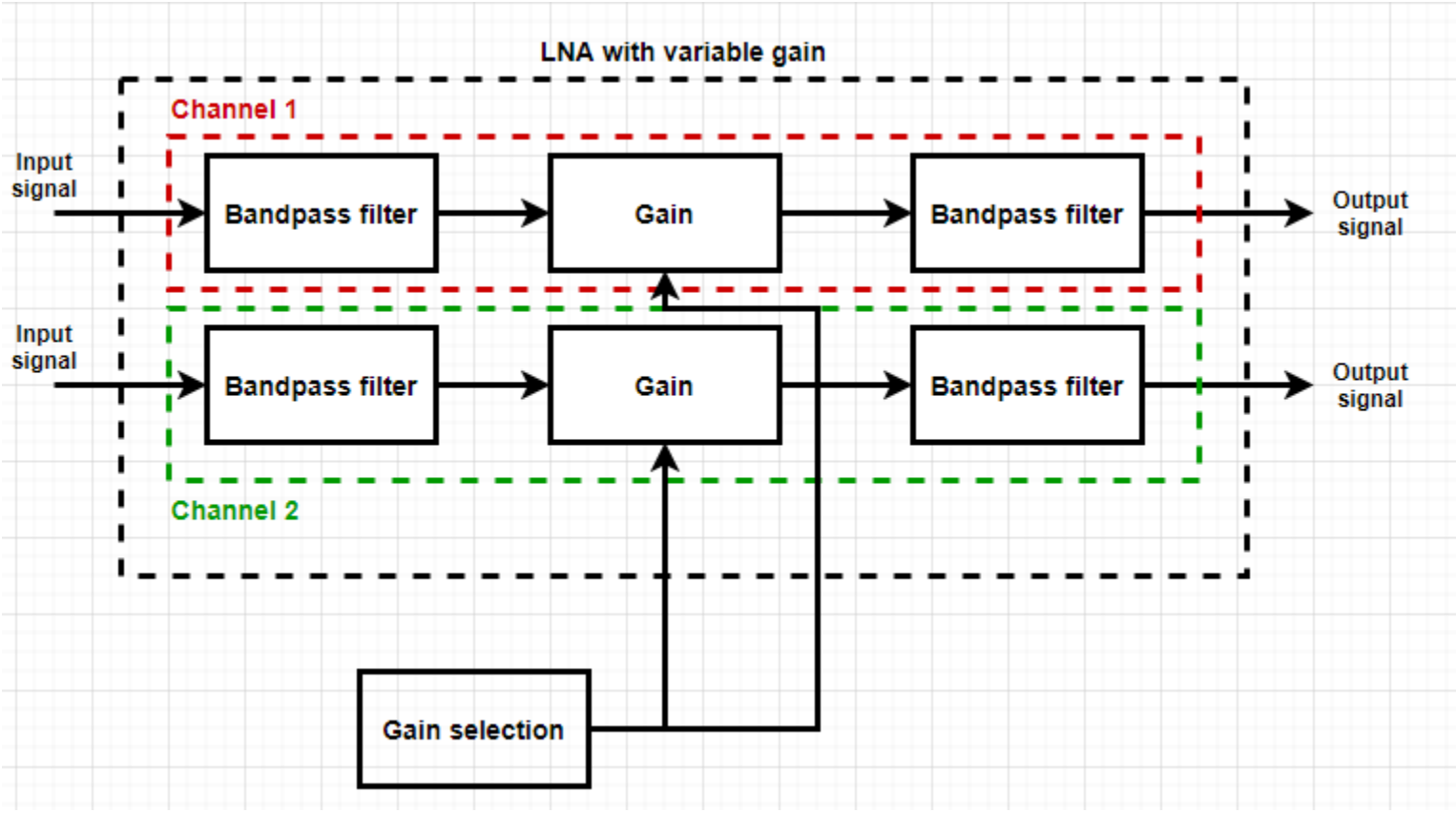
Project requirements (2)

- Final project requirements had a specific input and output limits, that were larger compared to the initial ones.
- The input signal should be [-6, 6] V.
- The output signal should be [-1.5, 1.5] V.
- The gains of the amplifier are defined as [0.25, 0.5, 2, 4].



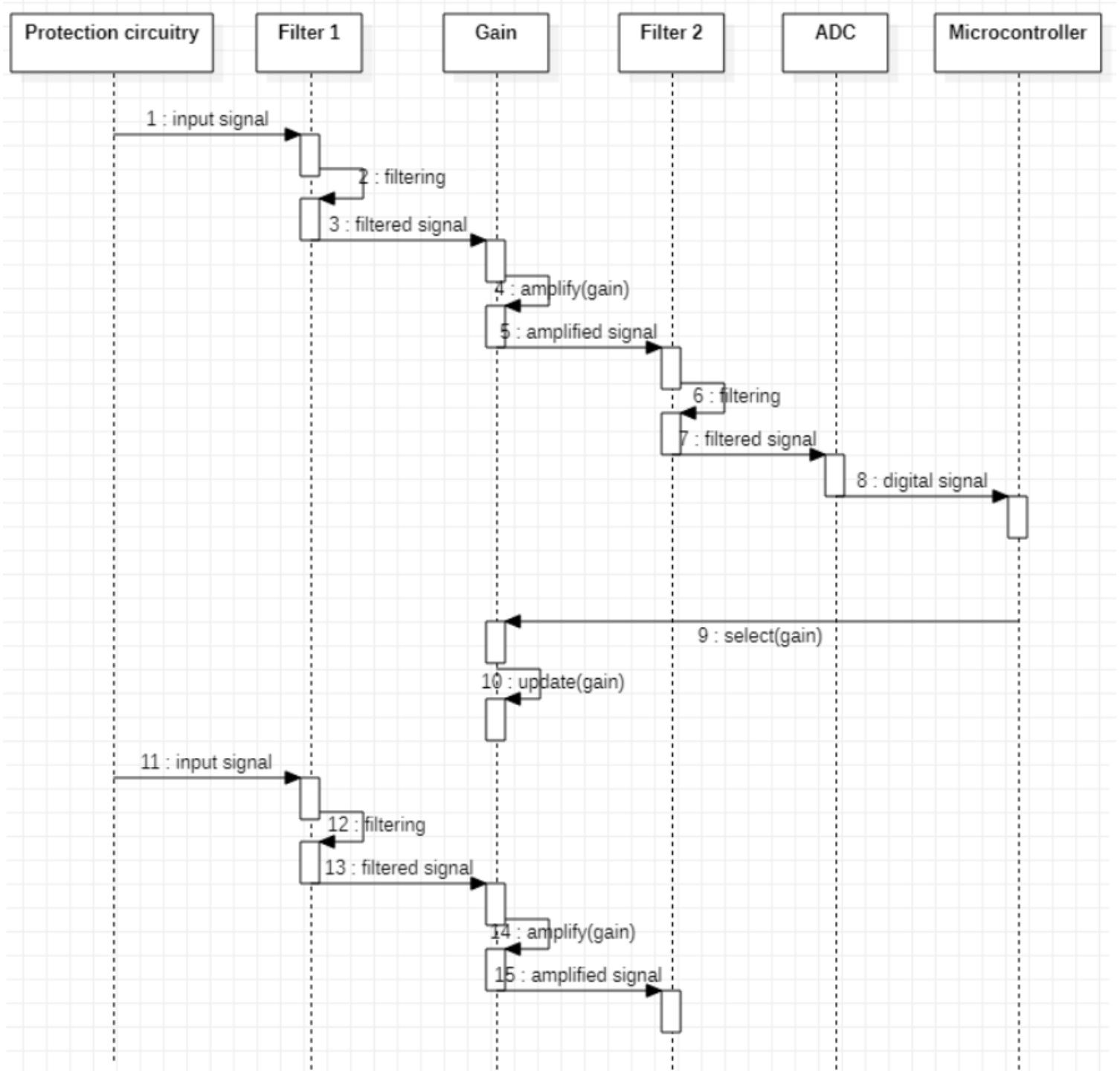
Block diagram of the system

- MIMO amplifier for two separate signals
- Both filter should be Bandpass filter
- Gain should be selected from the microprocessor



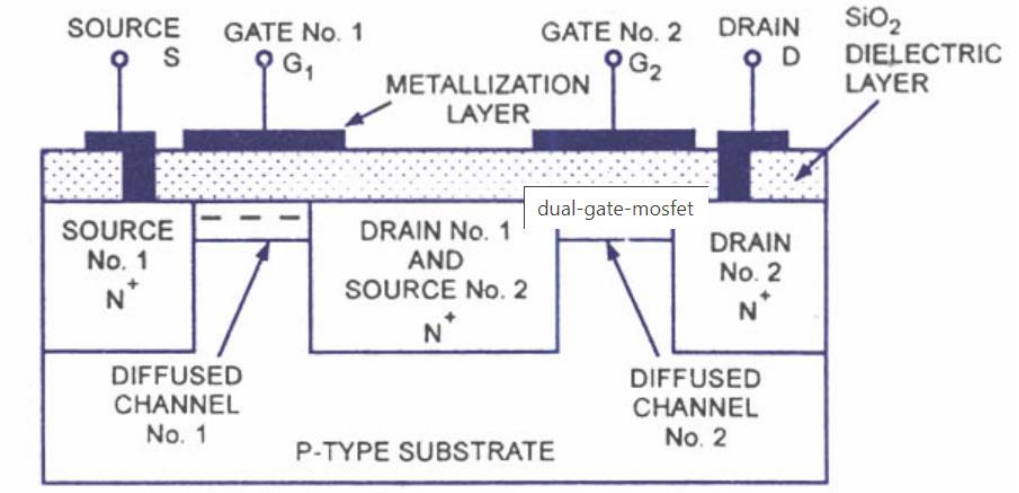
UML Diagram

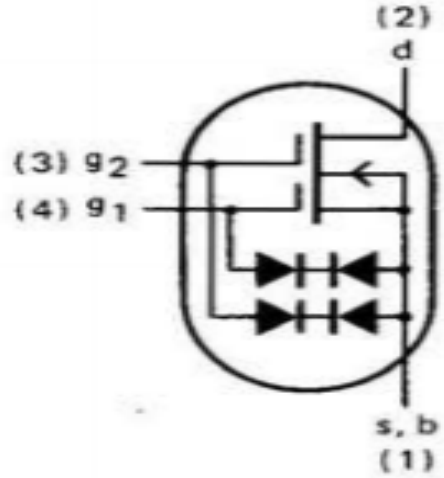
Sequence diagram of the system



Implementation-Dual gate MOSFET

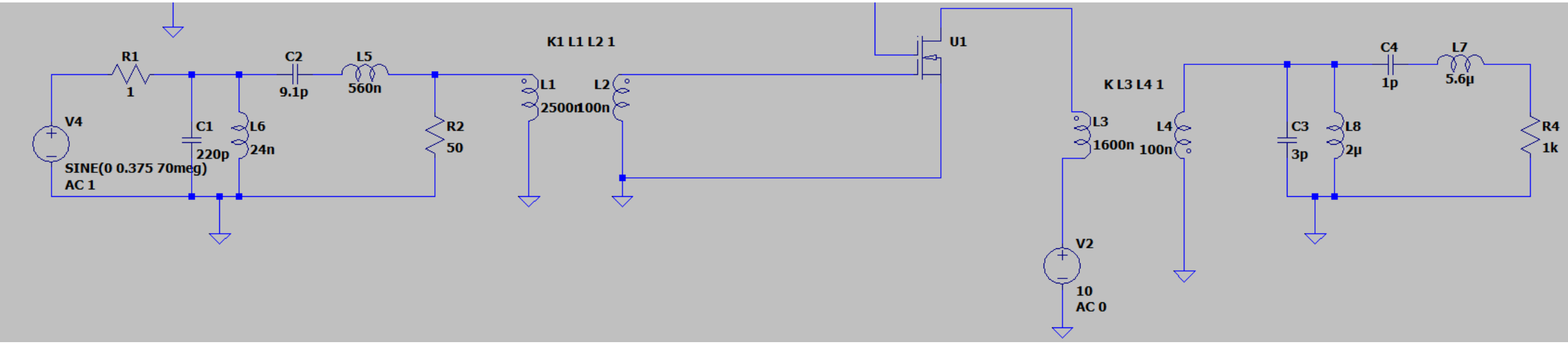
- It operates as if two FETS are connected in series.
- The dual gate MOSFET can be used in a number of applications including RF mixers /multipliers, RF amplifiers, amplifiers with gain control.
- Another circuit will be provided on the second gate to control the gain.
- In our schematics the BF981 n-channel dual gate MOSFET was used.





Schematic of the system

- Transformers were used for the impedance matching in the schematics.
- Numbers had to be adjusted for the higher input voltages, to meet the requirements.
- Two bandpass filters were added on the input and the output of the system, with central frequency 70MHz.



Variable gain circuit

- Depending on the bits that are sent from the microcontroller to adjust the gain of the amplifier, we need to secure the various voltage levels for the Gate 2 of the transistor.
- The idea: to use demultiplexer which will use the bits from the microcontroller as selector signals and constant voltage level of 5V as an input.
- The outputs of the demultiplexer will be used to obtain various voltage levels.

Variable gain circuit

- We used 1x4 demultiplexer
- E = 5V
- S1 and S2 – selector signals from microcontroller
- Y1, Y2, Y3, Y4 – output signals

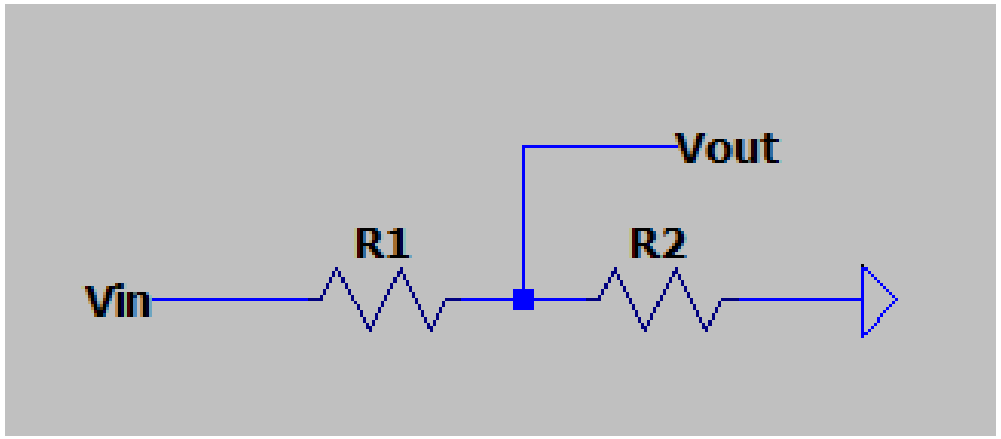
- We defined:
  - 00 – 0.85V (gain = 0.25)
  - 01 – 1.27V (gain = 0.5)
  - 10 – 8V (gain = 2)
  - 11 – 11V (gain = 4)

1x4 demux truth table

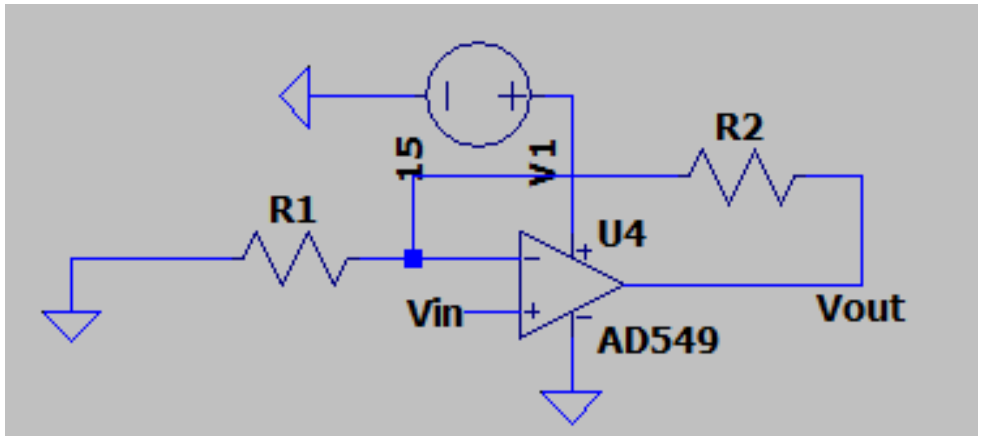
E	S1	S2	Y1	Y2	Y3	Y4
E	0	0	E	0	0	0
E	0	1	0	E	0	0
E	1	0	0	0	E	0
E	1	1	0	0	0	E

Variable gain circuit (2)

- For the first two gains, the voltage dividers were used to ensure the proper voltage level of the second gate, V_{G2S} .
- Due to the fact that for the remaining gains higher voltage levels are needed, a voltage amplifier was added to the circuit.

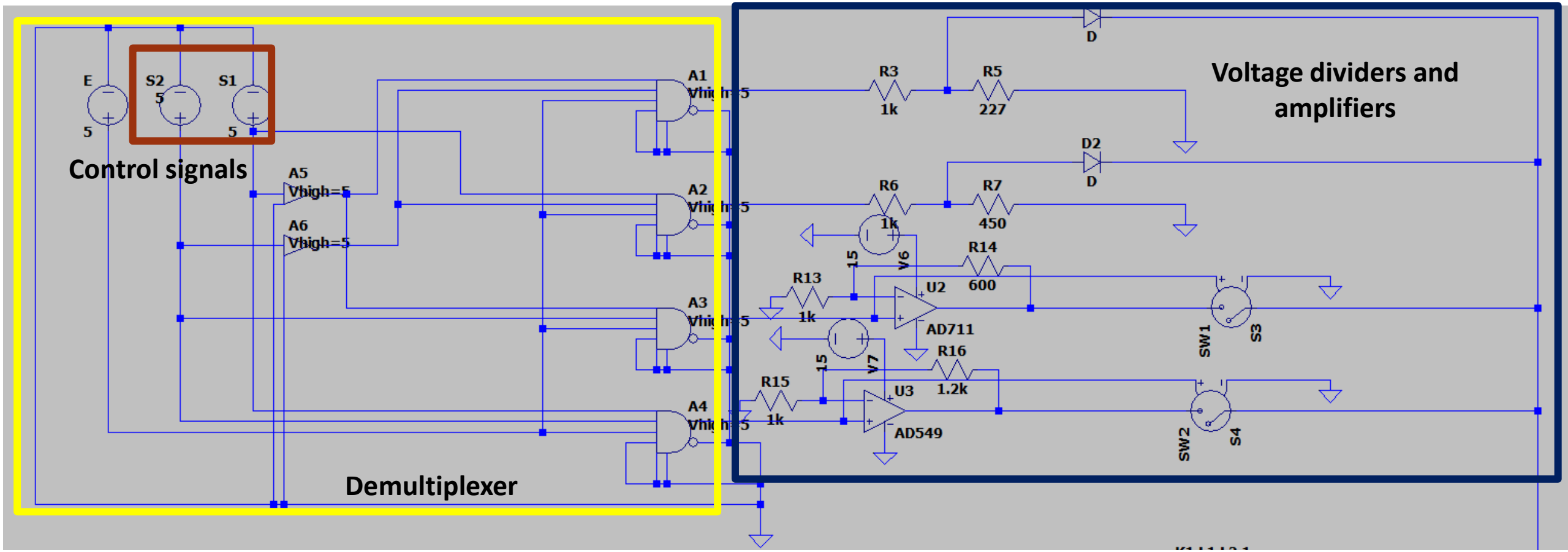


$$R_2 = R_1 \frac{V_{out}}{V_{in} - V_{out}}$$

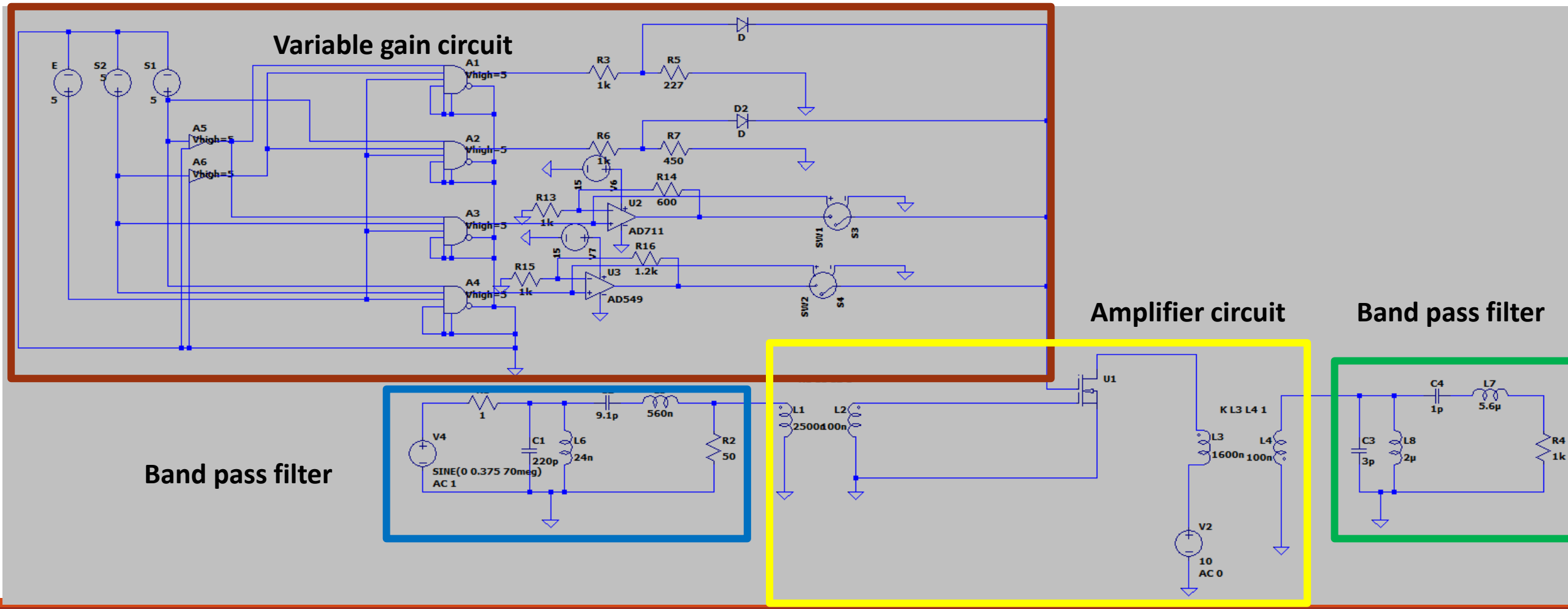


$$V_{out} = V_{in}\left(1 + \frac{R_2}{R_1}\right)$$

Variable gain schematic

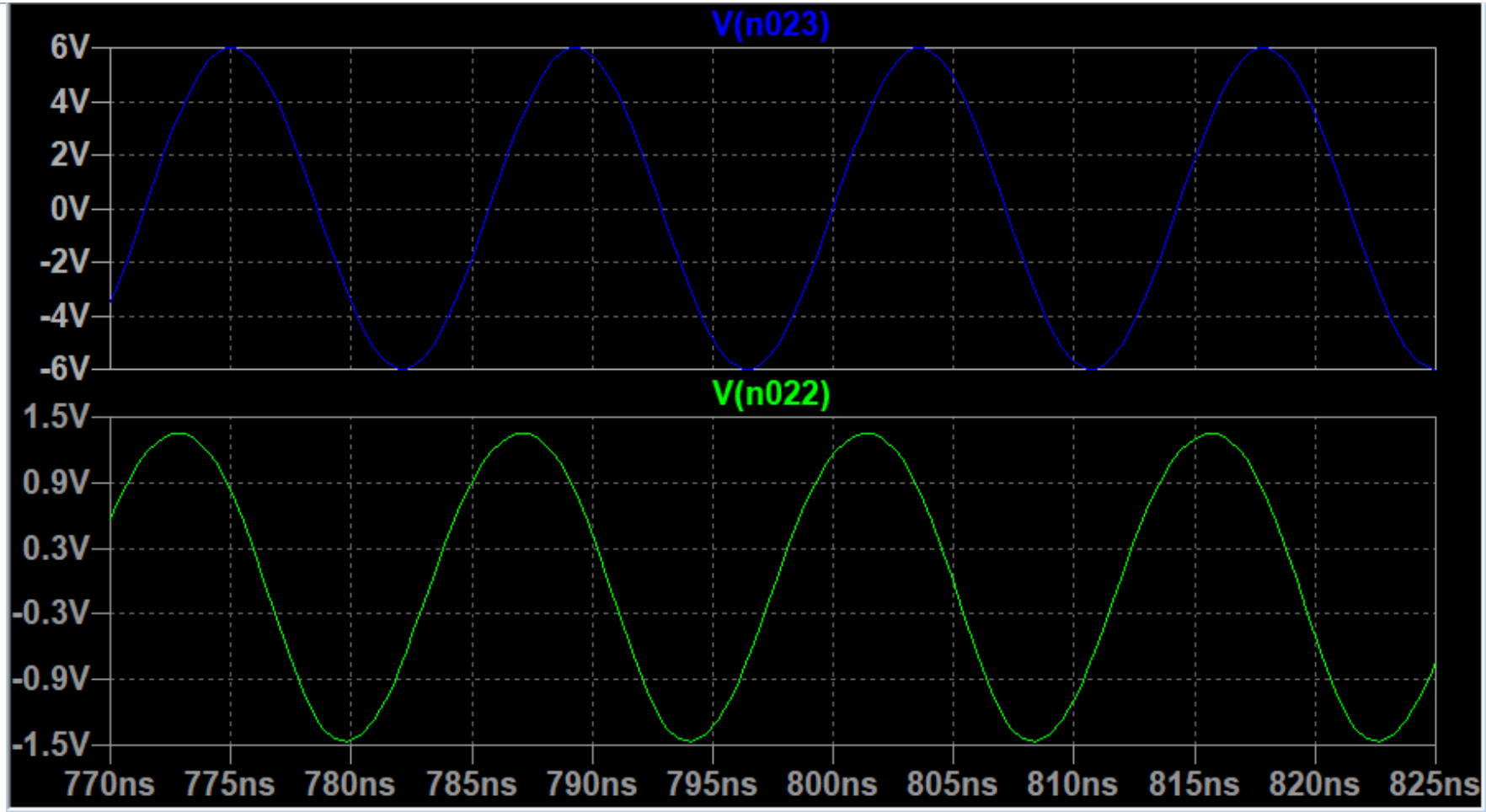


Schematic of the system



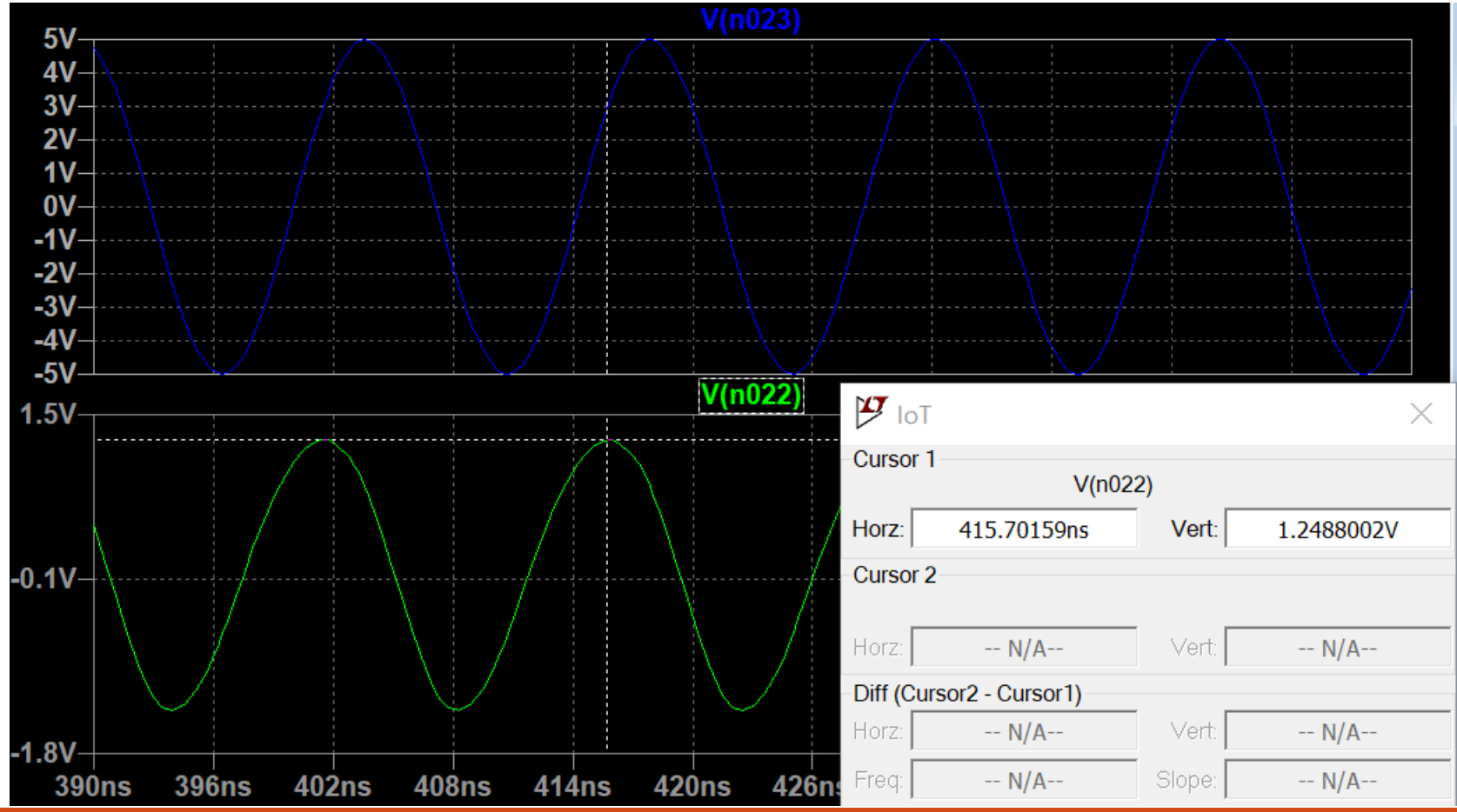
Simulation

- The input signal of the system has the amplitude of 6 V.
- The selected gain is 0.25, to ensure 1.5 V at the output.
- This is the maximum input voltage and the maximum output voltage must be ensured.



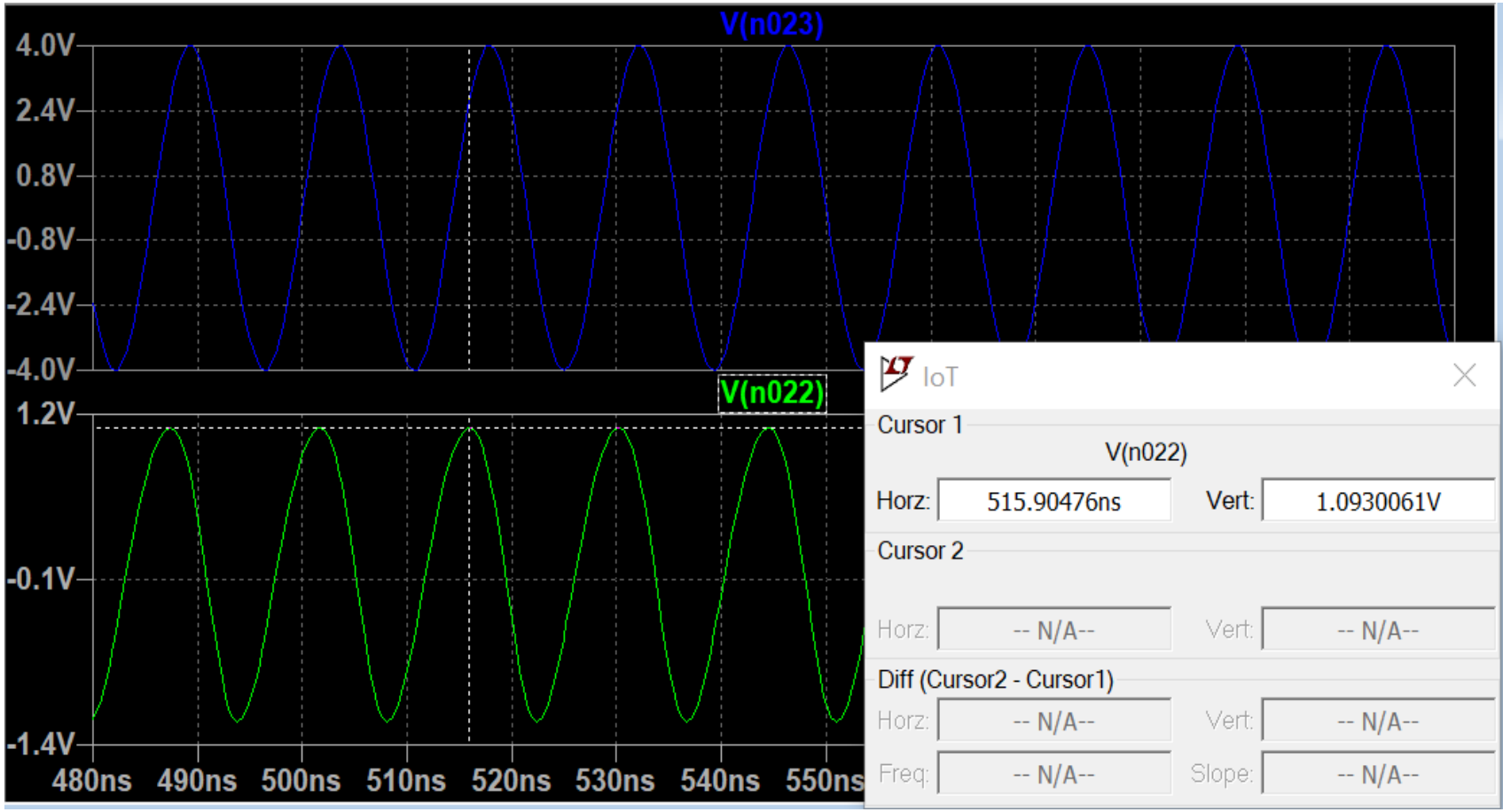
Simulation(2)

- To test if the gain of 0.25 is working properly, the input voltage was changed to 5 V.
- The output was around 1.25 V, as it was expected.



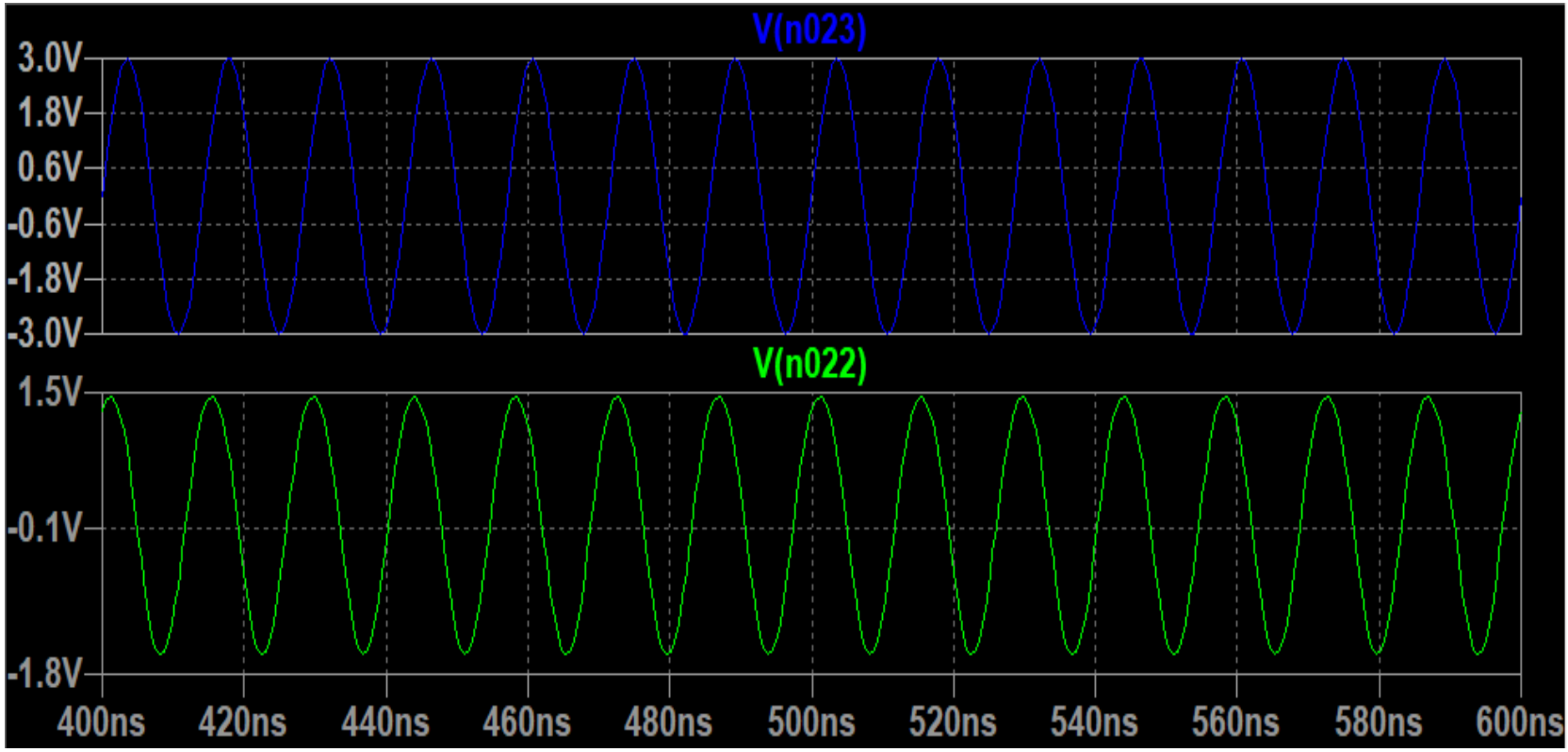
Simulation(3)

- The simulation was also tested for the input voltage of 4V.
- As it can be seen on the figure, the output voltage is around 1V, which was expected.



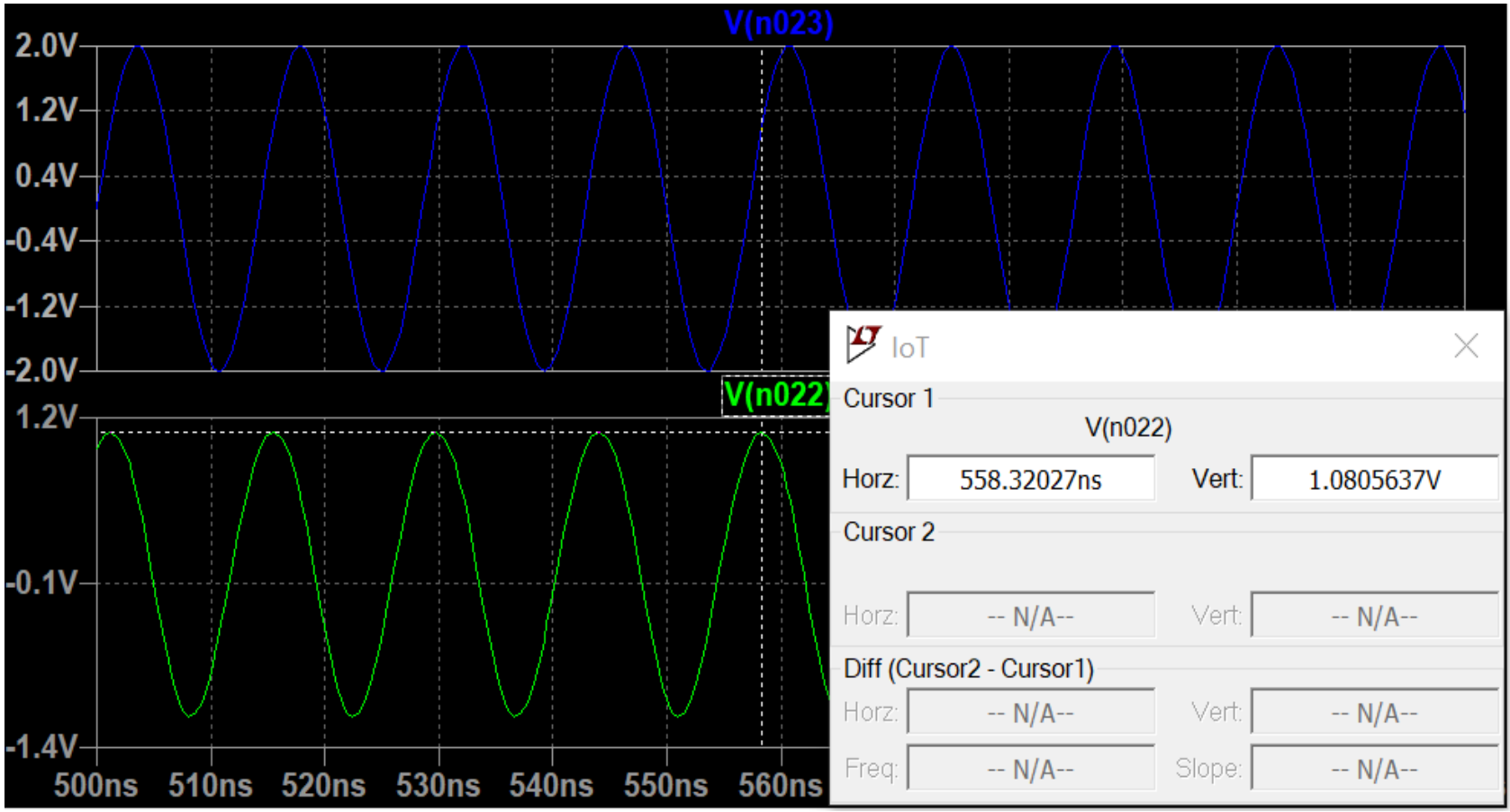
Simulation(4)

- For the voltage gain of 0.5, the maximum input voltage is 3 V.
- As it is shown on the figure, for the input voltage of 3 V, the maximum output voltage is achieved, around 1.5 V.



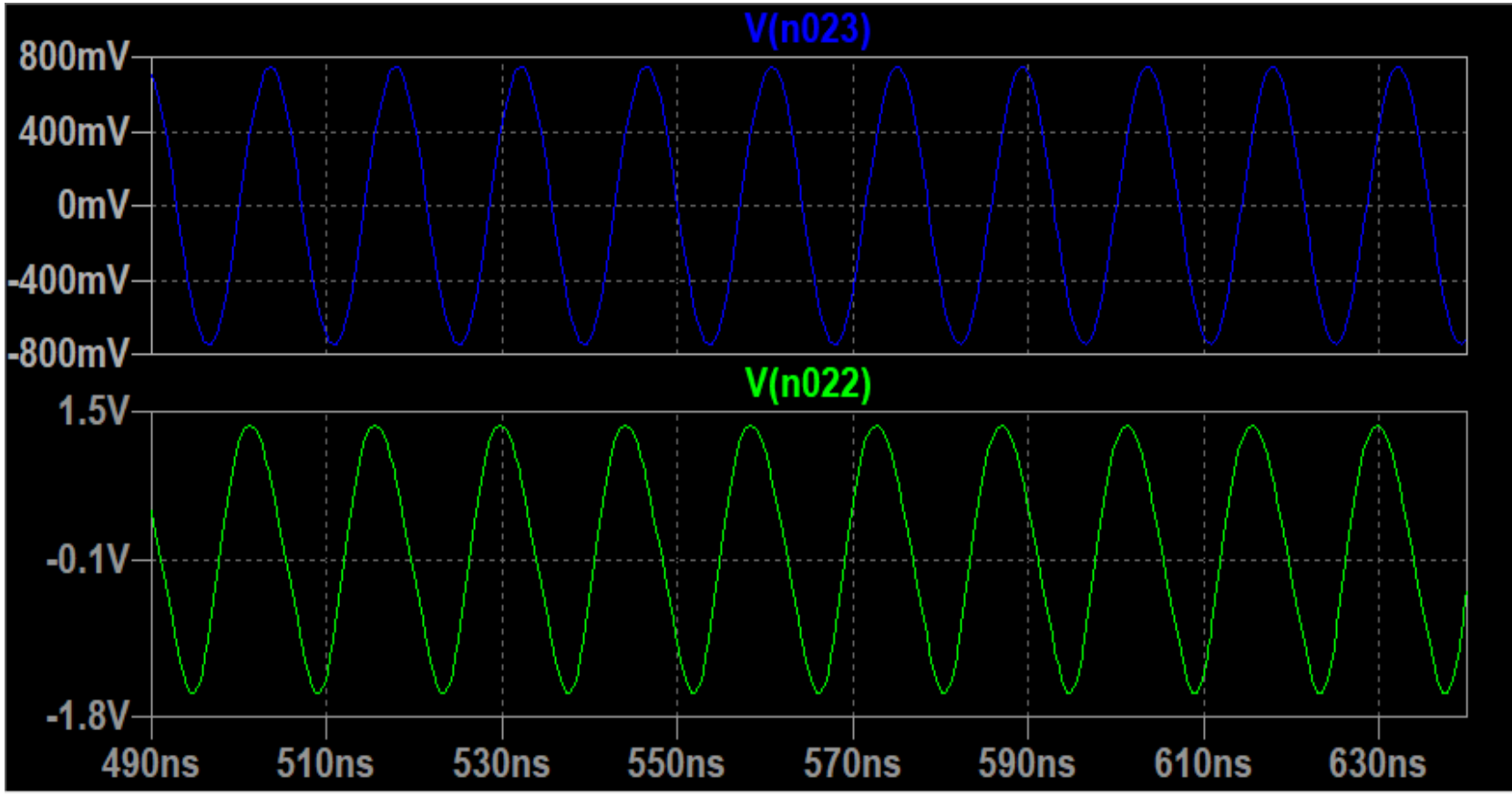
Simulation(5)

- Also, the input to the system of 2V was tested for this gain.
- The output voltage should be around 1V, which was the case, as it can be seen on the graphs.



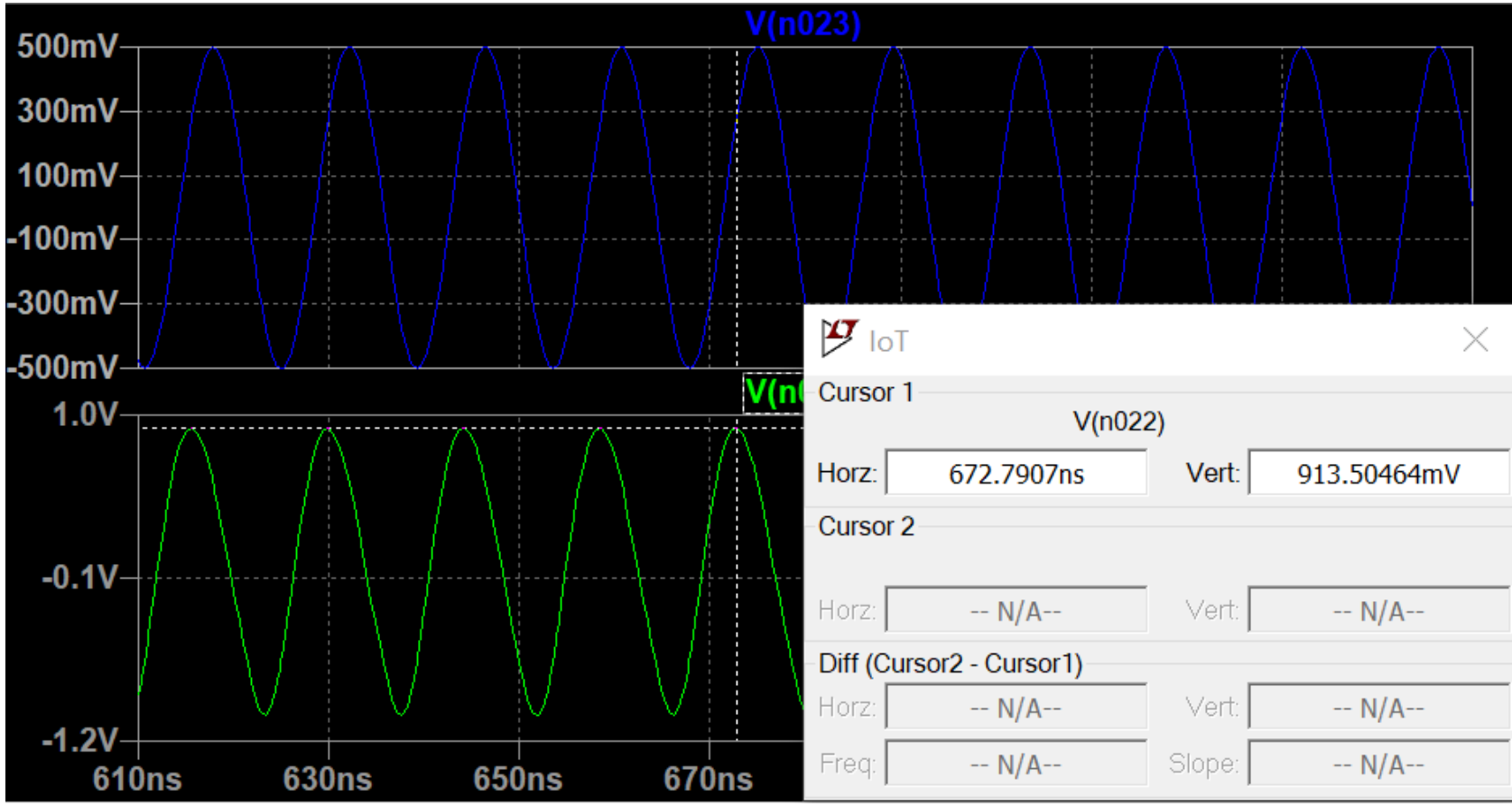
Simulation(6)

- Next simulations were done for the selected gain of 2.
- The maximum allowed input for this gain is 0.75 in order to achieve the maximum output of 1.5 V.
- As it can be seen on the graph, the output is around 1.5V.



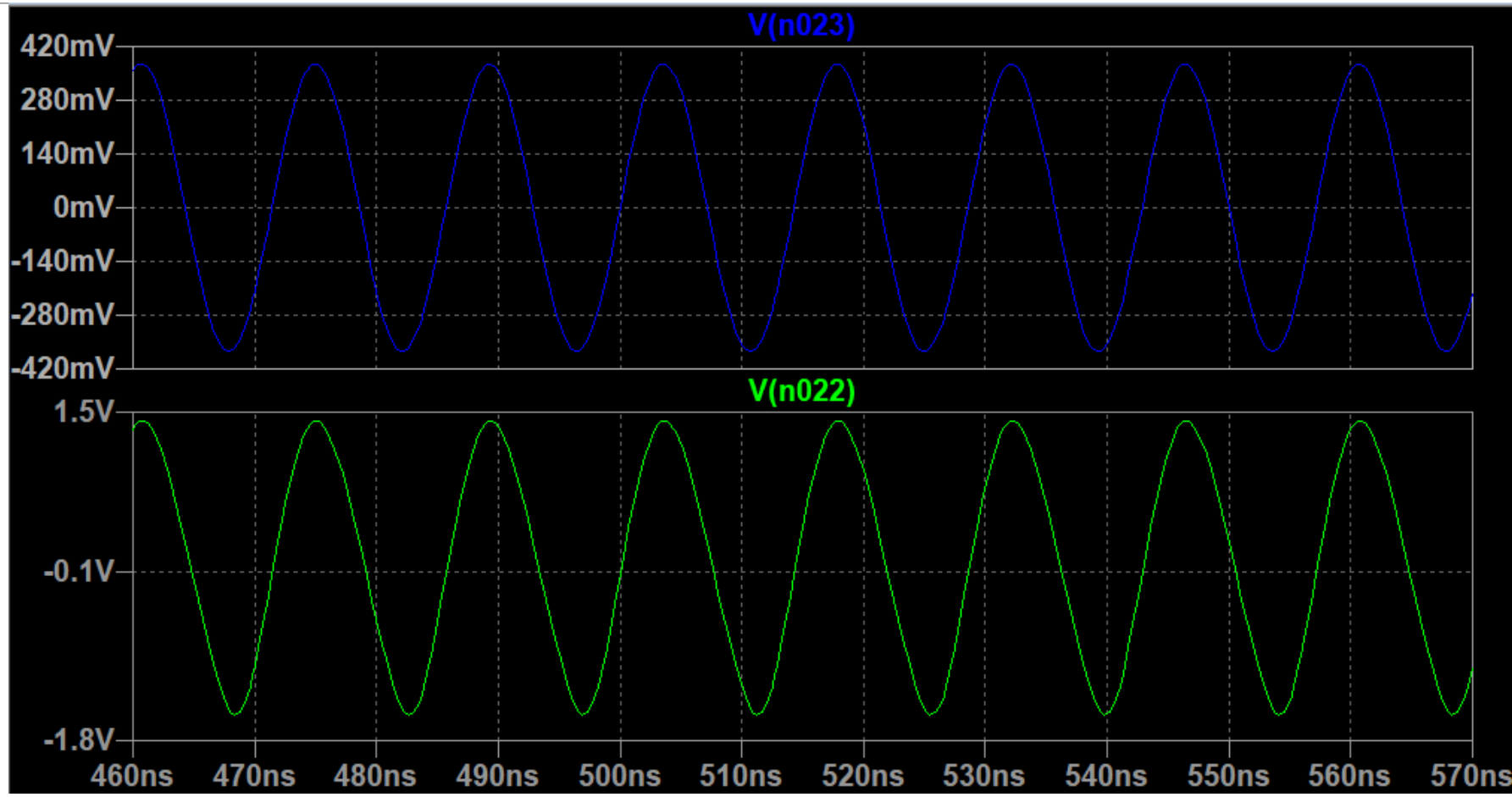
Simulation(7)

- The gain of 2 was also tested for the input of 0.5V.
- As it can be seen in the graph, the output is around 1V, as it was expected.



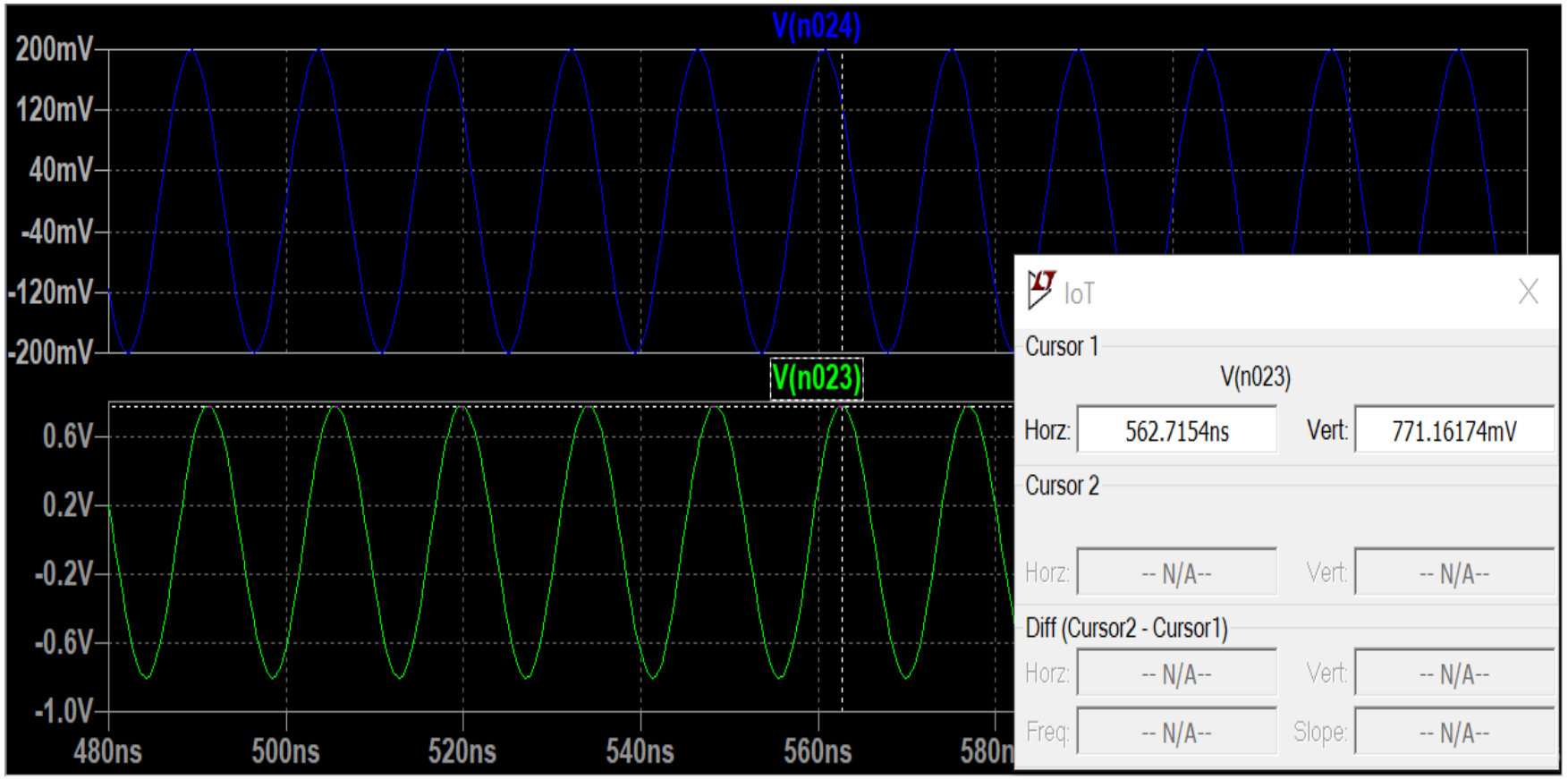
Simulation(8)

- For the selected gain of 4, maximum voltage at the input of the system is 0.375V.
- For this voltage, the maximum voltage of 1.5V should be achieved on the output.

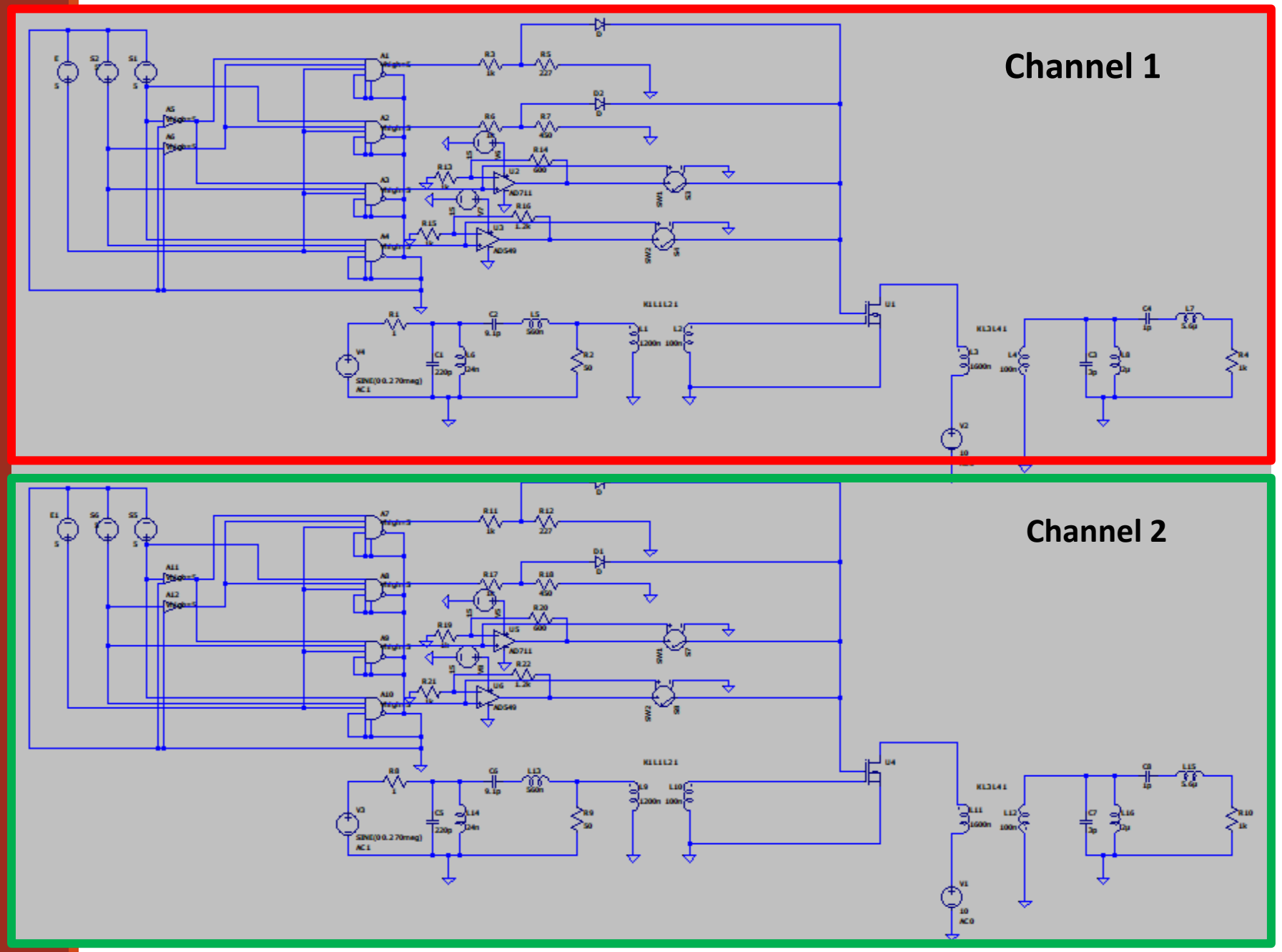


Simulation(9)

- The voltage gain of 4 was also tested for the input voltage of 0.2 V.
- The figure shows that the output voltage is around 0.8 V, which was expected.



2x2 MIMO low noise amplifier (LNA) with variable gain



Thank You!