EE 2EI4 - Electronic Devices and Circuit I

Project II

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Section 2C, Subsection I - Specific Value Settings

Test 1 will be used to test the switch in the ON and OFF state in the forward direction

Test 1A - Closed Switch **Test 1B - Open Switch**

Parameter	Values		Parameter	Values
$V_{control}$	$0V$		$V_{control}$	$5V$
V_{supply}	$5V$		V_{supply}	$5V$
V_1	$5V$		V_1	$5V$

Test2 will be used to test the switch in the ON and OFF state in the reverse direction

Test 2A - Closed Switch **Test 2B - Open Switch**

Parameter	Values		Parameter	Values
$V_{control}$	$0V$		$V_{control}$	$5V$
V_{supply}	$5V$		V_{supply}	$5V$
V_1	$5V$		V_1	$5V$

Section 2C, Subsection II - Specific Values Measured

For test 1A and test 2A I will measure V2 for switch type 1, and VA and VB for switch type 2 to verify that their values are equivalent to V1 for each case.

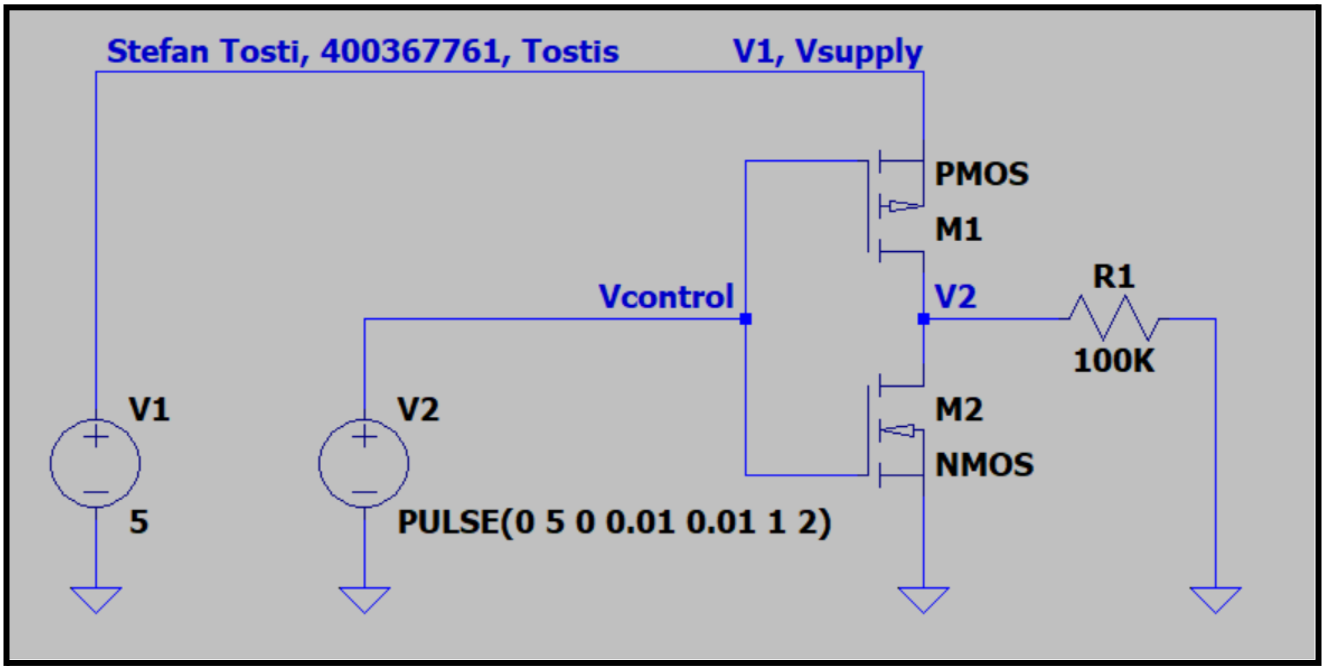
For test 1B and 2B I will measure V2 for switch type 1, and VA and VB for switch type 2 to verify that their values are as close to 0 as possible for each case.

Section 2C, Subsection III - Calculates Values

For test 1A and 2A I will measure the resistance of the switch in the ON state, using the voltage drop from input to output

For test 1B and 2B I will measure the leakage current will be calculated

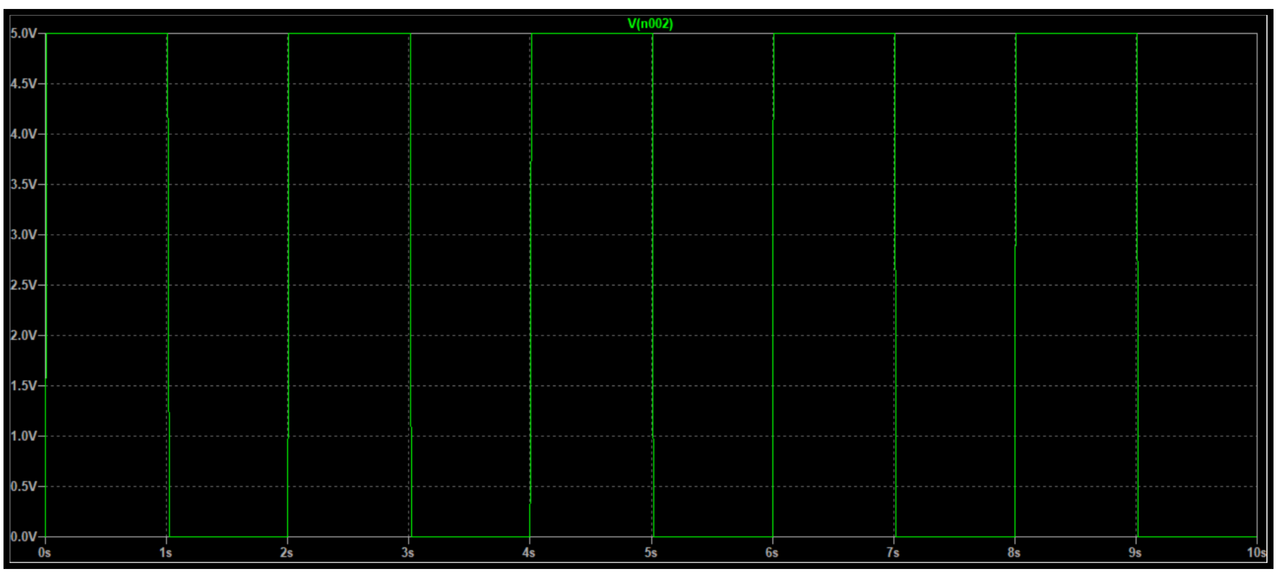
Switch Type 1, Subsection I - Circuit Schematic



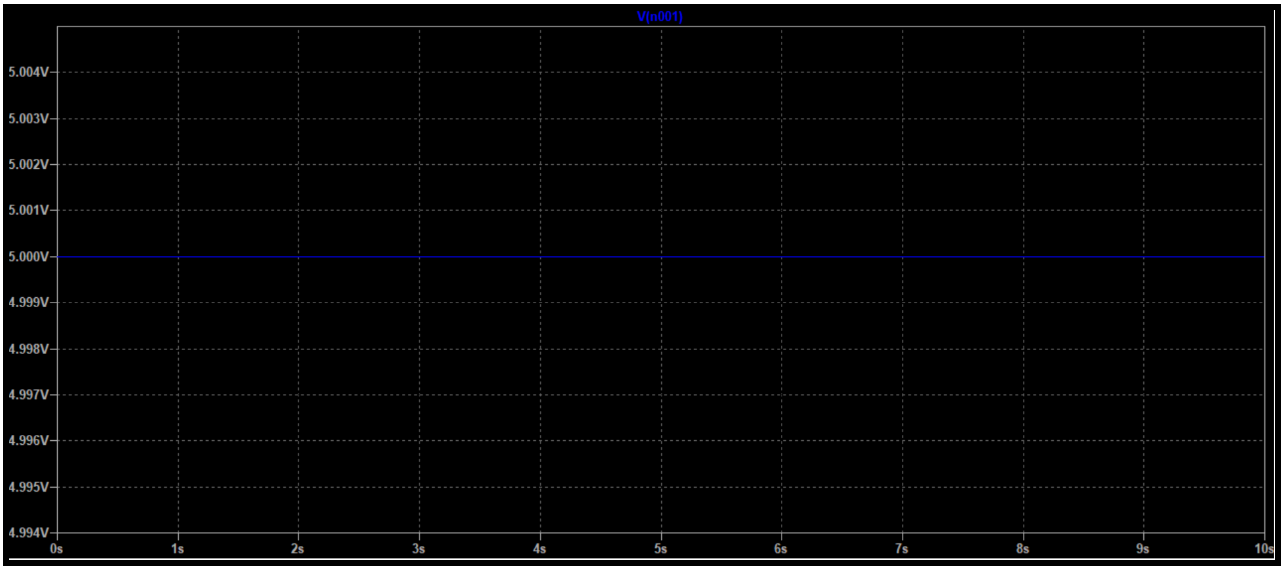
**** For the schematic shown above, please pay attention to the BLUE LABELS only, that is, the labels for Vcontrol, Vsupply, V1, V2. The black labels are created by default in LTSpice***

Switch Type 1, Subsection II - Measurements Performed

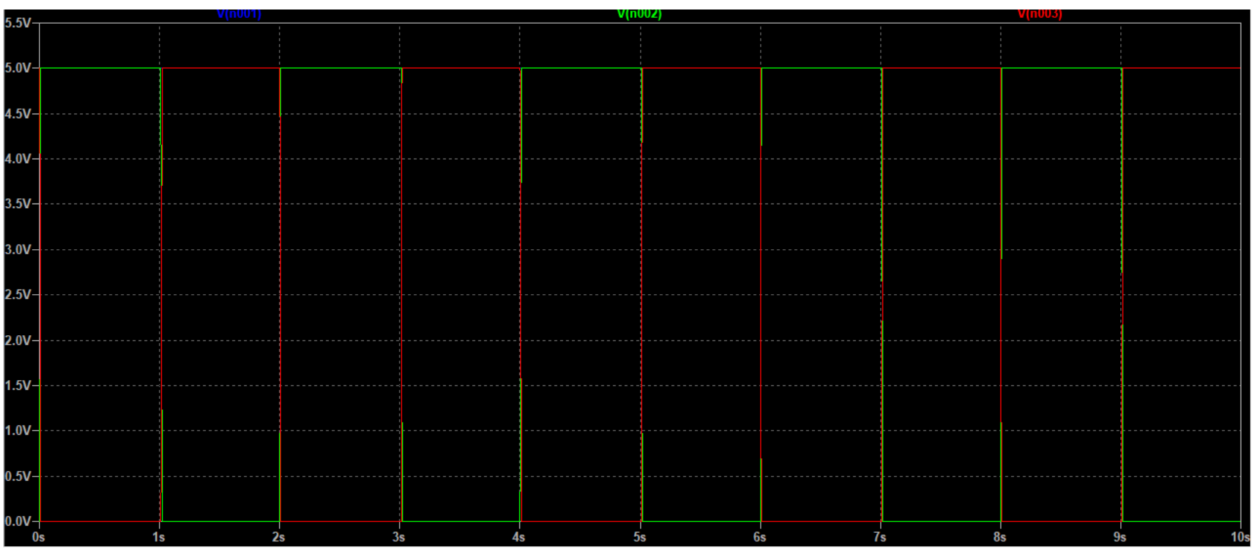
$V_{control}$ was set to a square wave, that stepped between 0V and 5V



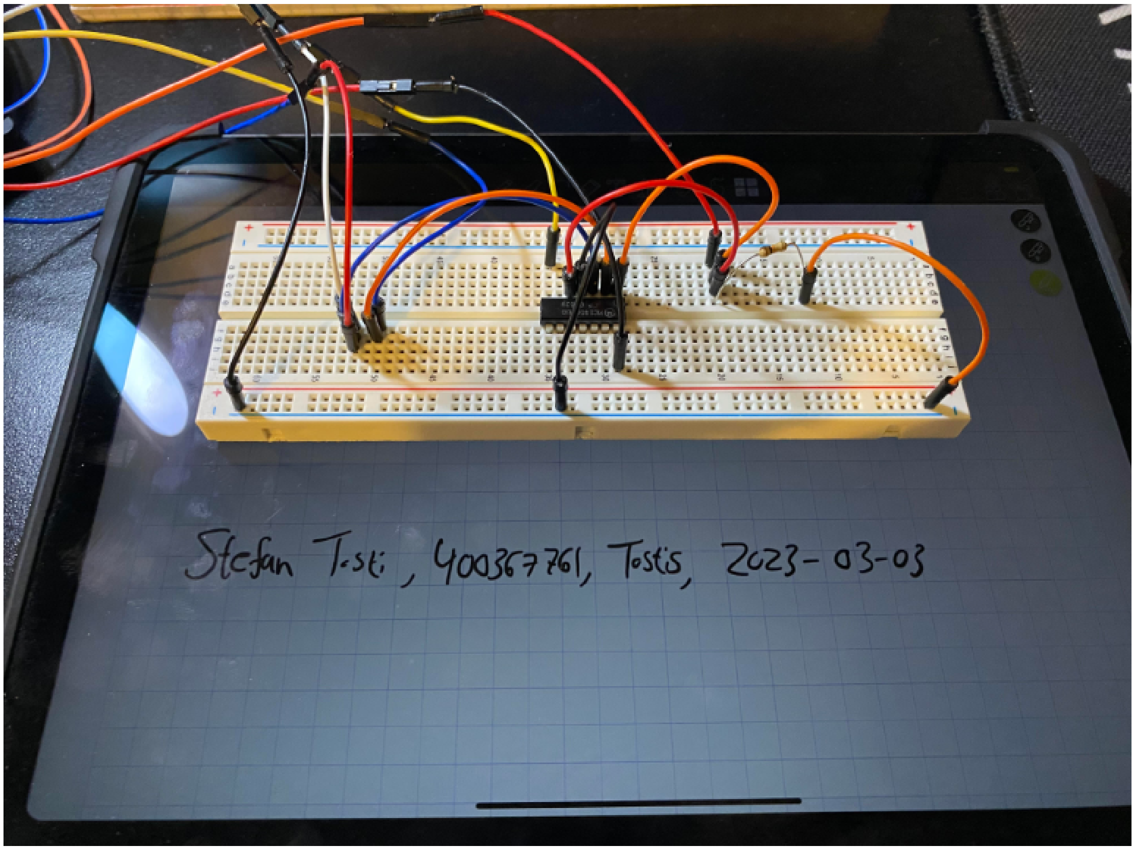
V_{supply} was set to 5V DC



The output below depicts V2 on the same axis as V1, V_{supply}, and $V_{control}$

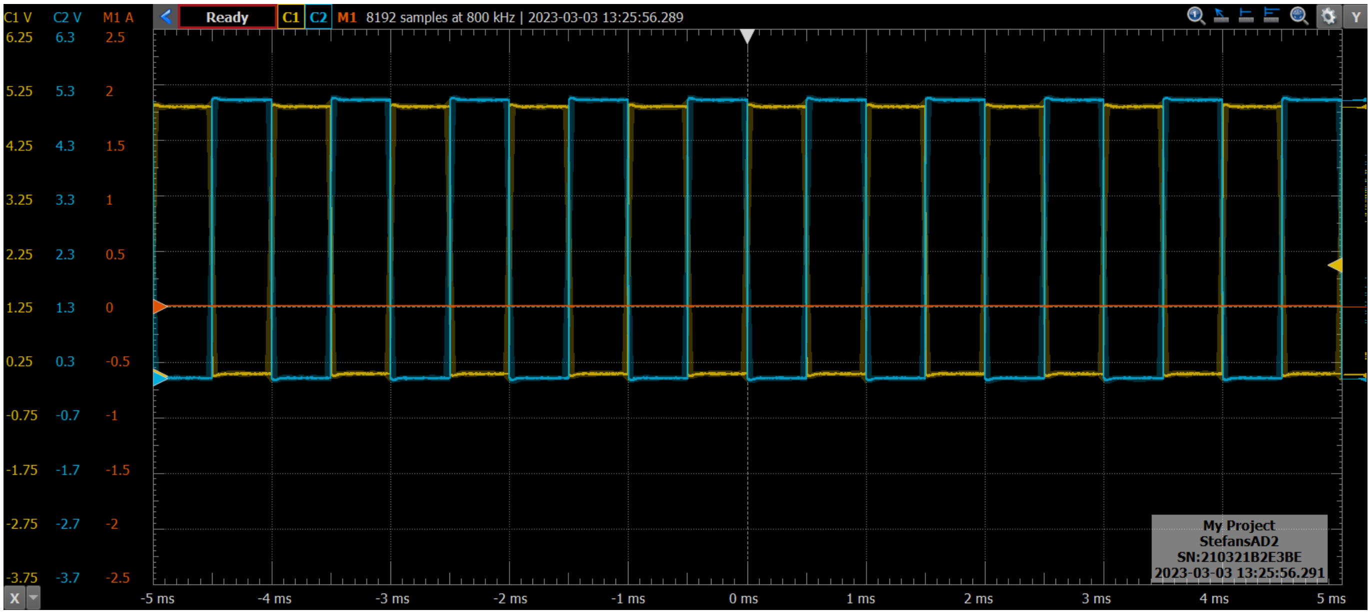


The following is the circuit that was built in real life



The following are the input values for $V_{control}$ and V_{supply}

The following plot shows C2 ($V_{control}$), C1 (V_2), and M1 (current through the 100K resistor)



Switch Type 1, Subsection III - Theoretical Explanation of obtained results

The switch design is bidirectional, as it was built having both an n-type, and p-type mosfet in the design. Bidirectionality is one of the main criteria that make up an ideal switch, thus it was important that my design took this into consideration. In the final output screenshot as seen above, we can see the behavior of the switch. In this case, $V_{control}$ is set to a square wave that differs from 0V to 5V. When the control voltage is 5V, the switch should be in the OFF state, and should exhibit the property that $I_1 = I_2 = 0$. When the control voltage is 0V, then the switch should be in the ON state, and should exhibit the property that V1 = V2.

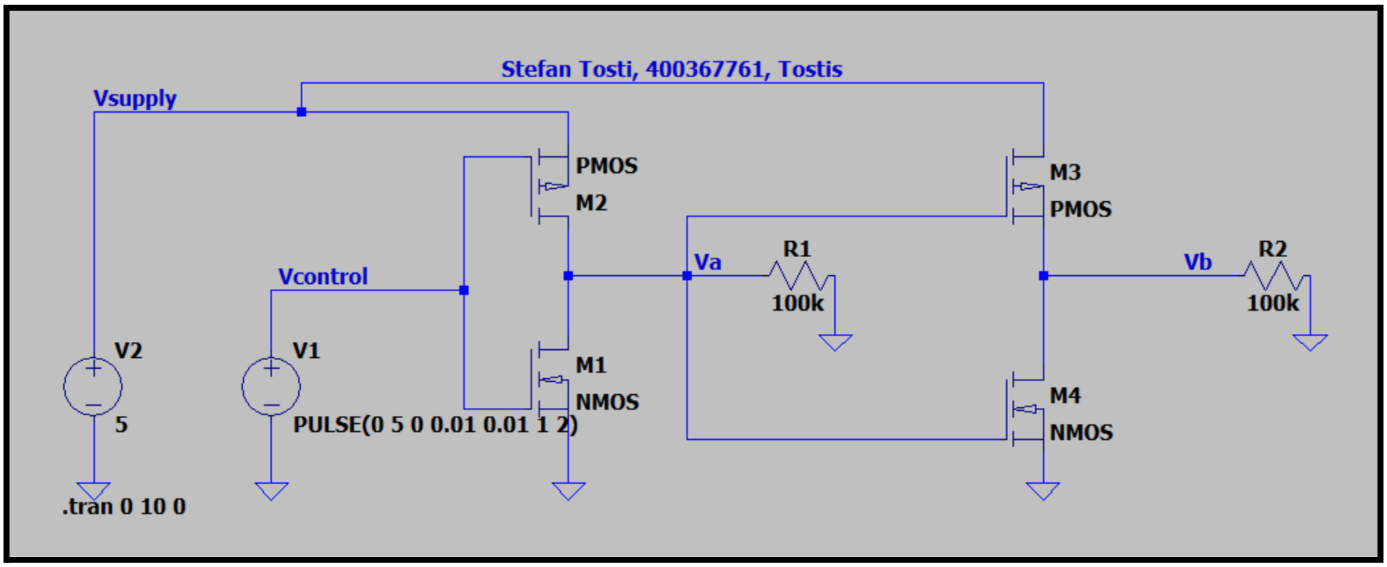
We can look at our finalized output to verify these theoretical values. When $V_{control}$ is 0V, V2 is being shown as 5V, which would be equal to V1 in this case. I added a 100k resistor to the output of the switch (from V2 to ground) and measured an experimental current of about 50uA . This verifies the property that in the ON state V1 = V2. When the value of $V_{control}$ is 5V, we can see that V2 is 0V, regardless of V1 being 5V.

We can verify these calculations mathematically as follows. In the ON state, $R_{ON} = \frac{5V - 5V}{50uA} = 0\Omega$. Additionally, in the OFF state, $R_{OFF} = \frac{0V - 5V}{15nA} = \infty\Omega$

Switch Type 1, Subsection IV - Design Tradeoffs

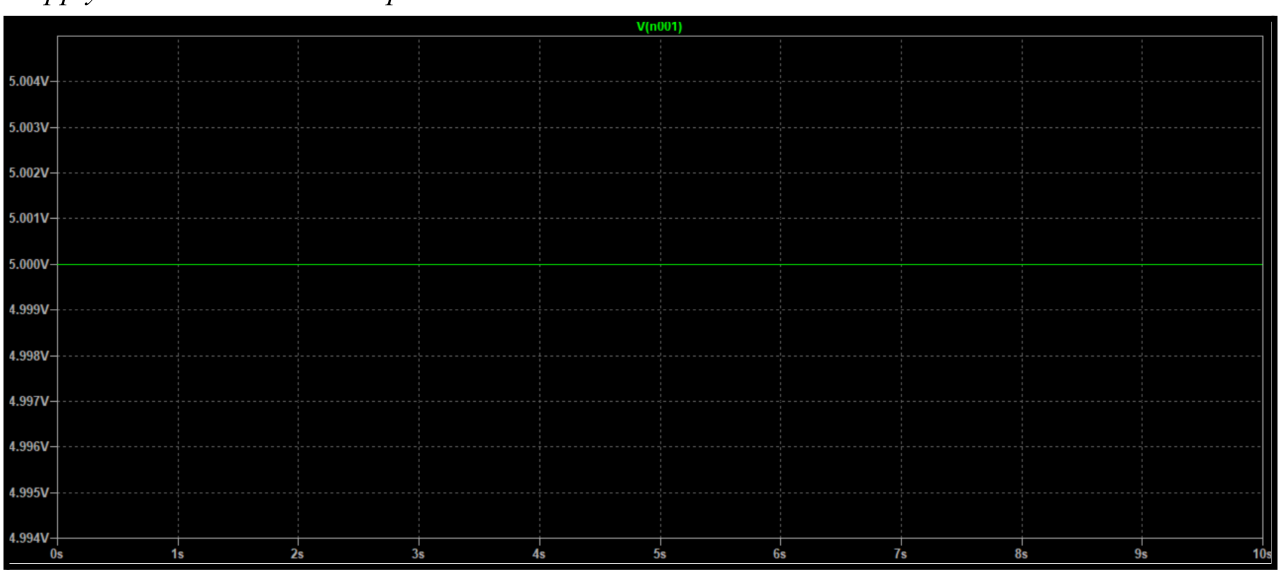
One tradeoff in this design was balancing all of the things that were required to prove, with the limitations in components that I could use. The simplest design that was considered made use of only a single MOSFET. This design, however, was not bidirectionally conducting, and was not used as the final design for this project. On the other hand, much more complex circuits included the use of 3 or 4 MOSFETS, but also included components like inverters, which was not allowed in the construction of the circuit. To balance complexity with simplicity, while also depicting all of the key components of an ideal switch, the design presented above was chosen.

Switch Type 2, Subsection I - Circuit Schematic

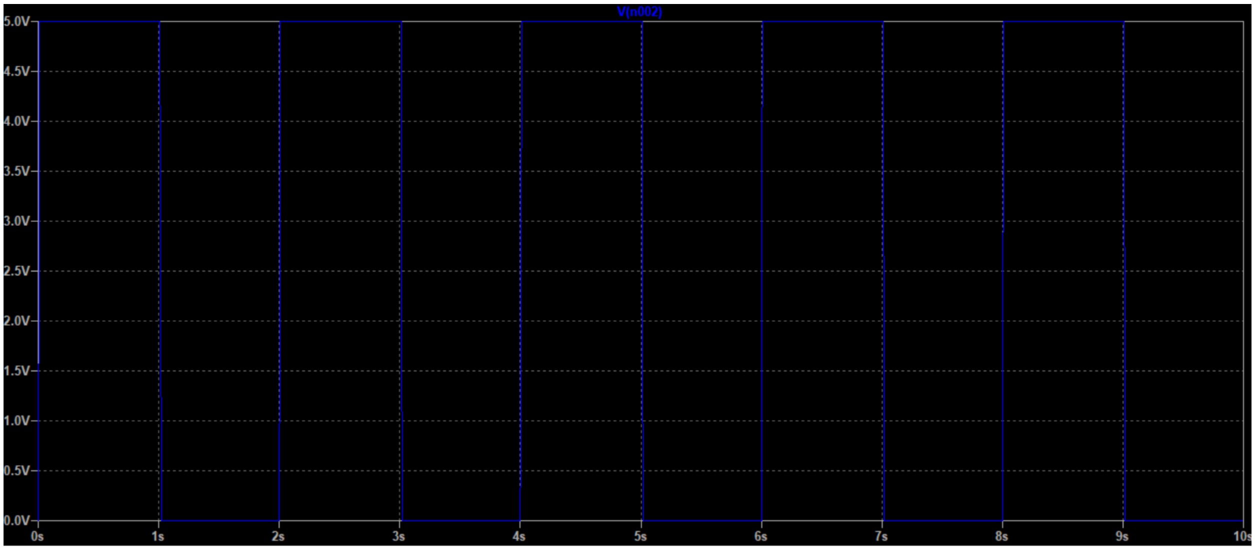


Switch Type 2, Subsection II - Measurements Performed

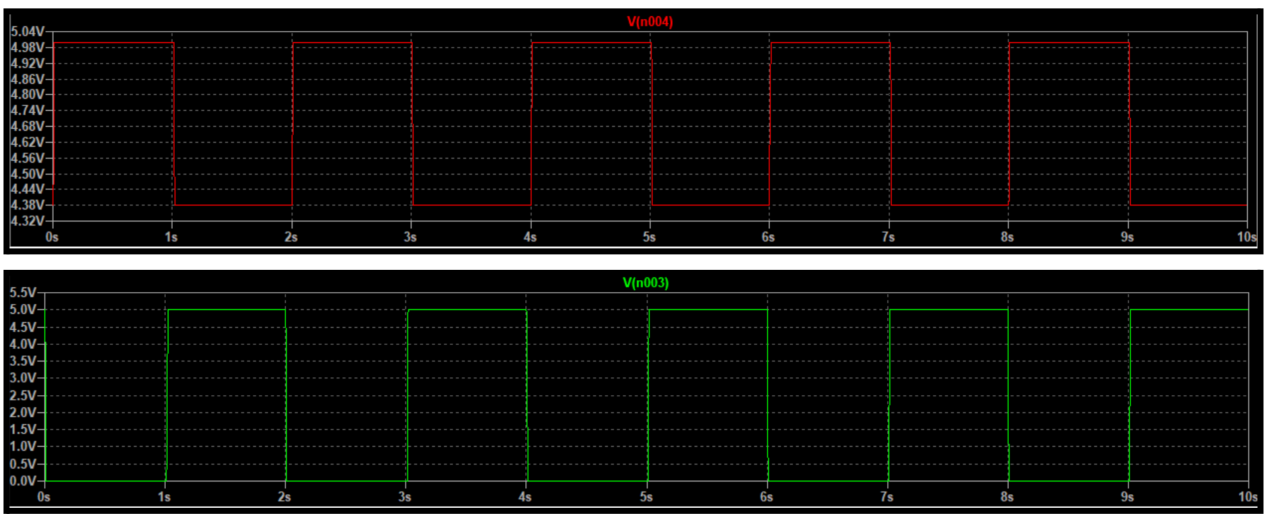
Vsupply was set to a 5V DC input



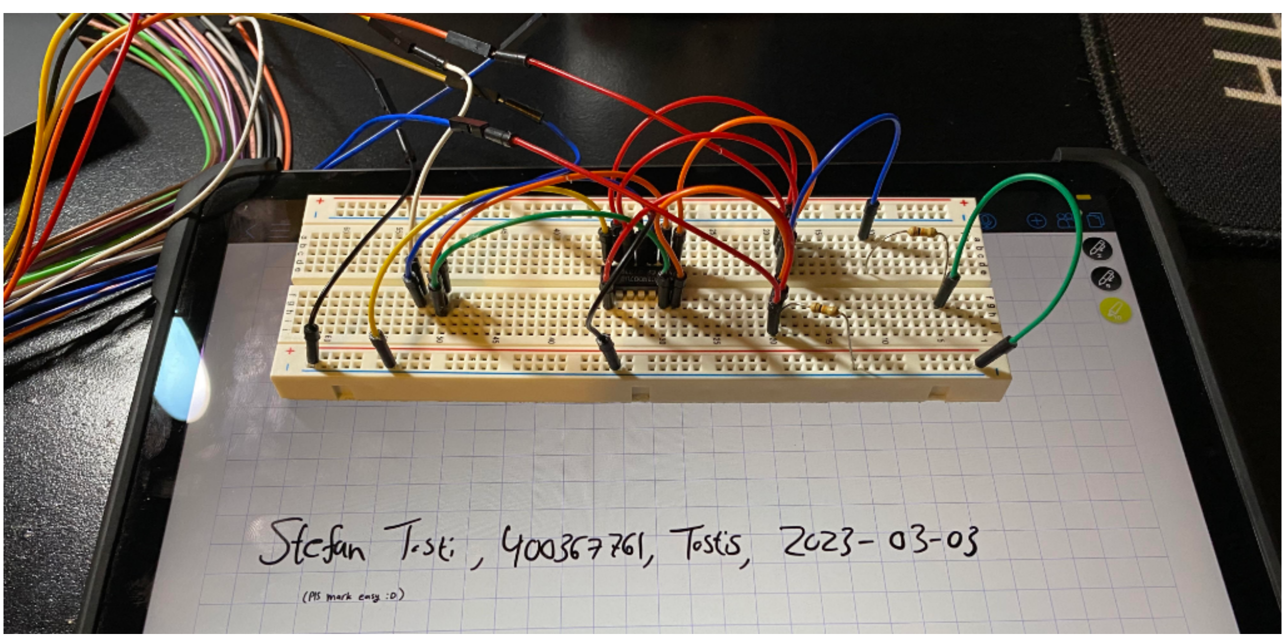
Vcontrol was set to a pulse varying between 0V and 5V



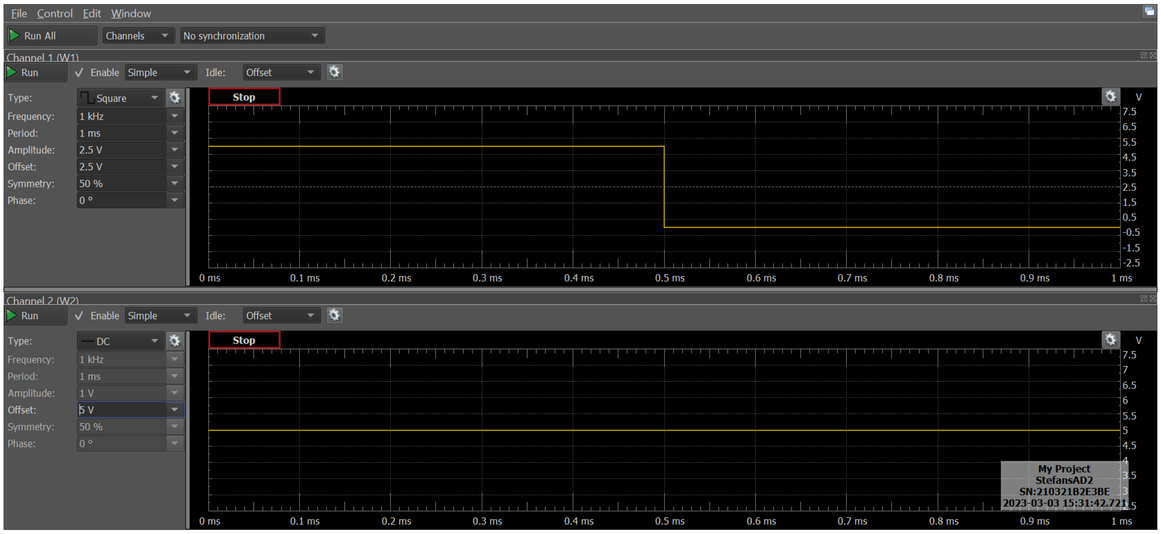
The outputs of Va (green) and Vb (red) waveforms



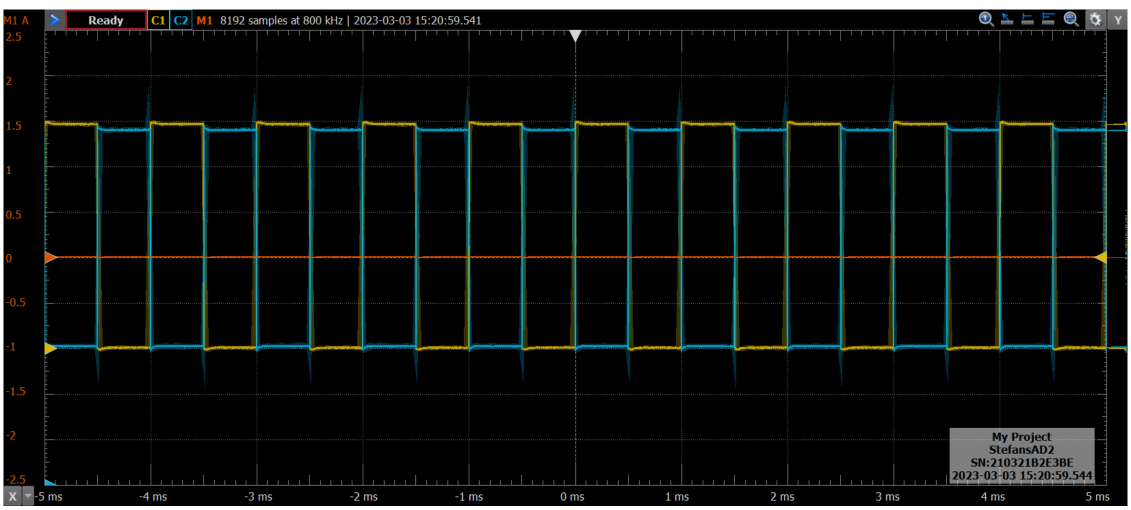
The following shows the circuit built in real time



The following plot shows V_{supply} and $V_{control}$



The following plot shows V_a and V_b



Switch Type 2, Subsection III - Theoretical Explanation of obtained results

Above are the simulation results from the switch type 2 design. To observe the functionality of the switch, VA, VB, and the current was used to determine the state of the switch outputs when the switch was receiving 0V from Vcontrol, and 5V from Vsupply. We know that when Vcontrol is 0V, the output of our circuit should be from VA, and when Vcontrol is 5V, VB should be our output. To check this, we can refer to the above graphs. When Vcontrol is 5V, Vb is 5V, and VA = 0V, but when Vcontrol is 0V, VA = 5V and VB = 0V, which means that the circuit is functioning as it should be. We can also determine the currents of the circuit, using the 100K resistor load that was included. Similarly, the current in the one state was measured to be about 50uA, and the off current measured to be about 250nA.

$R_{ON} = \frac{5V-5V}{50uA} = 0\Omega$. Additionally, in the OFF state, $R_{OFF} = \frac{0V-5V}{250nA} = \infty\Omega$

Switch Type 3, Subsection IV - Design Tradeoffs

There were several trade offs made in the construction in the second switch design. The main tradeoff was going with a slightly less comprehensive design out of simplicity. An alternative design for this switch used 6 MOSFETS in total (3 pMos, 3 nMos), this design was a much more comprehensive construction of this type of switch, but was so complicated to build and construct that a simpler approach was taken. The 6 mosfet design was recommended as a common use of MC14007UB IC in the chips datasheet.

References

[1] Dr. Mahmoud Shaker Al-Shemmary, *Power Electronics,* University of Babylon - Department of Electrical Engineering: University of Babylon, 2013.

[2] Adel s. Sedra and Kenneth C. Smith, *Microelectronic Circuits Eighth Edition*, United States of America: Oxford University Press, 2020.

[3] “Ideal and Practical Switch - Switching Devices - GATE Power Electronics”, *Youtube,* September 17. 2020. Available: https://www.youtube.com/watch?v=JaPo4FJJBxA. [Accessed: February 15, 2023]