
PROJECT 1: AC TO DC POWER SUPPLY

ELECENG 2EI4 – Electronic Devices and Circuits I

Section C01

Viha Tripathi (tripav2)

400504615

Submitted: March 3rd, 2025

Course Instructors: Dr. Yaser M. Haddara.

The student is responsible for performing the required work in an honest manner, without plagiarism and cheating. Submitting this work with my name and student number is a statement and understanding that this work is my own and adheres to the Academic Integrity Policy of McMaster University.

Viha Tripathi

400504615

Test Plans

Test Plan for Switch 1

To check if the first switch works correctly, both OFF and ON states will be tested. When the switch is OFF ($V_{\text{control}} = 5\text{V}$), V_2 is expected to be 0V. V_1 is set to 5V (from V_{supply}), V_2 will be measured at the output of the MOSFET connected to a 100k Ω resistor. To check leakage current, V_2 will be measured over the 100k Ω resistor.

When the switch is ON ($V_{\text{control}} = 0\text{V}$), V_1 remains at 5V, and V_2 should be 5V. To check how well the switch conducts, the difference between V_1 and V_2 is measured. If V_2 is lower than V_1 , it means there is some resistance inside the MOSFET (R_{on}). Additionally, it will be observed how V_2 responds when V_1 changes to different voltages.

Closed Switch (on)	
Parameter	Parameter
V_{Control}	0 V
V_{Supply}	5 V
V_1	5 V

Open Switch (off)	
Parameter	Value
V_{Control}	5 V
V_{Supply}	5 V
V_1	5 V

Test Plan for Switch 2

For the second switch, it will be observed if it properly switches between V_A and V_B based on V_{control} . In the first state ($V_{\text{control}} = 0\text{V}$), V_A is expected to follow V_1 (around 5V), while V_B should be 0V. When V_{control} changes to 5V, V_A should drop to 0V, and V_B should become 5V.

V_A and V_B will be measured in both states to confirm that the switch correctly redirects V_1 between them. Just like in Switch 1, R_{on} , voltage drop, and leakage current will be checked for to evaluate its real-world performance.

Closed Switch (on)	
Parameter	Parameter
V_{Control}	0 V
V_{Supply}	5 V
V_1	5 V

Open Switch (off)	
Parameter	Value
$V_{Control}$	5 V
V_{Supply}	5 V
V_1	5 V

Theoretical calculations for ON and OFF resistance in an ideal switch:

$$R_{on} = \frac{V_{on}}{I_{on}}$$

$$R_{on} = \frac{5V - 5V}{I_{on}} = 0$$

$$R_{off} = \frac{V_{off}}{I_{off}}$$

$$R_{off} = \frac{0 - 0V}{I_{off}} = 0$$

Switch type 1

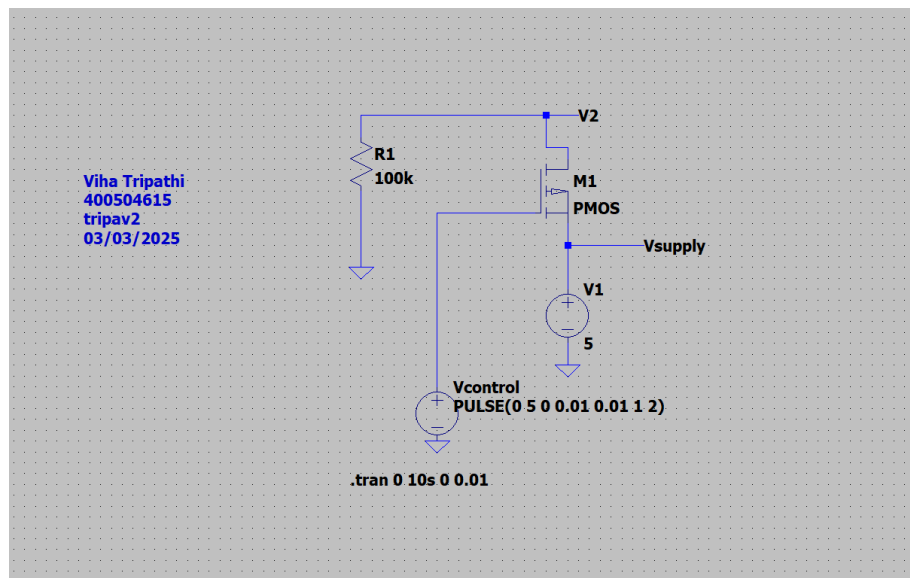


Figure 1: Switch 1 Schematic

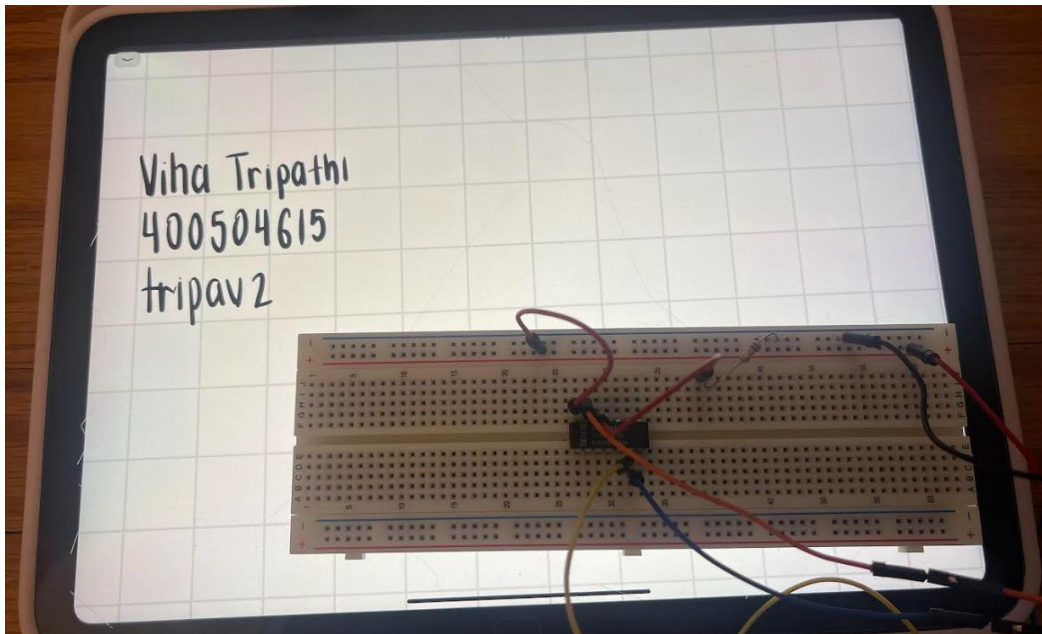


Figure 2: Switch 1 Physical Circuit

AD3 Results



Figure 3: Voltage of Switch Nodes Vs $V_{control}$

As shown, the control voltage (V_{control}) is set as a square wave between 0V and 5V. When the control voltage (Blue) is low, the output voltage (Channel 1) is high. Conversely, when V_{control} is 5V, the output voltage V_2 drops to 0V. This behavior is also true in reverse.

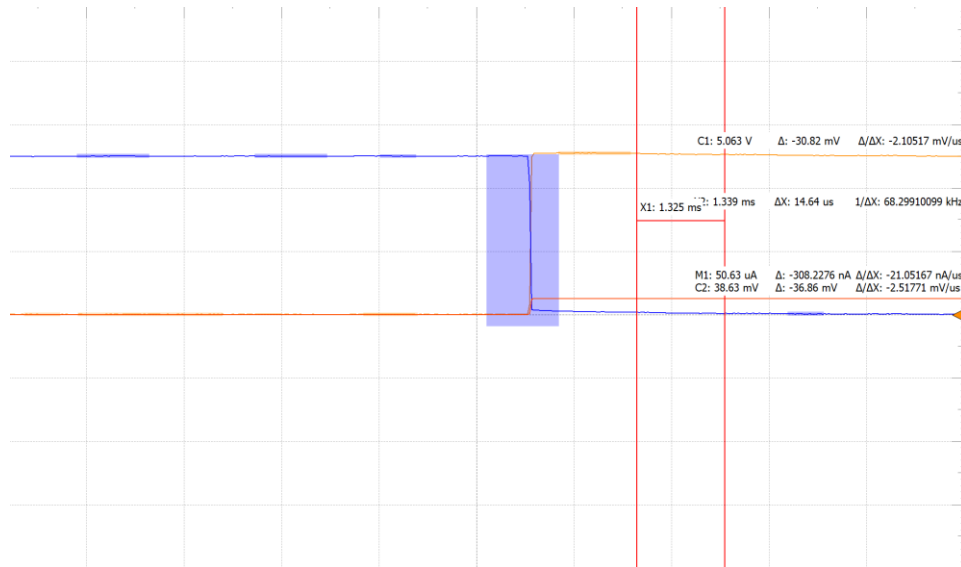


Figure 4: ON state Voltage and Current

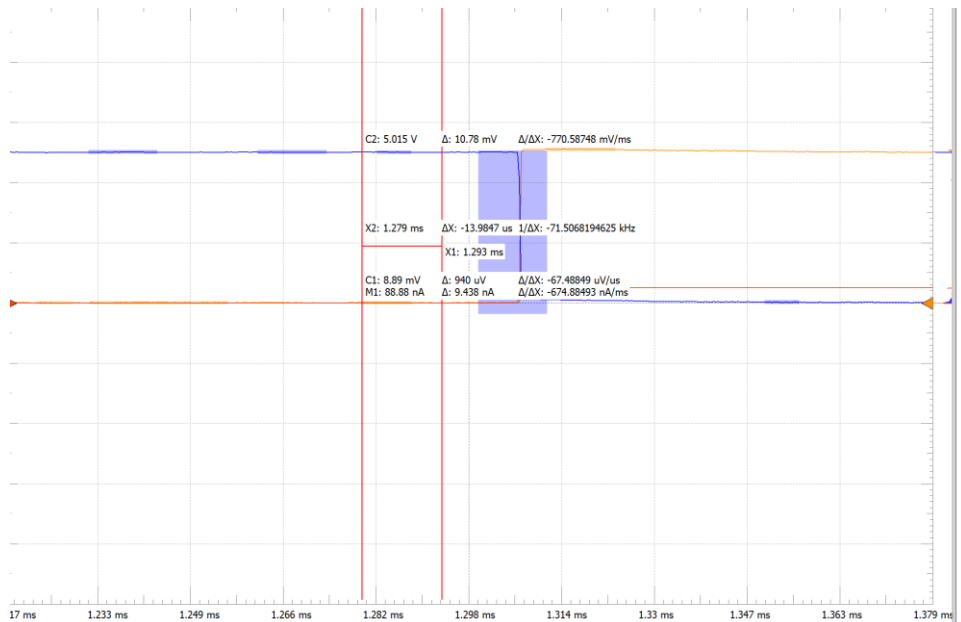


Figure 5: OFF State Voltage and Current

Leakage current was observed in the ON state of the switch, measured at about 50 microamperes. This shows the switch's non ideality. In the OFF state, there is also some current

present which is equal to about 8.925 nA. The output/input of the voltage is not exactly 5 V and the off-state voltage is not exactly 0, indicating that there is an off/on resistance present.

Theoretical Explanation:

The disparities between theoretical and observed values are due to non-idealities of the switch. One of the causes for this is the MOSFET's on-resistance, which leads to a voltage drop when the switch is turned on. Unlike an ideal switch, which has zero resistance, real MOSFETs have a resistance that is determined by its material qualities and manufacturing variances.

In an ideal switch, there should be zero current flowing. However, in practice, a small leakage current is present. Additionally, OFF-state leakage current is a source of divergence. When a switch is turned off, there should be no conduction or gate leakage, particularly in MOSFETs. This produces a small but noticeable current even when the switch is supposed to be entirely turned off.

Design trade-offs:

The switch 1 design prioritizes simplicity and cost-effectiveness through its use of a single MOSFET. However, the use of a single MOSFET has some trade-offs, most importantly the lack of bidirectionality. Since a single MOSFET relies on it, it can only control current flow in one direction, making it inappropriate for applications that require bidirectional switching. This trade-off is done to limit circuit complexity and save money but at the same time, it limits performance in situations where reversing the current would be helpful. Apart from this limitation, the design is still effective for many applications where unidirectional switching is used.

Switch type 2

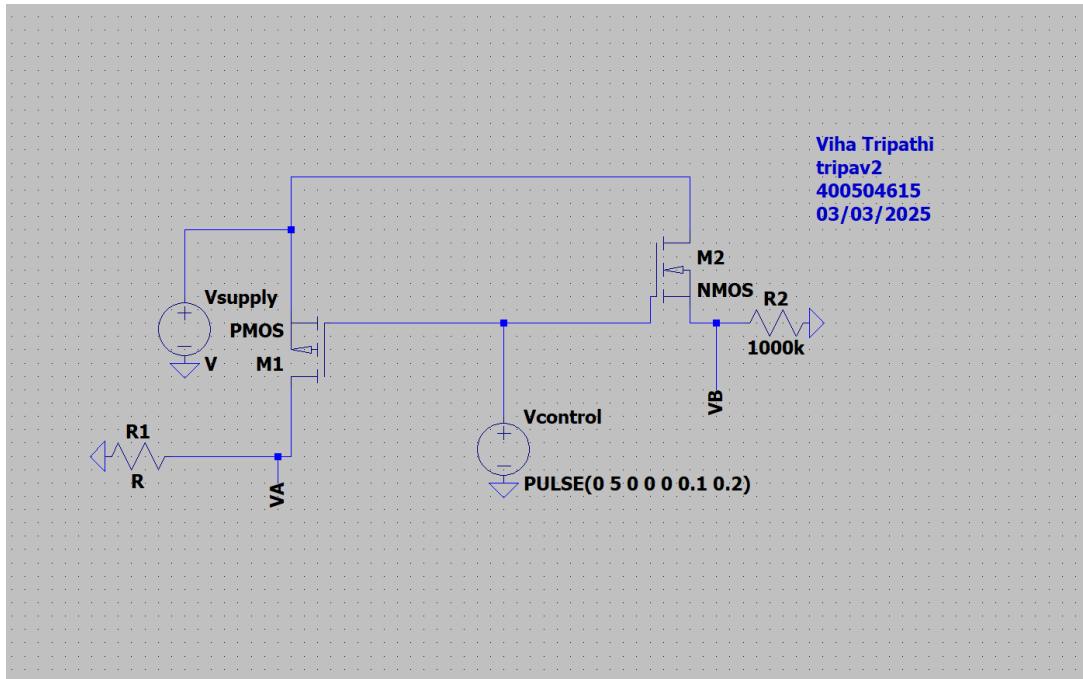


Figure 6: Switch 2 Circuit Schematic

2

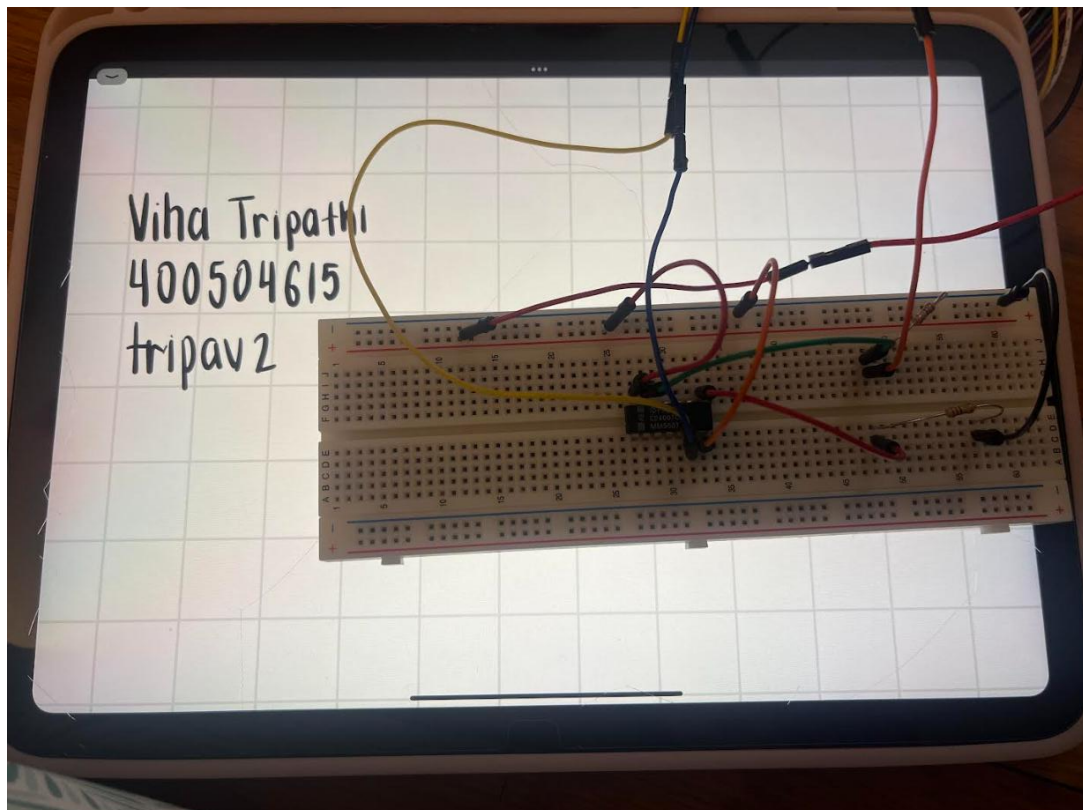


Figure 7: Physical Circuit of Switch 2

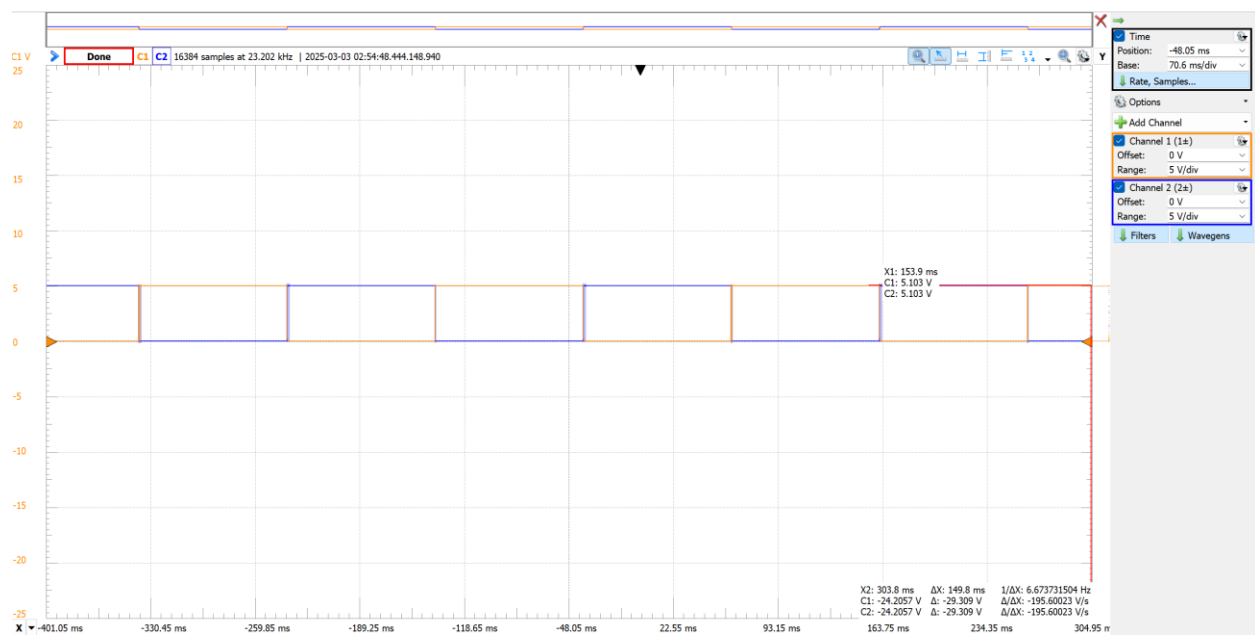


Figure 8: Voltage VA Vs Voltage VB of Switch 2

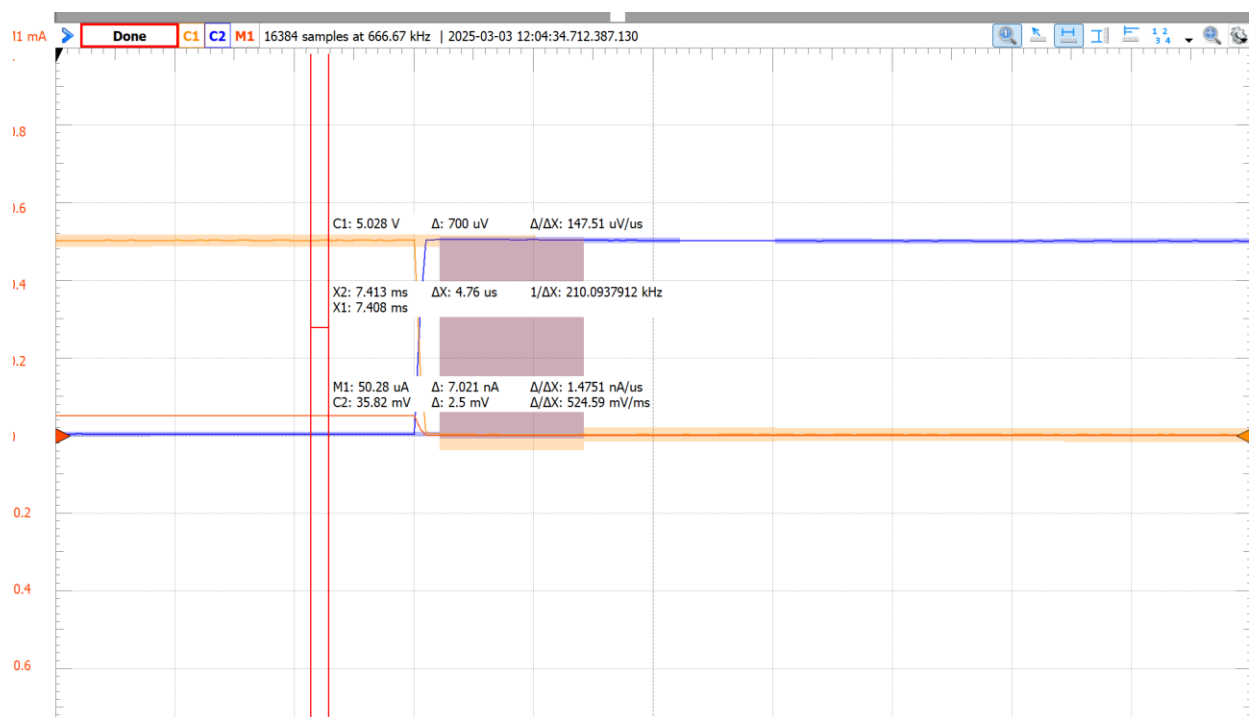


Figure 9: ON State Current And Voltage

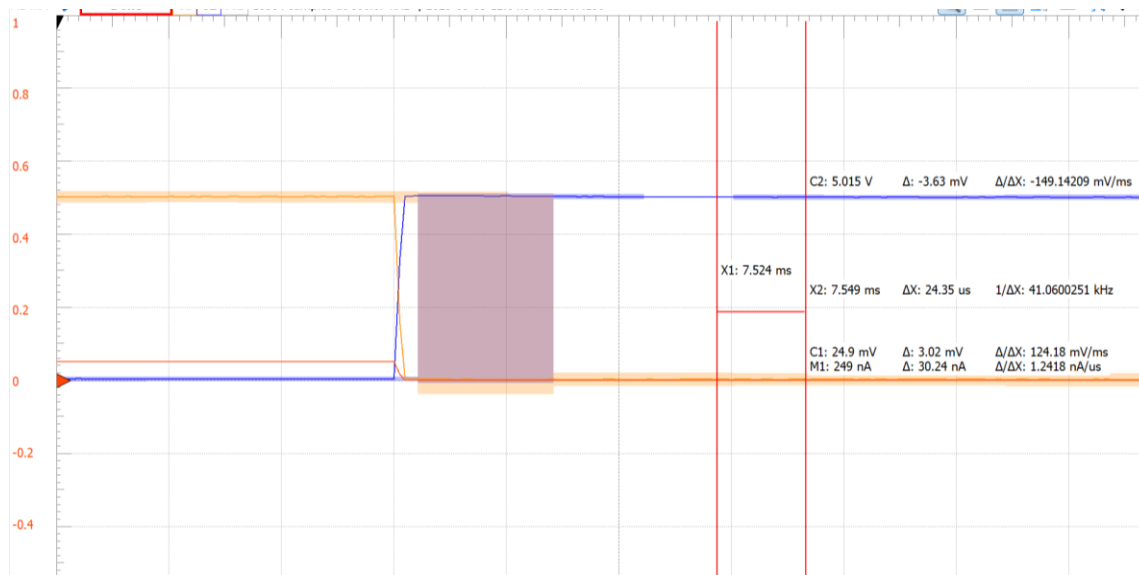


Figure 10: OFF State Current and Resistance

1. VA and VB Behavior

Because VA and VB alternate in opposing states, the first graph shows that the circuit functions as expected. VA displays a HIGH state (5V) and VB displays a LOW state (0V) when V_{control} is set to LOW (0V). This demonstrates that whilst the NMOS transistor is not conducting, the PMOS transistor is. PMOS conduction ends and NMOS conduction begins when V_{control} is increased to a HIGH state (5V), causing VA to drop to 0V and VB to rise to 5V. Because the circuit generates opposing voltage levels for VA and VB, this behaviour is consistent with the circuit operating as an inverter.

2. Leakage Current in Both ON and OFF States

Leakage current was detected in both the ON and OFF modes of the switch. Even in a conducting state, the MOSFET's on-resistance results in a negligible resistive loss, as seen by the observed leakage current of around 50 microamperes in the ON position. This finding supports the claim that the switch is not a perfect conductor with zero resistance. Even when the switch is in the OFF position and should ideally block all current, a small amount, around 250 nanoamperes, still manages to leak through. This leakage could be due to certain unwanted effects in the MOSFET, which hinder complete isolation in real-world applications.

Design Trade-offs

There are a few trade-offs that had to be made while constructing this switch. Firstly, the circuit is unidirectional, which means the current only flows in one way, making it useless for applications that need bidirectional functioning.

The other trade-off is the need of high value resistors ($2.2\text{M}\Omega$). These resistors help reduce power consumption but slow the switch's response time. Using lower-value resistors would make the switch faster but increase energy consumption. A choice had to be made between prioritizing speed or energy efficiency.

Despite these trade-offs, the switch effectively balances efficiency, reliability, and cost. It's suitable for situations where two-way electricity flow isn't needed, making it a practical choice for specific applications.