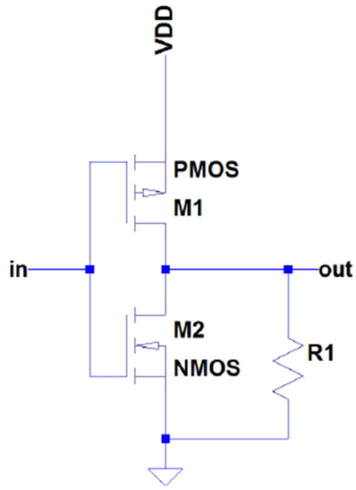
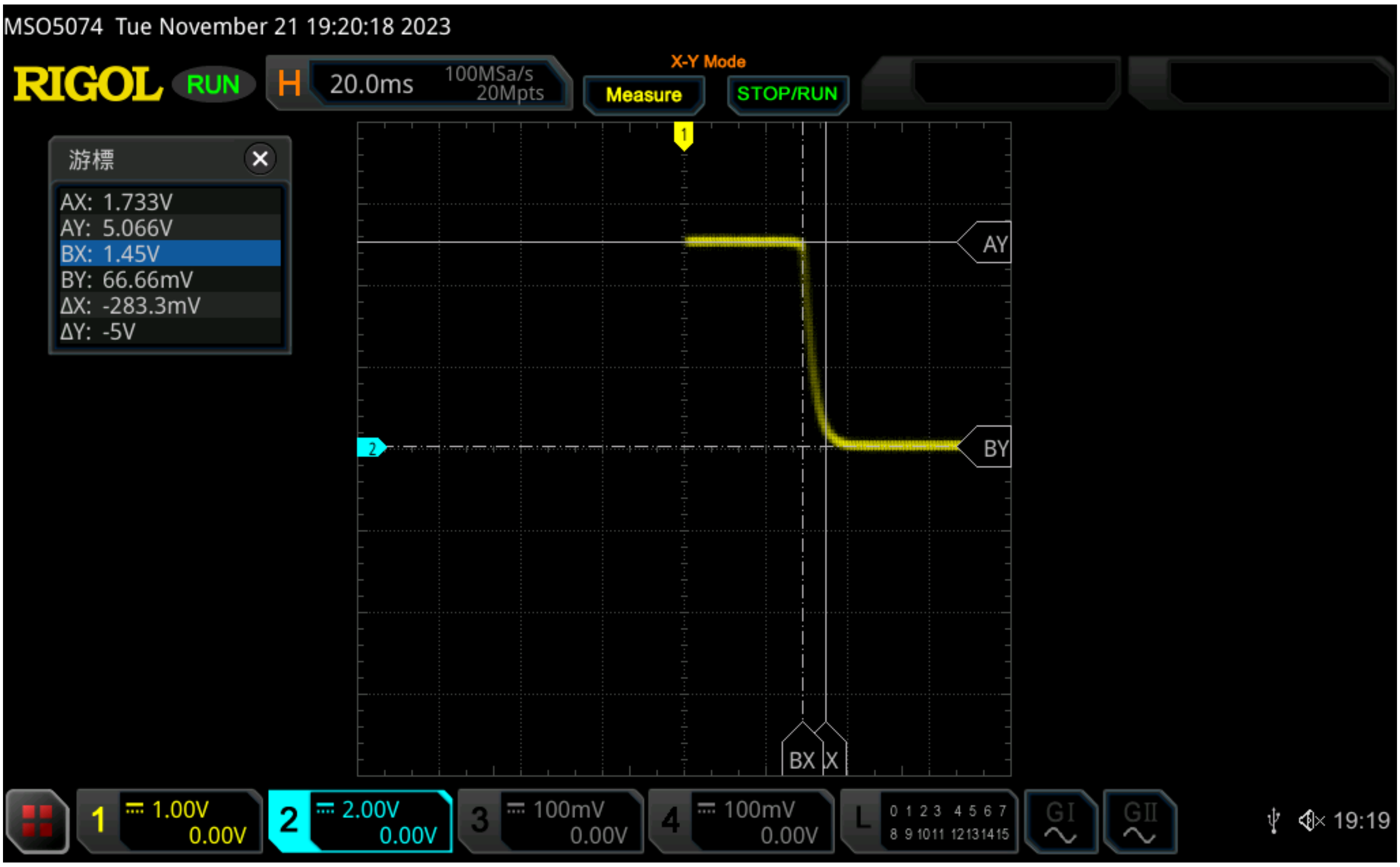
REPORT (PMOS 9540, NMOS 640)

Experiment 1: CMOS Inverter

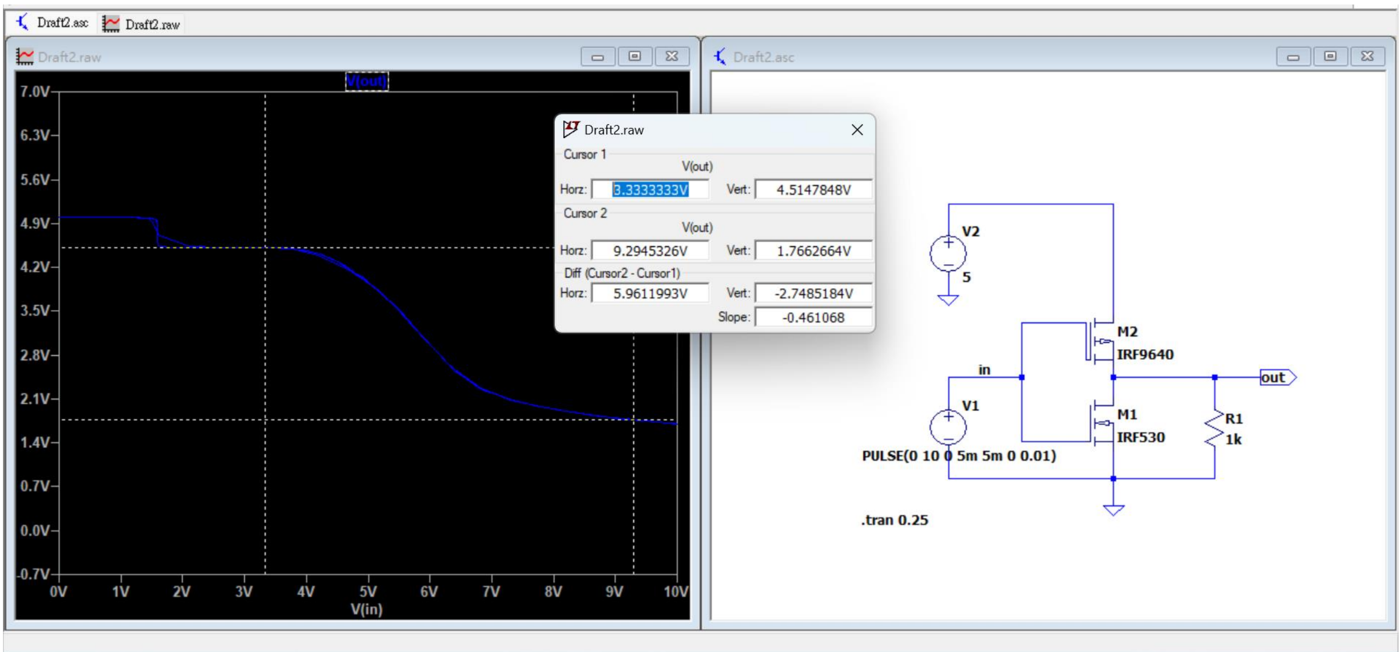


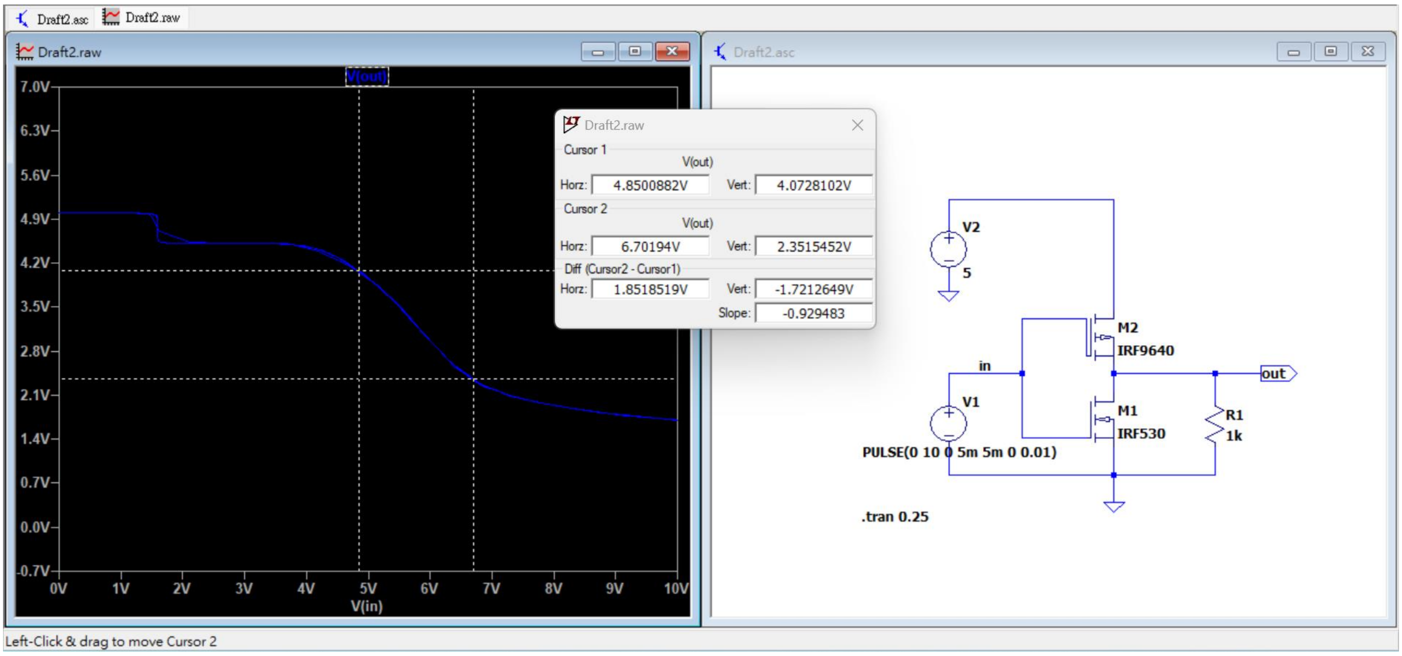
X-Y mode Graph (Set V_{in} as X axis and V_{out} as Y axis)



Find and record the following parameters:

V_{IL}(V)	1.45	V_{OH} (V)	5.166
V_{IH} (V)	1.733	V_{OL} (V)	166.6m



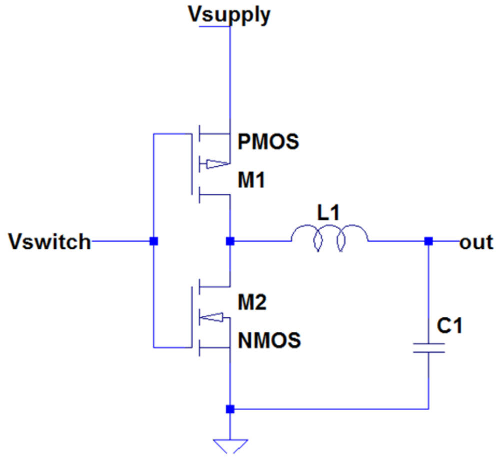


What is a CMOS inverter?

A CMOS (Complementary Metal-Oxide-Semiconductor) inverter is a fundamental building block in digital electronics. It's a type of logic gate that performs the logical operation of inversion or NOT operation. It consists of both NMOS (N-type Metal-Oxide-Semiconductor) and PMOS (P-type Metal-Oxide-Semiconductor) transistors connected in series between the power supply and ground. The input signal is applied to the gates of both transistors, and the output is taken from the common connection between the transistors, known as the drain for NMOS and source for PMOS.

When the input signal is low (logic 0), the NMOS transistor is in the off state (open switch), and the PMOS transistor is in the on state (closed switch), allowing the output to be connected to the power supply voltage, resulting in a high output (logic 1). Conversely, when the input signal is high (logic 1), the NMOS transistor turns on (closed switch), and the PMOS transistor turns off (open switch), causing the output to be connected to ground, resulting in a low output (logic 0).

Experiment 2: Buck Converter (Step-down Converter)

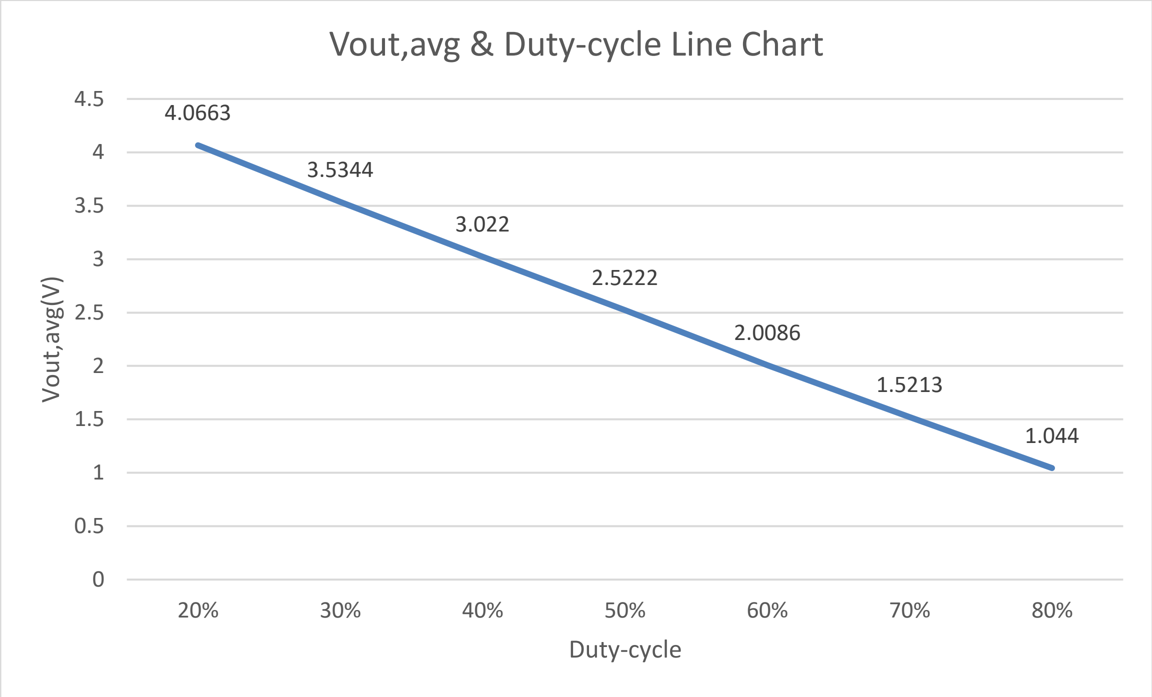


Duty-cycle (Vswitch) F.G.	20%	30%	40%	50%	60%	70%	80%
$V_{out,avg}$(V)	4.0663	3.5344	3.0220	2.5222	2.0086	1.5213	1.0440
$V_{out,ripple}$(V)	141.6m	183.3m	216.6m	250.0m	233.3m	183.3m	158.3m

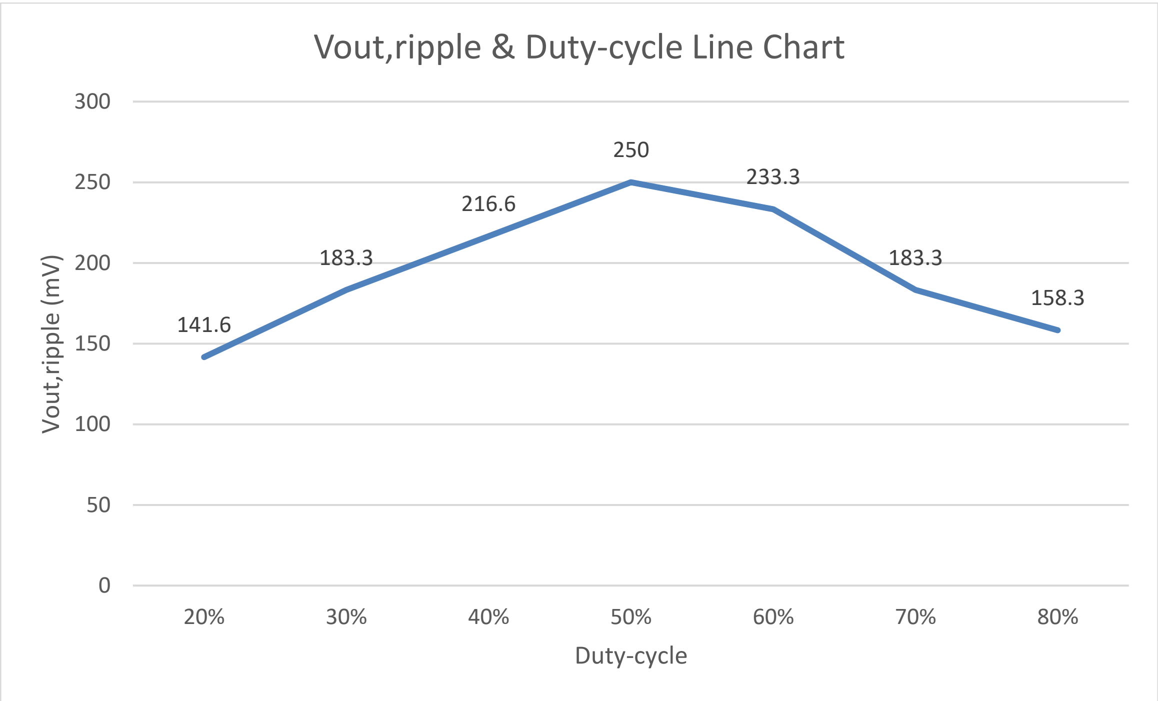
Hint: For higher accuracy, it could be helpful if you modify the vertical scale of the output waveform in an appropriate range.

Waveform requirements:

- Use DC channel coupling
- Show the following parameter on the screen
  - duty cycle of Vswitch
  - DC value and ripple magnitude of Vout

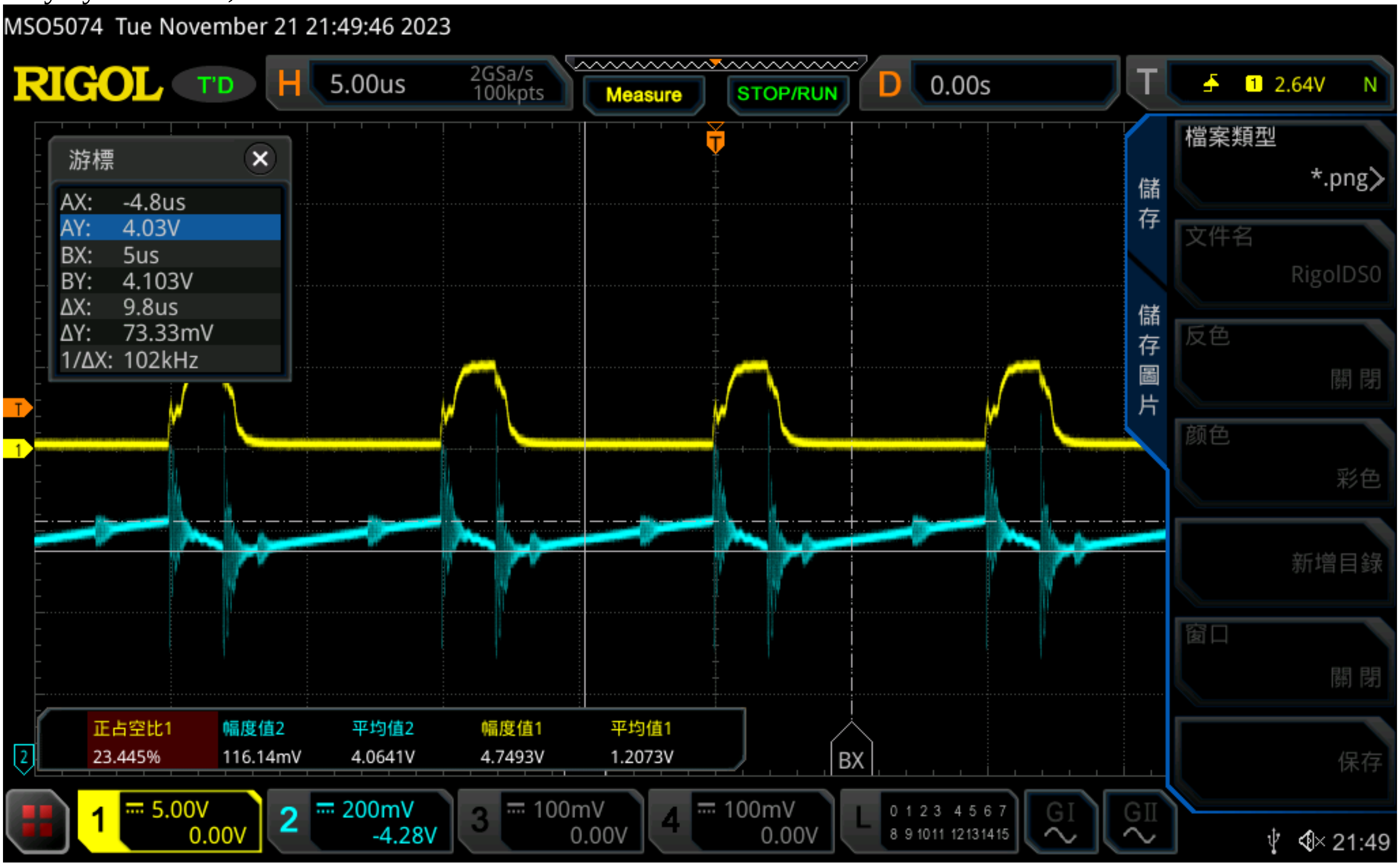


After graphing the Vout & duty-cycle relationship in a line chart, we can see that there is a linear correlation between the two. Voltage decreases linearly with the increase of duty-cycle.

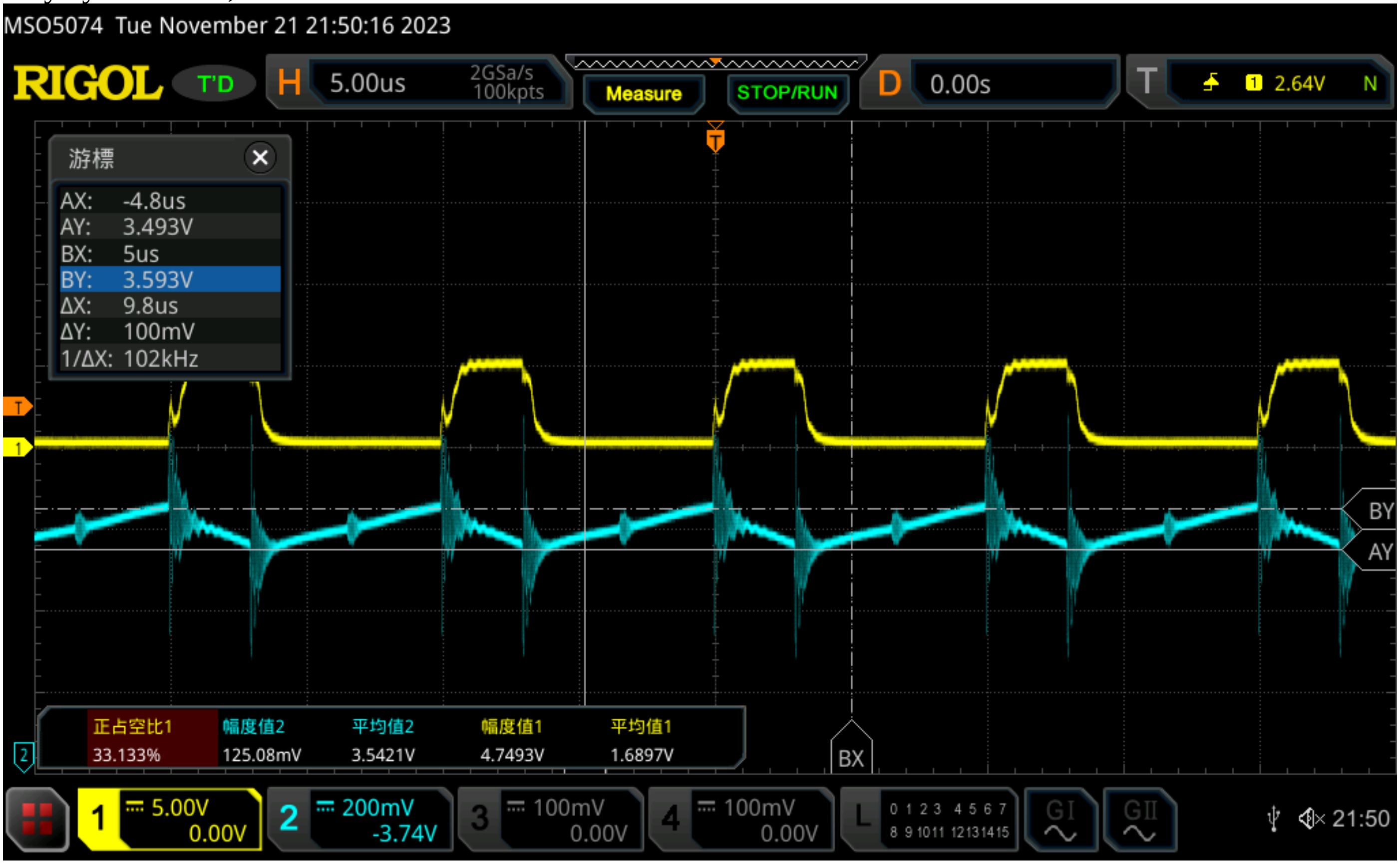


From this graph, we can see that Vripple peaks at 50% duty cycle, and falls off almost linearly towards either end of the spectrum.

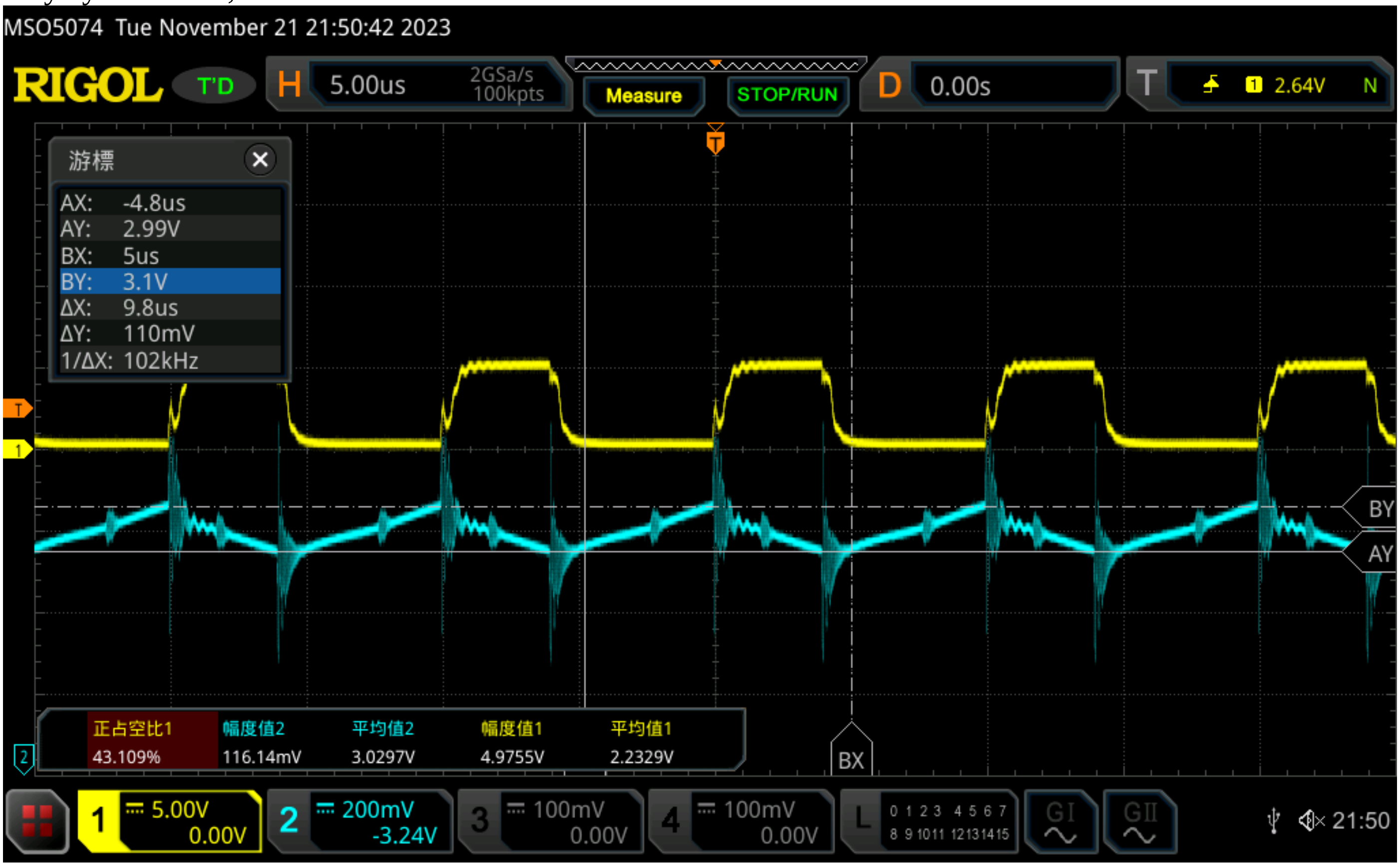
duty cycle = 20%, Vswitch and Vout waveform



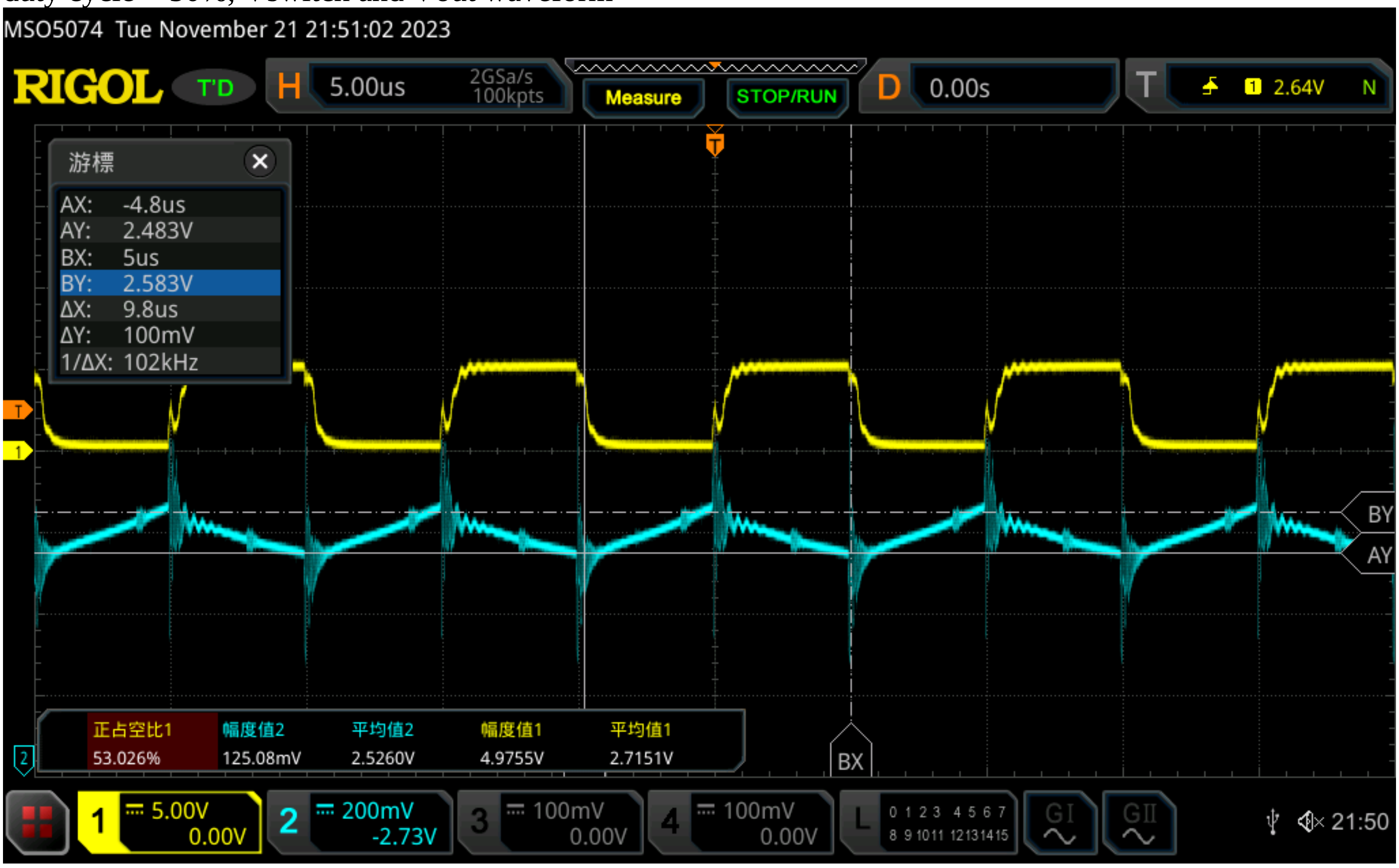
duty cycle = 30%, Vswitch and Vout waveform



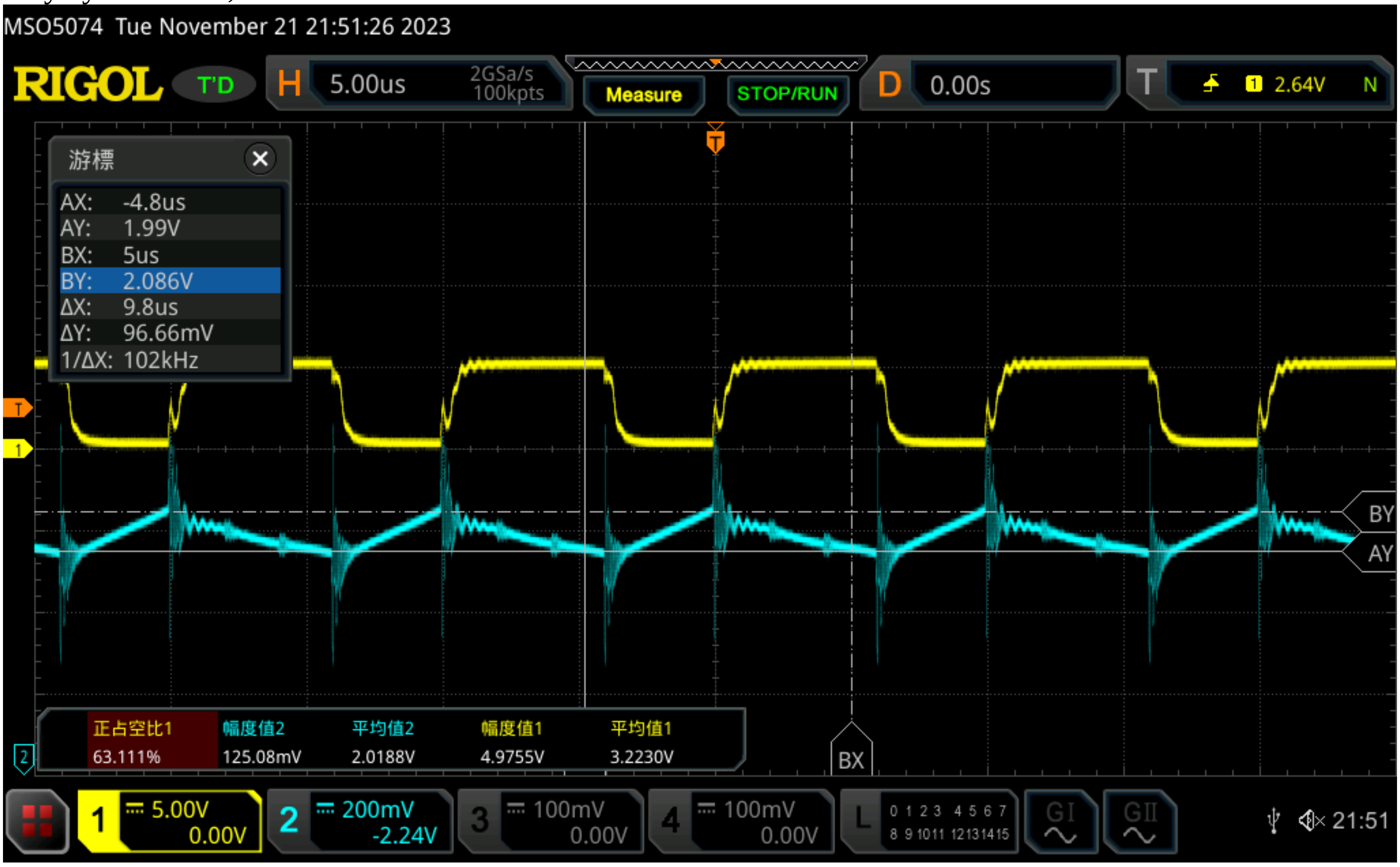
duty cycle = 40%, Vswitch and Vout waveform



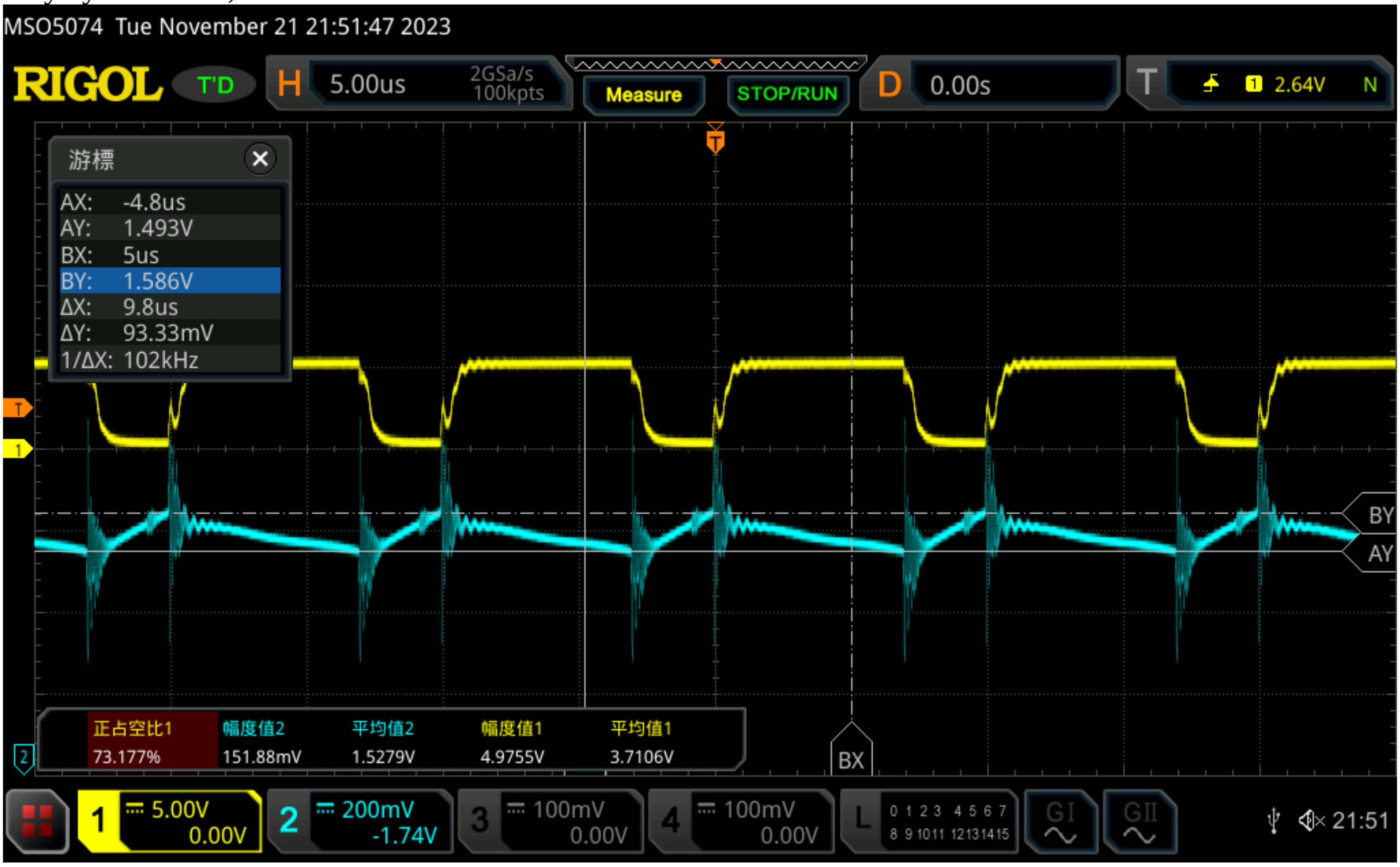
duty cycle = 50%, Vswitch and Vout waveform



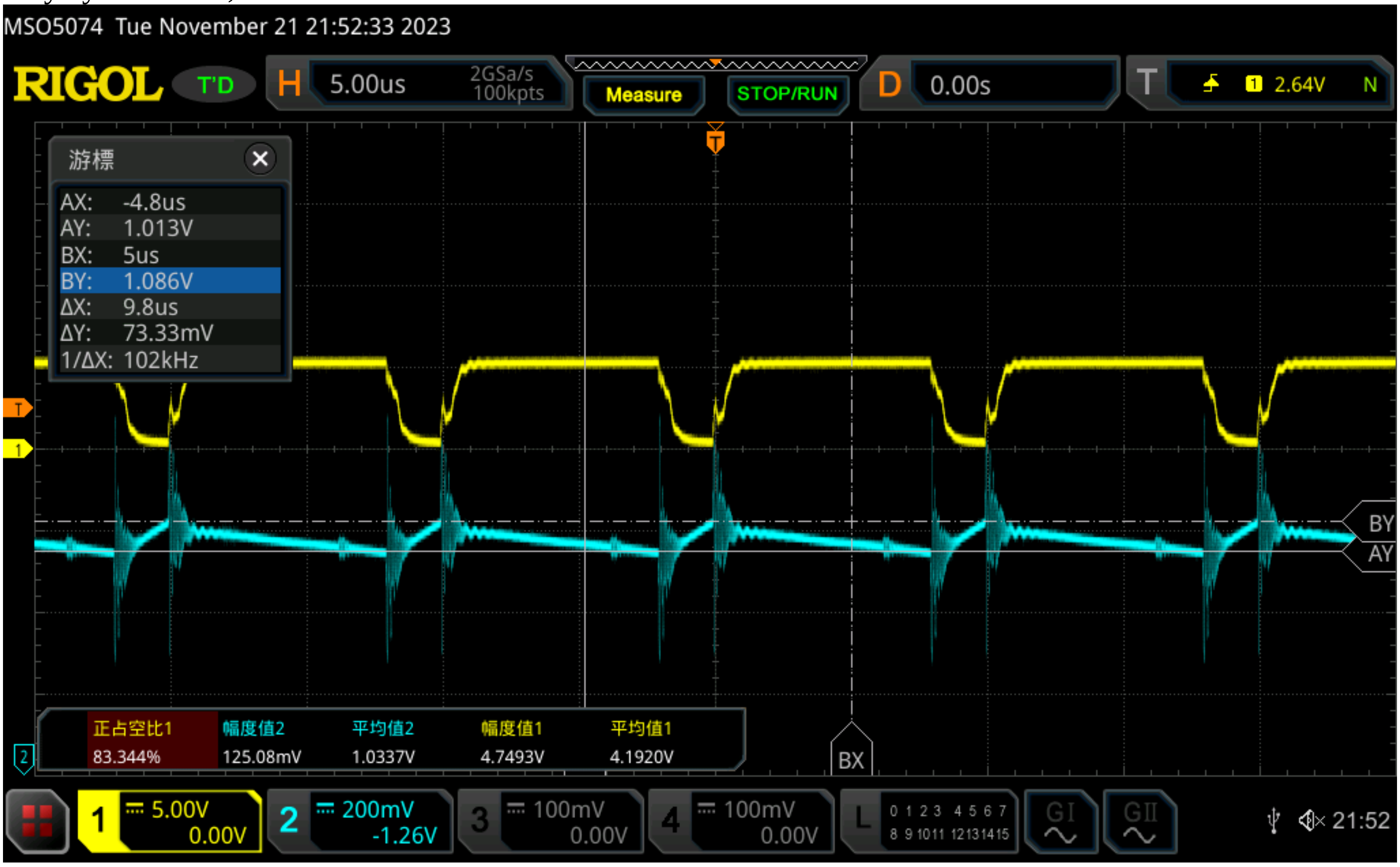
duty cycle = 60%, Vswitch and Vout waveform



duty cycle = 70%, Vswitch and Vout waveform



duty cycle = 80%, Vswitch and Vout waveform



2.

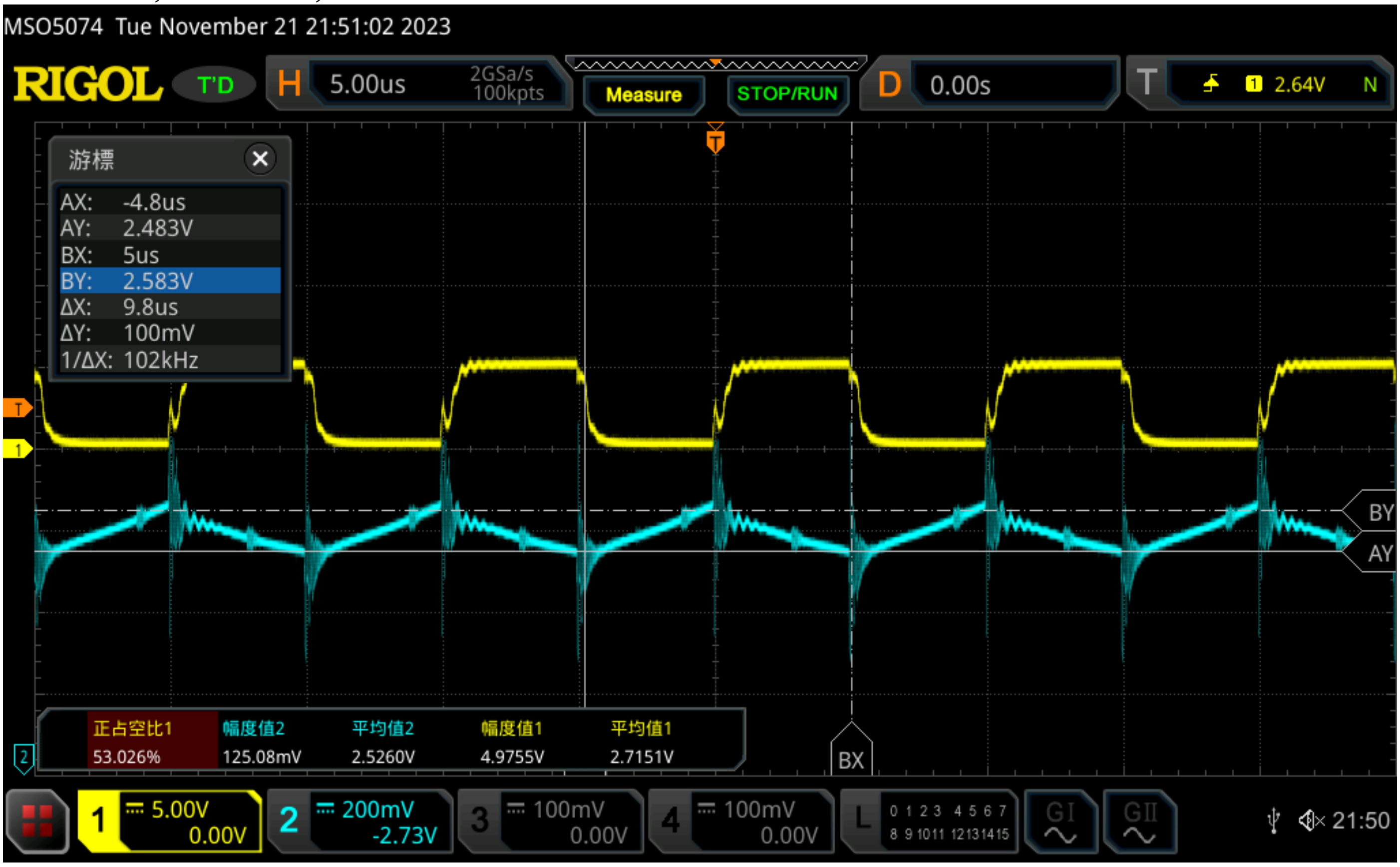
Find efficiency when RL=25 Ohm and Vout = 2.5V

Calculation process	Conditions or Methods	Result
I	RL=infinite; open, Vout=2.5V Psupply,idle= Isupply (2m) x Vsupply (0.29)	Duty cycle(F.G settings)≒ 50 % Psupply = 0.007A x 5V = 0.035 W
II	RL=25 Ohm, Vout=2.5V	Duty cycle(F.G settings)≒ 40 %
III	Psupply=Isupply x Vsupply	Psupply = 0.069 A x 5V = 0.345 W
IV	use voltmeter to confirm the value	Vout,avg = 2.53 V
V	Pload= $(Vout,avg)^2$ / 25 Ohm	Pload = 0.256036 W
VI	efficiency = Pload / Psupply	efficiency ≒ 74.213 %

Waveform requirements:

- Use DC channel coupling
- Show the following parameter on the screen
  - duty cycle of Vswitch
  - DC value and ripple magnitude of Vout

RL=infinite, Vout=2.5V, Vswitch and Vout waveforms



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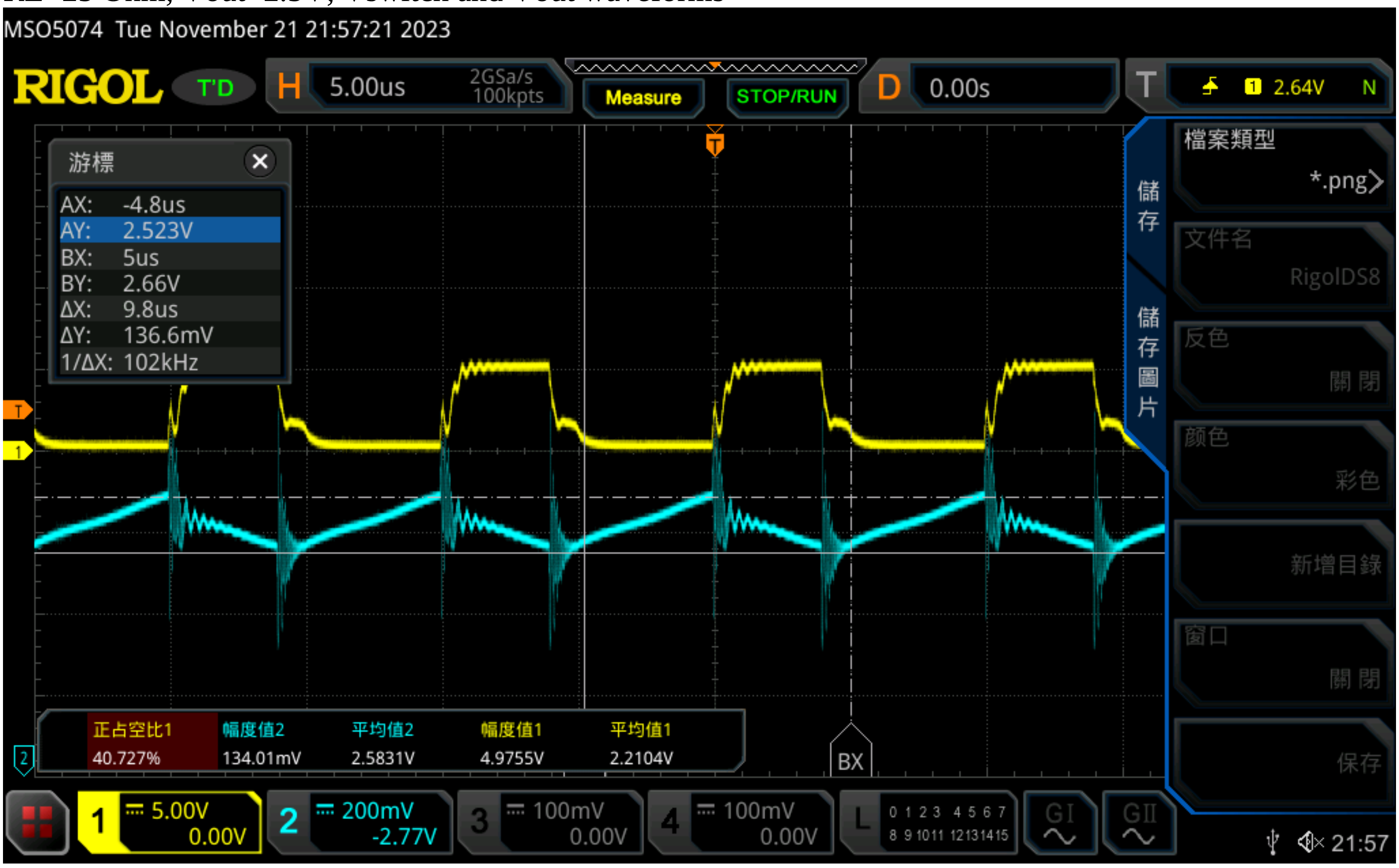
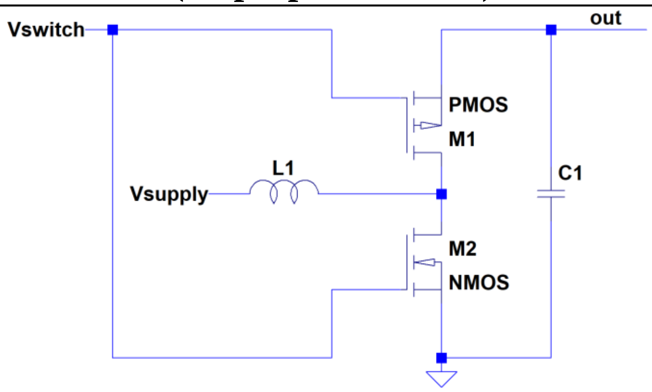
RL=25 Ohm, Vout=2.5V, Vswitch and Vout waveforms



What is a buck converter?

A buck converter is designed to convert a higher DC voltage to a lower DC voltage by rapidly toggling a switch on and off. In this case, the “switch” is a MOSFET. The switch alternates between on and off states at a high frequency. When the switch is on, current flows through the inductor, storing energy in its magnetic field. This energy is used to maintain the output voltage when the switch is off. As the switch turns off, the inductor releases its stored energy, causing the current to flow through the output load. By controlling the on-off timing of the switch, the average output voltage is regulated to a lower level than the input voltage.

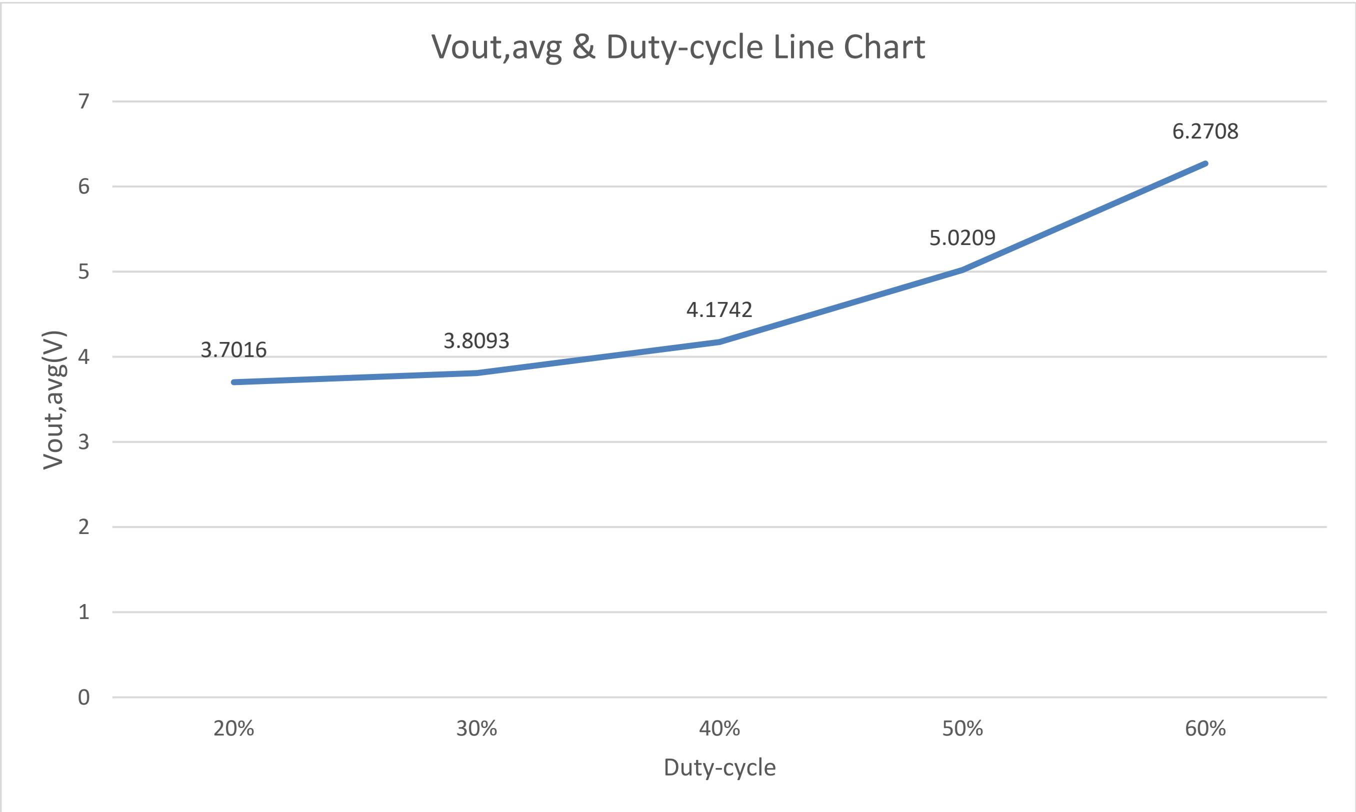
Experiment 3: Boost Converter (Step-up Converter)



Duty-cycle (Vswitch) F.G.	20%	30%	40%	50%	60%
$V_{out,avg}$(V)	3.7016	3.8093	4.1742	5.0209	6.2708

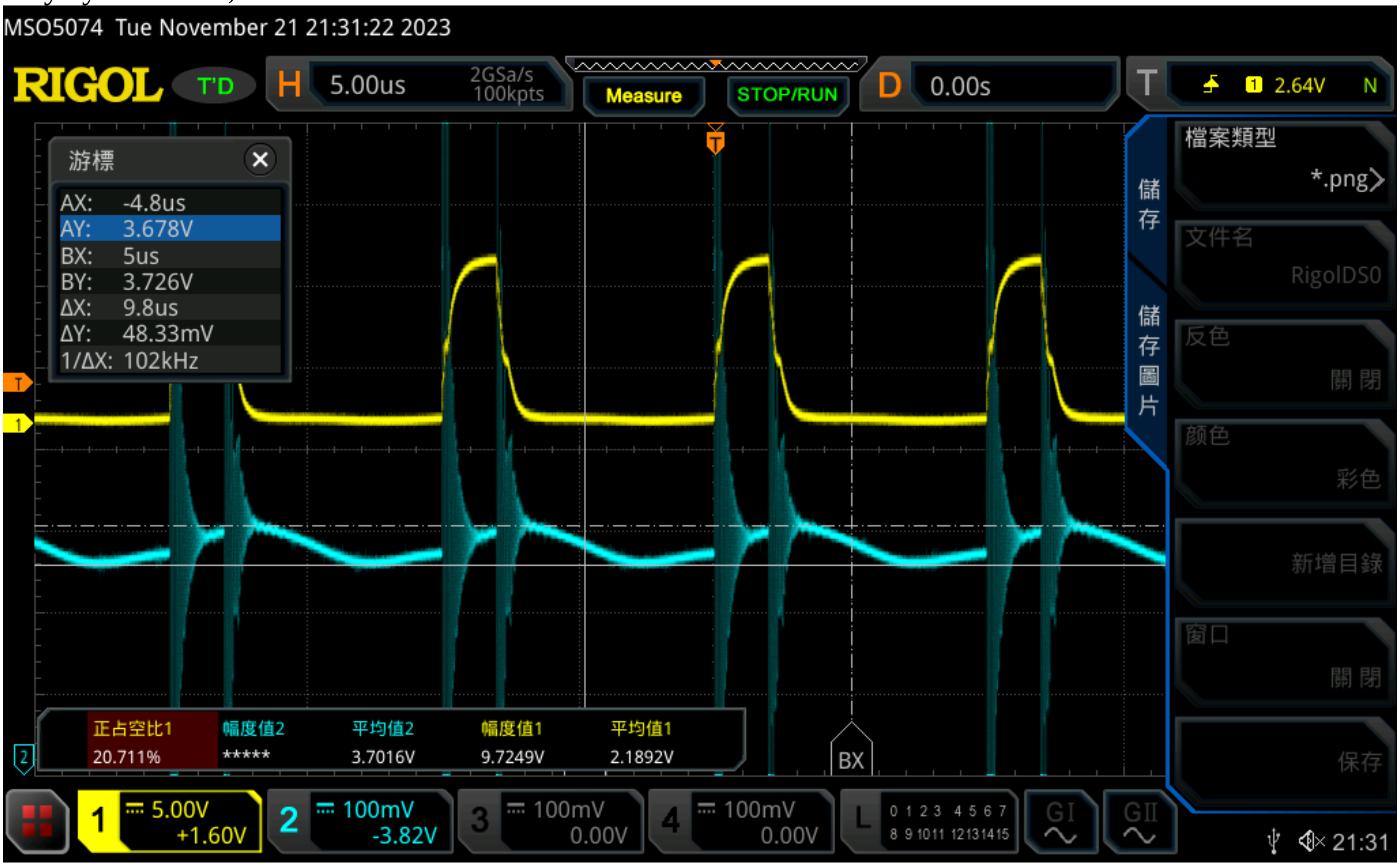
Waveform requirements:

- Use DC channel coupling
- Show the following parameter on the screen
  - duty cycle of Vswitch
  - DC value and ripple magnitude of Vout

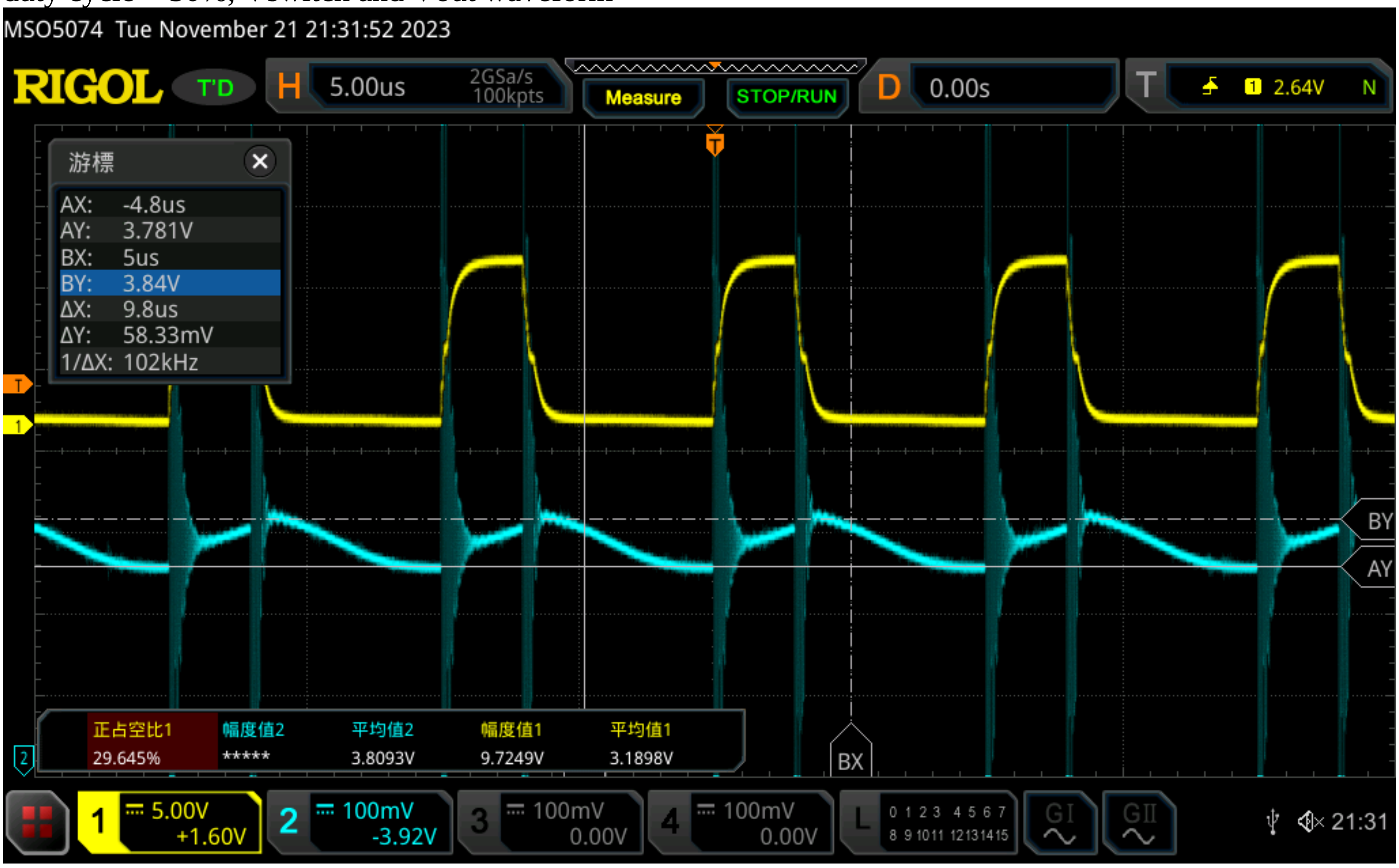


Looking at the graph, Vout appears to increase exponentially with duty-cycle.

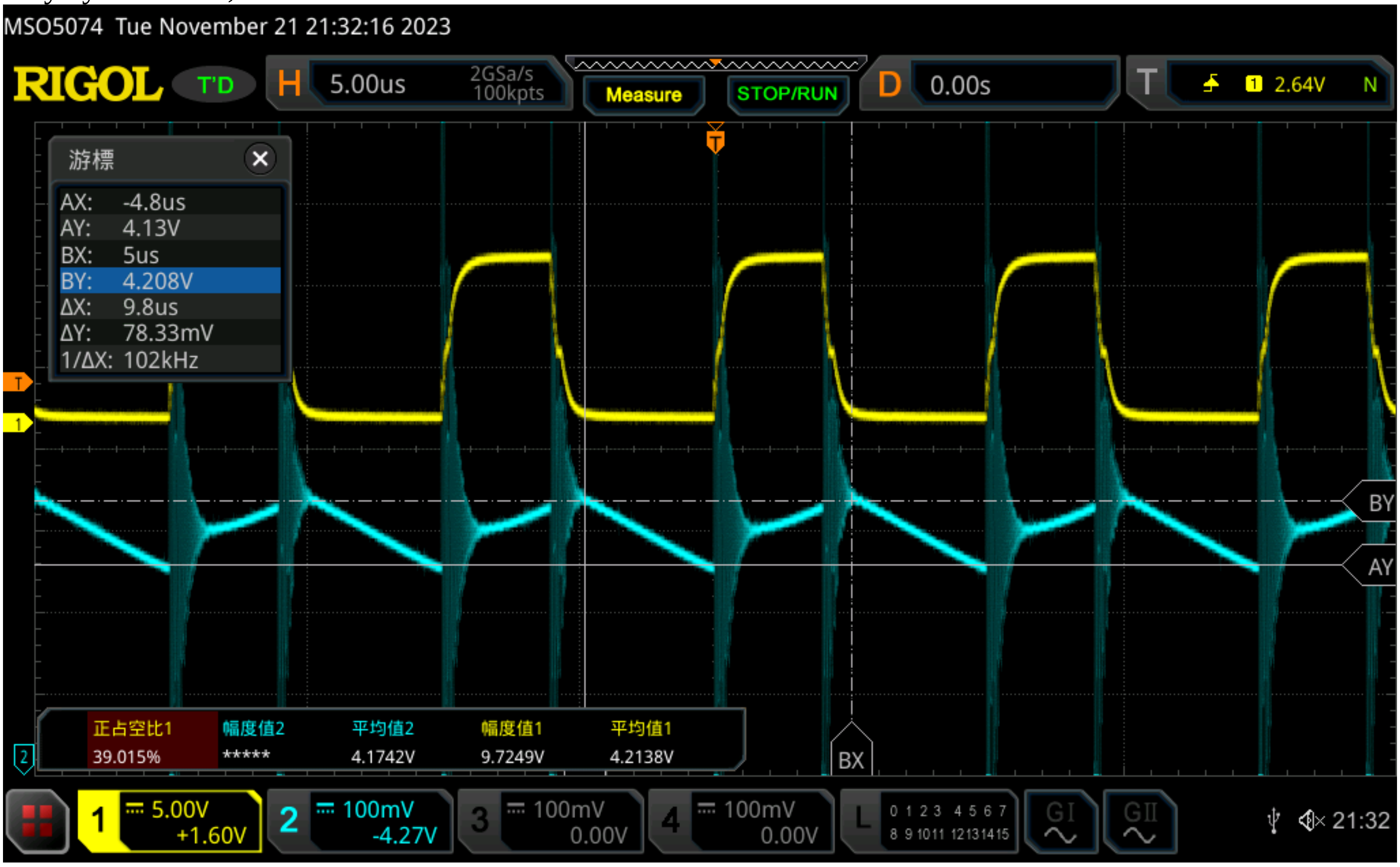
duty cycle = 20%, Vswitch and Vout waveform



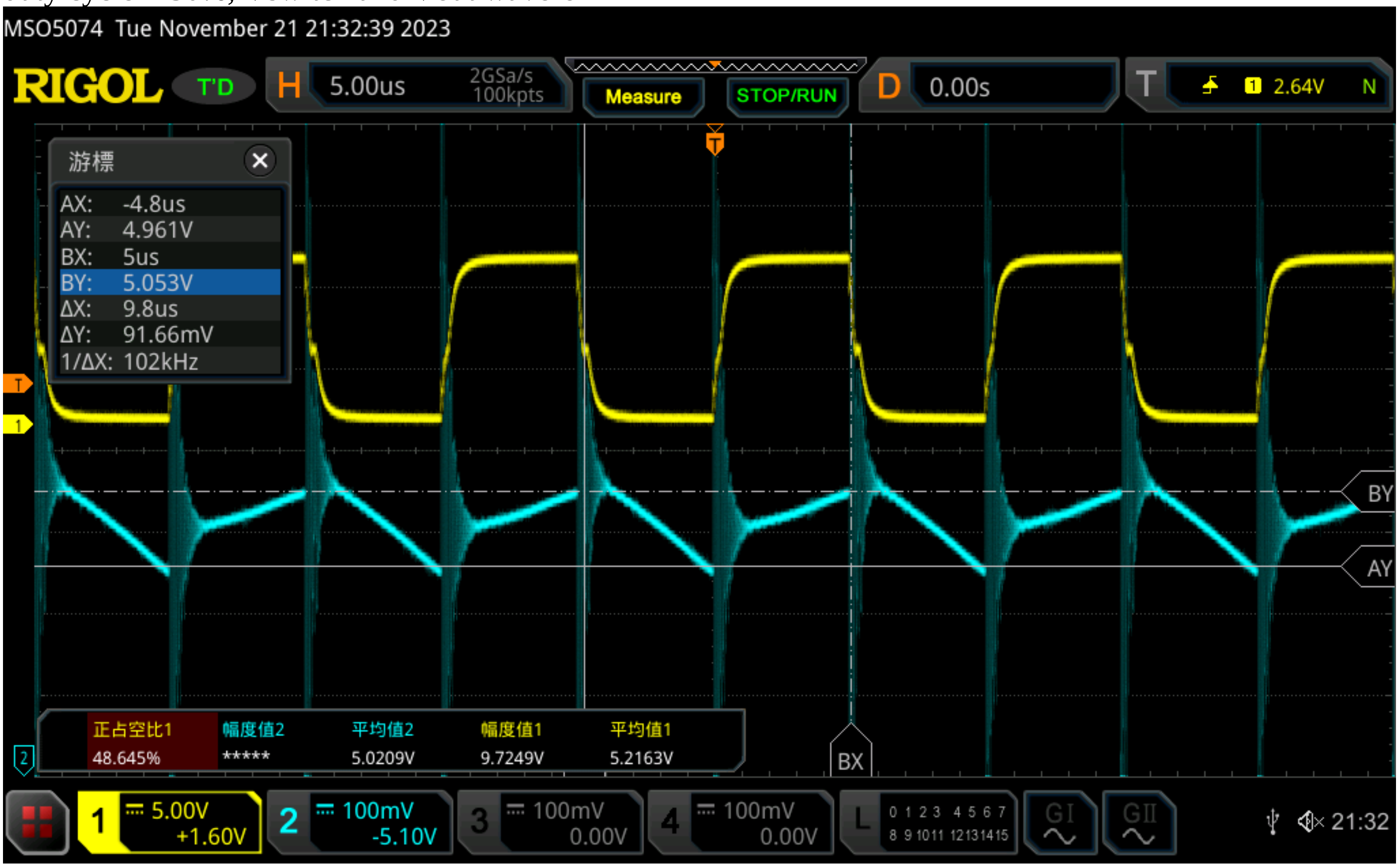
duty cycle = 30%, Vswitch and Vout waveform



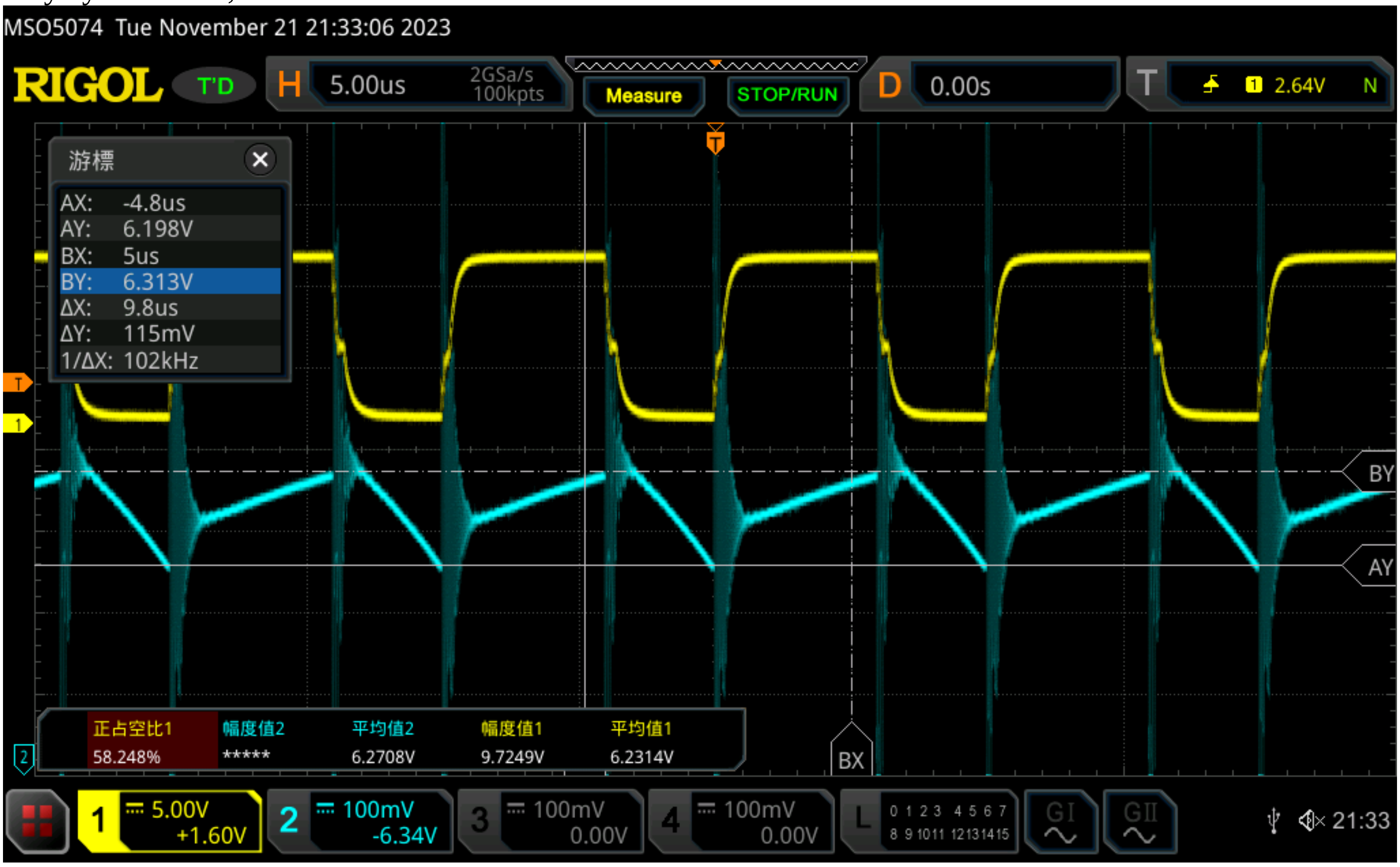
duty cycle = 40%, Vswitch and Vout waveform



duty cycle = 50%, Vswitch and Vout waveform



duty cycle = 60%, Vswitch and Vout waveform

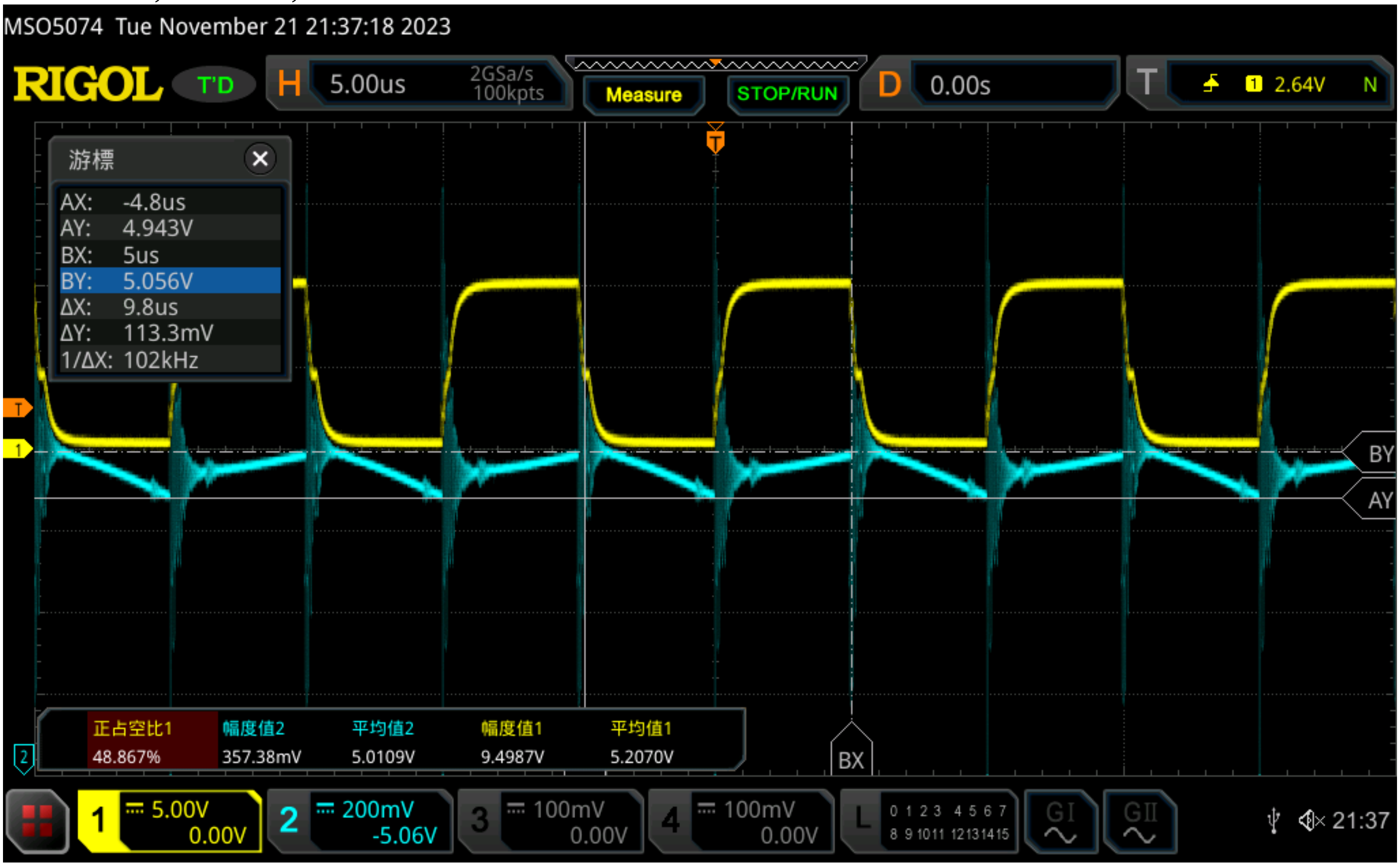


2.

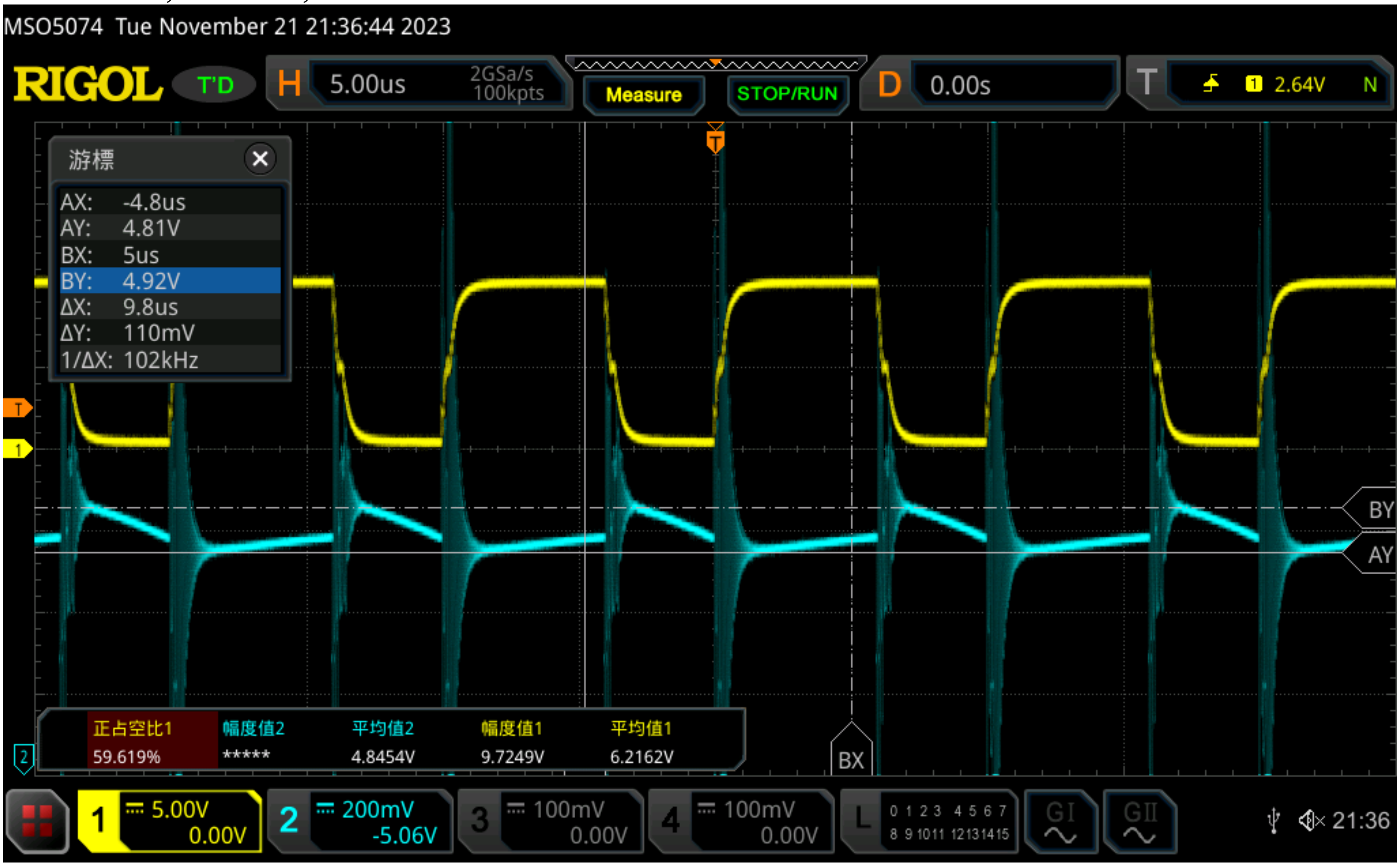
Find efficiency when RL=50 Ohm and Vout = 5V

Calculation process	Conditions or Methods	Result
I	RL=infinite; open, Vout=V Psupply,idle= Isupply x Vsupply	Duty cycle(F.G settings)≒ 50 % Psupply = 0.012 A x 2.5V = 0.03W
II	RL=50 Ohm, Vout=5V	Duty cycle(F.G settings)≒ 60 %
III	Psupply=Isupply x Vsupply	Psupply = 0.275 A x 2.5V = 0.6875 W
IV	use voltmeter to confirm the value	Vout,avg = 4.87 V
V	Pload= $(Vout,avg)^2$ / 50 Ohm	Pload = 0.474338 W
VI	efficiency = Pload / Psupply	efficiency ≒ 68.99 %

RL=infinite, Vout=5V, Vswitch and Vout waveforms



RL=50 Ohm, Vout=5V, Vswitch and Vout waveforms



What is a boost converter?

A boost converter does the opposite of a buck converter, increasing a lower DC voltage to a higher DC voltage level. Similar to a buck converter, a boost converter also uses a switch that switches on and off at a high frequency. When the switch is on, energy is stored in the inductor. When the switch is off, the inductor releases energy. Unlike the buck converter, here, the energy is sent to the output through a diode and a capacitor, effectively boosting the voltage. The capacitor smoothens the output voltage, which becomes higher than the input voltage. By controlling the on-off timing of the switch, the average output voltage is regulated to a higher level than the input voltage.

References:

1. BYJU's: CMOS Inverter – Properties & Voltage Transfer Characteristics
   https://byjusexamprep.com/gate-ece/cmos-inverter
2. Analog Devices: DC to DC Buck Converter Tutorial & Diagram
   https://www.analog.com/en/technical-articles/dc-to-dc-buck-converter-tutorial.html
3. Learn About Electronics: Boost Converter
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