BUCK CONVERTER

1) Lab Introduction

In this experiment, students construct a buck converter using discrete components, wiring, and standard power supply and measuring equipment. Then students compare Si and SiC MOSFETs as switches to discover their advantages and disadvantages. Students measure voltages and currents across various passive and active devices over a range of duty cycles (20-70%) and switching frequencies (10-50 kHz).

2) Materials and Supplies

The following are suggested:

1. PowerBox
2. dc power supply
3. Oscilloscope
4. Breadboard with passive capacitors and inductors
5. Variable-load power resistor
6. Two differential voltage probes
7. Two current probes
8. Multiple banana cables
9. Flathead screwdriver

3) Detailed Instructions

<u>Step 1:</u> Complete the buck converter circuitry by making the following connections: the source terminal of Si MOSFET 1 to one end of the inductor on the breadboard; the other end of the inductor to the upper pin of the capacitor; the cathode of Diode 1 to the same end of the inductor; the anode of Diode 1 to the lower pin of the capacitor; the positive lead of the dc power supply to the drain of Si MOSFET 1; the negative power supply lead to the anode of Diode 1; and the load resistor to the breadboard across the pins of the capacitor.

<u>Step 2:</u> Turn on the oscilloscope. Attach the differential voltage probes: one probe across the MOSFET, measuring drain to source voltage (V_{ds}), and another probe across the load resistor (V_{out}). Connect the current probes to the oscilloscope and degauss them. Attach one current probe between the source of the MOSFET and the anode of Diode 1 (I_d), and another current probe between the capacitor and the load resistor (I_{load}).

<u>Step 3:</u> Turn on the dc power supply while the power supply's output current remains OFF. The supply is set to 20 V. Ask a teaching assistant (TA) to check off the circuit before enabling the dc power supply output and switching on PowerBox (i.e., auxiliary circuitry and cooling system).

<u>Step 4:</u> Measure V_{ds} and observe the waveform on the oscilloscope. Use the screwdriver to adjust the duty potentiometer *(duty_pot)* until the duty ratio is 50%. Ensure the switching frequency is set to 10 kHz by using the screwdriver to adjust the frequency potentiometer *(freq_pot)*. Record the voltage across the MOSFET, power supply, and load voltage, as well as their respective currents as indicated in Step 2. Capture corresponding voltage and current waveform screenshots.

<u>Step 5:</u> Repeat Step 4 for duty ratios of 20%, 30%, 40%, 60%, and 70% without capturing screenshots, only recording the numbers. Set the switching frequency to 50 kHz and the duty ratio back to 50%. Repeat Step 4 at this new frequency.

<u>Step 6:</u> Turn off power and move connections from Si to SiC side of the PowerBox. Then reconnect the circuitry in the same orientation as in Step 1. Repeat similarly to Steps 2 to 5.

<u>Step 7:</u> Continuing the SiC setup, this time use the screwdriver to turn the SiC gate resistance potentiometer *(SiC-gate-pot-1)* clockwise until it stops. Change the gate switch *(gate-switch-SiC-1)* to its other position to enable gate drive tuning mode.

<u>Step 8:</u> Repeat Steps 4-5. Make a note of any differences observed in the waveforms. Similarly, adjust the gate resistance potentiometer until it is halfway between the fully clockwise and fully counterclockwise. Repeat Steps 4-5.

<u>Step 9:</u> Turn off the dc power supply, oscilloscope, and Powerbox. Disconnect probes and clean up the lab station.

4) Post Lab Questions

<u>Question 1:</u> Attach the oscilloscope captures of V_{ds} across the Si and SiC switches for a 50% duty ratio with the initial gate resistance. How do they compare at 10 kHz and 50 kHz, respectively? What about the diode currents' behaviors for the Si and SiC devices?

Question 2: Approximate the circuit's efficiency at 10 kHz and 50 kHz for the Si and SiC experiments at 50% duty ratio using the input and output voltage and current measurements. How do the efficiency numbers compare?

Question 3: Attach the screenshots of V_{ds} across the SiC switch with the varying gate resistances. Are there any differences between the waveforms? How does the higher gate resistance affect the switching action? What are some other consequences when changing gate resistances?