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## Lab 9: Practical Experimentation with Buck Converters

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Mastery of PWM Modulation Techniques and Application of DC-DC Converters

Work done by :

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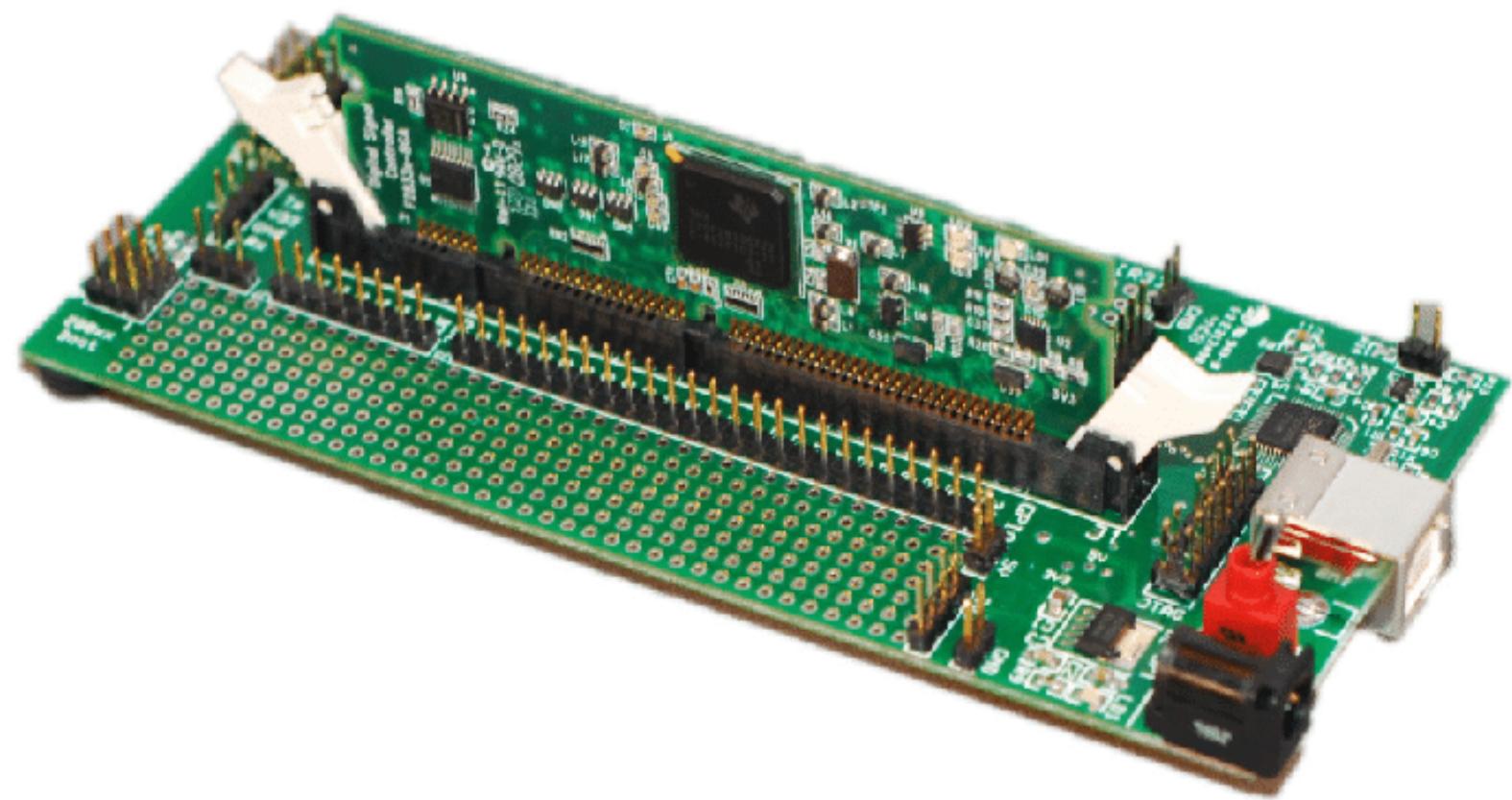
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# 1 Introduction

## 1.1 Objectives of the Practical Work

This practical work aims to enhance students' practical understanding of the operation and application of Buck converters. Through this practical work, the specific objectives are:

### 1. Understand and Apply Basic Concepts

- Review and apply the basic principles of Buck converters, including the theory of duty cycle and its impact on the output voltage.

### 2. Assembly and Experimentation

- Provide hands-on experience by assembling a Buck circuit using real components.
- Learn to adjust the duty cycle to achieve the desired output voltage.

### 3. Analysis and Interpretation of Results

- Observe and analyze the effects of duty cycle modifications on circuit performance.
- Understand the practical limits and challenges associated with the implementation of Buck converters.

### 4. Applying Theory to Practice

- Use measuring instruments such as oscilloscopes to visualize PWM signals and understand their relationship with circuit performance.

By the conclusion of this practical work, students should be able to design, build, and debug simple Buck circuits, and understand how these circuits can be adapted and used in more complex industrial or research applications.

## 1.2 Overview of Buck Converter Concepts

The Buck converter, also known as a step-down converter, is a type of DC-DC converter used to reduce an input voltage to a lower output voltage while maintaining power efficiency. It operates by temporarily storing energy in an inductor during the **ON** phase of the switching cycle and transferring this energy to the load during the **OFF** phase. The main components of a Buck circuit include an inductor, a capacitor, a diode, and a MOSFET transistor that acts as a switch.

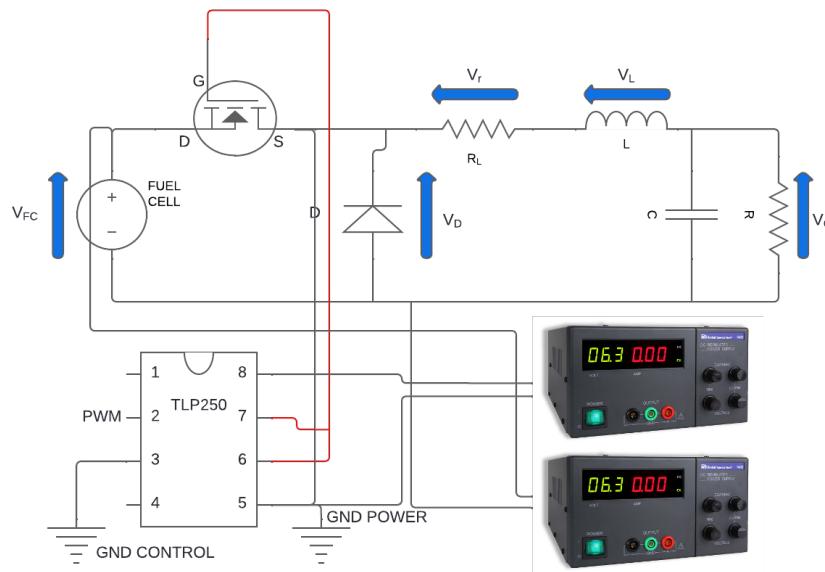


Figure 1: Schematic of the Buck Converter with TLP250

The operation of the converter is primarily controlled by the “duty cycle” of the PWM signal (*Pulse Width Modulation*) which determines the duration the switch remains closed in each switching cycle. The ratio of the output voltage to the input voltage is directly proportional to this duty cycle, making PWM an essential tool for regulating the output voltage according to the specific needs of the load.

### 1.3 Importance of PWM in Converter Modulation

Pulse Width Modulation (PWM) is a key technique for energy control in electronic circuits, particularly useful in managing Boost and Buck converters. By adjusting the ratio of the duration for which the signal is at a high level relative to the total cycle (duty cycle), PWM allows for precise control of the amount of energy transferred to the load. This directly influences the output voltage of the converter, enabling fine regulation without the need for expensive or complex analog components. The use of PWM also offers significant energy efficiency benefits, as it helps reduce power losses in switching devices.

By integrating these technologies, Boost and Buck converters, with the precise control provided by PWM, we can achieve high-performance voltage regulation suited to a wide variety of applications, from small mobile devices to large industrial power systems. This integration is essential for engineers and technicians who wish to develop more efficient and reliable electronic systems.

## 2 Assembly and Connection of the Circuit

### 2.1 Instructions for Assembling the Boost Circuit

To correctly assemble a Buck circuit following the details provided, here are the steps to ensure all components are correctly connected for efficient operation of the Buck converter.

### 2.2 Step-by-Step Assembly

#### 1. Connecting the Power Supply:

- **Positive Source:** Connect the positive terminal of the Power Supply to the Drain (D) pin of the MOSFET.

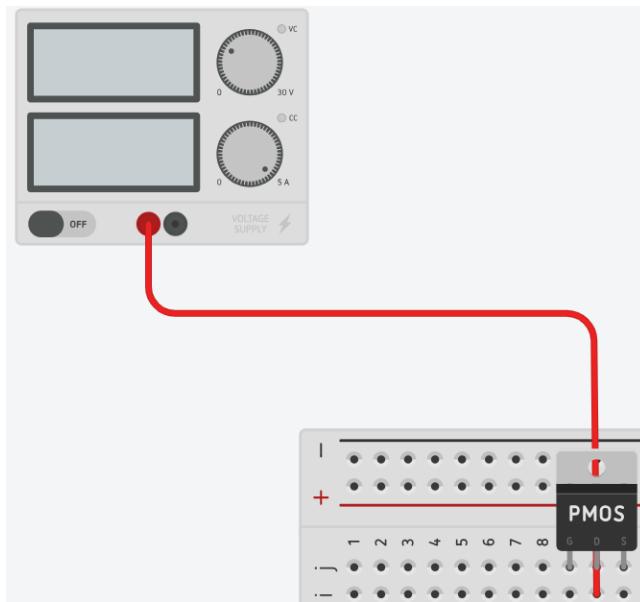


Figure 2: Connection of the power supply to the PMOS's Drain pin in a Buck converter setup.

#### 2. Setting up the MOSFET:

- **From the MOSFET to the Inductor:** Connect the Source (S) pin of the MOSFET to the input of the inductor.
- **From the MOSFET to the Diode:** Also connect the Source (S) pin of the MOSFET to the input of the diode.

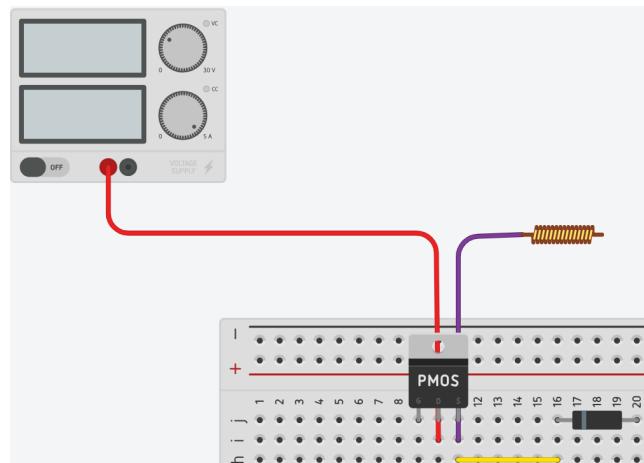


Figure 3: Illustration of the power supply connected to the source pin of the PMOS, and the PMOS connected to both the inductor and diode.

### 3. Configuring the Inductor and Diode:

- From the Inductor to the Capacitor:** Connect the output of the inductor to the positive terminal of the capacitor.
- From the Diode to the Negative Terminal:** Connect the output of the diode to the negative terminal of the Power Supply.

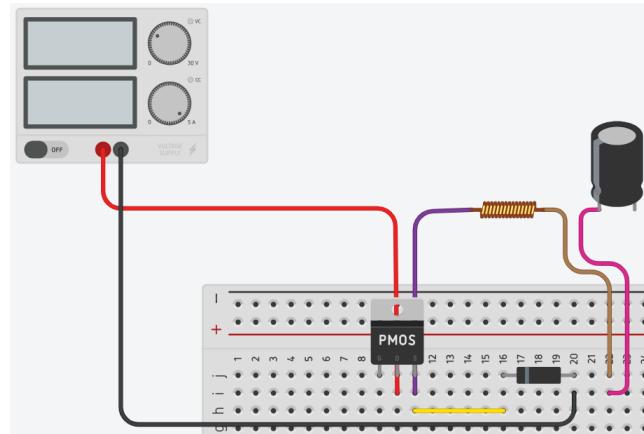


Figure 4: Illustration of a power supply connected to the drain pin of a PMOS, integrated in a Buck converter circuit.

### 4. Connecting the Load Resistances:

- From the Inductor to the Load Resistances:** Connect the output of the inductor to the input of the load resistances.
- Return of the Load Resistances and Capacitor:** Connect the output of the load resistances and the output of the capacitor to the negative terminal of the Power Supply.

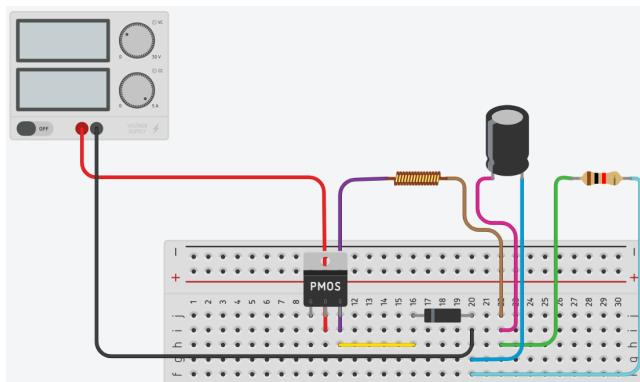


Figure 5: Complete Power Supply Connection for a Buck Converter Circuit

### 2.3 Circuit Diagram

Insert images or diagrams here to clearly illustrate the connections.

### 2.4 Safety and Verification Tips

- Connection Verification:** Before powering up, thoroughly check that all connections are secure and properly established to avoid the risk of short circuits.
- Initial Test:** Perform an initial test at low voltage to confirm that the circuit functions correctly without any smoke or excessive heat emission from components.
- Continuous Monitoring:** During operation, carefully monitor the circuit responses, particularly the voltage variations and behavior of the load resistances observed on the oscilloscope.

By following these precise instructions, you will ensure correct and efficient assembly of the Buck circuit, allowing for safe and reliable testing and experimentation.

## 3 Configuration of the Buck Circuit with TLP250

### 3.1 Reusing Connections from the Boost Practical Work

In order to simplify the assembly of the Buck circuit, we will reuse the connections already established in the previous practical work on the Boost. This approach not only saves time but also ensures pedagogical continuity for the students by allowing them to visualize the practical differences and similarities between the two types of converters.

#### 3.1.1 Connection Instructions

- Preparation:** Ensure that all necessary components and tools are available and in good condition. This includes the TLP250, the MOSFET, the power supply, and the connection cables.
- Connecting TLP250 to MOSFET:**
  - Pin 6 of TLP250 to Gate (G) Pin of MOSFET:** The pin 6 of TLP250, responsible for emitting the control signal, must be connected to the Gate pin of the MOSFET. This connection is crucial as it allows controlling the opening and closing of the MOSFET, thus regulating the energy flow in the Buck circuit.
  - Pin 5 of TLP250 to Source (S) Pin of MOSFET:** Connect the pin 5 of TLP250, which serves as the reference for the control signal, to the Source pin of the MOSFET. This connection ensures that the control signal of the TLP250 and the MOSFET share the same voltage reference, optimizing the reliability and performance of the control signal.

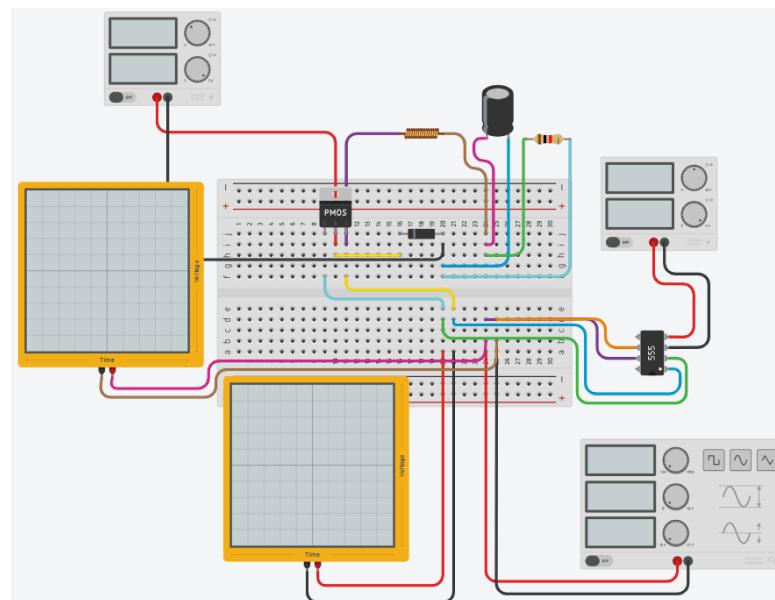


Figure 6: Illustration of the TLP250 connections to the MOSFET in the Buck circuit.

3. **Verification of Connections:** Once the connections have been established, double-check each connection to ensure they are secure and correct. A poor connection can not only prevent the circuit from functioning properly but also pose safety risks.

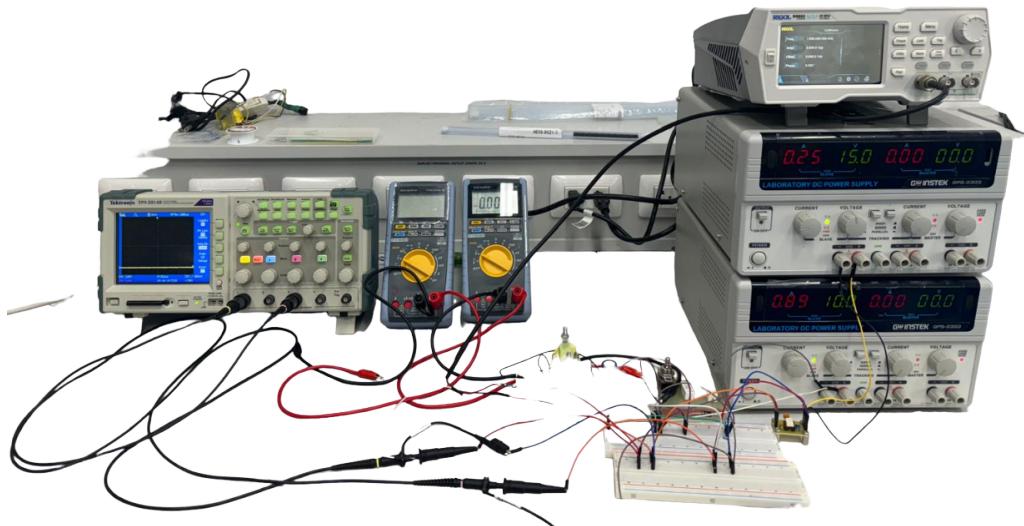


Figure 7: Real setup of the Buck circuit showcasing two power supplies, the TLP250, multimeters, a function generator, and an oscilloscope, demonstrating the practical implementation of the circuit and its testing equipment.

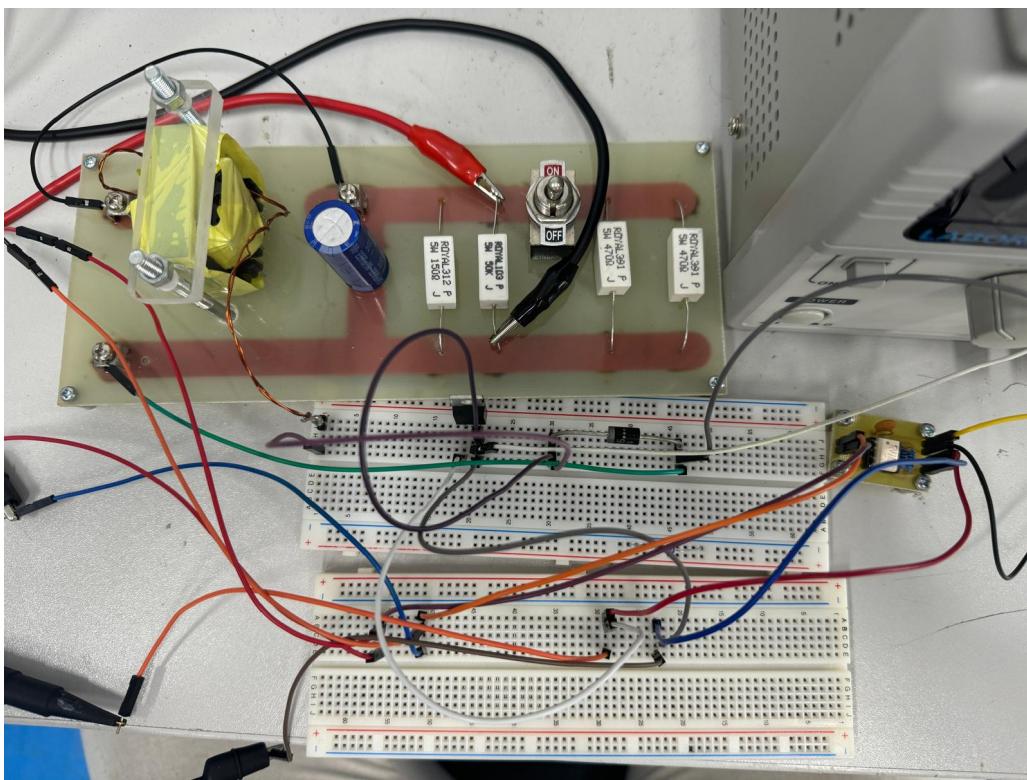


Figure 8: Detailed view of the Buck converter setup featuring the circuit and the TLP250 module, illustrating the practical implementation of the components on the breadboard.

By following these steps, you efficiently prepare the circuit for performance testing under controlled conditions, while effectively reusing resources and setups from the previous practical work. This method ensures a smooth transition to experimenting with the Buck converter, allowing students to focus on applying concepts rather than on the initial setup of components.

### 3.2 Power Supply Management

In this practical work, it is essential to manage power sources correctly to ensure optimal and safe operation of the Buck circuit in conjunction with the TLP250. Proper management is crucial to avoid electrical issues such as grounding conflicts that could affect performance or damage components.

#### 3.2.1 Using Two Power Sources

The Buck circuit and the TLP250 each require a separate power supply to avoid interference caused by ground potential differences between the two systems. Using two distinct power sources allows for:

- **Separating Grounds:** Each device has its own ground (GND), which prevents ground loops and electrical interference that could result from a common connection to the same ground.
- **Optimizing Performance:** Allows each device to operate at its optimal level without mutual influence, particularly in voltage regulation and signal response.



Figure 9: Two power supplies set up, demonstrating the different voltage settings for the Buck circuit and TLP250 as required in the experimental setup.

It is recommended to configure one power supply at 10V specifically for the Buck circuit and another at 15V to power the TLP250. This ensures that both devices operate independently, thus providing reliable and accurate test results.

### 3.2.2 Function Generator Settings

The function generator plays a crucial role in generating the PWM signal that controls the MOSFET in the Buck circuit. For this practical work, the settings of the generator must be adjusted as follows to match the requirements of the circuit:

- **Frequency:** Set at 10 kHz, this frequency is high enough to ensure good responsiveness of the circuit without being too fast to avoid excessive switching losses.
- **Amplitude:** Fixed at 3.3V, this amplitude is chosen to ensure adequate activation of the MOSFET's gate without risking overvoltage.
- **Offset:** An offset of 1.65V is used to center the signal around a mean value, allowing for better stability in controlling the MOSFET.
- **Duty Cycle:** A duty cycle of 50% is used to start the tests, providing a balanced basis to observe the effects of modulation on the output voltage.



Figure 10: Function generator set to specific parameters, demonstrating the desired settings for controlling the MOSFET in the Buck converter circuit.

By following these settings precisely, you prepare the circuit for a series of experiments that will reveal how adjustments to the PWM signal directly influence the performance of the Buck converter. These parameters are essential for exploring the efficiency of the design and for identifying potential improvements needed.

### 3.3 Tests and Observations

After correctly configuring and connecting all components of the Buck circuit with the TLP250, it is essential to conduct a series of tests to evaluate the circuit's performance. This step is crucial not only to confirm the proper functioning of the assembly but also to analyze the efficiency of the converter under various load and PWM signal conditions.

#### 3.3.1 Procedure for Testing the Performance of the Buck Circuit

1. **Initial Observation:** Use an oscilloscope to observe the signals at key points of the circuit, particularly at the MOSFET terminals and load points. This allows for direct visualization of the PWM signal's effect on the circuit.
2. **Connecting the Multimeter for Voltage Measurements:**
  - Connect a multimeter to the terminals of the load resistance, which is the output of the Buck circuit. This allows for direct measurement of the output voltage and verification if the circuit produces the expected voltage based on the duty cycle and other set parameters.
  - Ensure the multimeter is set to measure direct current (DC) voltage to obtain accurate readings.
3. **Measuring Output Voltages:** Use the multimeter to measure the output voltage at the load resistance. Compare this voltage to the input voltage to assess the efficiency of the Buck converter. Measurements were made with load resistances of 150 ohms and 92 ohms, producing output voltages of 6.142V and 5.352V respectively.
4. **Adjustments and Optimizations:** If necessary, adjust the duty cycle and other PWM signal parameters to optimize the output voltage and the circuit's response.

#### 3.3.2 Discussion of Expected Results versus Actual Observations

- **Expected Results:** Theoretically, for a Buck circuit with a 70% duty cycle, the output voltage should be approximately half of the input voltage. For example, with a 10V input, the expected output would be 7V.
- **Actual Observations:** In practice, measured voltages can differ from theoretical values due to several factors such as internal resistance of components, inductive and capacitive losses, and switching dynamics. Variations such as outputs of 6.85V and 6.53V indicate inefficiencies or needs for adjustment in the circuit or PWM signal.

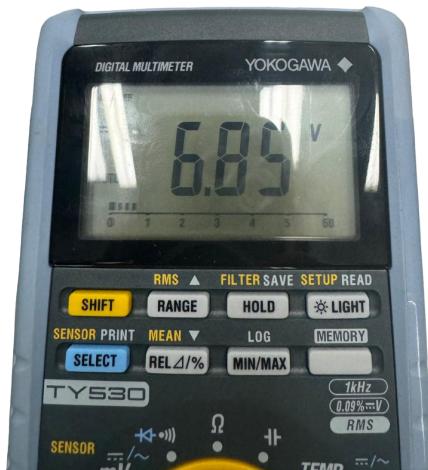


Figure 11: Measurement with a load resistance of 150 ohms

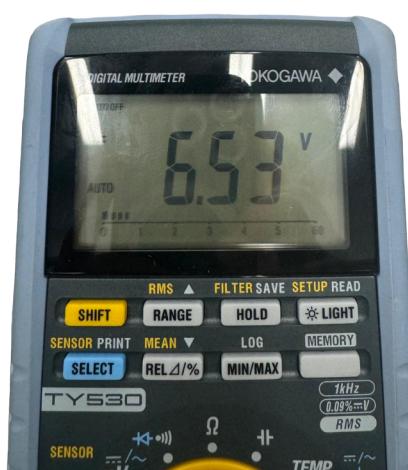


Figure 12: Measurement with a load resistance of 92 ohms

Figure 13: Output voltage measurements from the Buck circuit as displayed on the multimeter.

- Analysis of Discrepancies:** Discuss possible reasons for the observed discrepancies and propose hypotheses on necessary improvements or corrections. This may include adjustments of components, revising parameters of the function generator, or improvements in circuit design to minimize losses and optimize response.

By following this detailed procedure and openly discussing the results, students can better understand the practical nuances of operating Buck converters and learn to solve technical problems effectively.

## 4 Conclusion

At the conclusion of this practical work on the Buck converter, we have successfully applied theoretical knowledge acquired in previous sessions to a practical and interactive context. The use of the TLP250 to generate PWM signals and its integration into the Buck circuit has allowed us to deeply understand the impact of pulse width modulation on the performance of DC-DC converters.

## Summary of Activities

During this practical work, we executed precise assemblies to simulate real-world conditions of using a Buck converter. The steps of connecting the TLP250, as well as the necessary adjustments of the power sources to avoid grounding conflicts, were critical aspects of our experience. These activities highlighted the importance of a good understanding of electrical characteristics and safety precautions when handling complex electronic circuits.

## Observations and Results

The results obtained, although slightly divergent from theoretical predictions, have been extremely enriching. We observed that the output voltage of the Buck circuit did not precisely reach half of the input voltage, as theoretically expected with a 50% duty cycle. The deviations, though minimal, prompted us to investigate further into the design aspects and parameters of the circuit, confirming the importance of details in power electronics applications.

## Implications and Next Steps

This experience has not only reinforced our understanding of the operation of Buck converters but also highlighted paths for future improvements. By further exploring the settings of the function generator and optimizing the components of the circuit, we could further minimize discrepancies and enhance the overall efficiency of the system.

In conclusion, this practical work was not only an opportunity to apply theory to practice but also a chance to learn in a dynamic and engaging way. The skills and knowledge gained here will be essential for our future

projects and experiences in electronics and electrical engineering.

Please complete this table with your values.

$V_{in}(V)$	Duty Cycle (%)	$V_{out}(V)$
10	10	...
10	20	...
10	30	...
10	40	...
10	50	...
10	60	...
10	70	...
10	80	...
10	90	...
10	100	...

Table 1: Table of values of  $V_{in}$ , Duty Cycle and  $V_{out}$

Please complete this table with your values.

$V_{in}(V)$	Duty Cycle (%)	$V_{out}(V)$
...	...	...
...	...	...
...	...	...
...	...	...
...	...	...
...	...	...
...	...	...
...	...	...
...	...	...
...	...	...

Table 2: Table of values of  $V_{in}$ , Duty Cycle and  $V_{out}$