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Self Tuning Buck Converter

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Submitted in partial fulfilment of the requirements for
Bachelor of Engineering with Honours.

Abstract

Put in an abstract once the full report has been written.

Contents

Chapter 1

Introduction

I am very unsure on what I'm going to write here, if you have any suggestions that would be appreciated.

Switch-mode power supplies are commonly used in a wide variety of consumer and professional appliances to transform DC voltages with high efficiency. One such switch-mode supply is the buck converter, which steps down a DC voltage. The design of a buck converter is based around its tolerated inductor ripple, and will require specific components to design the output filter. These components can be difficult to purchase or accurately manufacture. This project will implement control systems to actively control with inductor ripple by modulating the switching frequency. This will allow engineers to design the converter directly for the inductor ripple, eliminating the need to design the output filter.

Chapter 2

Background

A Literature research was performed to inform design decision made in this project, and to evaluate any existing research. It will discuss buck converter design factors and topologies, as well as the various different methods of PWM generation. In performing this literature research, the following terms were used to search for articles from Google Scholar, Engineering Village, and Te Waharoa:

- Frequency Variable PWM
- Frequency-PWM converter
- Switching Frequency Converter

These searches returned no research relevant to the designs of this project, with the only related work focusing on the electromagnetic noise reduction using randomised frequency modulation [1, 2]. Because of this, research was instead performed to inform the design of the buck converter and the generation of PWM signals.

2.1 PWM Generation

- Discuss what PWM is, and how it is used in the context of a buck converter.
- Discuss the different methods of PWM generation.
  - Analogue
  - Digital (Microcontroller & FPGA)
- Discuss how PWM is used in the context of the project. Quickly overview how in this project it will be important to modulate both the PWM frequency, and the PWM duty cycle.

2.2 Buck Converters

The buck converters is a variant of a switch mode power supply that steps down a DC input voltage to a DC output voltage. They are commonly used in a wide variety of consumer and professional appliances such as laptops, phones, and chargers due to their high efficiency compared to other DC-to-DC step down converters such as linear regulators [3].

The basic operational components of a buck converter can be seen below in Figure 2.1. From this we see that a buck converter has three main elements, the input voltage source, two switching components, and an output filter across the load. In the case of Figure 2.1, the first switching component is an actively controlled switch such as a MOSFET or transistor, and the second a passive switching diode. This configuration of an active and a passive switch is known as the non-synchronous buck converter topology, if the passive diode were to be replaced with a second active switch the topology would be considered synchronous. Although both topologies function under the same fundamental principles, the non-synchronous topology is easier to implement with the drawback of higher losses and therefor lower efficiency.

It can also be seen from Figure 2.1 that a buck converter has two operating states that are controlled through the activation of these switching components. By toggling these switching components at high speed though the use of PWM, we can control the current flowing through the inductor of the output filter. By controlling this current we are also able to directly control the current through, and voltage across the output load of the converter. Using this, buck converters will often have a feedback control system in their design to be able to actively control and regulate the output voltage during usage. This controller will vary the duty cycle of the the switching PWM signal, thereby varying the output voltage of the buck converter as shown in equation 2.1

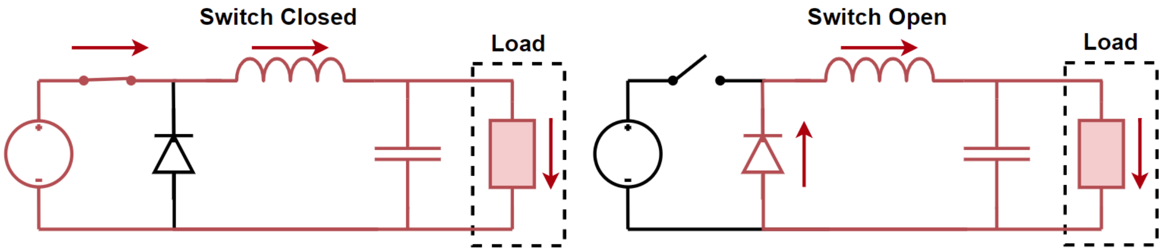

Figure 2.1: Operating states of a buck converter

2.2.1 Buck Converter Design

The design of a common buck converter has two main considerations, the output voltage of the converter V_0, and the inductor current ripple of the converter Δi_L. These considerations can be specified by designing the buck converter around the equations 2.1 & 2.2.

When designing a buck converter the first design specification that must be met is the output voltage. In equation 2.1 the output voltage can be directly related to the input voltage V_{in}, and the duty cycle D. Using this equation it is possible to directly set the output voltage of the buck converter.

$$V_o = D \cdot V_{in} \tag{2.1}$$

$$\Delta i_L = \frac{V_o \cdot (1 - D)}{L \cdot f_s} \tag{2.2}$$

2.3 Control Systems

Possibly not needed in this report as I have not designed any control systems yet for this project?

- Discuss in very general terms what a control system is what what it seeks to do in a system.
- Discuss what the control system will be doing in the case of this project. Talk about how a controller will be used to control both the output voltage of the converter, and the inductor ripple of the converter.

Chapter 3

Work Completed

3.1 System Architecture & Design

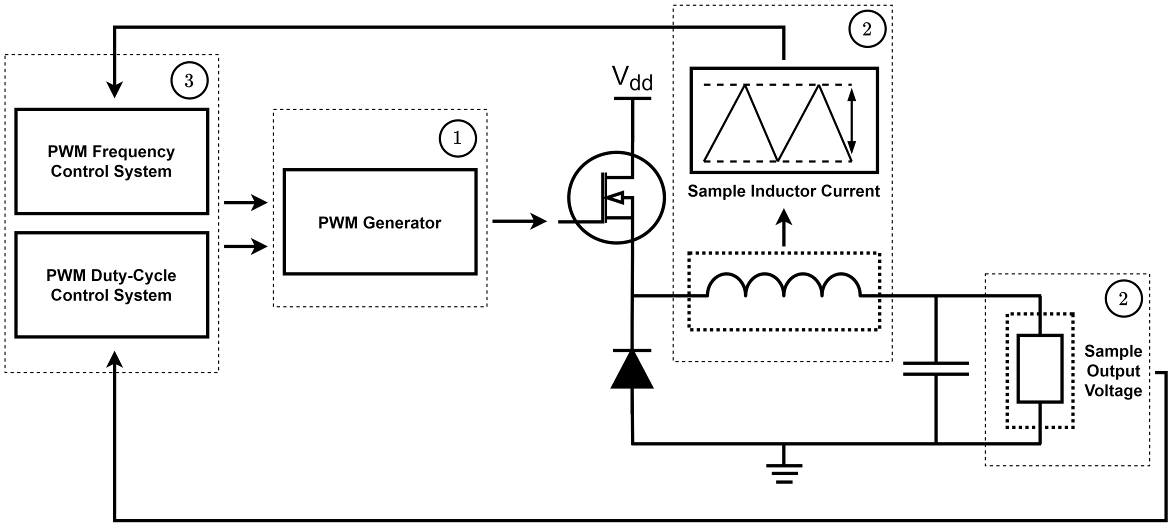

Figure 3.1: High level system overview

- Give an overview of the entire system architecture. This means a high level block diagram of what different inputs and outputs are, and what the different signals in the system are. This can be done with the help of a diagram that I will create.

3.2 Defining & Justifying System Specifications

- Discuss the requirements that were laid out in the project proposal for the evaluation of the system.

- Discuss how these system requirements needed to be translated into a set of quantitative system requirements that can be used to define and design the system.

- Discuss the system requirements that are required to effectively design the system (PWM frequency & duty cycle step size), and then outline how they were calculated.

- Discuss how these requirements will affect the design of the system

3.3 PWM Generation Design

- Discuss the different PWM generation methods outlined in chapter 2. Talk about each of their specific design implication, their advantages, and their disadvantages. This will be included in three different sections, analogue, microcontroller, FPGA.
- Discuss why I have selected a microcontroller for the PWM generation. And discuss how the design of this implementation affected the microcontroller selection.
- Discuss how the final design of the PWM generation was implemented, and what it's capabilities are. Show some images of it functioning, and attach the esp32 code in the appendix.

Chapter 4

Future Plan

4.1 Work to be Completed

- Discuss what work I still have to do before beginning the evaluation of the system.
  - Select sensors to measure peak-to-peak ripple current
  - finalise the circuit design for the project, this includes selection all other components needed for it's operation.
  - Create a final PCB for the design
  - Design the controller that will control both output voltage and inductor ripple

4.2 System Evaluation

- Discuss how the system will be evaluated, reference the project proposal as this will not have changed significantly.

4.3 Project Timeline

- Create another Gant chart that now more accurately breaks down the required tasks into the remaining time. Discuss this chart and why it is set out the way that it is.

Feedback

- I want to ask for some suggestion on evaluating the final artefact. The evaluation described within my proposal has not changed, and it seems to be very simple at the moment.

Bibliography

[1] J. R. Roman, "PWM regulator with varying operating frequency for reduced EMI," Mar. 2001.

[2] Y. L. Familiant and A. Ruderman, "A Variable Switching Frequency PWM Technique for Induction Motor Drive to Spread Acoustic Noise Spectrum With Reduced Current Ripple," *IEEE transactions on industry applications*, vol. 52, no. 6, pp. 5355–5355, 2016.

[3] N. Mohan, *Power Electronics a First Course*. Don Fowley, 2012.