Design and Control of a 800 W Single-Stage PFC Active Clamp Flyback

Degree programme: Master of Science in Engineering
Thesis advisor: Prof. Dr. Sébastien Mariéthoz
Expert: Dr. Maxime Moreau

Motivated by the goal of decreasing the charging times of electric bicycles battery packs and, thus, helping popularize the product, we present in this thesis the study, design, implementation and testing of a 800 W PFC ac-dc converter. By employing a flyback with GaN semiconductors, we expect to increase the converter efficiency while reducing its size and keeping a low parts count, resulting in a superior yet affordable charger.

Viviane Louzada Wisniewski
Energy and Environment

Introduction

E-bikes require consumers to plan their use carefully to avoid having to charge their batteries at undesirable times. A search through some manufacturers' websites shows that 4 to 6 hours are needed to refill the most common battery packs, and the most powerful versions display an average charging power of only 187 W. The appealing idea of having shorter charging times by means of a more powerful converter is the main motivation behind this work.

Concept

The architecture of choice is a synchronous, single-stage PFC flyback converter. The use of GaN FETs allows for high-frequencies of operation, and with their low parasitics, it is possible to obtain a high-efficiency converter. The challenge of scaling up the power rating to 800 W, despite the well-known intrinsic limitations, is tackled with the use of an active clamp on the primary FET, which protects it from from dangerous voltage oscillations.

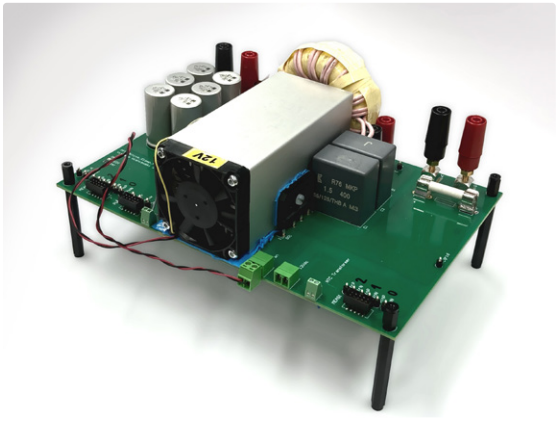
Goals

This work is a follow up of a semester project, where the prototype was designed from scratch and minimally tested. In order to reach the concept described above, the subsequent tasks were outlined:

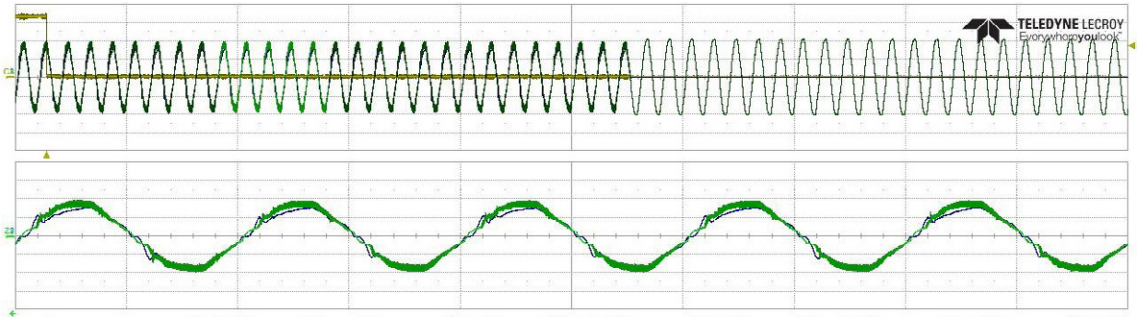
- Verify experimentally that the active clamp circuit for the primary FET with an ac input voltage works
- Implement the synchronous rectification
- Validate a control strategy for the single-stage PFC flyback that achieves a power factor of at least 0.98

Results

The main goal of presenting a first investigation of the proposed converter, with focus on the control and experimental investigation, was achieved. However, the results were obtained at an operating point of 115 W, as we realised that the secondary FET also needed a clamp circuit to withstand its voltage stress. Still, the feasibility of directly supplying the flyback with an ac input voltage and operating the active clamp, and attaining a high power factor of 0.9879, were validated.



The assembled flyback converter.



Grid voltage (green, 20 V/div) and grid current (blue, 5 A/div). Time scale 100 ms/div (top), 10.0 ms/div (bottom).