Project Title: DSP Controlled Resonant Converter

Students: Shlomo Gore
Sharon Heller

Director: Prof. Shmuel Ben-Yaacov

Abstract

The main objective of this project is to design and build a resonant DC–DC converter that is a closed-loop controlled by a DSP. The converter should be suited to function as a quick battery charger fed from the electrical reticulation system and supply at least 1KW RMS output power when loaded by a 48V battery.

Keywords: Resonant Converters
Zero Voltage Switching (ZVS)
Full-Bridge
Digital Control

Overview

The converter is based on a Full-Bridge Load-Resonant LC–LC topology (see Figure 1) that has been presented in [1] as a suitable topology for battery chargers. In addition, the article presented some design guidelines that were found to be suitable for that application. In the simulations we performed under the presented design considerations, the converter was found to have suitable characteristics: low dependency of output current vs. output voltage and ZVS in a wide switching-frequency range. Those characteristics allow very low output current (at high switching frequencies) at maintained zero-switching stress for the switching stage. In addition, the ability to significantly lower the converter transmission by increasing the switching-frequency is being used by the soft-start algorithm and can also be used for complementary charge in further application development.

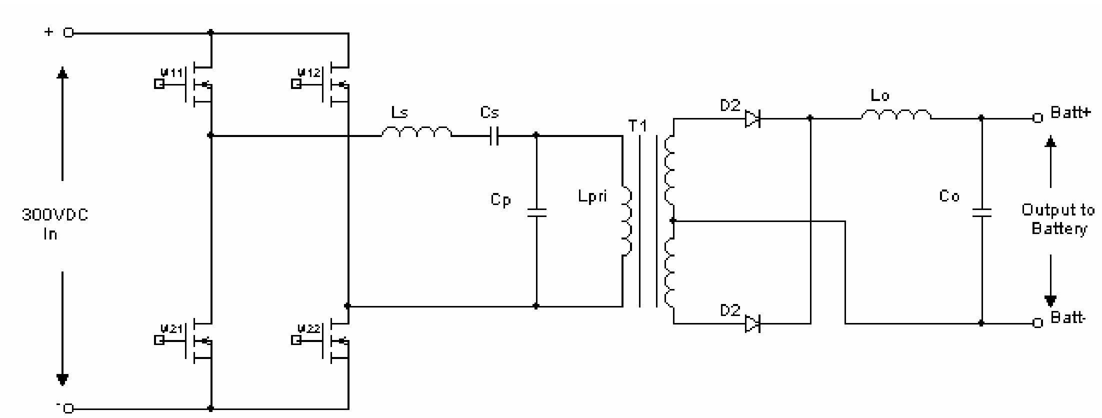


Figure 1: Full-Bridge Load-Resonant LC-LC topology.

The switching is done at a variable frequency and 50% duty-cycle. The objective is to work with high switching frequencies, allowing the use of a smaller isolating transformer and smaller reactive components.

In order to work with high switching frequencies, while maintaining low power dissipation, high-speed Power-MOSFETs are used and a Zero Voltage Switching (ZVS) method is applied by operation above the resonance frequency.

Closing of the control loop is done by a system based on a DSP device from Texas Instruments' TM320C24x series of DSPs that are designed for control applications. The control system consists of an evaluation module that was purchased with the DSP and an interface connecting the board terminals and the converter. Software development has been accomplished by means of a development kit which consists of an Assembly compiler installed on a PC and an emulator that connects the PC to the evaluation board and allows software download and real-time debugging.

Results

The circuit was tested at input voltages in the range of 80V to 100V instead of 300V, because of safety considerations. The battery was replaced by a 2.2 Ohm resistor as an equivalent dummy load. The resonant tank parameters and the suited switching frequency range were calculated as proposed in [1]. Since the resonance frequency is slightly below 300KHz, the switching frequency range was chosen to be 300KHz to 400KHz.

Figure 2 presents the Drain-to-Source voltage (the higher trace) and the Gate-to-Source voltage on one of the low-side transistors. It appears that the Gate is driven ON after the almost complete fall of V_{DS}, i.e., the transistors are zero-voltage switched.

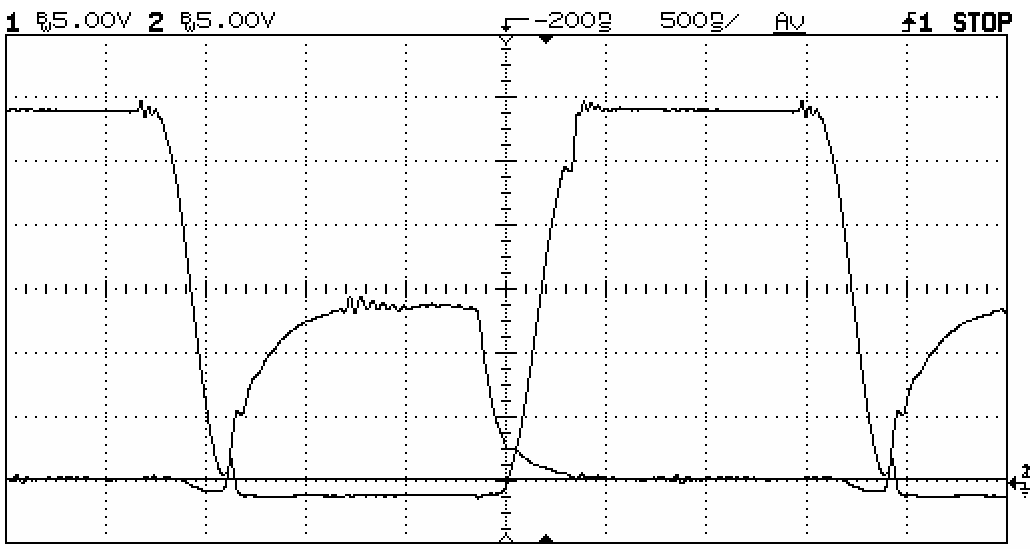


Figure 2: ZVS implementation on the switching transistors.

It can be seen from Figure 3 that the voltage across the series resonant capacitor is almost sinusoidal and its frequency is the frequency of the first harmonic of the switching signal (the switching frequency here is 400KHz).

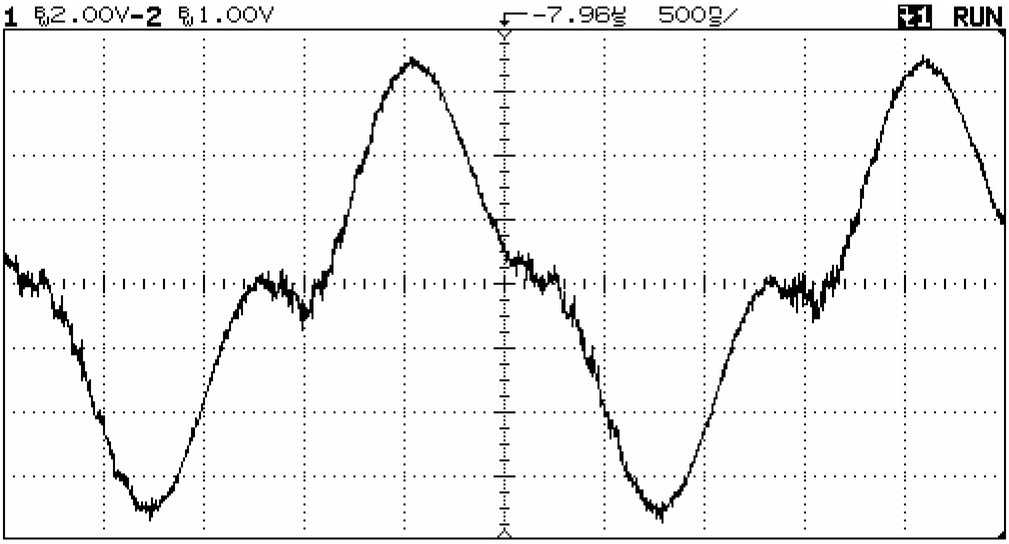


Figure 3: The voltage across the series resonant capacitor.

Figure 4 shows the step response of the closed loop at 1Hz. It can be seen that there is an overshoot. Above control frequency of 3Hz, the step response is almost zero. This relatively low bandwidth had probably been caused by the timing of the samples and incomplete implementation of the control algorithm.

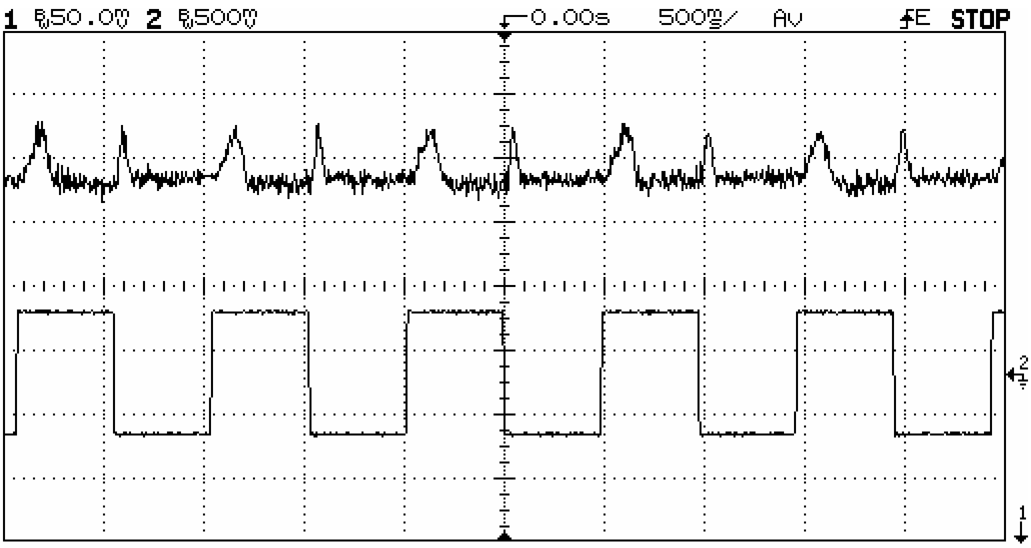


Figure 4: Step response of the closed loop at 1Hz

References

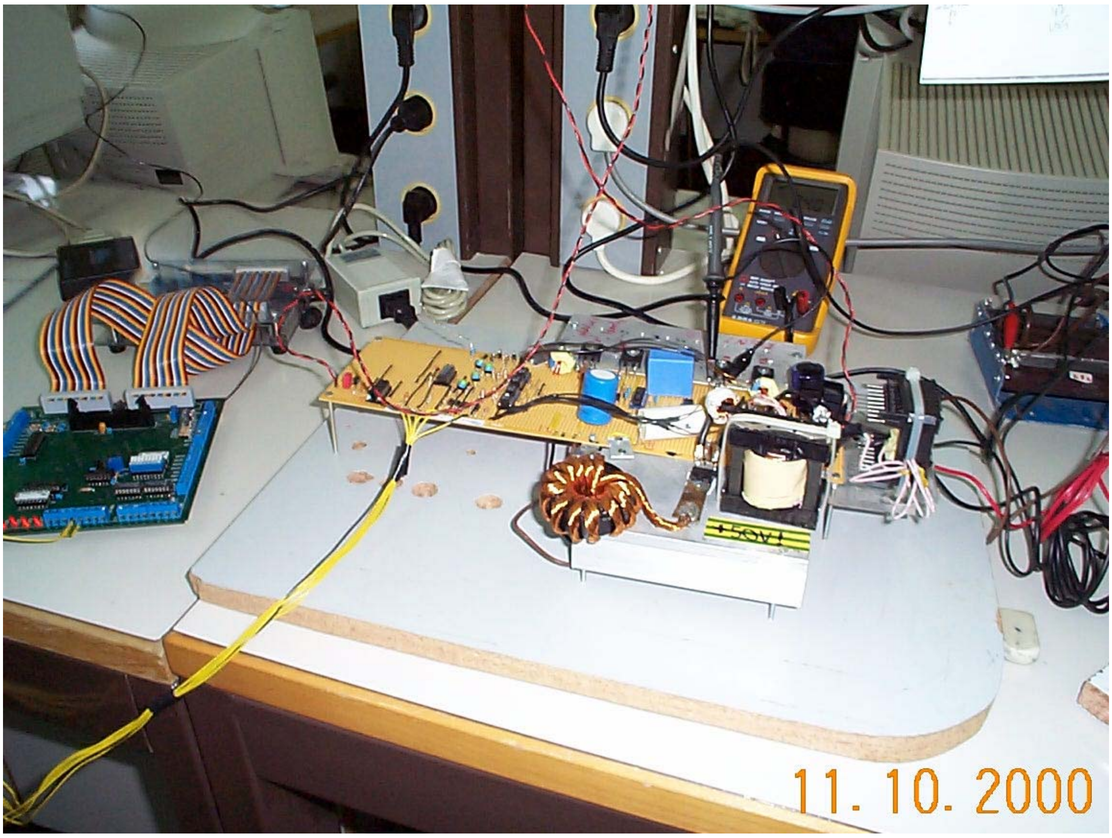
[1] JG Hayes, MG Egan, JMD Murphy, SE Schulz, JT Hall. Wide-Load-Range Resonant Converter Supplying the SAE J-1773 Electric Vehicle Inductive Charging Interface. IEEE Transactions on Industry Applications, 35(4), pages, July/August 1999

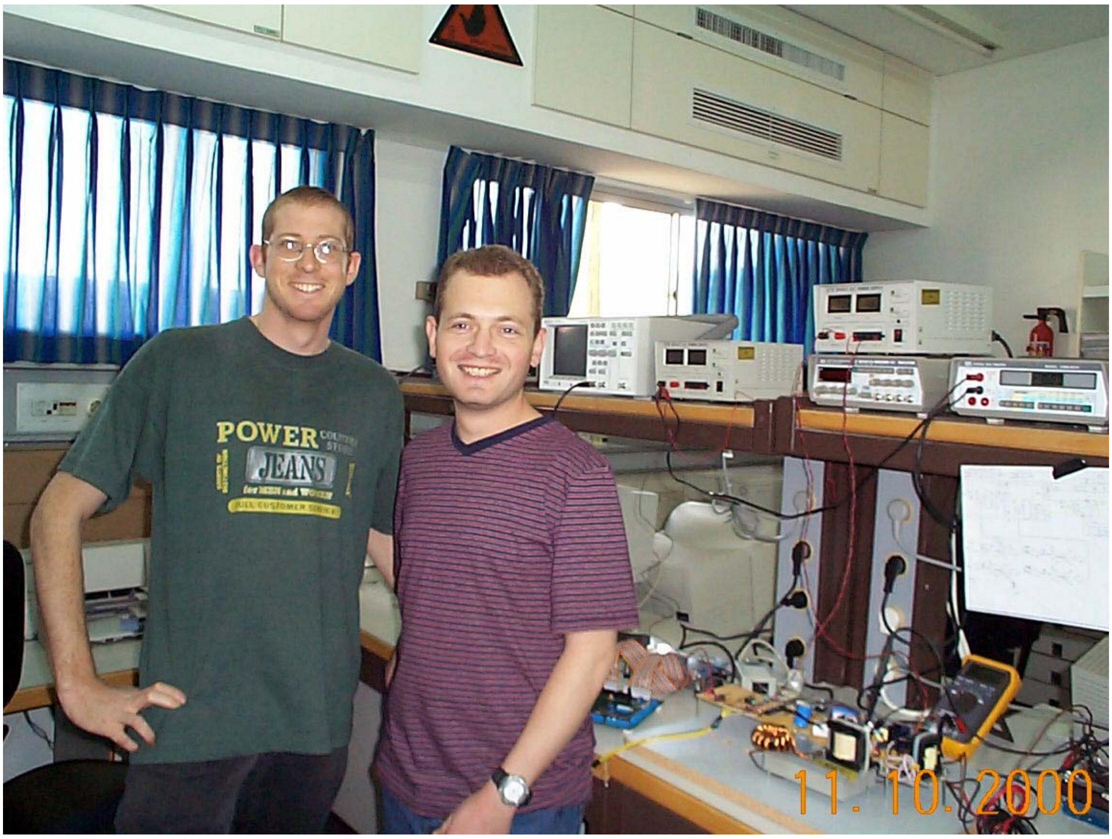
[2] N Mohan, TM Underland, WP Robbins. Power Electronics – Converters, Applications and Design. John J. Wiley and Sons, 1989, page numbers.

[3] J Laeuffer, Converter Control, IEEE Power Conversion, June 1999 Proceedings.

[4] R Chassaing, Digital Signal Processing with C and the TMS320C30. John J. Wiley & Sons, Inc., 1992.

[5] PF Kocybik, KN Bateson. Digital Control of a ZVS Full-Bridge DC-DC Converter. IEEE No. 0-7803-2482-X/95, 1995.




POWER
JEANS
11. 10. 2000