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Analysis of Current-Bidirectional Buck-Boost Based Switch-Mode Audio Amplifier

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Abstract. The following study was carried out in order to assess quantitatively the performance of the buck-boost converter when used as switch-mode audio amplifier. It comprises of, to begin with, the delimitation of design criteria based on the state-of-the-art solution, which is based in a differential mode buck-based amplifier with a boost converter as power supply. The averaged switch modelling of the differential mode current bidirectional topology is also used, in order to analyze the steady state and frequency-wise behaviour of this converter and parameterize it to meet the design criteria. Next, several piecewise-linear simulation results are shown with detail enough to emphasize the features of the converter. A simple prototype is implemented to verify the main predicted features. Presently no previous publication could be found containing a thorough analysis of this topology in such configuration when applied for audio.

Key words

Boost, losses, modelling, audio, amplifier.

1. Introduction

Despite the advantages featured by the buck-boost converter, no industrial application of this circuit can be found in the literature, using it directly as a DC-AC converter for audio, probably because of the risk of instability due to the right half plane (RHP) zero as well as the non-linearity of the DC gain characteristic, which normally leads to non acceptable distortion in the output.
This task is usually accomplished by a two-stage solution, normally with a buck converter as generator for the AC output.
The use of differential voltage in the load in stead of common voltage is currently applied in the state-of-art solution for automotive audio and will be applied here because of some advantages, as better noise immunity and response to DC much closer to linear in the working duty-cycle region. The converter non-linearity will be addressed in the subsequent article, which will deal with controller design for this specific configuration.

2. Design Considerations

The simulations were all carried out considering equal switch on-state-resistances of 15 mΩ and ESR of the inductor of 5 mΩ. The load was considered equivalent to the series association of an 8 Ω resistor and a 10 μH inductor.

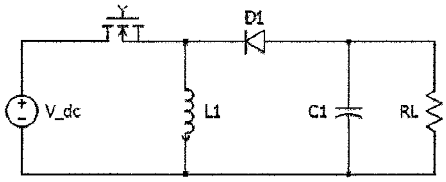

Fig. 1. Classic single-ended, Buck-Boost diagram

The nominally 12 V lead-acid battery works normally at the floating DDP of 14.2 V, and peaks up to 19 V may occur. When the battery voltage goes below 10 V, the audio subsystem must not draw currents higher than 50 A. The subsystem current must be below 40 A when the battery voltage is below 9 V, and not draw any current when is goes lower than 7 V. This means that considering that the system has two 250 W channels, even with purely resistive load, the battery will be able to provide power only enough for the sound system when it's about 10 V, and below this voltage the amplifier shall have a constant maximum gain of 6.32 until the battery voltage reaches 9 V, below which voltage the maximum gain will be reduced to 5.00, and shut down completely when the voltage reaches below 7 V.

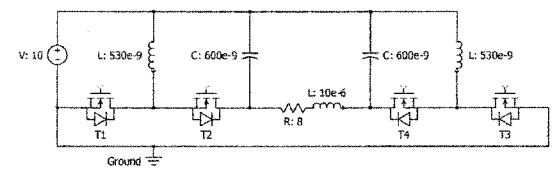

Fig. 2. Inverted, doubled and power-bidirectional version of the Buck-Boost converter