Power losses modelling of DC-DC buck converters (SJK3-16)

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Introduction

A buck converter is a circuit that steps down voltage. It is used in everyday electronics ranging from servers to cell phones where it steps down the voltage from the power supply of the device (such as a laptop battery at 12V) to the lower voltages required by components of the device (such as the CPU, which requires 1.4V or the GPU, DRAM etc.) while providing the high currents required by these components.

Objectives & Implementation

The goal of this project is to reduce the cost of producing buck converter circuits for any application. This is done by using the power loss model developed in this project, which provides 3 important pieces of information shown in the block diagram below (outputs).

- Power loss of system (split into its individual constituents)
- Efficiency of system (at different load currents)
- Junction temperature (at different load currents)

Evaluation of Results

The results showed that as the power loss of the system increased, so did the temperature of the components as power loss and temperature change are directly proportional. The efficiency results showed that generally, as the load current increases the efficiency of the system decreases. This holds true for CCM, but for DCM it is the opposite. It can be seen that the major areas of power loss are the LS MOSFET’s conduction loss, the HS MOSFET’s switching loss and the inductor loss.

The results obtained by this model calculate the power loss of the system to ~4%. This verification was done by obtaining experimental results of the same circuit (i.e. same driver, MOSFETs, inductor and capacitor) and comparing the efficiency and power loss to the results derived from the model. The results from the model are very close to the experimental results and show that it can be used commercially to model the power loss of buck converters before production, thereby saving time and reducing the cost of production.

Results

The graphs output by the model are the results for this project. They are all shown below and are compared with the current solutions and the experimental data, if available. These results are explained and compared in the Evaluation of Results panel.

A buck converter consists of four main components—two MOSFETs, one inductor and one capacitor. The two MOSFETs work together, by switching on and off, to deliver a square wave to the inductor and capacitor, which turn the square wave into a DC voltage with a small ripple. The output current also has a ripple, which is much higher than the voltage ripple. The on time of the MOSFET determines how much the input voltage is stepped down by. These components are not ideal and have parasitic elements associated with them. These parasitic elements are responsible for the power losses. Examples of parasitic elements include resistors and capacitors. When current passes through these elements power is lost in the form of heat. Heat and power losses are both unwanted by-products of any circuit operations.

A block diagram is shown below, which illustrates the power flow through the buck converter and the various components involved.

The table above shows only a few of the equations for the purpose of explaining the model.