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Application Note

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Determining the Maximum Output Current for the MC34700 Switching Regulators

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1 Introduction

The MC34700 is a multi-rail power supply IC, consisting of three switch-mode power supplies (SMPS, also known as DC/DC converters), and one low-dropout (LDO) regulator.

All three SMPS regulators are based on a step-down topology. This means that each SMPS regulator generates a voltage at its output that is less than the voltage applied at its input.

The goal of this application note is to provide guidelines to help users determine the maximum current that the converters integrated in the MC34700 can deliver at their output.

It should be noted that this document focuses only on the maximum output current of a single SMPS regulator, without taking into account other aspects (such as thermal behavior or output voltage ripple) related to the actual operating conditions of the MC34700 in the user's application.

2 Determining the Maximum Output Current

In a step-down converter under steady-state conditions, the average current in the inductor I_L is equal to the output current I_{OUT}. Figure 1 represents the inductor current vs. time in CCM (Continuous Conduction Mode, i.e. the inductor is never fully discharged and its current never reaches zero). As shown, the inductor current is not constant, but varies around I_{OUT} between a maximum and a minimum value, whose difference ΔI_L is the peak-to-peak inductor current ripple.

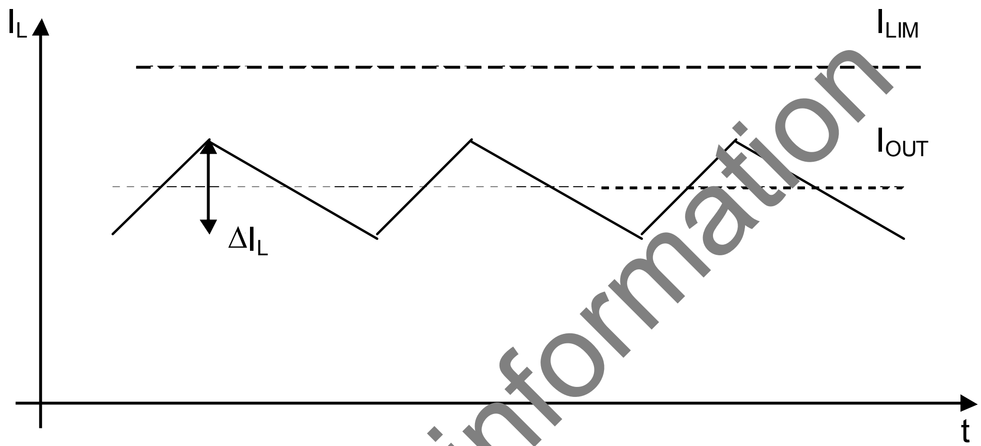

Figure 1. Inductor Current in a Step-down Converter

ΔI_L is influenced by several factors related to the operating conditions. It can be found that the following relationship applies to ΔI_L:

$$\Delta I_L = \frac{(V_{IN} - V_{OUT}) \cdot V_{OUT}}{V_{IN} \cdot f_{sw} \cdot L}$$

where

V_{IN}: converter's input voltage (in V)

V_{OUT}: converter's output voltage (in V)

f_{sw}: converter's switching frequency (in Hz)

L: inductance (in H)

ΔI_L: peak-to-peak inductor current ripple (in A)

Once V_{OUT} is determined in the application, the largest ΔI_L value ($\Delta I_{L,MAX}$) occurs at the maximum input voltage occurring in the application:

$$\Delta I_{L,\max} = \frac{(V_{IN,\max} - V_{OUT}) \cdot V_{OUT}}{V_{IN,\max} \cdot f_{sw} \cdot L}$$

For proper operation, it must be ensured that the maximum inductor current $I_{L,MAX}$ is always less than the converter's peak current limit $I_{LIM,MIN}$ (the minimum value specified in the MC34700 Data sheet). Expressed in mathematical terms:

$$I_{L.\max} = I_{OUT,\max} + \frac{\Delta I_{L,\max}}{2} < I_{LIM,\min}$$

Rearranging the previous formula, it follows that:

$$I_{OUT,\max} < I_{LIM,\min} - \frac{\Delta I_{L,\max}}{2}$$

As can be seen in this formula, the maximum output current $I_{OUT,MAX}$ that a converter can provide, will depend on the current limit specified in the data sheet, as well as on the operating conditions of the application and the inductance L chosen by the user.

Adequate margin needs to be selected at the application level to keep the maximum inductor current $I_{L,MAX}$ sufficiently below the converter's peak current limit $I_{LIM,MIN}$.

The previous procedure can be applied to any of the three step-down converters available in the MC34700.

3 Example

Now examine a numerical example, based on BUCK CONVERTER 1 of the MC34700, and calculate the maximum output current that can be achieved with a given inductance. For a worst-case analysis, consider the maximum input voltage, the minimum switching frequency, the minimum peak current limit, and the minimum inductance.

Assuming the following operating conditions for a given user's application:

- $V_{IN,MAx}$ = 12 V (maximum input voltage in the user's application)
- V_{OUT} = 5.0 V (output voltage in the user's application)
- L = 6.8 μH nominal (inductance chosen by the user); for worst-case analysis, manufacturing tolerances and inductance loss due to current flow must be considered. For this numerical example, if a 30% inductance decrease is assumed, then L = 4.76 μH must be considered in the calculations. The data sheet of power inductors should always be inspected carefully to determine the actual inductance value.

The following parameters for BUCK CONVERTER 1 should be considered:

- f_{SW} = 760 kHz (minimum switching frequency, see the Switching Frequency parameter in the Electrical Characteristics of the MC34700 Data sheet)

- $I_{LIM,MIN}$ = 2.5 A (minimum peak current limit specified for BUCK CONVERTER 1. See the Peak Short-circuit Current Limit parameter in the Electrical Characteristics of the MC34700 Data sheet)

Start by calculating the maximum peak-to-peak inductor current ripple. From the following formula:

$$\Delta I_{L,\max} = \frac{(V_{IN,\max} - V_{OUT}) \cdot V_{OUT}}{V_{IN,\max} \cdot f_{sw} \cdot L_{\min}}$$

the worst-case current ripple is calculated as:

$$\Delta I_{L,\max} = 0.8A$$

If a design margin of 20% of $I_{LIM,MIN}$ is chosen by the user, then the maximum inductor current $I_{L,MAX}$ must be kept below 2.0 A.

Therefore:

$$I_{L.\max} = I_{OUT,\max} + \frac{\Delta I_{L,\max}}{2} < 2A$$

Replacing $\Delta I_{L,\max} = 0.8A$ in the previous formula, the maximum output current is found by:

$$I_{OUT,\max} = 1.6A$$

With the operating conditions and the inductance assumed at the beginning of this numerical example, the maximum current that BUCK CONVERTER 1 can provide is 1.6 A.

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