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APPLICATION NOTE 6498

EXPLAINING VALLEY CURRENT PROTECTION FOR MAX20730, MAX20733, MAX20734, MAX20735, MAX20743, AND MAX20745

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Abstract: The MAX20730, MAX20734, and MAX20743 switching regulators with PMBus operate from 4.5V to 16V and require up to 35A. When using switching regulators for 12V bus systems, overcurrent protection (OCP) is important. This application note explains how to use Maxim's implemented valley current-mode algorithm to set the OCP values. This application note also applies to the MAX20733, MAX20735, and MAX20745 devices without the PMBus interface.

Introduction

For 12V distributed bus systems for communication, networking, servers, and storage equipment, Maxim Integrated offers a series of integrated step-down regulators with PMBus operating from 4.5V to 16V and requiring up to 35A. As with all switching regulators, overcurrent protection (OCP) is a crucial and important operation circuit function. For these point-of-load (POL) converters, Maxim implements an advanced valley current-mode algorithm that supports all MLCC output capacitors and fast transient response. The purpose of this application note is to clearly explain how to interpret the OCP data sheet specifications.

How to Set OCP Values

For the [MAX20730](#), [MAX20734](#), [MAX20743](#), the OCP values can be set using the PGMB pin. For the [MAX20733](#), [MAX20735](#), and [MAX20745](#), the OCP values can be set using the PGM3 pin. The PGM pins are used to set up some of the key programmable features of the regulator IC. A resistor and capacitor are connected to the PGM pins and their values are read during power-up initialization (e.g., power must be cycled to re-read the values). **Table 1** found in the MAX20743 data sheet outlines the resistor values for a given OCP setting with four possible OCP settings for each R_{GAIN} value. For the MAX20730, MAX20733, MAX20734, MAX20735, and MAX20745 OCP settings, refer to the respective IC data sheet.

Additionally, the overcurrent protection level can be adjusted via PMBus for the MAX20730, MAX20734, and MAX20743. Refer to application note 6042, "[PMBus Protocols for Controlling and Monitoring the MAX20743/MAX20730 Switching Regulators](#)" for more details.

Table 1. MAX20743 PGMB OCP Settings

Number	R (k Ω) $\pm 1\%$	R _{GAIN} (m Ω)	OCP (A)
1	1.78	3.6	20
2	2.67	3.6	25
3	4.02	3.6	30
4	6.04	3.6	35
5	9.09	1.8	20
6	13.3	1.8	25
7	20	1.8	30
8	30.9	1.8	35
9	46.4	0.9	20
10	71.5	0.9	25
11	107	0.9	30
12	162	0.9	35

Defining the Valley Current Inception Point

To define and explain the valley current inception point, it is necessary to do a quick review on how to calculate the peak-to-peak inductor current to provide greater clarity on the valley current inception point and the actual overcurrent clamp value.

Step 1: Calculate Duty Cycle

$$D = V_{OUT} / (V_{IN} \times \eta) \quad (\text{Eq. 1})$$

where:

V_{IN} = input voltage

V_{OUT} = desired output voltage

η = efficiency of converter (near OCP limit)

Step 2: Calculate Inductor Ripple Current

$$\Delta I_L = ((V_{IN} - V_{OUT}) \times D) / (f_S \times L) \quad (\text{Eq. 2})$$

where:

V_{IN} = Input voltage

V_{OUT} = desired output voltage

D = duty cycle calculated from Equation 1

f_S = switching frequency

L = inductor

We use the [MAX20743EVKIT](#) as a typical application for a 12V to 1V conversion. Using the following typical values:

V_{IN} = 12V

V_{OUT} = 1V

L = 170nH

f_{SW} = 400kHz

OCP = 35A

I_{LOAD} = 34A

Typical Efficiency = 84% (taken from data sheet)

Using Equations 1 and 2:

Duty cycle = 0.099 or 9.9%

ΔI_L = 16.014A, this is the peak-to-peak current through the inductor.

In current-mode control architecture, these parts provide inherent current limiting and short-circuit protection. The bottom switch's instantaneous current is monitored using integrated current sensing and controlled on a cycle-by-cycle basis within the control block. Current clamping occurs when the minimum instantaneous ("valley") low-side switch current level exceeds the I_{OCP} threshold current, as shown in **Figure 1**, where I_{OCP} is the value found in the data sheet. In this situation, turn-on of the high-side switch is prevented until the current falls below the threshold level. Since the valley current is the parameter being controlled, the average current delivered during positive current clamping remains a function of several system level parameters. Note that I_{OCP} has hysteresis and the value drops down to I_{OCP2} once it has been triggered, as shown in Figure 1.

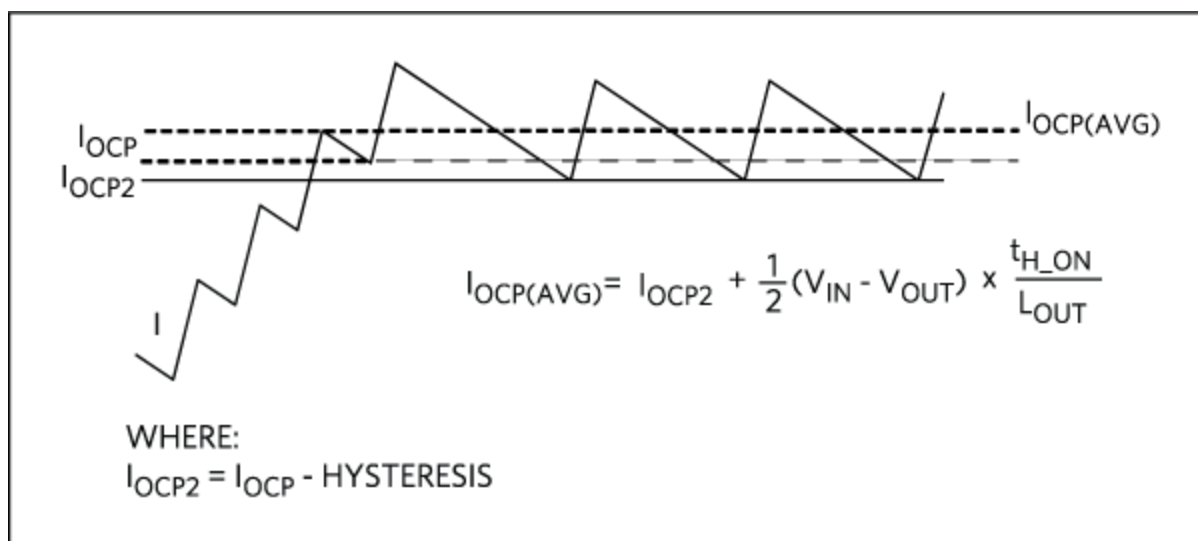


Figure 1. Overcurrent protection current clamping.

In explaining Figure 1, the stated equation for $I_{OCP(AVG)}$ is the value of the average current once the converter operates in current clamping mode. The I_{OCP} value indicates the current OCP inception point at the minimum valley current. In Figure 1 the current is increasing and when the current in the inductor is decreasing and greater (at its lowest point) than the I_{OCP} value, the part enters the current limit upon reaching the I_{OCP} threshold. Once in current limit, the current in the inductor actually ramps below the I_{OCP} due to built-in hysteresis to ensure a predictable turn-on of the high-side FET. **Figure 2** is an actual waveform of the inductor current going into current limit.

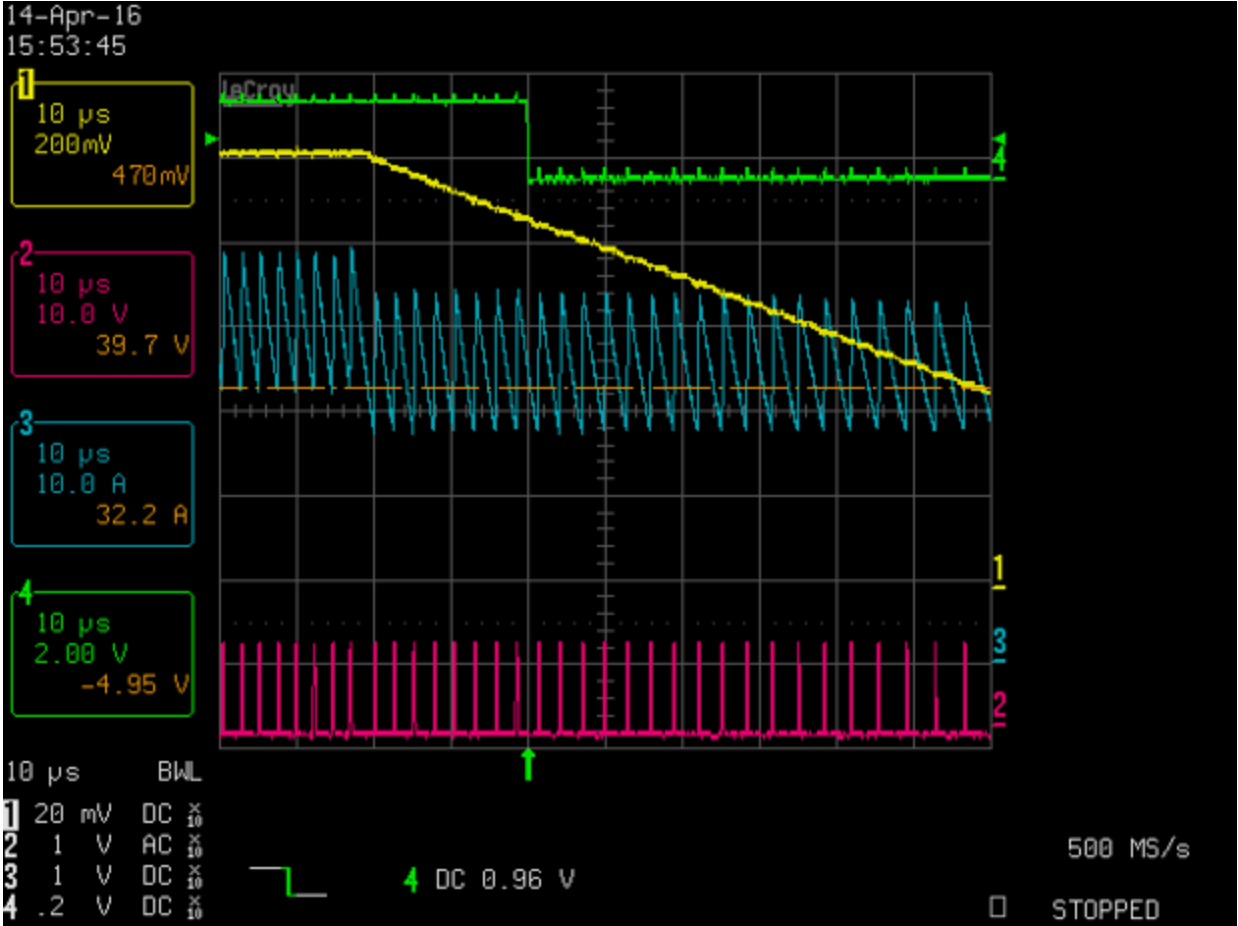


Figure 2. OCP inception point waveform: CH1 (yellow): V_{OUT} , CH2 (pink): V_x , CH3 (blue): L_{Ind} , CH4 (green): $Stat$.

Summary

From Figure 2 it can be shown that the average current just before current limit occurs is actually $I_{OCP} + 1/2$ inductor peak-to-peak current (calculated from equations 1 and 2). This is shown in the beginning of the inductor current waveform (blue) before V_{OUT} (yellow) starts to drop. The second half of the waveform where V_{OUT} starts decreasing shows the average OCP current, which is defined by the equation in Figure 1

when the inductor current decreases to $I_{OCP(AVG)}$. The $I_{OCP(AVG)}$ is the actual average clamped current when the MAX207xx is in current limit. From the previous example for a 12V to 1V conversion, we calculated the peak-to-peak inductor current to be 16.014A. So, for an OCP inception point of 35A, the actual average output current just before OCP is activated is slightly less than $35 + 1/2 \times 16.014 = 43.007A$. From the equation in Figure 1 we can calculate that the I_{OCP} average clamping current is equal to 36.0A for this example.

Related Parts	
MAX20730	Integrated, Step-Down Switching Regulator with PMBus
MAX20733	Integrated, Step-Down Switching Regulator
MAX20734	Integrated, Step-Down Switching Regulator with PMBus
MAX20735	Integrated, Step-Down Switching Regulator
MAX20743	Integrated, Step-Down Switching Regulator with PMBus
MAX20743EVKIT	Evaluation Kit for the MAX20743
MAX20745	Integrated, Step-Down Switching Regulator

More Information

For Technical Support: <https://www.maximintegrated.com/en/support>

For Samples: <https://www.maximintegrated.com/en/samples>

Other Questions and Comments: <https://www.maximintegrated.com/en/contact>

Application Note 6498: <https://www.maximintegrated.com/en/an6498>

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