Application Note V1.0
2013-07-23

TLE8245XSA Over-Current Detection Determination

(for B13 level silicon)

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Edition 2011-02-02
Published by
Infineon Technologies NA
Livonia, MI   USA

Revision History: 2013-07-23, V1.0

Previous Version: none

Subjects: **Short-to-Battery or Short-to-Ground Detection Method**

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1 Introduction

The following narrative is an explanation of how the Over-Current (OVC) detection process works in the TLE8245xSA, Dragon Integrated Circuit (IC), as specified in Data Sheet TLE82453_ds_10 for B13 level silicon [1]. An OVC condition occurs when an unexpected high current flows through one or more of the output channels of the Dragon IC due to a short to the battery condition when in a low-side configuration or a short to ground condition when in a high-side configuration. The Dragon IC is designed so that current spikes or fast intermittent shorts will not cause an unwanted diagnostic flag setting and subsequent halting of the Dragon IC operation. The operation is similar to a deglitching filter. An important point is that the primary operational objective of the Dragon is to provide the exact current requested by the system software. This means the Dragon was designed to attempt to supply the set point current regardless of system disturbances.

2 Dragon IC Over-Current Detection Overview

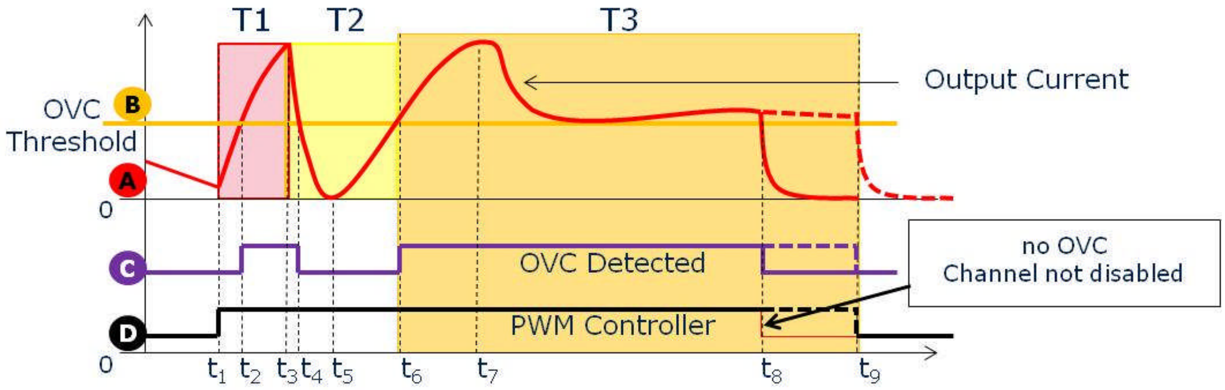

Figure 2.1: Dragon Over-Current Detection

Figure 2.1 above is used to illustrate the diagnostic feature. The following is a description of the various parts of the figure:

Line A, the red line: represents the output current of the Dragon IC
Line B, the yellow line: represents the OVC detection threshold of the Dragon IC
Line C, the purple line: represents an OVC is present from the OVC detector logic
Line D, the black line: represents the Pulse Width Modulation (PWM) controller output to the output stage
Region T1, light red: Starts at the beginning of a PWM period (time point $t_{1)}$, after a short time the OVC logic turns off the output at time point t_3

Region T2, light yellow: time required for the OVC logic to initiate the OVC timer window (T3), turn on the output stage (t_5) and the start of an OVC condition at time point t_6
Region T3, light orange: OVC detection timer window approximately 10us required

For Figure 2.1, we will assume the Dragon is set up in a low-side configuration and there is an actual short from one of the outputs of the Dragon IC to the battery line of the module. The Dragon is commanded to deliver a current (determined by whatever is commanded by the software through the SPI communication line) while the output of the Dragon IC is in a short circuit condition. Line A, the red line, represents the output current of the Dragon IC. It can be seen on the far left of Figure 2.1 prior to Region T1 that Line A (channel output current) is coming down from the previous Pulse Width Modulation (PWM) cycle. Time point t_1 is the start of the next PWM cycle as indicated by the rise of Line D, the black line, of the PWM control loop. Since there is an actual shorted condition, Line A shows that high current immediately starts to flow through the Dragon IC and rises above the OVC Threshold level (Line B, the yellow line) at time point t_2. The Dragon IC recognizes the rise of the output current above the OVC Threshold at time point t_2 as a possible shorted condition and shuts the output transistor off after a short period of time as indicated at time point t_3.

In Region T2, the output current, Line A, falls below the OVC Threshold at time point t_4. This results in no additional actions. At time point t_5 the OVC timer window is ready to measure and the output transistor is turned on (internal chip function). If the output current rises again above the OVC Threshold as indicated at time point t_6 in region T3 of Figure 2.1, the Dragon IC starts the OVC detection timer window indicated by the rising edge of Line C as represented in region T3 of Figure 2.1. The length of time of region T3 is approximately 10 microseconds. As the output current, Line A, rises above the OVC Threshold level (Line B), the Dragon IC goes into a self protection mode by limiting the output current to a level just above the OVC Threshold level as illustrated at time point t_7. The output current is allowed to stay higher than the OVC Threshold level so that the internal OVC detection feature can determine if a true short circuit condition exists while keeping the current at a level that does not cause damage to the Dragon IC.

The final part of the OVC detection feature is the setting of the OVC fault flag. An OVC fault flag is set if the output current, Line A, stays above the OVC Threshold level, Line B, for approximately ten microseconds (time point t_9).

3 Determining a True OVC Fault

There is a possibility that an OVC fault flag may not be set when a true short circuit condition occurs. This may occur when the PWM “on” cycle, Line D, turns off at time point t_8 (less than 10 microseconds) before the OVC detection timer window T3 is completed (approximately ten microseconds) causing the output current, Line A, to fall below the OVC Threshold level (Line B). This possibility can occur when there is a true short circuit condition, set point currents are low, and the PWM frequency is high. As mentioned earlier in this discussion, the primary objective of the Dragon is to deliver very accurate average current to the load. The Dragon will internally adjust the parameters it has control of in order to try to maintain this very accurate average current. This includes modifying the PWM frequency in order to maintain the accurate average current. For example, if the set point current is 50mA and there is a short circuit condition, the 50mA average current may be obtained with only a fraction of the programmed PWM cycle or said in a different way, the average output current is reached with a smaller than expected duty cycle. In this example, the on time required is less than 10 microseconds. This means the Dragon will internally change the PWM frequency so that the PWM "on" time is shorter than the OVC detection window timer (~ten microseconds). This would result in the Dragon IC continuously repeating the OVC detection feature without setting an OVC fault flag if a true shorted condition is present for low set point currents. Figure 3.1 provides a graphical representation of the calculated minimum set point currents at the associated programmed PWM frequency and System Clock Frequency (Fsys) that may result in the Dragon IC not recording an OVC fault flag in a short circuit condition.

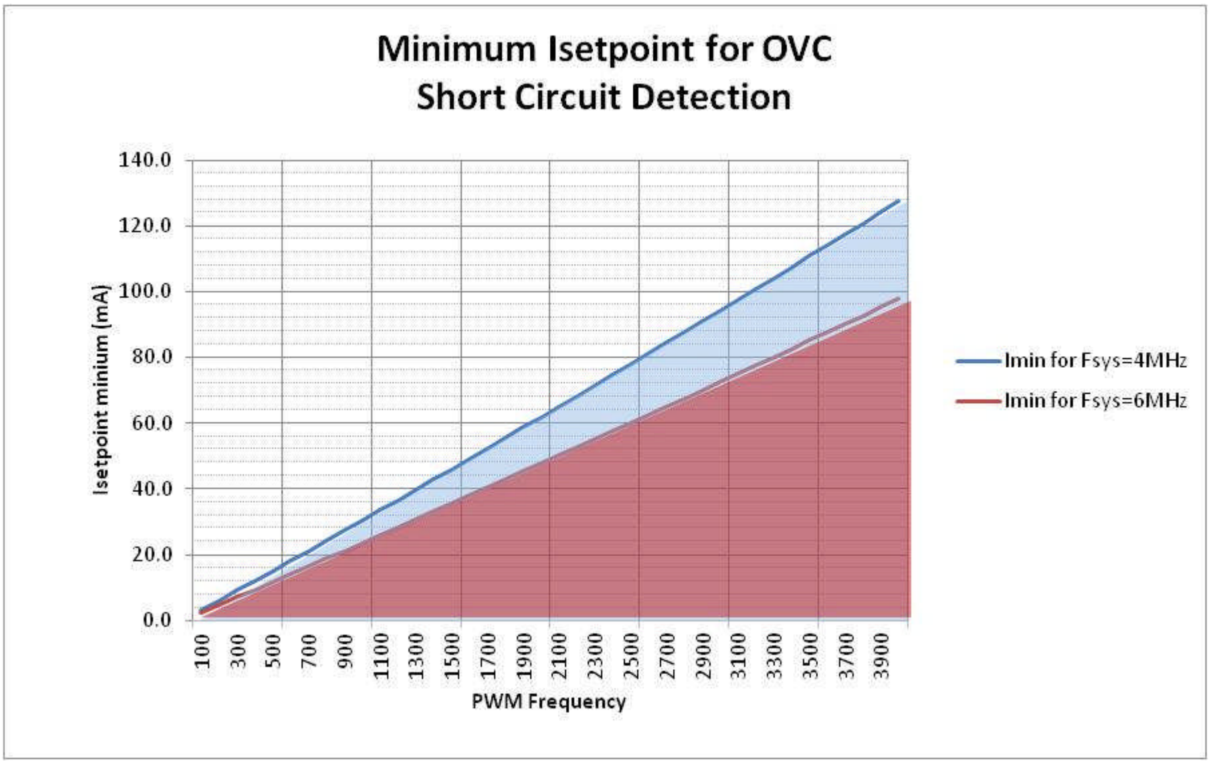

Figure 3.1: Dragon Minimum Set-Point Current for OVC Fault Flag Detection

It can be seen from Figure 3.1 that the minimum set point current that the Dragon IC will reliably set a fault flag in a short circuit condition when the Fsys clock equals 4MHz falls along or above the BLUE line and for the Fsys clock equal to 6MHz the along or above the RED line. As an example, for IC parameters set so the Fsys clock equals to 4MHz and PWM frequency 2.5KHz, the Dragon IC may not be able to consistently set the OVC fault flag for current set points less than 80mA. Any current set points above 80mA for these same IC settings the Dragon IC will reliably set a fault flag if a short condition exists.

Likewise, if the IC parameters are set such that Fsys is equal to 6MHz and the PWM frequency 2.5KHz, the minimum set point current is approximately 62mA. The Dragon IC may not consistently set a fault flag for a true shorted condition for current set points below 62mA but will consistently set a fault flag in a shorted condition for current set points above 62mA with Fsys equal to 6MHz and PWM equal to 2.5KHz. Therefore, the Dragon IC may not reliably set a fault flag in a short circuit condition for current set points under the BLUE line for the associated PWM frequency with Fsys equal to 4MHz and current set points under the RED line for the associated PWM frequency with Fsys equal to 6MHz.

A method to determine if a true short circuit condition exists (when operating the Dragon IC below the RED or BLUE line as depicted in Figure 3.1) is to monitor the MIN/MAX current feedback register. The MIN/MAX current feedback register will provide the maximum current and the minimum current within the switching envelope as the IC is operating. Therefore a rough average output current of the IC can be determined by adding the peak current reading and the minimum current reading, then divide by two. Ideally, in a non-short circuit condition, this calculated average current should be close to the commanded set-point current. For this test procedure for set-point currents that are relatively low (below 120mA for PWM frequency equal to 4kHz and Fsys equal to 4MHz), if the calculated average current is above 400mA, then there is a very high probability that a true short circuit condition exists.

4 References

[1] Infineon Technologies AG: TLE82453_ds_10, TLE82453SA 3 Channel High-Side and Low-Side Linear Solenoid Driver IC, V1.0, April 10, 2013.