Application Note

Understanding OOB Operation

Lishuang Zhao, Miranda Gu

ABSTRACT

Out-of-Bounds (OOB) overvoltage protection protects the output load at a much lower overvoltage threshold above the target voltage. OOB protection does not trigger an overvoltage fault, which is an early non-fault overvoltage protection mechanism.

This application note presents a detailed introduction to this OOB feature based on TPS56C230, including OOB operation principle, the differences between OOB and overvoltage protection (OVP), OOB operation logic and OOB advantages in load transient.

Table of Contents

List of Figures

List of Tables

Trademarks

All trademarks are the property of their respective owners.

1 OOB Operation Principle

TPS56C230 has the Out-of-bounds (OOB) overvoltage protection that protects the output load at a much lower overvoltage threshold of 8% above the target voltage. OOB does not trigger overvoltage fault protection. OOB protection operates as an early no-fault overvoltage protection mechanism, differs from fault overvoltage protection (OVP).

During the OOB operation, the device operates in forced PWM mode by turning on the low-side FET to discharge the output capacitor, thus causing the output voltage to fall quickly toward the target value. Turning off low-side FET logic is controlled by either triggering the cycle-by-cycle negative overcurrent (NOC) limit or output voltage falling below target value (FB voltage falling below reference voltage). For TPS56C230, OOB control logic allows maximum 16-cycle NOC triggered in order to ensure the safe operation of internal FETs. After 16-cycle NOC triggered, the device would stop switching to wait OVP or output falls to target voltage.

OOB operation is blanked in forced continuous conduction mode (FCCM), since the control logic of FCCM-mode itself allows continuous current until the output voltage decreases to target value.

2 Differences Between OOB and OVP

OOB is an early non-fault overvoltage protection when output voltage is higher than OOB threshold. The OOB can help device fast recovery to normal operation. OVP is a fault protection when OVP threshold is triggered.

Taking TPS56C230 as an example, OOB threshold is 108% of output/reference voltage, while OVP threshold is 125% of output/reference voltage. When OOB is triggered, device is forced PWM controlled with maximum 16-cycle NOC triggered. PG will be high if output is lower than 115%. While, when OVP is triggered, the output will be discharged after a wait time of 120 μs and PG is low.

OOB operation only gains benefit in Eco-mode by forced PWM control with maximum 16-cycle NOC triggered. OOB operation is blanked in FCCM-mode. OVP is the protection no matter Eco-mode or FCCM-mode.

Table 2-1 summaries the differences between OOB and OVP based on TPS56C230.

Table 2-1. Differences Between OOB and OVP

	OOB	OVP
Triggered Threshold	FB>=108%*Vref	FB>=125%*Vref
Triggered Behavior	Forced PWM, maximum 16-cycle NOC triggered and PG High (FB<115%*Vref)	Output discharge and PG Low
Fault Behavior	Non-fault	Fault
Operation Mode	Eco-mode	Both Eco-mode and FCCM-mode

3 OOB Operation Logic

3.1 Case 1: <OV Threshold, >OOB Threshold

Figure 3-1 shows the logic of OOB behavior when the output voltage is larger than OOB threshold (108%) but lower than OV threshold (125%). As the output voltage doesn't reach to OV threshold, device internal OV signal is kept low as well as OV_Latch signal.

When the output voltage is higher than 108% of target output value, the OOB_comparator outputs high, the OOB_Output signal is triggered which turns on low-side FET beyond zero inductor current to discharge output until reaches to NOC (if heavy external force) or output lower than target (if light over-voltage, for example load transient), then low-side FET is turned off and high-side FET is turned on. After maximum 16-cycle NOC triggered, OOB_Output signal will be ended.

The OOB_Output signal can be reset by OV signal or output falls below target (normal PWM control) or EN enabled.

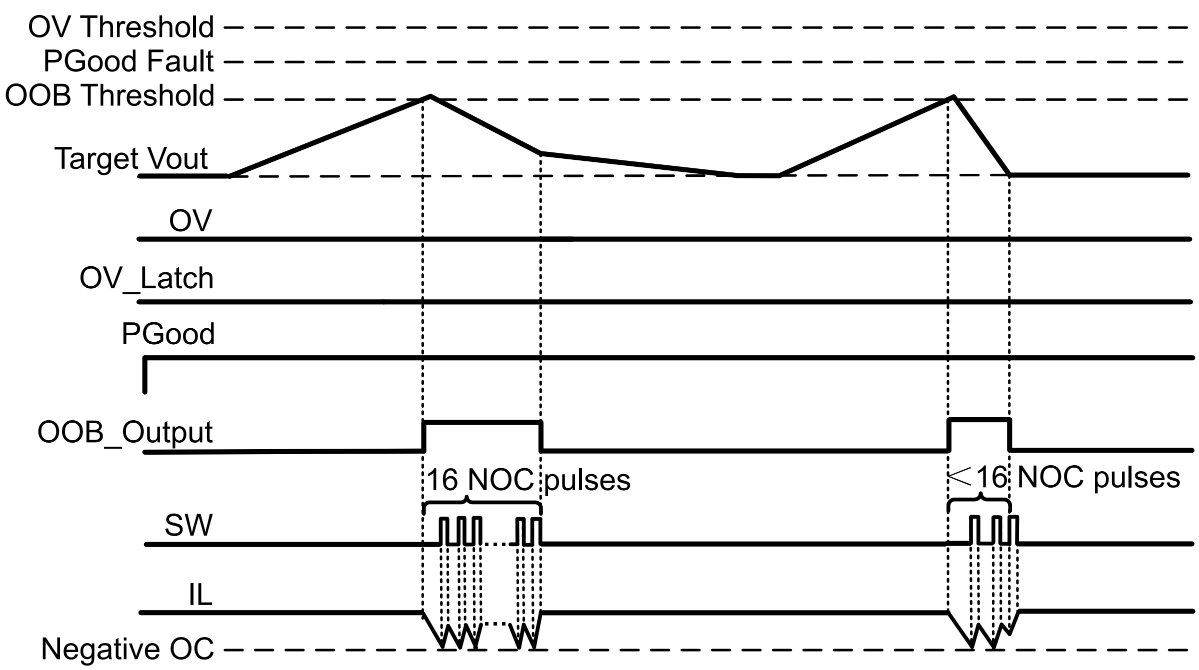

Figure 3-1. The Logic of OOB Behavior when <OV Triggered

Figure 3-2 and Figure 3-3 show the bench test waveforms for TPS56C230, test conditions are 12Vin, 1.2Vout, Eco-Mode, force external 1.4V to Vout. When output is higher than 108% of target, 2 cycles of NOC are triggered and output is discharged. During the third cycle of low-side FET on, output voltage is discharged lower than target, so low-side FET is off and high-side FET is on without triggering NOC. The bench behaviors match with Figure 3-1 logic diagram.

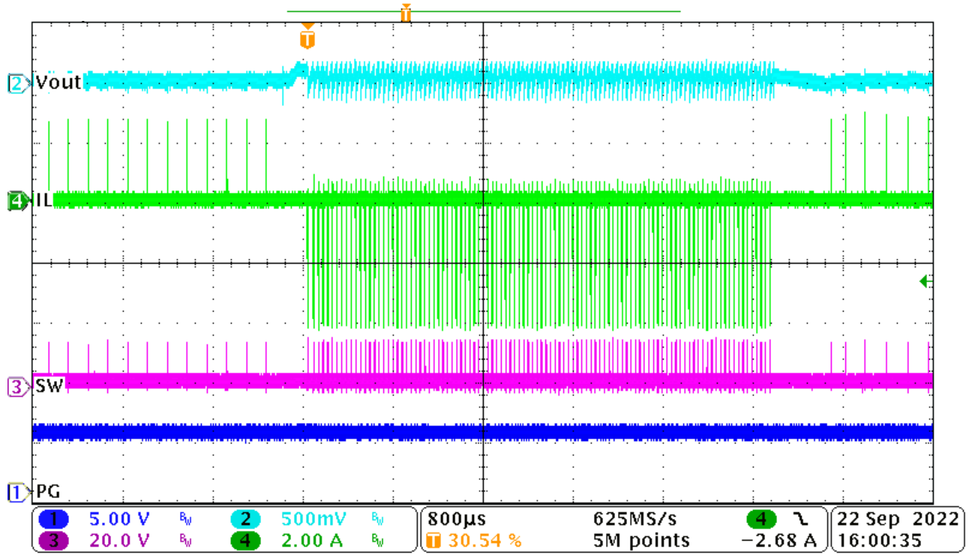

Figure 3-2. Bench Waveform of OOB Behavior when <OV Triggered (Full Waveform)

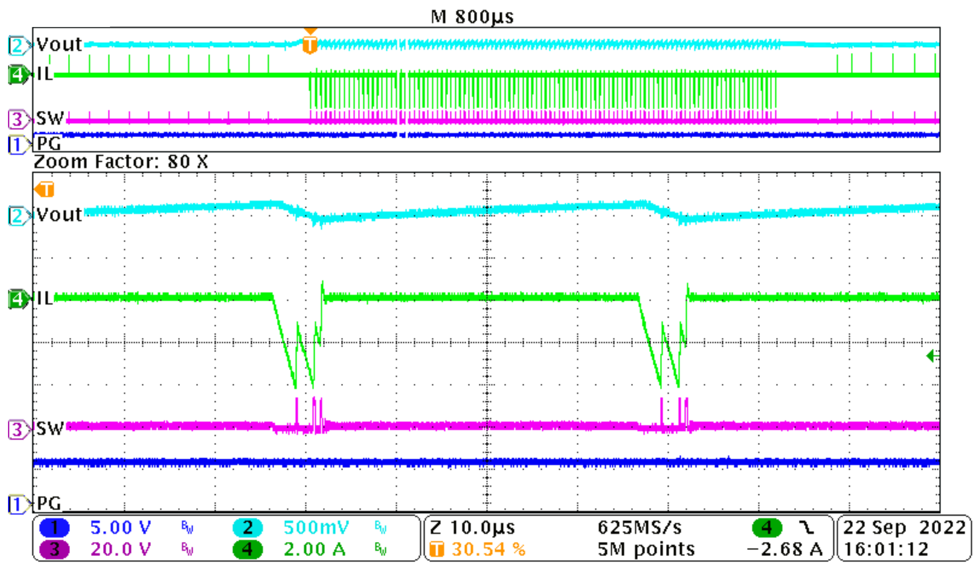

Figure 3-3. Bench Waveform of OOB Behavior when <OV Triggered (Zoom-in Waveform)

3.2 Case2: >OV Threshold

Figure 3-4 shows the logic of OOB behavior when the output voltage is larger than OV threshold (125%). When the output voltage is higher than 108% of target output value, the OOB function is activated, like Case1, the OOB_Output signal is triggered. After maximum 16-cycle NOC triggered, output voltage is still higher than target value, OOB_Output signal ends.

When Vout is increased to 125% of target value, the OV signal is pulled high, after a OVP deglitch time, the OV_Latch signal is on, the device enters OVP protection to discharge output by internal discharge resistor. Until the Vout is lower than 125%, OVP signal and OVP_latch signal is removed, OOB function works again.

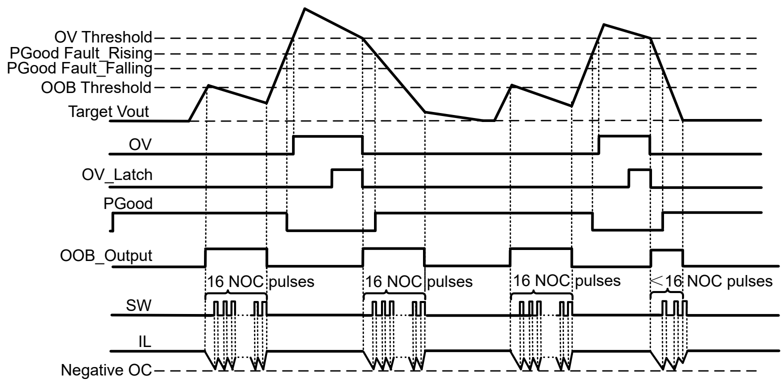

Figure 3-4. The Logic of OOB Behavior when >OV Triggered

Figure 3-5 shows the bench test waveform for TPS56C230, test conditions are 12Vin, 1.2Vout, Eco mode, force external 2V to Vout. In the zoom-in waveform of voltage rising Figure 3-6, 16-cycle NOC is triggered. Then, PG is pulled low due to output voltage higher than PGood Fault_Rising (115%). After external force power is removed, output is discharged as shown in Figure 3-7. Several cycles of NOC triggered PWM drive output voltage back to normal. After deglitch time of 64us, PG is back to high.

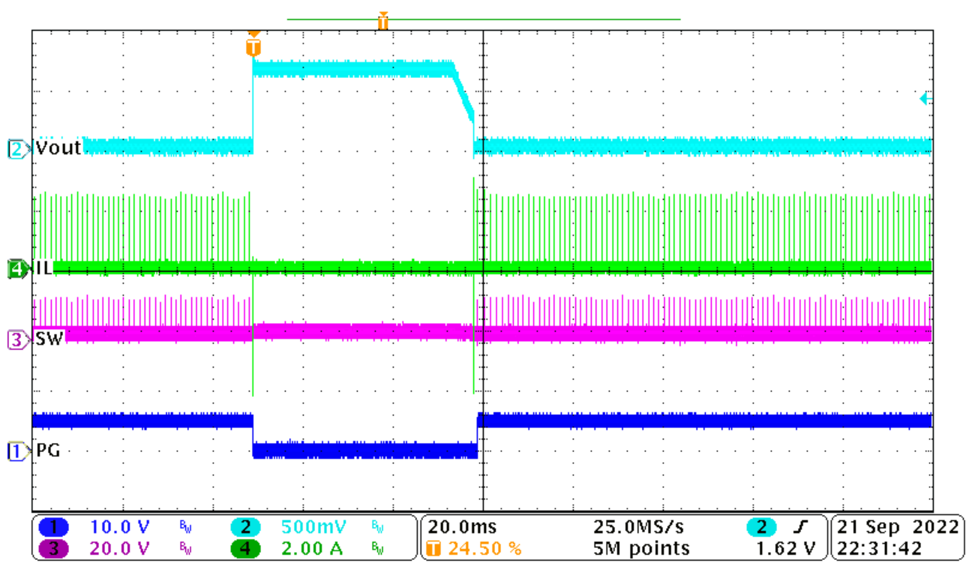

Figure 3-5. The Waveform of OOB Behavior when >OV Triggered (Full Waveform)

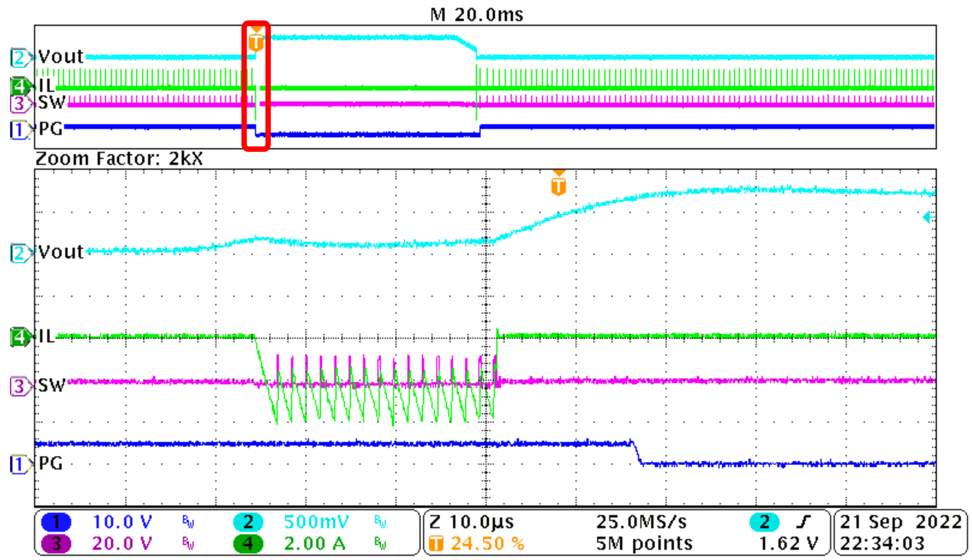

Figure 3-6. The Waveform of OOB Behavior when >OV Triggered (Zoom-in Vout Rising Waveform)

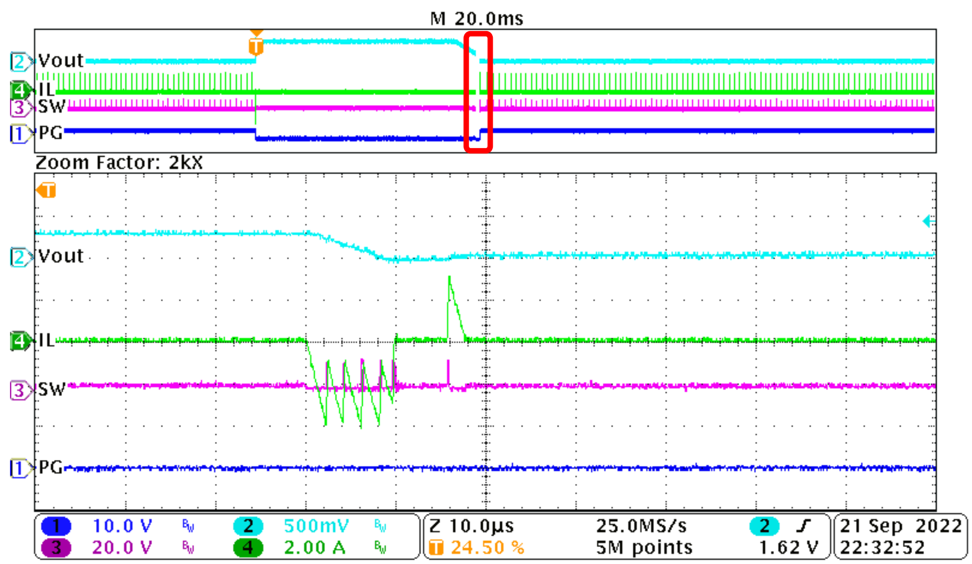

Figure 3-7. The Waveform of OOB Behavior when >OV Triggered (Zoom-in Vout Falling Waveform)

4 OOB Advantage in Load Transient

OOB function is beneficial for the settle time during load transient. There could be a output overshoot when load current changes from high to low, as shown in Figure 4-1 and Figure 4-2. TPS56C230 with OOB function will turn on low-side FET to discharge output voltage, and its Vout becomes stable quicker than TPS51397A without OOB function. Test condition: 12Vin-1.2Vo-Eco mode-Load Transient 1-10A.

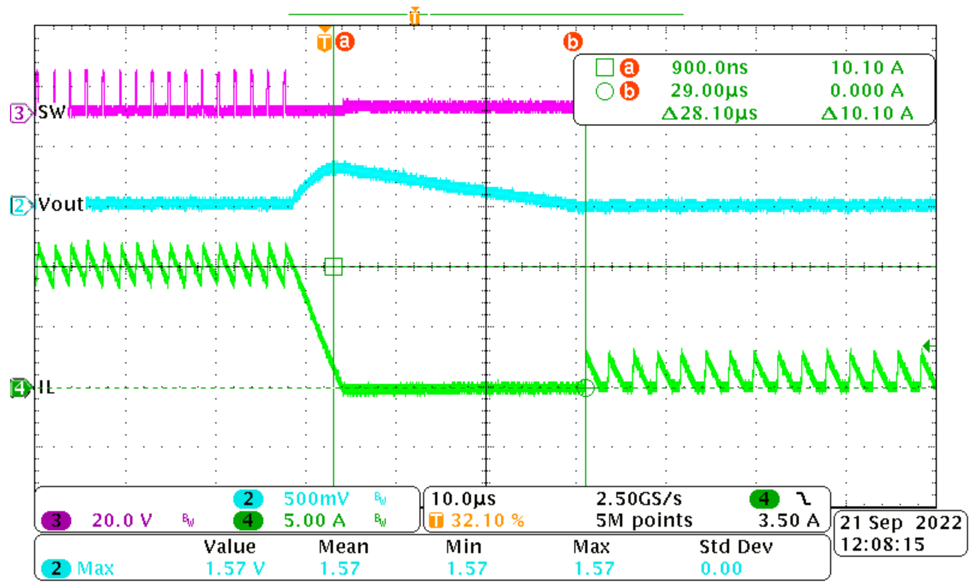

Figure 4-1. TPS51397A Load Transient (without OOB)

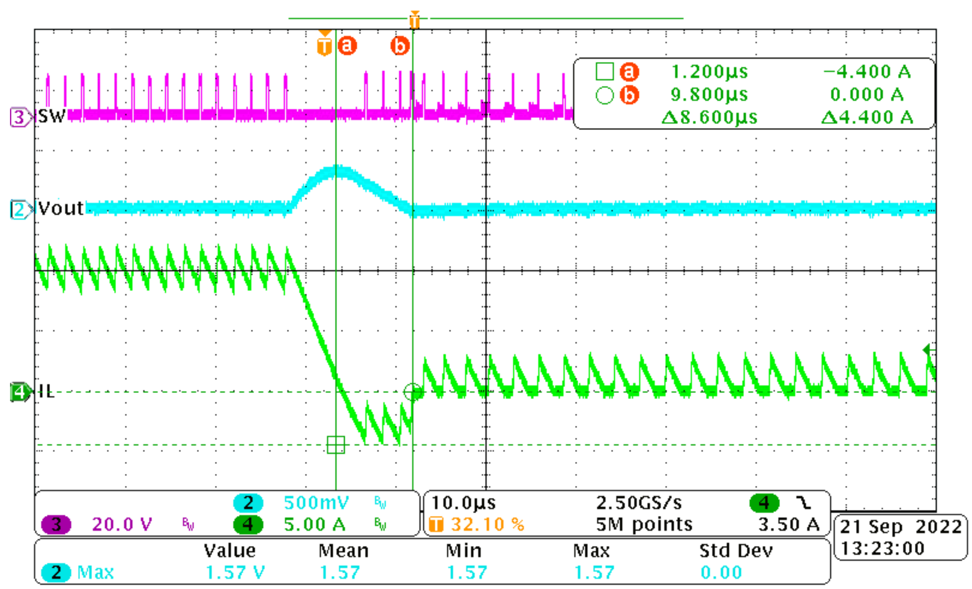

Figure 4-2. TPS56C230 Load Transient (with OOB)

5 Summary

This application note introduces the principles of TPS56C230 OOB operation and the differences between OOB and OVP, demonstrates OOB operation logic diagrams and bench test waveforms, at last shows OOB benefits for the settle time in load transient.

6 References

- Texas Instruments, *TPS56C230 3.8-V to 18-V Input , 12-A Synchronous Step-Down Converter*, data sheet

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265