Technical Article

When Pulses Are Omitted in Switch-Mode Power Supplies

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Even switch-mode power supplies with a fixed switching frequency do not always show a continuing pattern of pulses. In some conditions, pulses are omitted for various reasons. This is important to consider for output ripple voltage and EMI effects.

A switching regulator for voltage conversion normally operates with an adjustable or fixed switching frequency. This value is usually stated on the first page of the data sheet for a switching regulator IC. For the power supply circuit, the selected switching frequency is important because the size and cost of the external passive components are affected by it. The achievable conversion efficiency also is influenced by the switching frequency. For the overall electronic circuit—that is, not just the power converter but also other circuit segments in the system—the selected switching frequency is also important. The switching frequency is usually chosen in a frequency range at which the overall system is the least disturbed. The switching frequency of a power supply is usually coupled through capacitive and inductive coupling to many segments of an electrical circuit due to parasitic effects on a printed circuit board.

After properly selecting the switching frequency, circuit designers are often in for a big surprise when they evaluate the real circuit. The designed circuit often does not switch as expected at the selected switching frequency. There are two common reasons for this.

Burst Mode

Many applications need very high conversion efficiencies, even with low output loads. If the required output power is just a few mW, the supply current for the switching regulator itself is weighted heavily out of proportion. This is especially true if the efficiency is expressed as a percentage. To increase the efficiency in these cases, the switching regulator IC is frequently equipped with a special burst mode. Figure 1 shows the voltage over time of a switching regulator in Burst Mode®. The switching node switches once before changing over to a longer pause phase. During this pause phase, numerous functions of the switching regulator IC are put into a sleep mode in which only a very low amount of supply energy is needed. The switching node voltage, the inductor current, and the output voltage are shown in Figure 1.

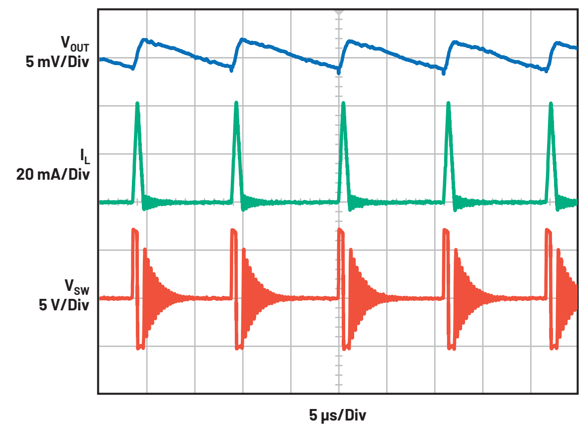

Figure 1. The concept of Burst Mode in a switch-mode power supply.

The voltage ripple of the output voltage is higher during operation in Burst Mode. It has a much lower frequency than the voltage ripple set in normal operation by the switching frequency. Depending on the voltage converter IC and the circuit conditions, operation during the burst phase is implemented with a very small number of pulses—for example, one pulse or with a large number of pulses. Usually, as many pulses as necessary are generated until the output voltage reaches a set upper threshold. This is followed by a pause that lasts until the output voltage falls below a minimum threshold. Here, switching still occurs with the selected switching frequency during the pulses, but the much lower frequency defined by the burst phases and the pause phases also appears in the spectrum.

Pulse Skipping Mode

Another mode is the pulse skipping mode. It can be found in many different types of power converters. In many topology designs, each time there is a pulse at the switching node, a certain amount of energy based on a normal minimum on time is moved from the input side to the output side of the power converter. However, if at this time, no energy or just a small amount is required by the load, the output voltage rises. Some pulses are skipped to prevent the output voltage from rising too much. Here, too, the voltage ripple of the output voltage increases. The pulse skipping mode is usually activated through an overvoltage comparator at the feedback node. If, for example, every second pulse is left out, a switching frequency corresponding to half of the set switching frequency will be visible in the spectrum (FFT representation).

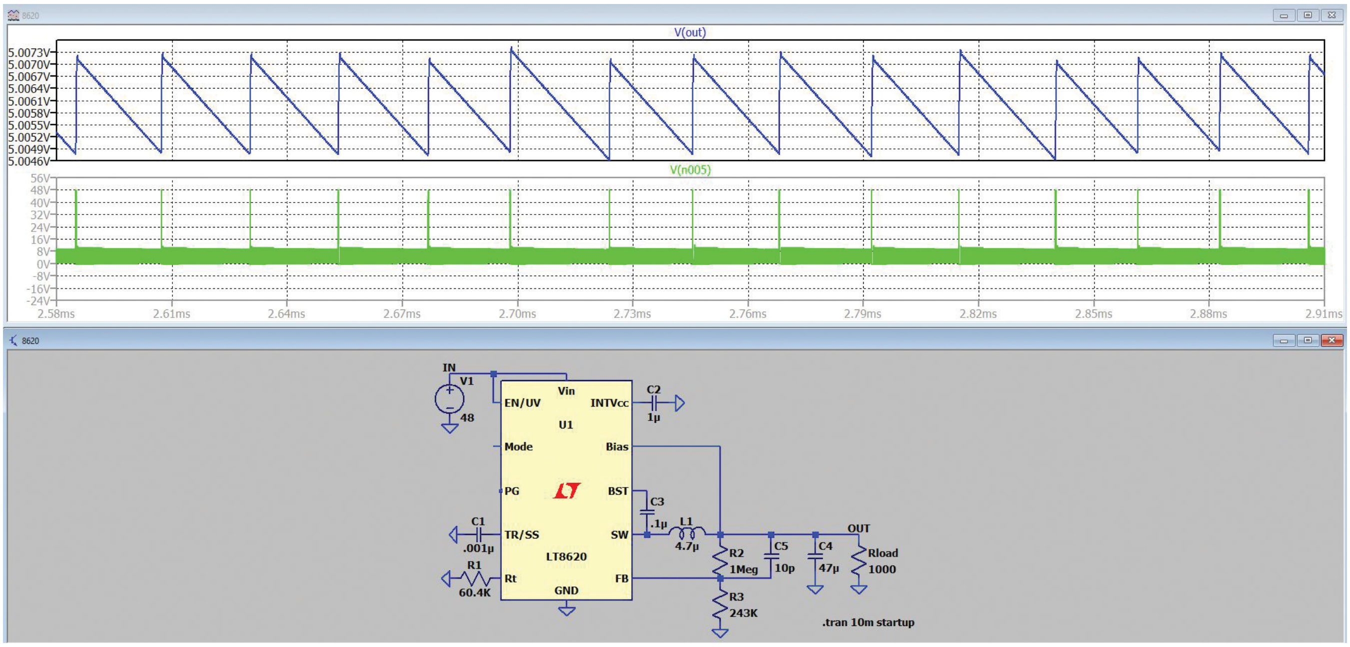

Figure 2. Simulation of an LT8620 step-down switching regulator in Burst Mode with LTspice®.

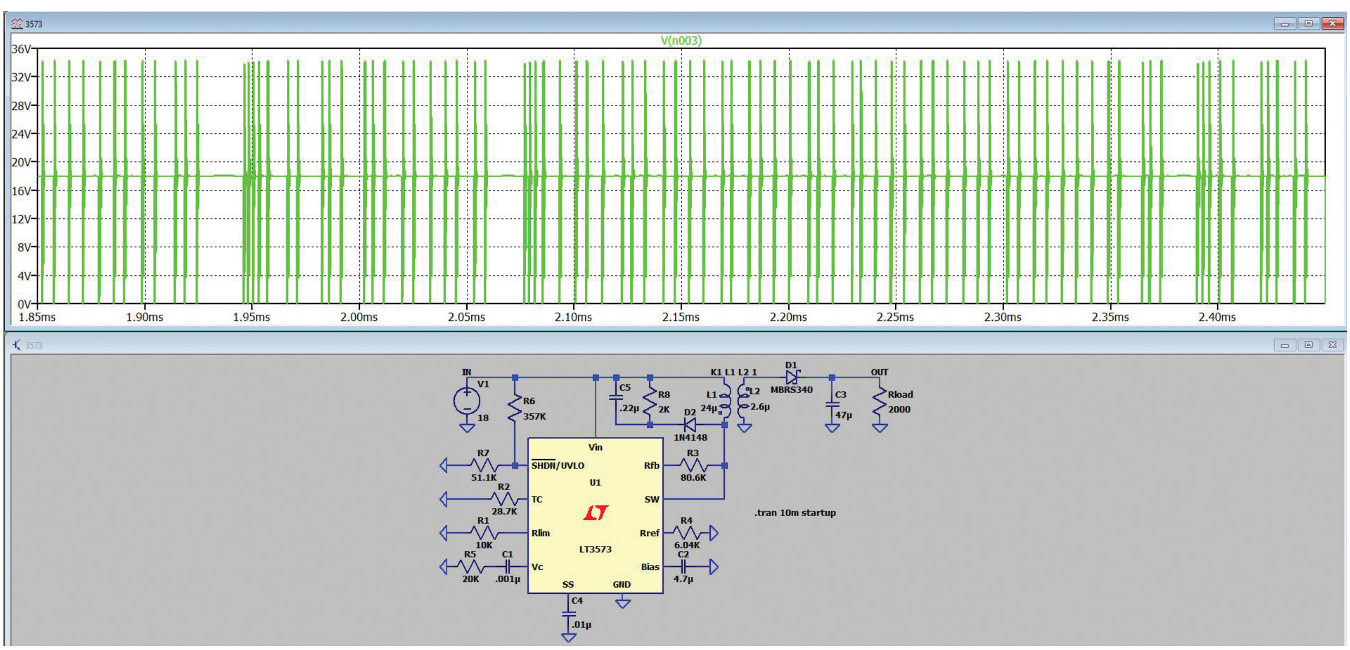

Figure 3. An LT3573 in pulse skipping mode with a low load.

In contrast to Burst Mode, the pulse skipping mode only involves keeping the output voltage within a certain range and does not save any significant amount of energy. The conversion efficiency thus only improves slightly.

Therefore, if a switching regulator switches at a different switching frequency than the one set, it could be because the circuit is in Burst Mode or a pulse skipping mode.

There may, however, be other reasons for the occurrence of discontinuous pulses at the switching node. These include general control loop instability, reaching an existing current limit, heating above a thermal shutdown limit, and many more.

Conclusion

Switch-mode power supplies may run in pulses, different to the expected switching frequency. This usually happens in low load conditions. Understanding the mechanism behind this behavior is helpful when evaluating a switch-mode power supply circuit. A designer can then confidently deduce that the power supply is indeed running reliably.

About the Author

Frederik Dostal studied microelectronics at the University of Erlangen in Germany. Starting work in the power management business in 2001, he has been active in various applications positions including 4 years in Phoenix, Arizona, where he worked on switch-mode power supplies. He joined Analog Devices in 2009 and works as a field applications engineer for power management at ADI in München. He can be reached at frederik.dostal@analog.com.

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