Understanding TPS61175's Pulse-Skipping Function

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PMP - DC/DC Controllers

ABSTRACT

This application report explains how TPS61175 behaves in Pulse-Skipping mode and how the frequency of the pulse skipping varies with change in different components.

Pulse-Skipping Mode of TPS61175

The TPS61175 is 3A high voltage boost converter with soft start and programmable switching frequency. The TPS61175 regulates the output voltage with current mode pulse width modulation (PWM) control. Once the PWM switch is turned on, the TPS61175 has minimum ON pulse width of 60-ns. This sets the limit of the minimum duty cycle of the PWM switch, and it is independent of the set switching frequency. As the output current drops, the boost converter enters discontinuous conduction mode (DCM). In DCM, the on time is a function of load current. If a very light load current only requires the switch on time to be less than 60 ns typical (110 ns maximum), the IC enters pulse-skipping mode. In this mode, the device prevents the switch from turning on for one or more switching cycles to prevent the output voltage from rising above the regulated voltage. Compared to normal PWM operation, the output ripple in pulse skipping will be larger.

In a device without pulse skipping, the PWM cycle starts at the rising edge of the clock whenever the PWM comparator output is low. The PWM cycle ends when PWM comparator output goes high. (see cycles T1, T2 and T4 in Figure 1).

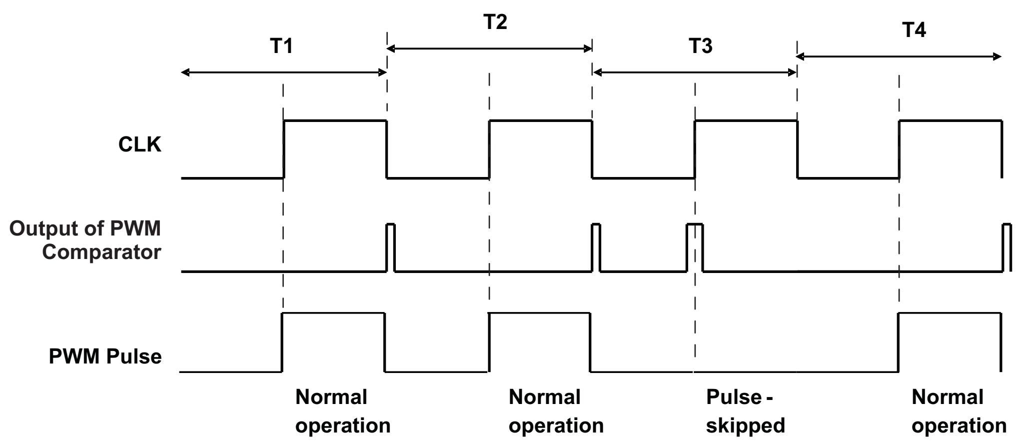

Figure 1. Operation of TPS61175

The TPS61175's pulse skip circuitry operates by checking the output of the PWM comparator just before the CLK rising edge. If the PWM comparator output is high at this moment then one cycle (or pulse) is skipped. The exact relationship between pulse skip frequency and load current is a complex function of L, Co, Vin, Vo and the control loop. Since one input to the PWM comparator is the output of the error amplifier (i.e., the IC's COMP pin), changing the compensation components changes not only the time between switching bursts in pulse skip mode (i.e. the pulse skip frequency) but also the number of pulses within each burst. Specifically, the pulse skipping frequency, f_{PS} varies inversely with the compensation capacitance value and directly with the compensation resistance value. In other words, f_{PS} varies directly with the loop bandwidth of the converter.

Calculation of Skip Threshold Current

The peak current through the inductor in discontinuous mode is given by Equation 1.

$$\text{Ipeak} = \sqrt{2 \times \text{Iload} \times \frac{\text{Vout} + \text{Vf} - \text{Vin}}{\text{L} \times \text{Fs}}} \tag{1}$$

And the On-time Ton is given by Equation 2.

$$\text{Ton} = \text{L} \times \frac{\text{Ipeak}}{\text{Vin}} \tag{2}$$

Where,

Ipeak = Peak current through inductor L in discontinuous mode
Iload = Load current for entering pulse-skipping mode
Vout = Output voltage
Vf = Forward voltage of Schottky diode
Vin = Input voltage
Fs = Switching frequency
Ton = On time of the PWM

Rearranging gives

$$\text{Iload} = \frac{\left(\text{Ton}^2 \times \text{Vin}^2 \times \text{Fs}\right)}{\left(2 \times \text{L} \left(\text{Vout} + \text{Vf} - \text{Vin}\right)\right)} \tag{3}$$

For instance, if we have Vin=12.75V, Fs = 750kHz, L = 22µH, Vout = 24V, Vf = 0.35V :

for Ton = 30nS, Iload = 215µA
for Ton = 22nS, Iload = 115µA

Example:

Given below are some practical results measured on TPS61175 EVM.

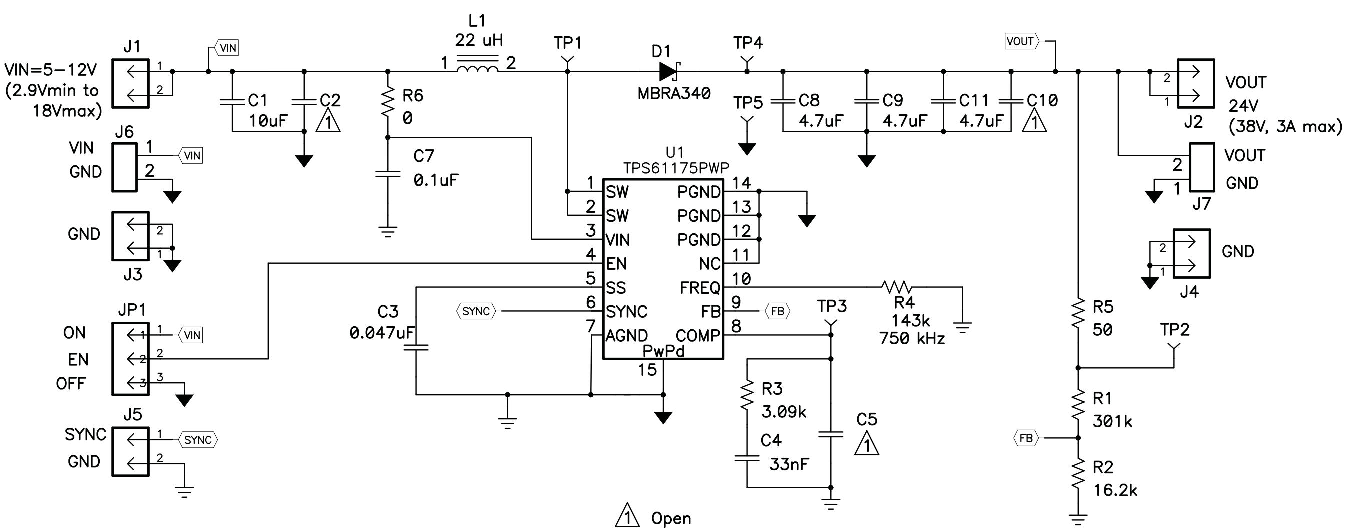

Figure 2. Schematic of TPS61175 EVM

Legends for waveforms in Figure 3 through Figure 8 are as:

Table 1. Waveform Legend

Channel	Corresponding Waveform	Vertical Scale	Time Scale
Channel 1 (Yellow)	Switch-node voltage waveform	50 V/div	1 ms/div

Table 1. Waveform Legend (continued)

Channel	Corresponding Waveform	Vertical Scale	Time Scale
Channel 2 (Red)	AC-coupled output voltage waveform	200 mV/div	1 ms/div
Channel 3 (Blue)	Voltage waveform on COMP pin	200 mV/div	1 ms/div
Channel 4 (Green)	Load Current waveform	200 mA/div	1 ms/div

1. For Output current = 220 µA
   a. R3 = 3.09 kΩ, C4 = 33 nF → $\mathbf{f_{PS}} \approx$ **599.91 Hz**

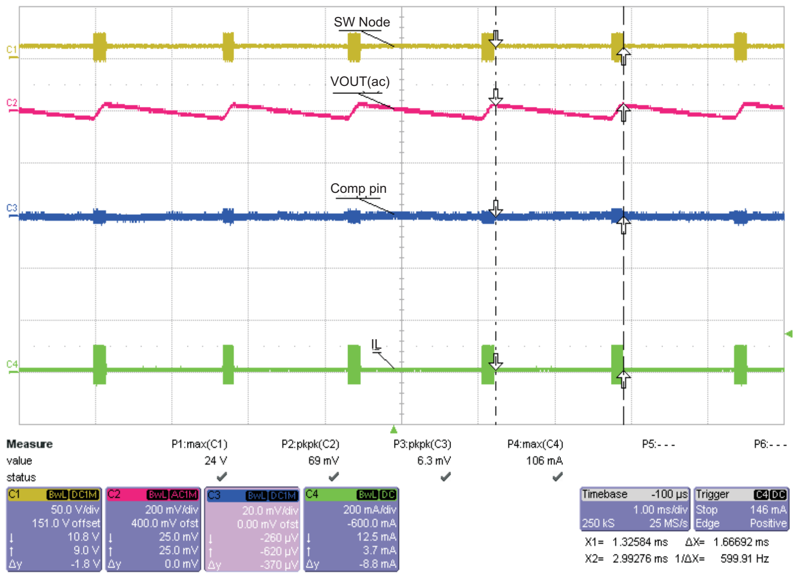

Figure 3. Test Condition 1(a)

   b. Same R3 = 3.09 kΩ, larger C4 = 68 nF, lower loop crossover → **lower $\mathbf{f_{PS}}$ = 755.171 Hz**

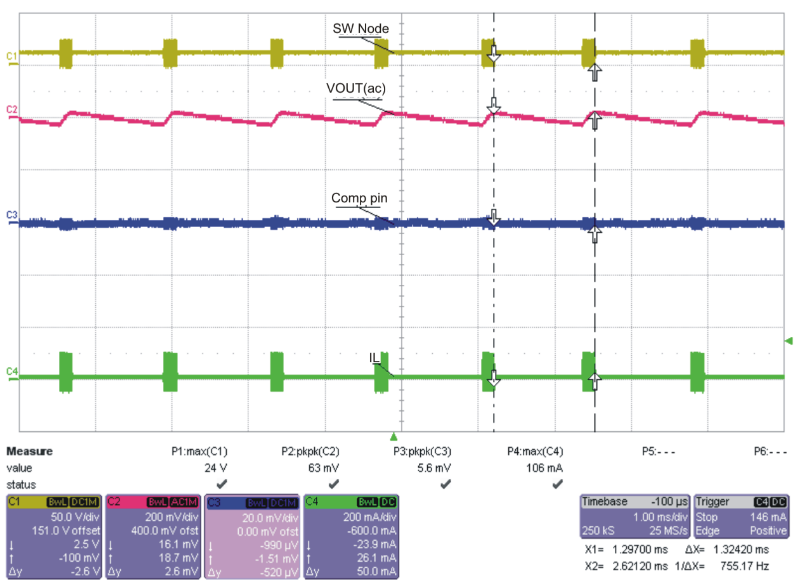

Figure 4. Test Condition 1(b)

   c. Smaller R3 = 1 kΩ, same C4 = 33 nF, lower loop crossover → **lower $\mathbf{f_{PS}}$ = 314.039 Hz**

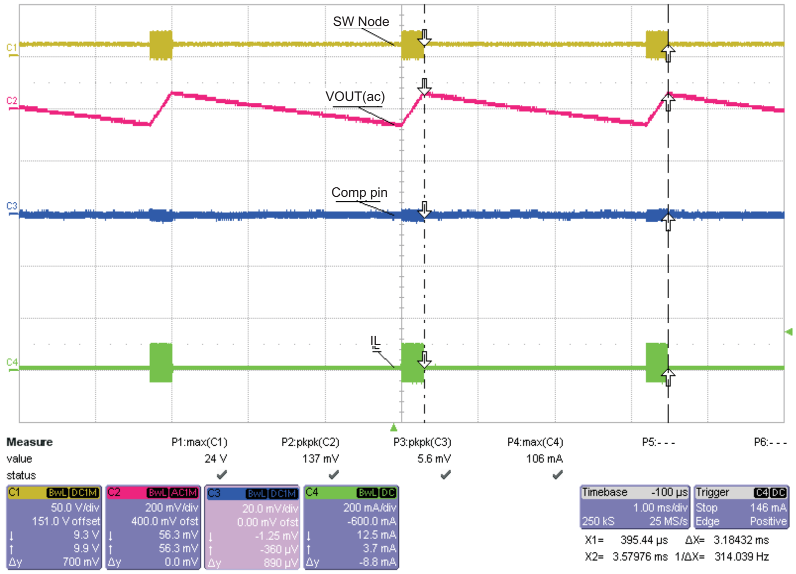

Figure 5. Test Condition 1(c)

2. For Output current = 110 µA
   a. R3 = 3.09 kΩ, C4 = 33 nF → **f_{PS} = 340.532 Hz**

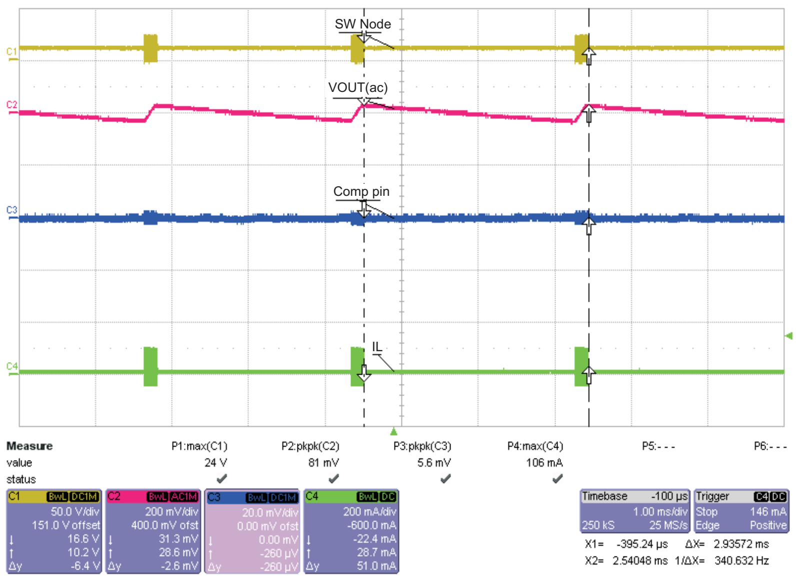

Figure 6. Test Condition 2(a)

   b. Same R3 = 3.09 kΩ, larger C4 = 68 nF, lower loop cross over → **slower f_{PS} = 533.15 Hz**

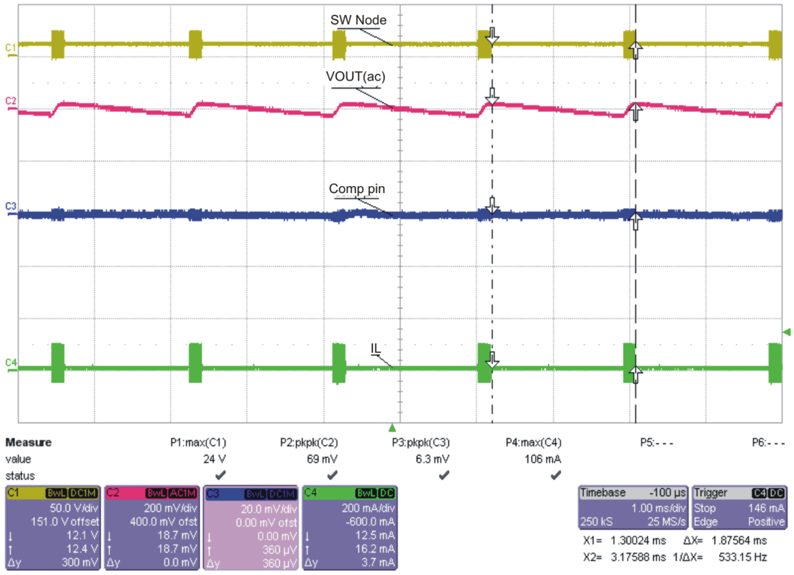

Figure 7. Test Condition 2(b)

c. Smaller R3 = 1 kΩ, same C4 = 33 nF, lower loop crossover → **lower f_{PS} = 230.352 Hz**

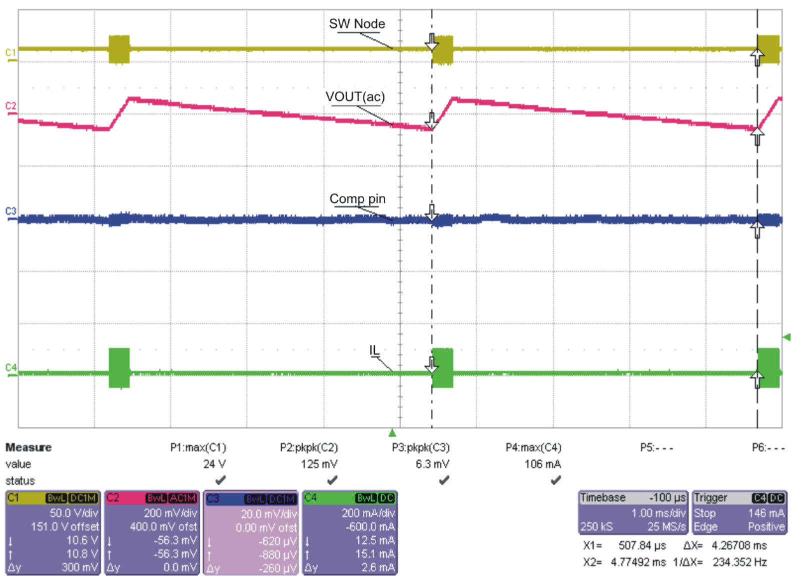

Figure 8. Test Condition 2(c)

Conclusion

The TPS61175 pulse skipping feature operates by simply blanking out the clock pulse, thereby not turning on the FET, if the PWM comparator output is high at the beginning of each clock cycle. The skip cycle threshold can be found using the on time equation in DCM mode; however, the frequency between pulse skip operation bursts varies inversely with the compensation capacitance value and directly with the compensation resistance value. In other words, it varies directly with the loop bandwidth of the converter.

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