Application Report
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Factors That Determine Light Load PSM Switching Frequency for TPS6102x Boost Converters

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ABSTRACT

This application report explains the factors that determine the low output power switching frequencies when using the TPS6102x step up converters.

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1 Introduction

To increase light load efficiency, the TPS6102x family of switching converters operate in power save mode (PSM). In PSM, the converter only switches when the output voltage is below the programmed threshold which results in a reduced switching frequency at light loads. The output voltage is user programmable for the TPS61020, TPS61028 and TPS61029 using an external resistor divider and is factory programmed for the TPS61024-TPS61027. When the voltage at FB falls to 98.4% of the reference voltage (500 mV typical), the IC begins switching. The IC switches at a constant switching frequency (600 kHz typical) with a duty cycle determined by the ratio of the input voltage and the voltage at FB. As the IC switches, the output voltage steadily rises. The IC reduces the on-time of the power switching MOSFET as the FB voltage rises. Reducing the on-time results in the inductor current falling to zero, which triggers the IC to stop switching. It normally takes several pulses for the inductor current to drop to zero, depending on the input/output voltage. For this document, the PSM frequency is defined as the timing of these groups of pulses. At light or no load, this is the larger *frequency* component of the output ripple. As the load increases, the PSM frequency increases until the IC's off time is reduced to zero. At this point, the IC transitions back into fixed frequency PWM mode at the 600-kHz internal oscillator frequency. Figure 1 illustrates the difference between light load and heavy load output ripple to clarify this point. Both of these waveforms are taken with an output of 5 V and an input of 3.6 V.

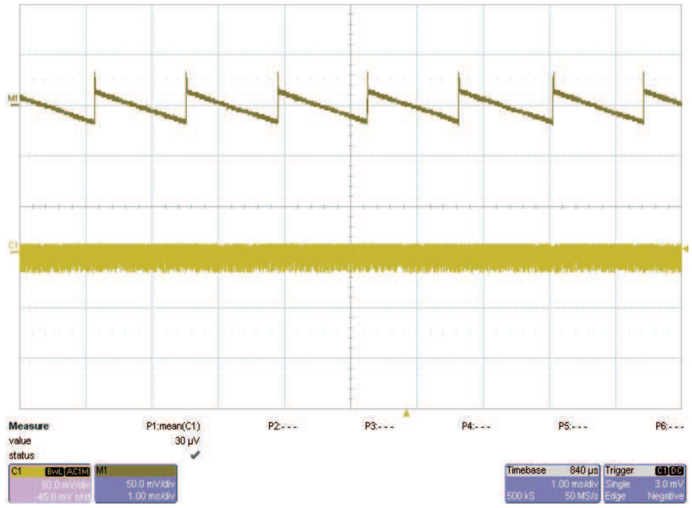

Figure 1. PSM Output Ripple (Top Waveform) 50 mV/div vs PWM Output Ripple (Bottom Waveform) 50 mV/div

As the load increases in PSM mode, the number of pulses in the rising edge increases and the fall time decreases. This results in higher switching frequencies for heavier loads. The switching frequency at light loads is dependant on factors such as output load, the input and output voltage, and external component values.

1.1 Input/Output Voltage

The input and output voltage determine the IC's duty cycle during the switching cycles. The duty cycle changes the peak-to-peak current in the inductor. This in turn affects the rate at which the output capacitor is charged during each switching cycle. The output voltage also affects the amount of voltage drop required to trip the error amplifier. Since the voltage at FB is resistor divided down from the output, the higher the output, the more the output voltage must fall before FB falls below 98.4% of the reference. Conversely, the more the output must rise to come back into regulation. This means that a higher output voltage has a lower switching frequency. Figure 2 through Figure 11 show PSM switching frequency vs load current for several input and output voltage combinations.

1.2 Output Capacitance

The output capacitance determines the fall time of the output voltage as well as part of the rise time. As the load bleeds the charge out of the output capacitors, the output falls. Once the output falls below 98.4% of the feedback threshold of the error amplifier the IC switches to bring the output back into regulation. The rate at which the output falls for a given load is totally dependant on the output capacitance. With more output capacitance, the longer it takes for the output to fall. This longer output fall time results in a lower frequency. At very light or no load conditions, this fall time dominates the total period. During the switching cycles, the output capacitor determines the rate at which the output rises during each cycle. As energy is transferred from the inductor to the output capacitor, the output voltage rises. With a larger output capacitor, it takes longer for the output to rise. Increasing the size of the output capacitor decreases the switching frequency substantially because it affects both rise and fall time of the output. Figure 2 through Figure 6 show the affect of output capacitance on switching frequency. The graphs illustrate the PSM frequency. The endpoint of the graphs is the point at which the IC operates in PWM mode.

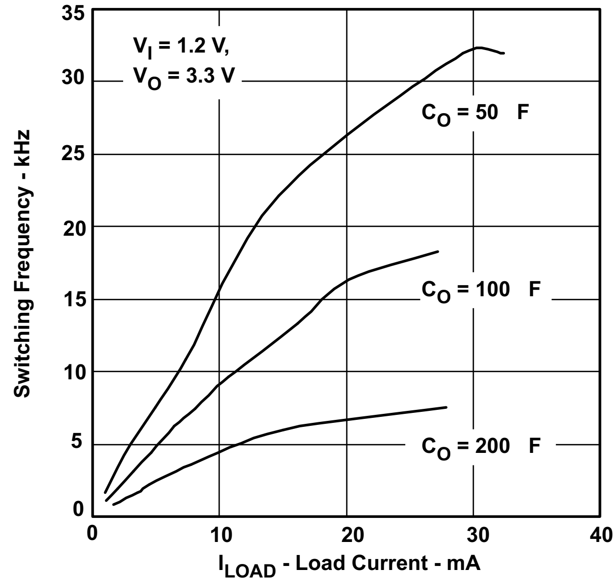

Figure 2. Output Capacitance Effect on Switching Frequency

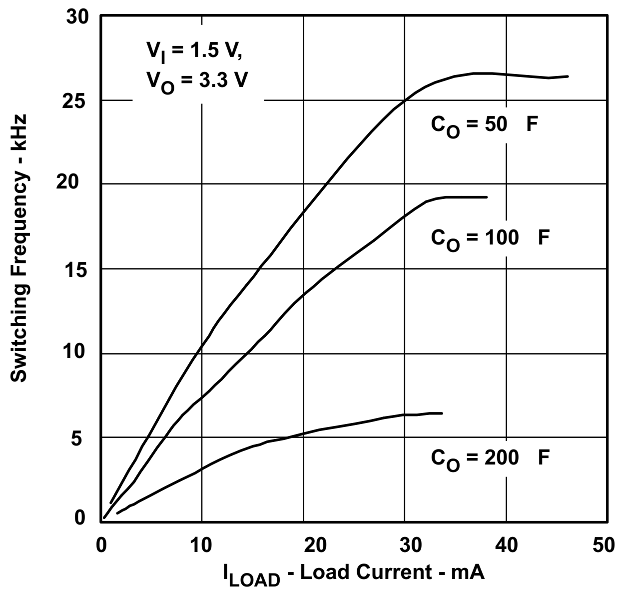

Figure 3. Output Capacitance Effect on Switching Frequency

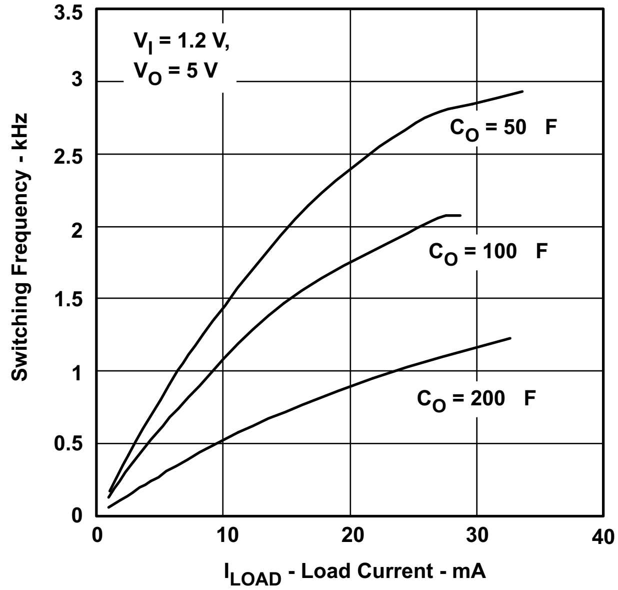

Figure 4. Output Capacitance Effect on Switching Frequency

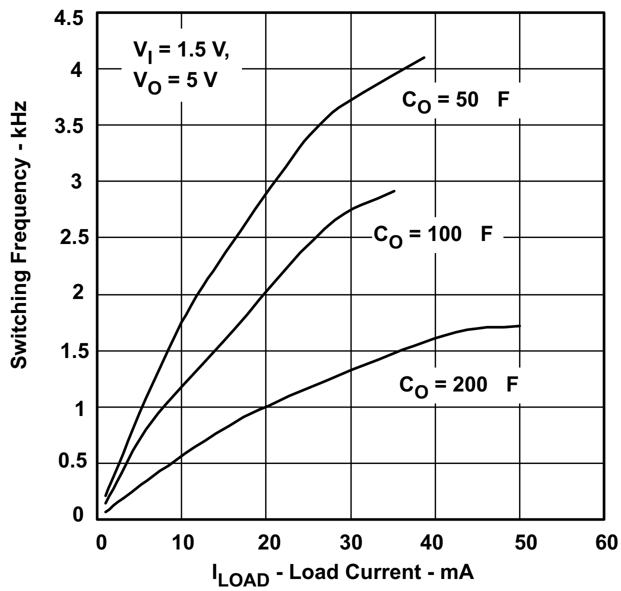

Figure 5. Output Capacitance Effect on Switching Frequency

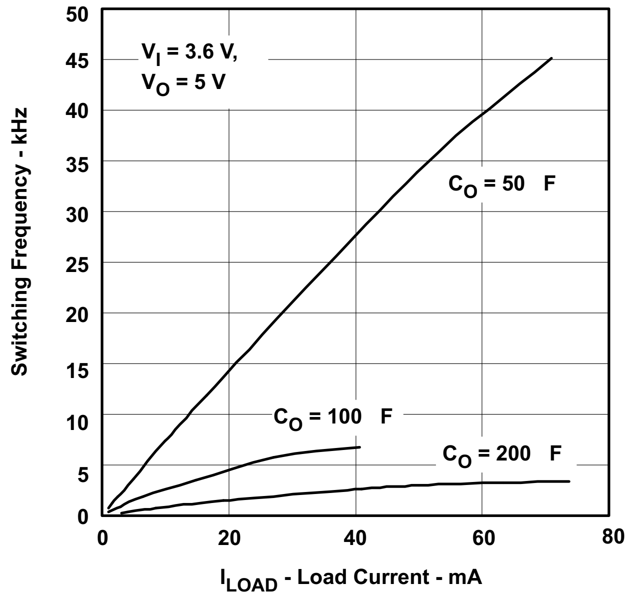

Figure 6. Output Capacitance Effect on Switching Frequency

1.3 Inductor Value

The inductor value determines how much energy is transferred to the output capacitor during each switching cycle. A larger inductor produces lower current ripple. This translates to a lower switching frequency because the output is not charged up as much during each switching cycle. See Figure 7 through Figure 11 for examples of the inductor's effect on switching frequency.

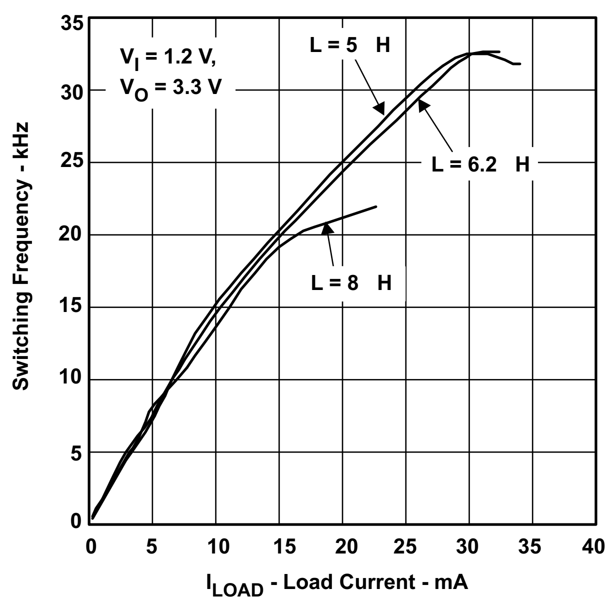

Figure 7. Inductor Effect on Switching Frequency

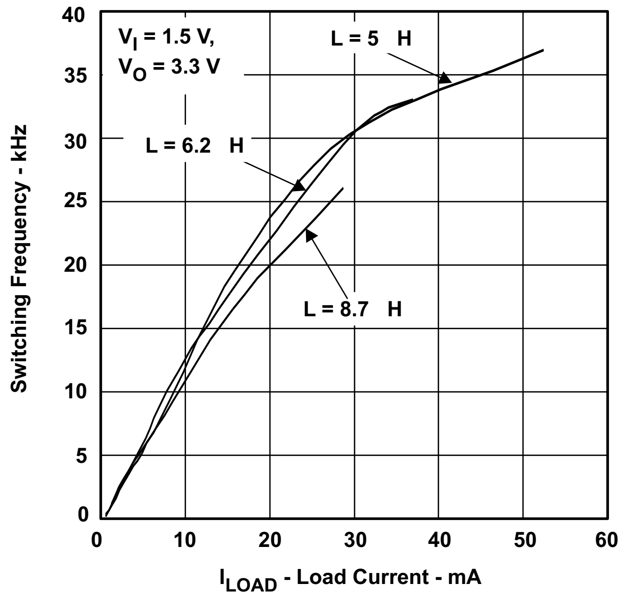

Figure 8. Inductor Effect on Switching Frequency

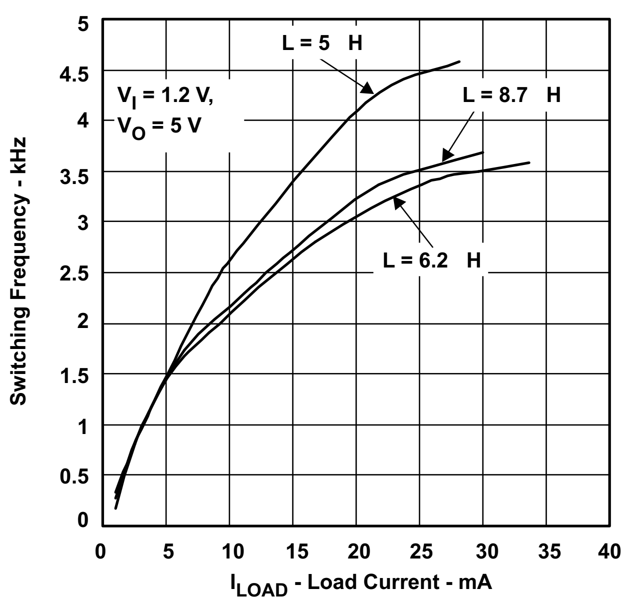

Figure 9. Inductor Effect on Switching Frequency

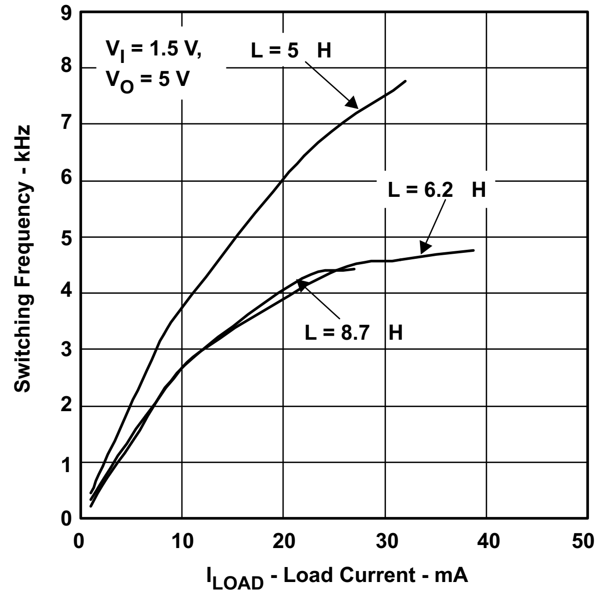

Figure 10. Inductor Effect on Switching Frequency

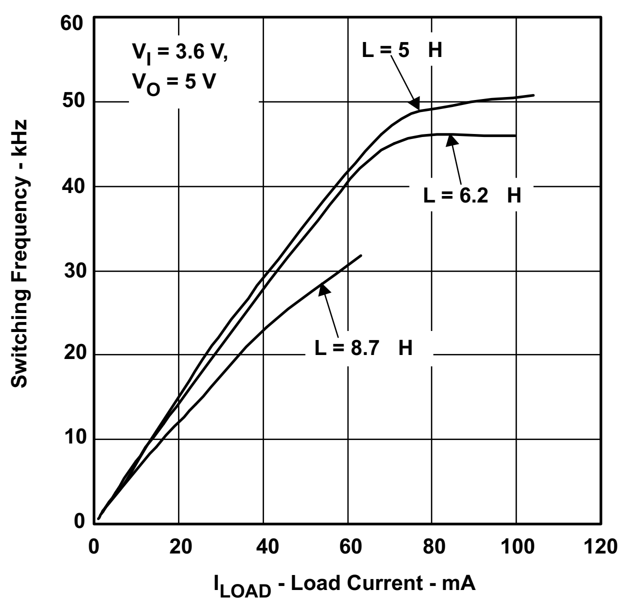

Figure 11. Inductor Effect on Switching Frequency

PSM frequency is dependant factors such as input/output voltage, external components and load current. The graphs in this appnote provide the user with a good starting point. The end circuit should be prototyped in order to verify that the circuit operates at the required PSM frequency for the end application.

2 References

1. TPS61020 Data sheet (SLVS451D)
2. TPS61020EVM User's Guide (SLVU100)

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