TPS54618-Q1 High-Frequency (2.35 MHz) Operation

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ABSTRACT

This document describes the TPS54618-Q1 High-Frequency (2.35 MHz) operation and (2.5 MHz) simulation test results. This application report is applicable to TPS57114-Q1 and TPS54388-Q1 devices also as these two devices belong to the same family as the TPS54618-Q1 device.

1 Introduction

The TPS54618-Q1 device is a full-featured 6-Vin, 6-A, synchronous step-down current-mode DC-DC converter with two integrated metal-oxide-semiconductor field-effect transistors (MOSFETs). The TPS54618-Q1 device can operate in a wide range of switching frequencies from 200-KHz to 2-MHz. The switching frequency can be set using a pulldown resistor or an externally applied signal at the RT pin as shown in Figure 1. Refer to *Interfacing TPS57xxx-Q1,TPS65320-Q1 Family, and TPS65321-Q1 Devices With Low Impendence External Clock Drivers* (SLVA755), for more information regarding interfacing an external clock to TPS54618-Q1 family of devices.

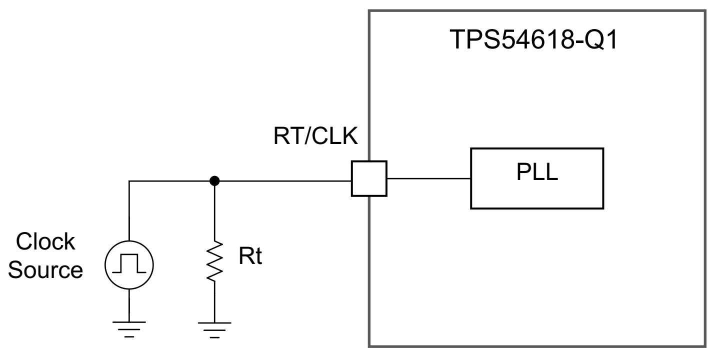

Figure 1. Synchronizing to a High-Impedance External Clock Source

The regulated output voltage at no load is given by Equation 1:

$$V_{out} = V_{in} \times t_{ON} \times f_{SW}$$

where

- V_{in} = input voltage
- V_{out} = output voltage
- t_{ON} = ON time

and

- f_{SW} = switching frequency (1)

For given input and output voltages, as switching frequency is increased, t_{ON} will reduce. If t_{ON} falls below the minimum value allowed by the internal circuit design, the output voltage may not track the internal 0.8-V reference and would therefore not be regulated. To maintain the regulation at higher switching frequencies, t_{ON} must be kept above a minimum value. If the switching frequency is less than or equal to the data sheet maximum value of 2 MHz, t_{ON} will always be above designed minimum value and the output would be regulated.

2 2.35-MHz Operation

Bench test and chip-level simulations were done to check whether the TPS54618-Q1 can remain in regulation while switching at a frequency higher than 2.0 MHz.

The test conditions for the bench test and chip-level simulation were as follows:

- Supply input voltage: 5.33 V
- Regulated output voltage: 1.35 V
- Operating switching frequency in bench setup: 2.35 MHz synchronized to an external clock as shown in Figure 1.

Under these test conditions, the on time at a 100-mA load for the TPS54618-Q1 to maintain regulation was verified by bench measurements to be 109.6 ns, compared to the value estimated by Equation 2:

$$(1.35\text{ V} / 5.33\text{ V}) \times (1 / 2.35\text{ MHz}) = 107.8\text{ ns} \tag{2}$$

Minimum controllable on time at higher frequency and input voltage is verified to be less than 90 ns, confirmed by the simulations in Section 3.

3 2.5-MHz Operation Simulation Results

A full chip breaking-point simulation is performed at 2.5-MHz clock frequency using the input and output voltages specified in the following list to determine the minimum controllable t_{ON} allowed by internal circuit design. The 2.5-MHz clock frequency is chosen to have some margin for oscillator tolerances and to be sure that it works for 2.35-MHz clock frequency.

- Input voltage swept from 5 V to 6 V
- Output voltage programmed to 1.35 V
- Load current set to 10 mA using a 135-Ω resistor
- L_{OUT} = 0.33 µH, C_{OUT} = 33 µF
- R_{COMP} = 3.83 kΩ, C_{ZERO} = 1.5 nF, C_{POLE} = 0 pF

Simulation results:

- Transient turn on behavior appears normal

Table 1 lists the simulation results across process corners and across temperature with 10-mA load current.

Table 1. Breaking Point Simulation Data With 10-mA Load at 2.5 MHz

Process Corner / Temperature	Simulated V_{REF} (mV)	V_{IN} (V)	Actual V_{out} (V)	F_{SW} (MHz)	Calculated t_{ON} (ns)	Simulated t_{ON} (ns)
Nominal / 27°C	819	6	1.352	2.5	90.1	94.9
Weak / –40°C	814	6	1.343	2.5	89.5	94.5
Weak / 150°C	835	6	1.382	2.5	92.1	96.2
Strong / –40°C	809	6	1.335	2.5	89.0	91.8
Strong / 150°C	823	6	1.362	2.5	90.8	96.3

Based on the simulation results, the minimum controllable on-time is found to be lower than 100 ns at a 10-mA load.

4 Conclusion

The switching ON time for an input voltage of 5.33 V and a regulated output voltage of 1.35 V and a switching frequency of 2.35 MHz is calculated to be 107.8 ns during no load conditions. This is higher than the minimum controllable ON time of 105 ns allowed by internal circuit design based on simulations. The TPS54618-Q1 is expected to be capable of maintaining regulation without entering pulse-skipping mode up to 2.35-MHz switching frequency under this operating condition. This result has been verified by bench measurements to be accurate under extreme temperature corners on typical devices.

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