

Slew-Rate Limitations on the REFIN Pin of the TPS54X72 Family of Tracking DC/DC Converters

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ABSTRACT

Tracking dc/dc converters must track a reference voltage. However, the rate of change in the reference voltage that the output voltage can successfully track is limited. This application report presents a typical application circuit and the reasons for these limitations, along with waveforms showing circuit performance when the reference voltage slew rates are increased above the maximum.

Some dc/dc converter applications require that output voltage be dynamically changed by an external reference signal. For these applications, the TPS54x72 series of tracking dc/dc converters can be used. These devices feature a REFIN pin which provides the tracking capability of an internal reference. Combined line and load regulation with a static voltage on the REFIN pin typically falls within ± 0.5 percent at 25°C. ambient temperature. The REFIN pin design allows an input voltage range from 0.2 V to 1.75 V, but practical limits exist on the rate at which this input reference voltage can be changed. These limits are not imposed by the input circuitry of the REFIN pin itself, but rather by the closed-loop control circuitry inherent in switching power supplies and the built-in current limit circuitry of the high-side power FET.

In the circuit of [Figure 1](#), a TPS54372 provides a 2-A output at an output voltage between 0.2 V and 1.8 V that is determined by the voltage at the REFIN pin.

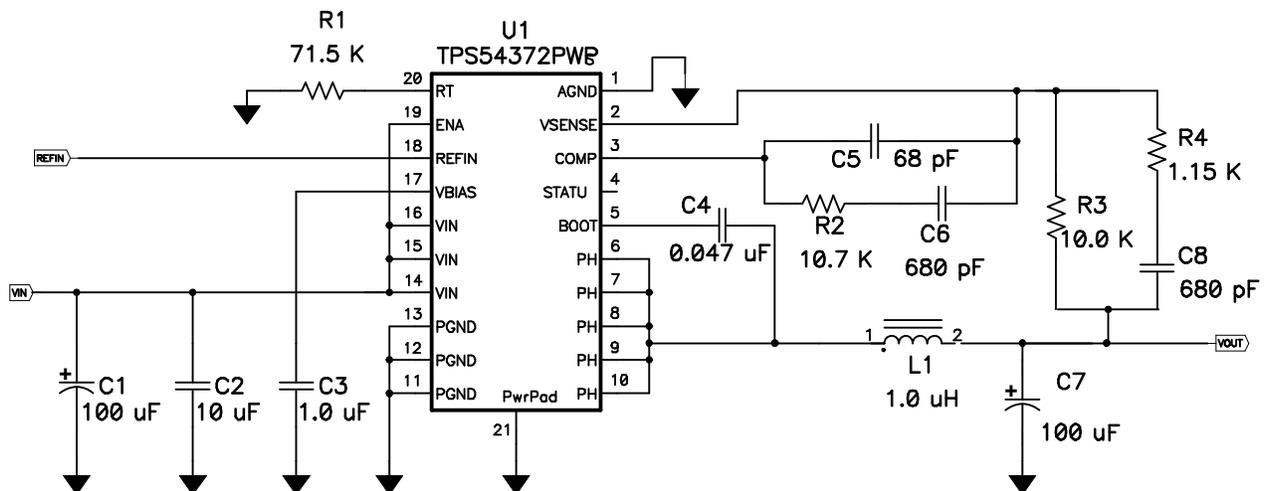


Figure 1. Typical TPS54372 Application Circuit

When the output voltage imposed on the C7 output capacitor tracks a REFIN voltage that changes with a linear rising or falling edge signal, the following equation holds:

$$dv/dt = I/C$$

Where dv/dt is the REFIN voltage rate of change, C is the output capacitance, and I is the resulting constant current to charge the capacitor.

So, for a constant slew rate (dv/dt), the current charging the capacitor must be constant. If there is no additional load on the output, that charge current is the total average current flowing in the inductor.

Consider the waveform of [Figure 2](#).

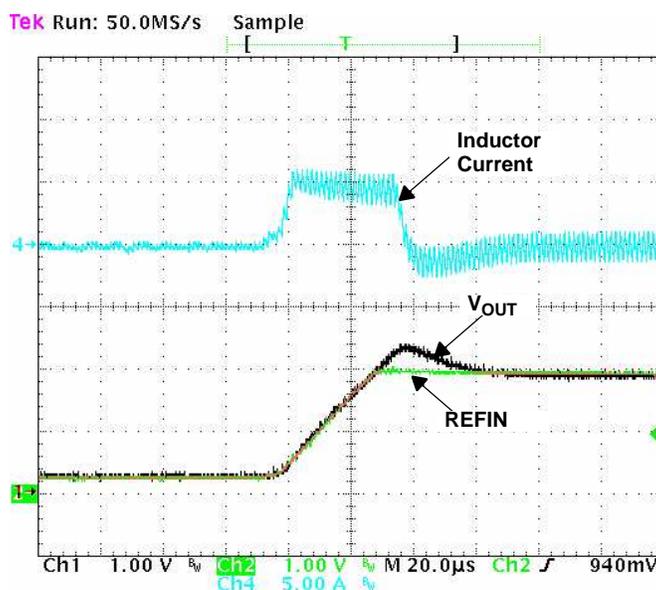


Figure 2. REFIN Rising-Edge Slew Rate at Maximum

The Ch 1 trace is the output voltage; the Ch 2 trace is the REFIN voltage; and the Ch 4 trace is the inductor current. This channel assignment is the same for all the following waveforms. As the REFIN voltage starts to ramp up at a constant rate of about 50 mV/ μ sec, the inductor current immediately adjusts to a constant 5-A level. The rate at which the current can change from 0 A to 5 A is limited by the inductor size and the speed of the control loop, but this response time is fast compared to the REFIN rise time. The inductor current continues at this rate until the REFIN voltage reaches its final value, and the output capacitor is charged to the new output voltage level. Note that some overshoot is on the output voltage as the inductor current decreases back to 0 A.

If the REFIN slew rate is increased beyond this rate, the current cannot increase further; so, the output charges at the same rate as before, lagging behind REFIN. This condition is shown in [Figure 3](#).

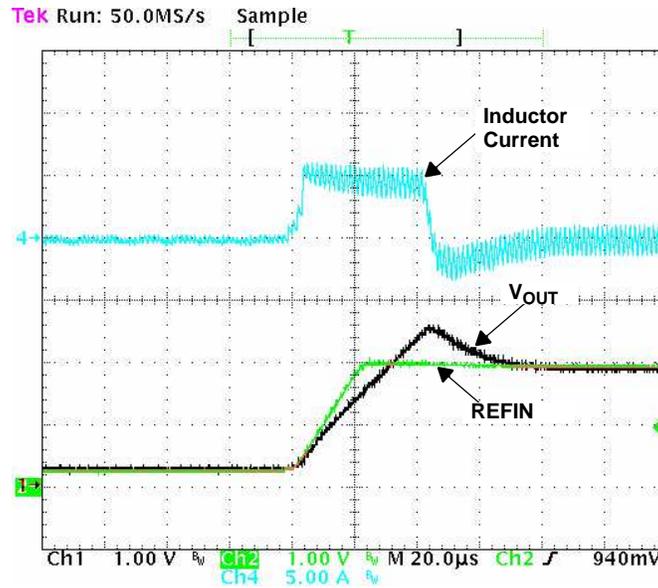


Figure 3. REFIN Rising-Edge Slew Rate Above Maximum

Figure 4 shows the result of increasing the load current to 2 A, while maintaining the same rise time for the REFIN signal. Because the inductor current cannot increase above the device current limit set point and 2 A is being drawn by the external load, the amount of current available to charge the output capacitor is decreased and the output voltage takes longer to reach the REFIN voltage.

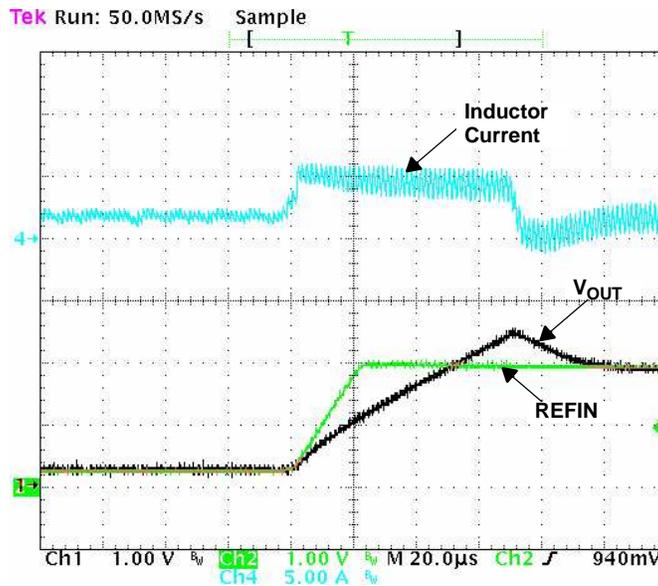


Figure 4. REFIN Rising Edge with 2-A Output Current

The situation for the falling-edge response is similar, but with an important difference; there is no direct current limit function in the device for the low-side FET or for the high-side FET when the device is sinking rather than sourcing current. The device needs to sink current when the REFIN signal transitions from a higher voltage to a lower voltage level. Normal operation is shown in Figure 5. The REFIN signal is transitioning at a rate of about 1.7 V / 52 µsec, requiring approximately 3.3 A of discharge current in the output capacitor. Although that is above the rated sink current capability of the device, the device is capable of sinking that current because there is no low-side current limit, and the output voltage tracks the REFIN signal properly. This sink current level shown in Figure 5 is the maximum amount that can be handled by the TPS54372.

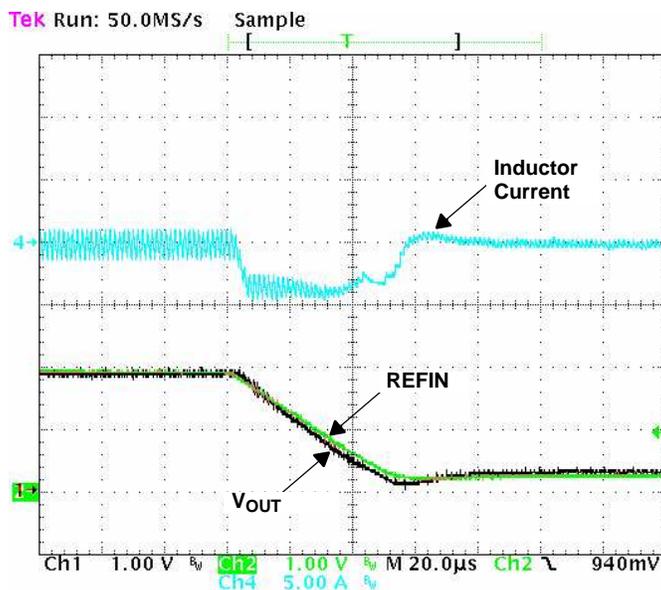


Figure 5. REFIN Falling-Edge Slew Rate at Maximum

Figure 6 shows the result of increasing the falling-edge slew rate beyond that point. The device cannot sink the required level of current and momentarily stops its switching function and re-starts.

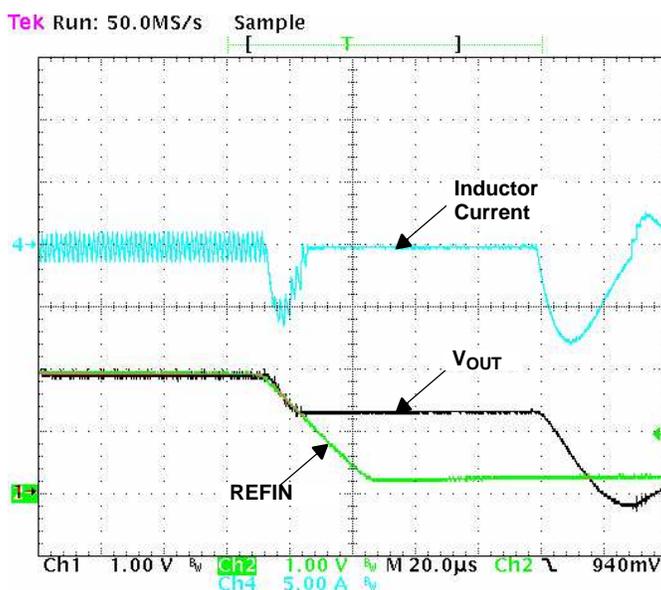


Figure 6. REFIN Falling-Edge Slew Rate Above Maximum

Figure 7 shows the effect of increasing the load current to 2 A. Note that it is possible in this case to increase the slew rate on the falling edge because the load current helps to discharge the output capacitor.

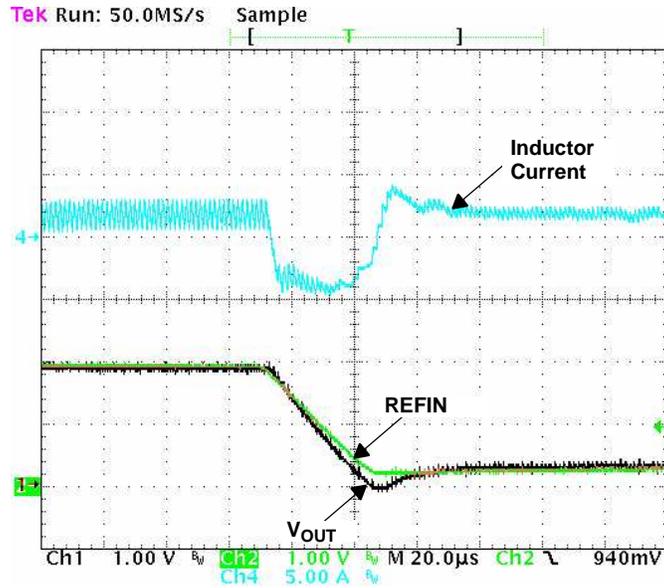


Figure 7. REFIN Falling Edge with 2-A Output Current

For specified operation, the commanded dc current levels should not exceed the device rated sink and source current of 3 A. For rising-edge slew rates, it is permissible to operate up to the device current limit for short durations. Operating the device in this condition for large percentages of time or at extended ambient temperature may cause the device junction temperature to exceed the thermal limit of 150°C and shut down. For the falling edge, it is recommended to never exceed the rated dc sink current. Shutdown current is not specified except to be beyond the rated level.

In summary, the recommended rising- and falling-edge ramp rates are:

Rate = I/C where $I = 3\text{ A}$ and C is the total output capacitance. For this case, $C = 100\text{ }\mu\text{F}$, so the maximum slew rate is $30\text{ mV}/\mu\text{sec}$.

The limitation is almost entirely due to the sink and source current ratings of the device. The loop response of the circuit only affects the overshoot of the output voltage as it responds to changes in REFIN. If faster slew rates are required, use a device with a larger output current rating such as the TPS54672 (6 A), TPS54872 (8 A) or the TPS54972 (9 A). The analysis is valid for these higher output current devices so long as the current (I) is increased to reflect the higher output capability.

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