Improve the TPIC74100-Q1 Load Transient Performance with Suitable Inductor and Capacitor

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ABSTRACT

The application report firstly introduces the control method used in TPIC74100-Q1 to reduce the output voltage undershoot. Then the output voltage waveforms at different conditions are measured to verify the impact of the external components. Finally suitable inductor and capacitor are suggested to get good load transient performance.

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1 Introduction

The TPCI74100-Q1 is voltage control mode buck-boost converter. It regulates the output voltage to 5V for a wide input voltage range. When the device operates in BUCK mode, it integrates a special circuit to reduce the output voltage undershoot when the loading suddenly increases. The application report introduces the control method of the special circuit and suggests suitable inductor and capacitor to fully utilize this function

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2 Special Control Circuit in BUCK Mode

The power stage and simplified control circuit are shown in Figure 1. In BUCK mode, the Q3 is always on and the Q4 is always off. The Q1 and Q2 turn on and off alternatively to regulate the output voltage VOUT. When the load is stable, the output voltage is controlled by the error amplifier EA. The duty cycle of the BUCK is proportional to the EA output voltage. If the output current suddenly increases, the VOUT will drop down because of the response time of the EA and the inductor current. Once the VOUT decreases more than 90mV, the comparator Comp will outputs logic high signal. This logic high signal will force the high side MOSFET Q1 on, ignoring the EA output signal. The inductor current linearly increases when the Q1 turns on. The VOUT starts to increase after the inductor current is higher than the loading. The comparator will be logic low again when the VOUT is only 40mV (typical) lower than the setting voltage 5V (typical).The duty cycle of the Q1 is controlled by EA output voltage once comparator output low logic. However, the duty cycle may be still too low to support loading. The VOUT could drop down to 90mA again and repeat the above process. During the repeating process, the EA voltage slowly increases as the average output voltage is lower than 5V (typical). The comparator will not be triggered after the EA is high enough.

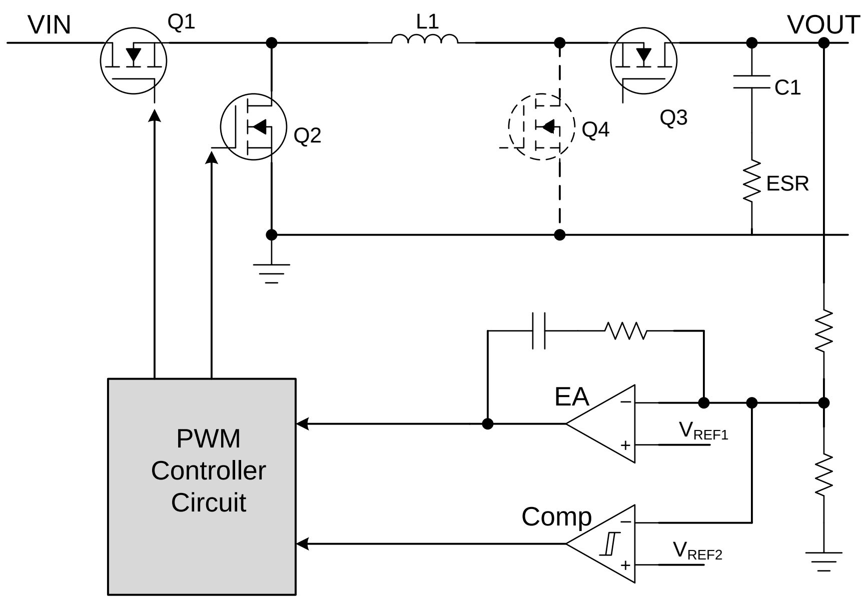

Figure 1. Simplified Control Circuit of the TPIC74100-Q1

The Figure 2 shows the transient performance of the TPIC74100EVM when the loading increase from 50 mA to 500mA. The output capacitor in the TPIC74100 is a tantalum capacitor 594D476X0016C2T, which has 47µF effective capacitance and approximately 110mΩ ESR. From the waveform, the inductor quickly increases to reduce the output voltage undershoot when the special circuit is triggered. The VOUT drops down again if the special circuit exits. The process repeats several times until the EA is higher enough to support the loading.

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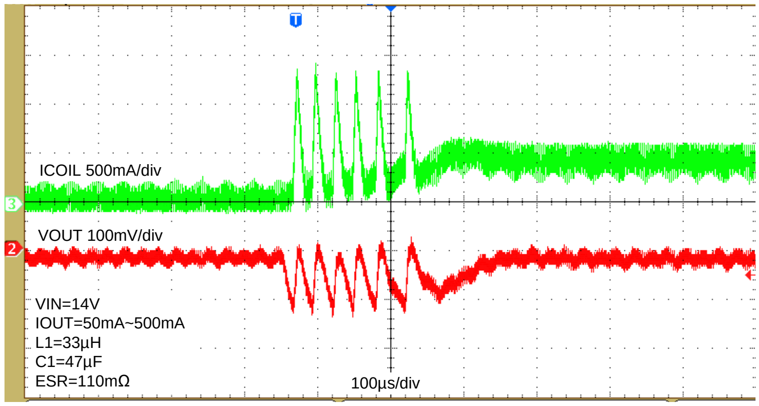

Figure 2. Load Transient Performance of the TPIC74100EVM

Improper external components could lead to overshoot in the VOUT after the special circuit exits. If the overshoot is so large that the average voltage of the VOUT is equal to 5V (typical). The EA output can't increase to the voltage level required by the loading. So the special circuit will be repeatedly triggered, which will result in large output voltage ripple. The behavior is shown in Figure 3. The waveform is tested by changing the TPIC74100EVM output tantalum capacitor to ceramic capacitor GRM32ER61A107ME20. The effective capacitance of the GRM32ER61A107ME20 is approximately 46µF at 5-V bias condition. The ESR of a ceramic capacitor is much smaller than tantalum capacitor.

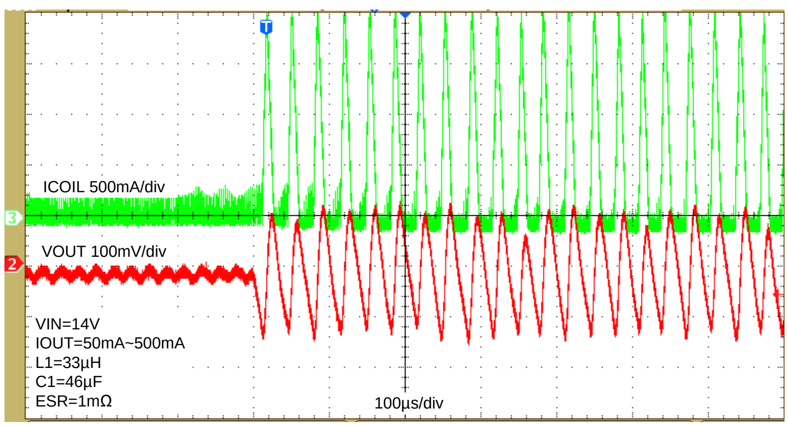

Figure 3. Load transient performance with ceramic capacitor

3 Impact of the External Components

To avoid the behavior as in Figure 3, the overshoot in the VOUT should be limited. The overshoot of VOUT is impacted by the input voltage, inductor L1, output capacitor C1 and its ESR.

- High input voltage increase the overshoot as more energy flowing to the output capacitor.
- High inductance increase the overshoot as the inductor stores more energy before the comparator outputs logic low.
- High output capacitance reduces the overshoot.
- High ESR of the output capacitor reduces the overshoot. Because the voltage drop on the ESR helps to change the comparator output to logic low quickly. However, large ESR also increase the output ripple at stable condition.

The Figure 4 and Figure 5 are the load transient performance at 14-V and 26-V input voltage respectively. the inductor current is higher at 26 V condition which results in higher overshoot in the VOUT.

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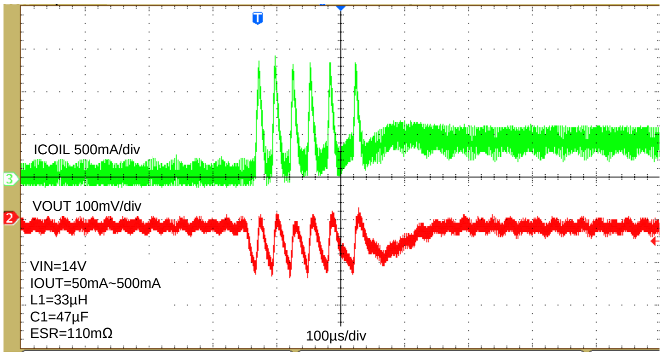

Figure 4. Load transient performance at 14-V input

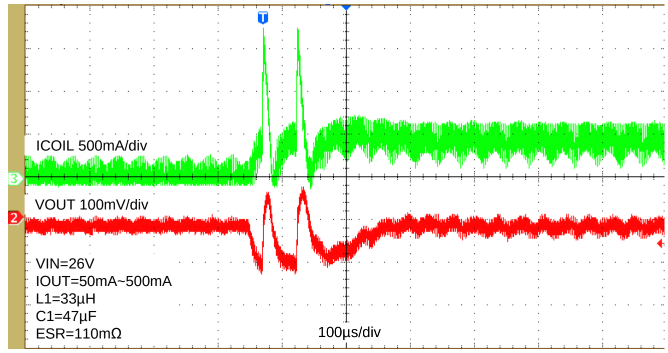

Figure 5. Load transient performance at 26-V input

The Figure 6 and Figure 7 show the load transient performance at 33µH and 22µH inductor respectively. With 33µH inductor, the inductor stores more energy before the special circuit exits. The energy causes a little higher overshoot in the VOUT.

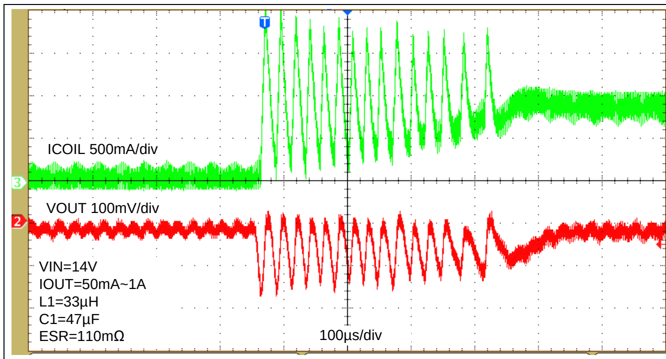

Figure 6. Load transient performance at L1=33µH

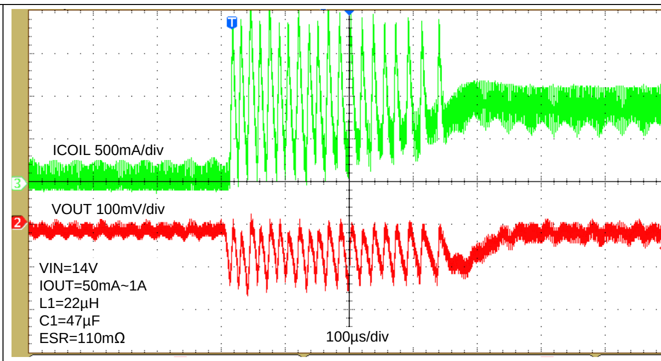

Figure 7. Load transient performance at L1=22µH

The Figure 8 shows the load transient performance when output capacitor is pure ceramic capacitor GRM32ER61A107ME20 of which the ESR is only 1mΩ. Without enough ESR, the inductor increases to high level before the special circuit exits. The high current in the inductor causes high overshoot in the VOUT. With 82mΩ resistor in series with the output capacitor, the inductor peak current greatly decreases, so the VOUT overshoot is much smaller in Figure 9.

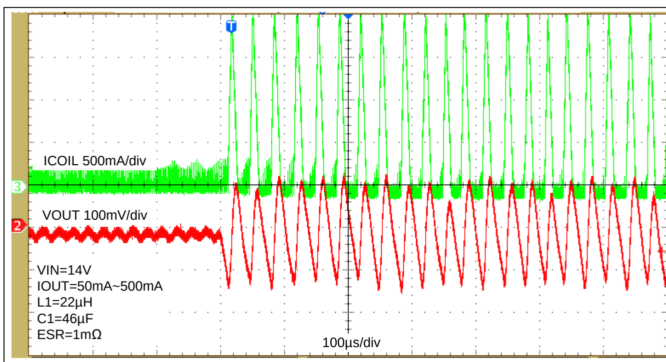

Figure 8. Load transient performance with small ESR

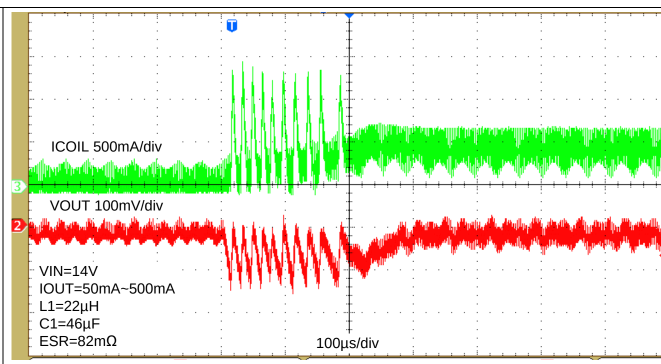

Figure 9. Load transient performance with large ESR

The Figure 10 is measured with a ceramic capacitor GRM32ER61A107ME20 and a 82mΩ ESR. While in Figure 11, the output capacitor increases to three GRM32ER61A107ME20 in parallel and the ESR is still 82mΩ. The waveforms show that larger capacitance also help to reduce the overshoot of the VOUT.

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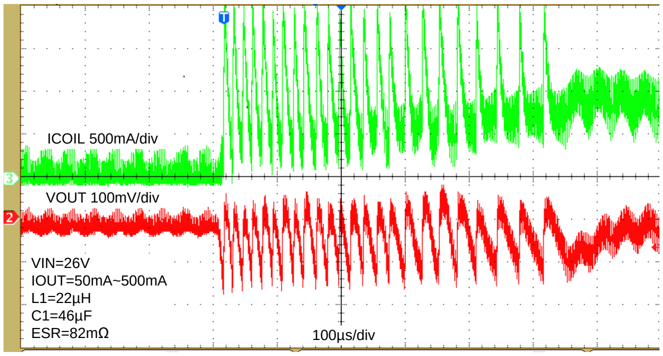

Figure 10. Load transient performance with one GRM32ER61A107ME20

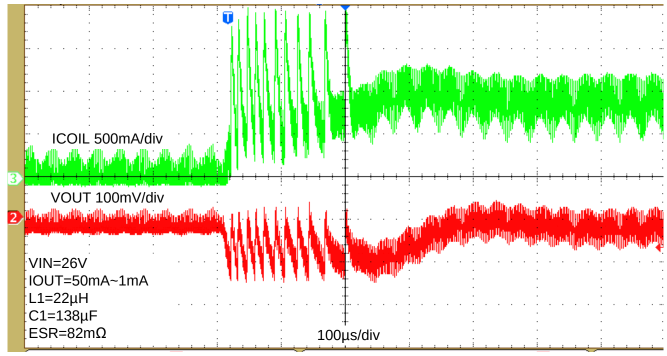

Figure 11. Load transient performance with three GRM32ER61A107ME20 in parallel

Based on above measurements, following external components are suggested to improve the load transient performance of the TPS74100-Q1.

Table 1. External components suggestion

Input Voltage VIN	Inductor L1	Effective output capacitance C1	ESR of the output capacitor
VIN < 18V	22µH	100µF ≤ C1 ≤ 470µF	50mΩ ≤ ESR ≤ 150mΩ
VIN < 26V	22µH	150µF ≤ C1 ≤ 470µF	100mΩ ≤ ESR ≤ 150mΩ

4 Conclusion

The application report introduces the special control circuit of the TPIC74100-Q1 in BUCK mode. This control circuit is designed to reduce the undershoot of the VOUT when the loading is suddenly applied. However, improper selection of the external components would result in high output ripple after the load transient. To overcome this issue, the application report investigate the impact of each external component and finally suggest the suitable components for different input condition.

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