TPS65250/1/2/3 Output Filter Selection Guidelines

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ABSTRACT

The output filter is a crucial piece of the operational characteristics of TPS65250, TPS65251, TPS65252, and TPS65253 devices. Through careful selection properties such as output ripple, transient response, and efficiency can be adjusted to meet the needs of your application. The output filter of these devices consists of an LC network. While optimal component values are dependent on input voltage, output voltage, and switching frequency; 4.7uH and 22uF are recommended starting values.

Texas Instruments

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1 TPS65250/1/2/3 Output Filter Selection Guidelines

The choice of output filter components depends on a number of parameters related to:

- Output ripple (in conjunction with output capacitor),
- Converter efficiency especially at light load,
- Low power operation,
- Proper ramp creation for current mode operation,
- Transient response,
- Real estate, and
- Cost.

1.1 Inductor Selection

To calculate the value of the output inductor, use the following equation

$$Lo = \frac{Vin - Vout}{Io \cdot K_{ind}} \cdot \frac{Vout}{Vin \cdot fsw}$$

K_{IND} is a coefficient that represents the amount of inductor ripple current relative to the maximum output current. In general, K_{IND} is normally from 0.1 to 0.3 for the majority of applications, and the chosen value is a trade-off between different and sometimes opposite requirements.

The follow frequencies of interest should be assumed: 500 and 775 kHz. Table 1 shows the inductor values proposed. For the purpose of evaluation, the following inductors were chosen: 3.3µH, 15mΩ; 12µH, 38mΩ; and 21µH, 61mΩ.

Table 1. Inductor Values Chosen

f /Kind	0.1	0.3	0.5
500 kHz	29.3 µH	9.8 µH	5.9 µH
775 kHz	18.9 µH	6.3 µH	3.8 µH

1.2 Output Ripple

Low KIND values produce smaller ripple values for a given output capacitor. All tests are done at 500 kHz, and 2A load. Figures 1-3 show readings of the ouput ripple under certain test conditions. Also, the figures inside the drawings in Figures 1-3 are the ripple calculation as per TPS6525x calculator.
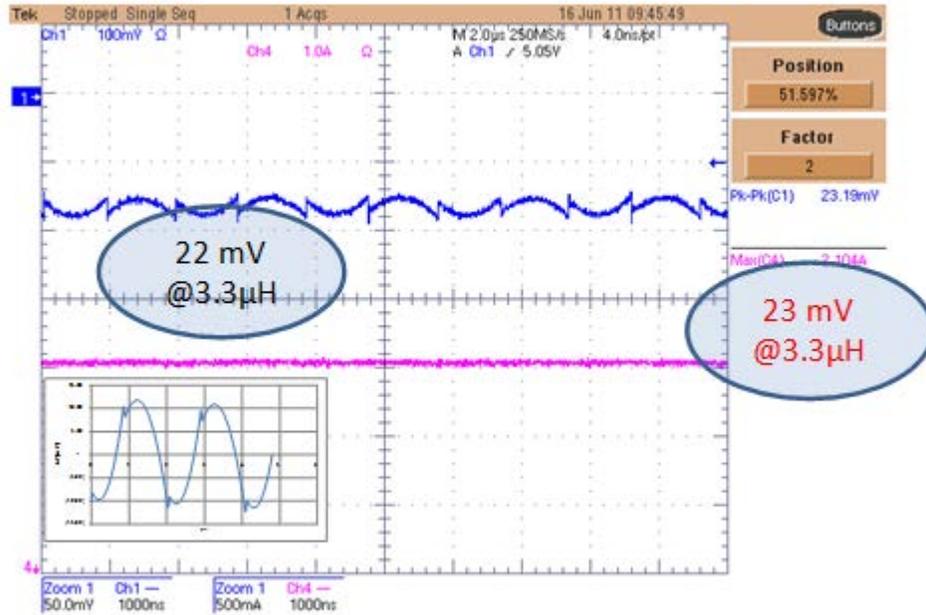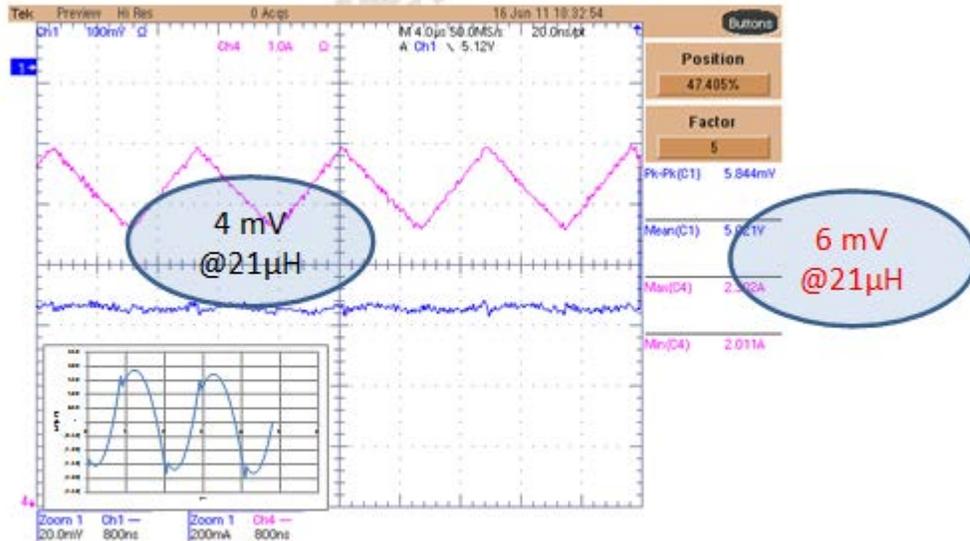
Figure 1. Output Ripple (23mV @3.3µH)

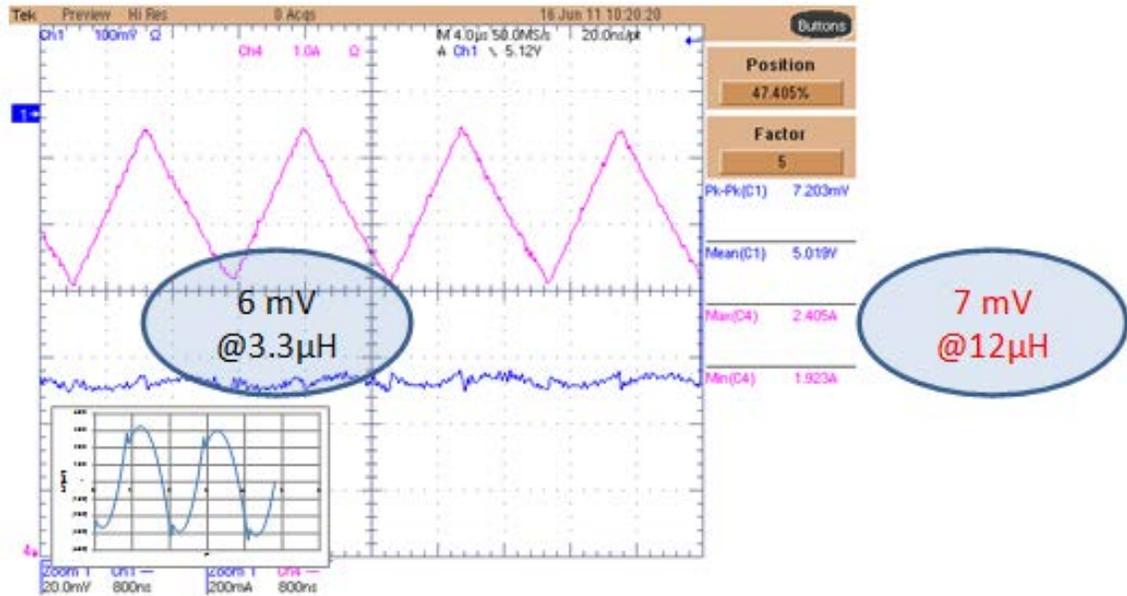**Figure 2. Output Ripple (6mV @21 µH)**

Figure 3. Output Ripple (7mV @12µH)

1.3 Converter Efficiency

The inductor choice greatly affects light load efficiency performance. Using PFM mode in conjunction with proper inductor selection will show greater performance for loads under 100mA. Figure 5 shows that the output filter selection does not play a large role in high load efficiency.
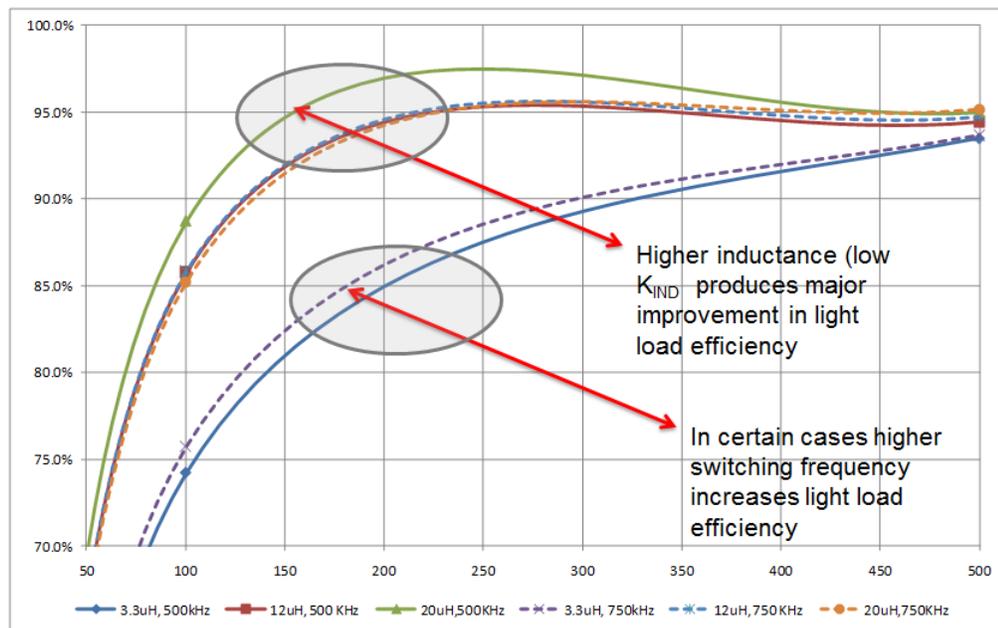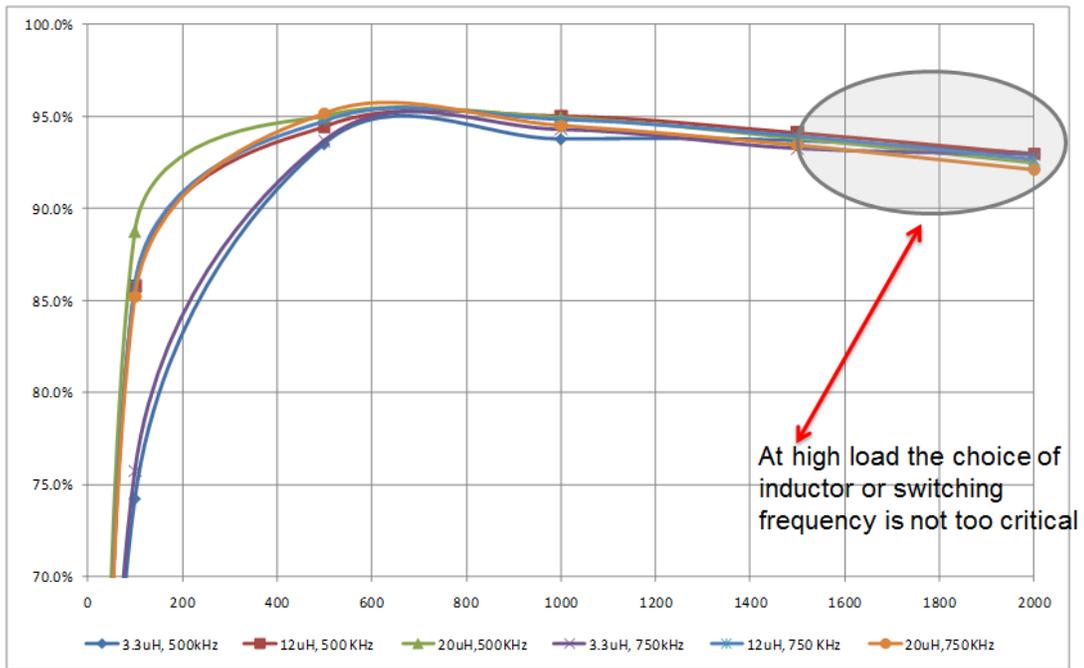
Figure 4. Converter Efficiency, Light Load

At high load the choice of inductor or switching frequency is not too critical

Legend: 3.3uH, 500kHz | 12uH, 500 KHz | 20uH,500KHz | 3.3uH, 750kHz | 12uH, 750 KHz | 20uH,750KHz

Figure 5. Converter Efficiency, High Load

1.4 Choosing K_{IND}> 0.3

Choosing K_{IND}>0.3 will affect the quiescent current at no load (standby power). K_{IND}>0.3 is too high. Many systems require less than 1W of standby power, and this includes AC-DC losses leaving less than 500mW for the DC-DC conversion, which is shown in Table 2. For this reason, it is therefore recommended to stay within 0.1<K_{IND}>0.3 to reduce the inductor ripple current.

Table 2. AC-DC Losses

Vo=5V	500 kHz		775 kHz	
L	Iin	Pin	Iin	Pin
3 µH	14 mA	168 mW	11 mA	132 mW
12 µH	6 mA	72 mW	6 mA	72 mW
21 µH	4 mA	48 mW	4 mA	48 mW

For applications where cost is critical, but low power is not, use the highest K_{IND} value. Figure 6 shows the K_{IND} for cost critical low power applications, and Figure 7 shows the effects the inductor choice has on the efficiency.
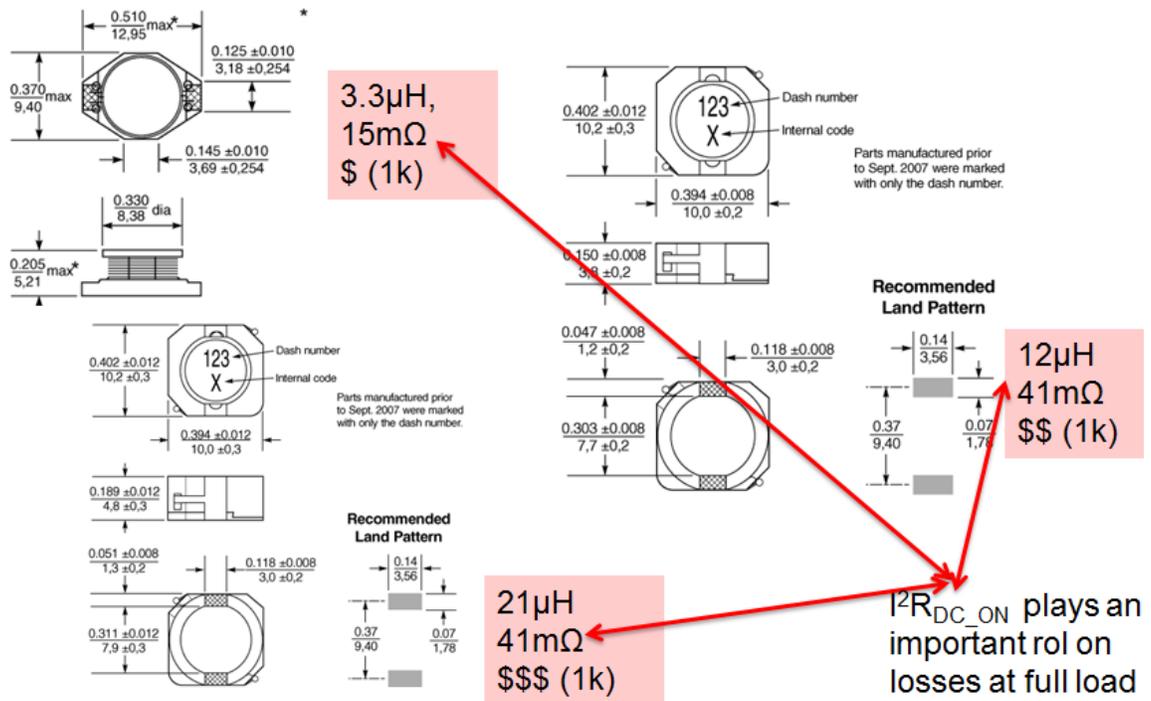

Figure 6. K_{IND} for Cost Critical, Low Power Applications
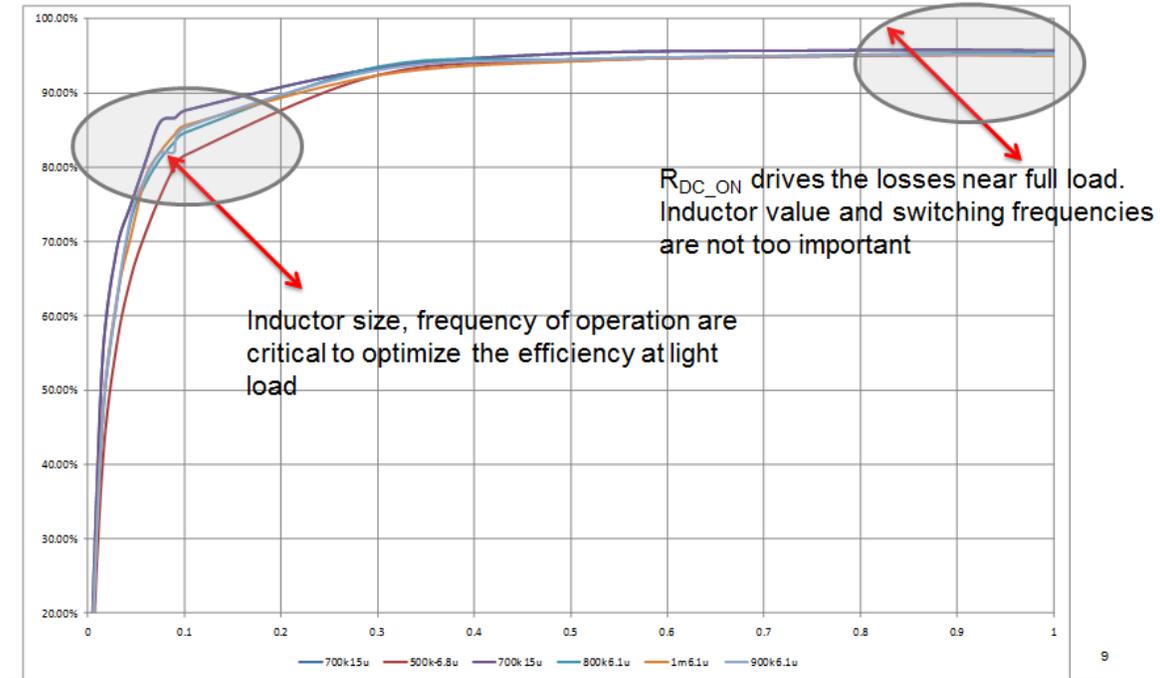
Figure 7. Effects of Inductor Choice on Efficiency Plots (5V Output Case)

1.5 Inductor Selection and Low Power Mode

Δ_{VOUT} decreases with increased inductance. Limited effects of switching frequency for K_{IND} are high.

Table 3. Induction Selector and Low Power Mode

	500 kHz		775 kHz	
L	ΔVOUT	Iin	ΔVOUT	Iin
3 µH	64 mV	575 µA	60 mV	568 µA
12 µH	33 mV	573 µA	19 mV	567 µA
21 µH	22 mV	572 µA	12 mV	570 µA
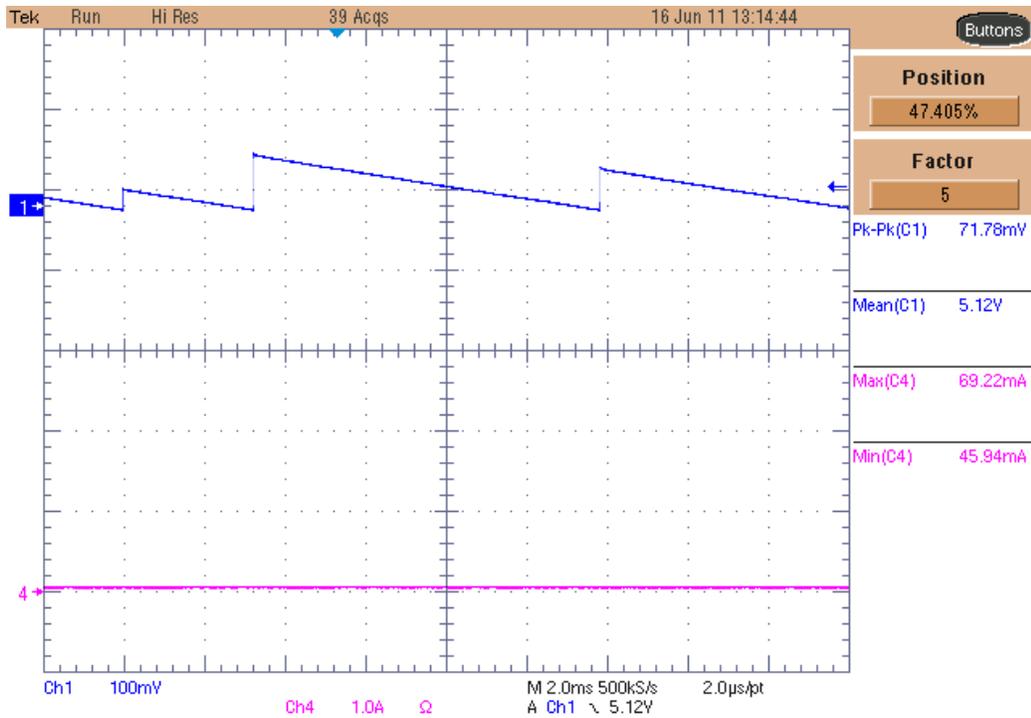
Figure 8. Low Power 3.3µH, 500 kHz
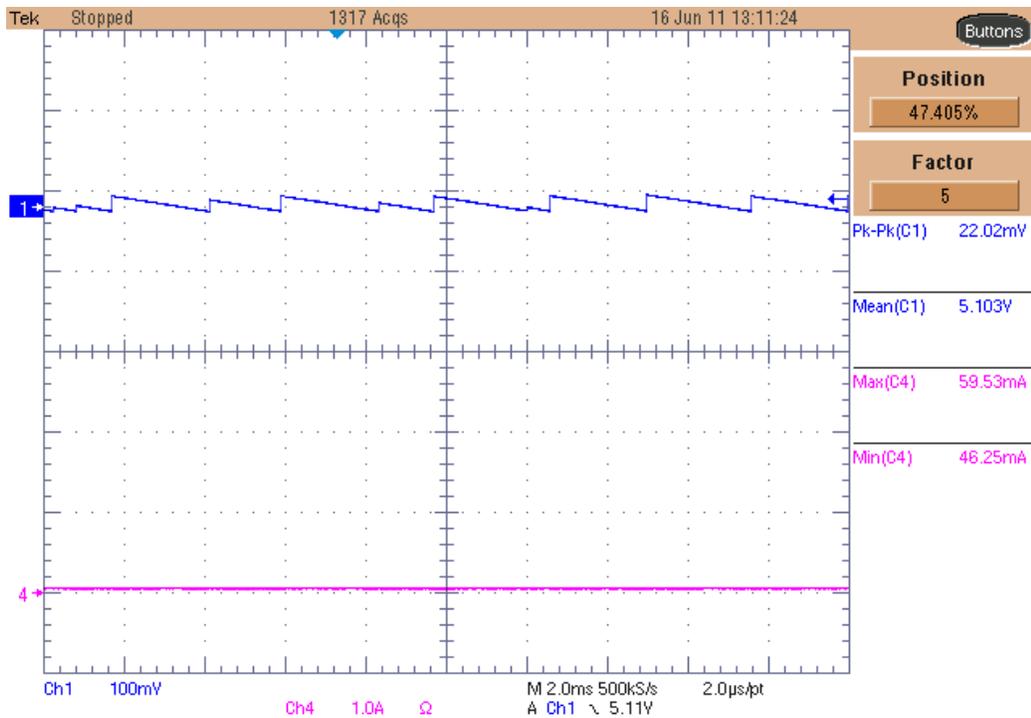
Figure 9. Low Power 21µH, 500 kHz

1.6   Inductor Selection and Proper Ramp Creation Mode Control

The ramp slope is a function of inductor choice. If K_{IND} is smaller than 0.1, it should not be used. The switching mode for the jitter should be checked, K_{IND} should be increased if needed. Figure 10 shows the schematic of the proper ramp creation current mode control.
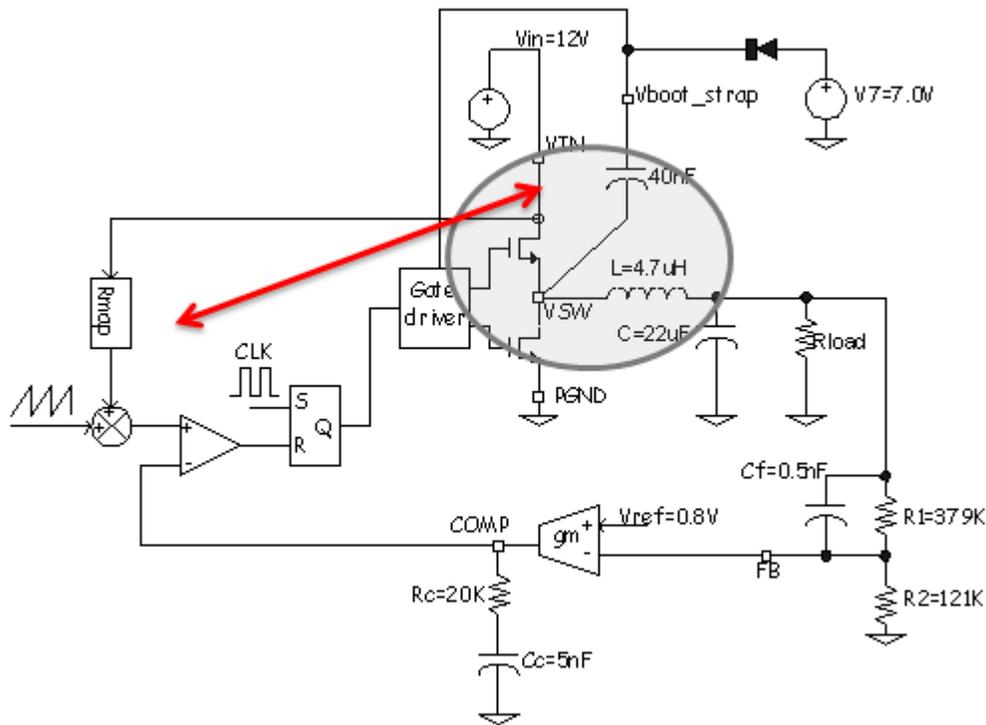
Figure 10. Proper Ramp Creation Current Mode Control

1.7 Transient Response and Inductor Choice

System responses are limited by the size of the chosen inductor as it will dictate how fast current can be built to respond to sudden load steps (in either direction). The smaller the inductor, the faster the system will respond. Figures 11 and 12 show the transient response at three different inductances.

Figure 11. Transient Response and Inductor Choice (0.5-1.5A step, 12µH)
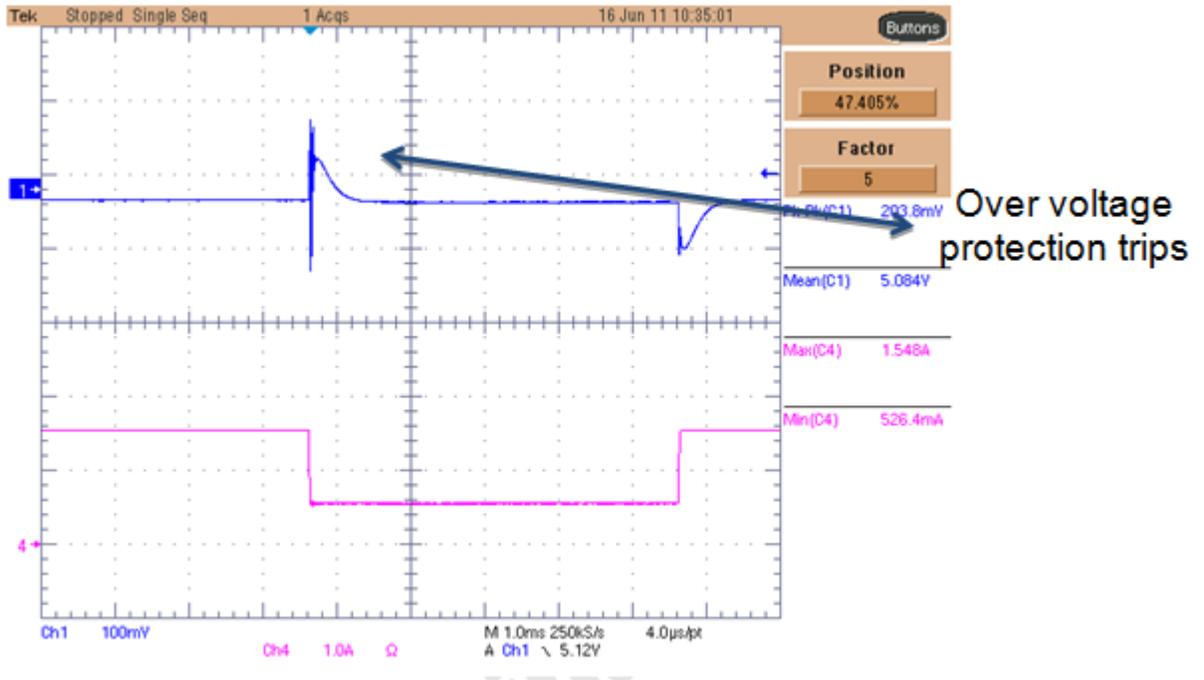
Figure 12. Transient Response and Inductor Choice (0.5-1.5A step, 21 µH)

As a generic rule the choice of inductor does not affect greatly the dynamic response when load step transient is not critical (ΔI is less than 50% full load, Δt is more than 5µS). In cases where major load steps happen or a "load dump" (load suddenly drops to zero or steps to maximum value) condition happens, it is advisable to choose the inductor based on the system dynamic response.

In Figure 13 and 14, the load dump is shown at 5V and 2A. For Figure 13, the 5V rail dips to 4.8V. The control loop is stable. For Figure 14, the 5V rail dips to 4.29V, and the control loop is not stable.
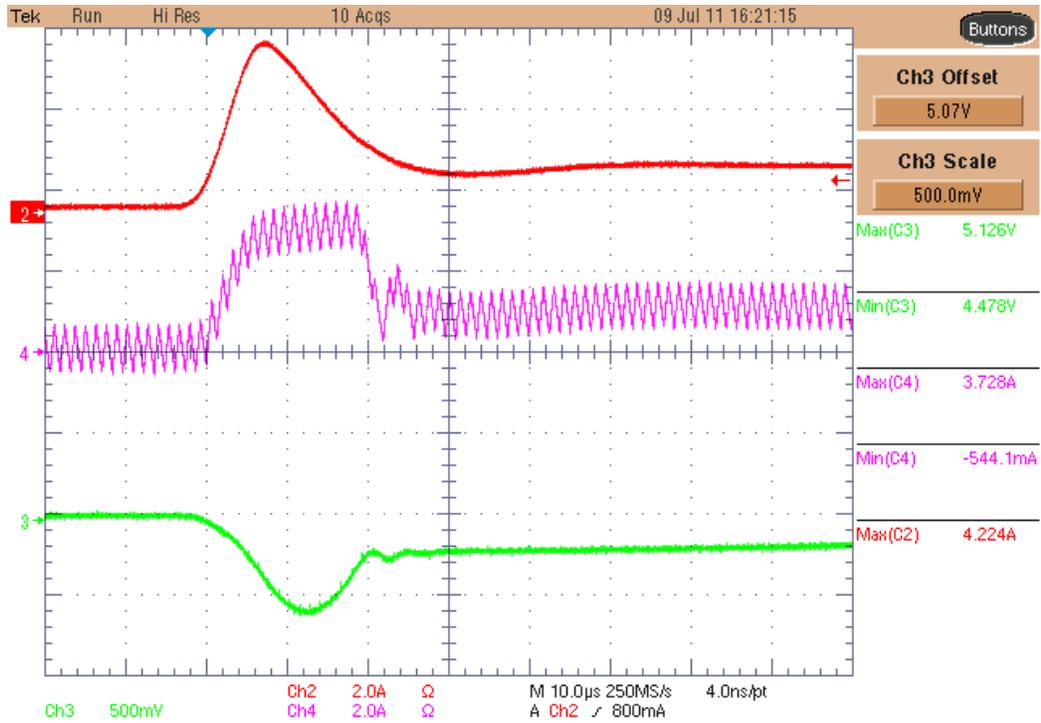
Figure 13. Load Dump (2A step, 3.3 µH, 47µF)
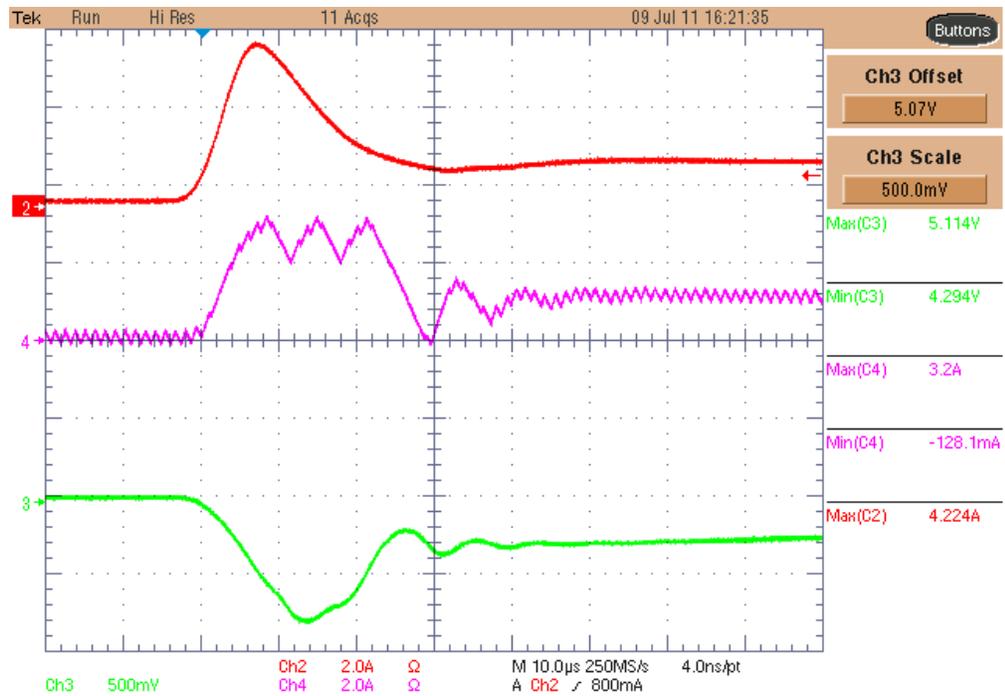
Figure 14. Load Dump (2A step, 12 µH, 47µF)

1.8 Capacitor Selection (Ripple is not Critical Parameter)

$$C = \frac{1.21 \times I_{tr}^2 \times L}{\Delta V^2}$$

I_{tr} = Transient current
L = output filter
ΔV^2 = Maximum voltage excursion

Note that this equation is an approximation. The value it produces should be considered to be an absolute minimum amount. The exact value will have to be determined through experimentation.

IMPORTANT NOTICE

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