

Understanding Compensation Network for the TPS54120

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ABSTRACT

The TPS54120 uses current-mode control on the integrated step-down switcher. One of the benefits of current-mode control is that system stability is easily achieved using Type-II compensation design. Type-III compensation further boosts the crossover frequency and phase margin and improves the transient response of a current mode integrated buck converter. This application report explores Type II and III compensation networks for the TPS54120.

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1 Introduction

The TPS54120 is a 17-V, 1-A, integrated synchronous step-down (buck) converter and low-dropout (LDO) regulator. To improve performance during line and load transients the device implements a constant frequency, peak current-mode control which also simplifies external frequency compensation. The wide switching frequency range of 200 kHz to 1200 kHz allows for efficiency and size optimization when selecting the output filter components.

Figure 1 represents a small signal model for the compensation network for the TPS54120. The error amplifier is a transconductance amplifier with a g_m of 1300 $\mu\text{A/V}$. The resistor R_{oea} (2.38 M Ω) and capacitor C_{oea} (20.7 pF) model the open-loop gain and frequency response of the error amplifier. The power stage transconductance gain (g_{mps}) is 12 A/V for this device. This model is used to drive the compensation poles and zeroes of the device.

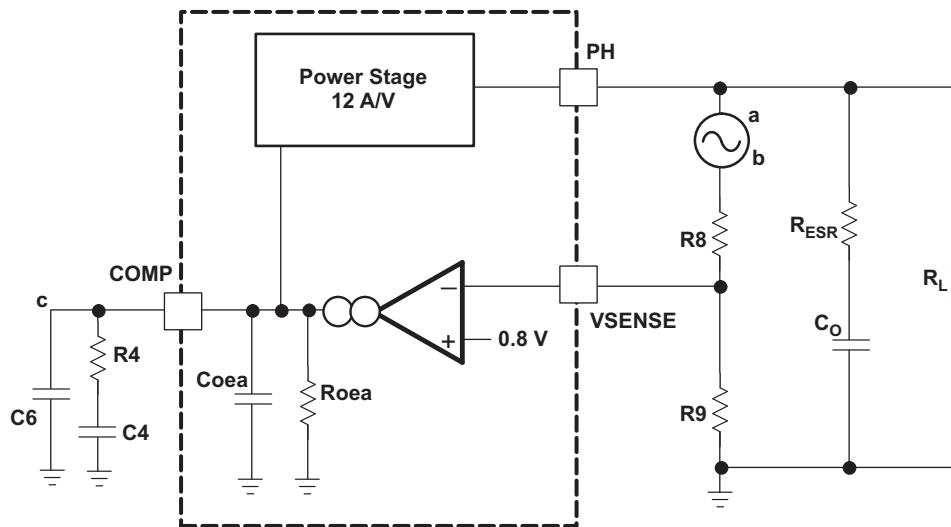


Figure 1. Small Signal Model for the Compensation Network

2 Compensation Network

The external compensation network of the TPS54120 must be compensated by the designer to ensure the stability of the overall loop response. In power-supply design, a power supply is typically defined to be stable if the gain margin is greater than 6 dB and the phase margin is greater than 45°. The requirement for stability is typically met if the overall gain crosses 0 dB with a slope of -20 dB/Decade.

Figure 2 shows the typical open-loop system gain of the TPS54120 without compensation. The locations of the two poles and zero are highlighted in Figure 2. The gain crosses 0 dB with a slope of -40 dB/Decade which is undesirable for the stability of the power supply, therefore, compensation is required to reshape the gain and help stabilize the IC.

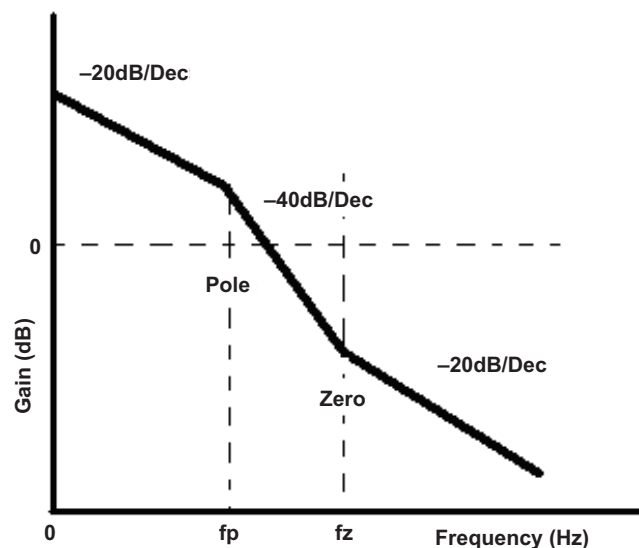


Figure 2. Converter Gain Without Compensation

3 Type II and Type III Compensation Network

There are two types of compensation that can be used for the TPS54120: Type II and Type III. The two types are divided into two sub-types: A and B. Type III, unlike Type II, has an additional capacitor (C_c) on the feedback network of the switcher (shown in Figure 3 and Figure 5). This capacitor adds another zero and pole near the cross-over frequency. The additional pole is always placed at a higher frequency than the zero. Type A, unlike type B, has an extra high-frequency pole; this pole is created by an additional capacitor connected in parallel with the RC compensation network. For more details see Table 1.

3.1 Type II Compensation

Figure 3 shows Type II (A and B) frequency compensation circuit. Type II-A has an additional capacitor in parallel with R_4 and C_4 .

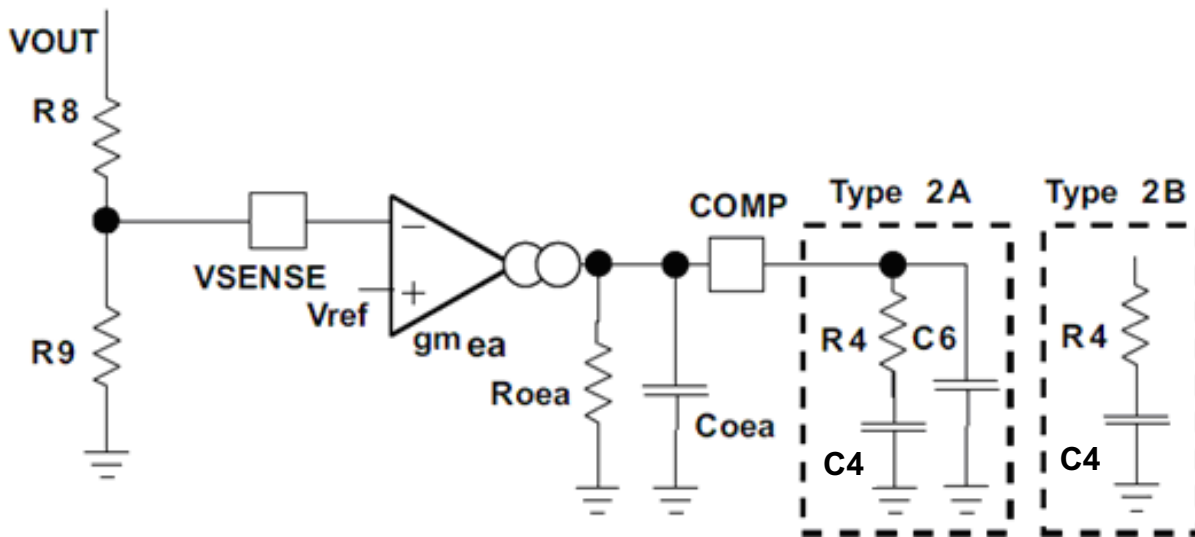


Figure 3. Type II (A and B) Compensation Network for the TPS54120

Figure 4 shows a generic Type II-A compensation gain and converter gain with and without compensation. This compensation network helps shape the profile of the gain with respect to frequency while also providing a 90° phase boost. This boost is necessary to counteract the effects of the resonant output filter at the poles of the converter.

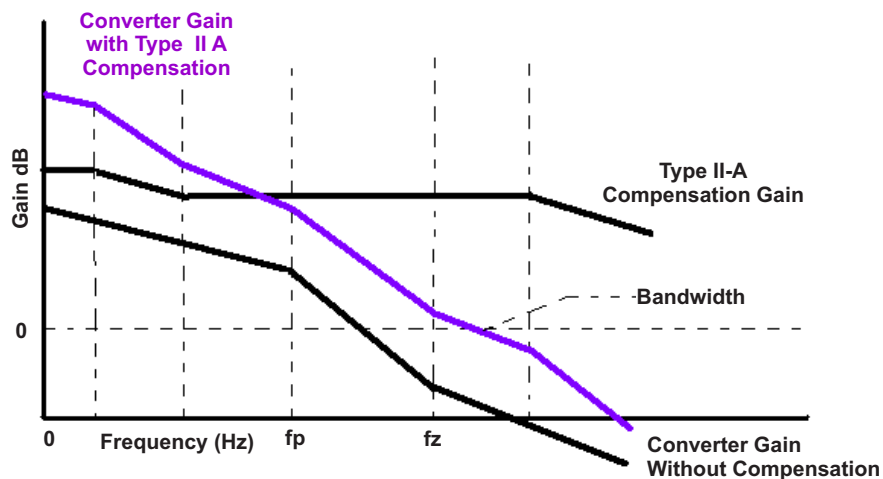


Figure 4. System Gain With Type II-A Compensation

3.2 Type III Compensation

Figure 5 shows a Type III (A and B) frequency compensation circuit. Type III-A has an additional capacitor in parallel with R4 and C4.

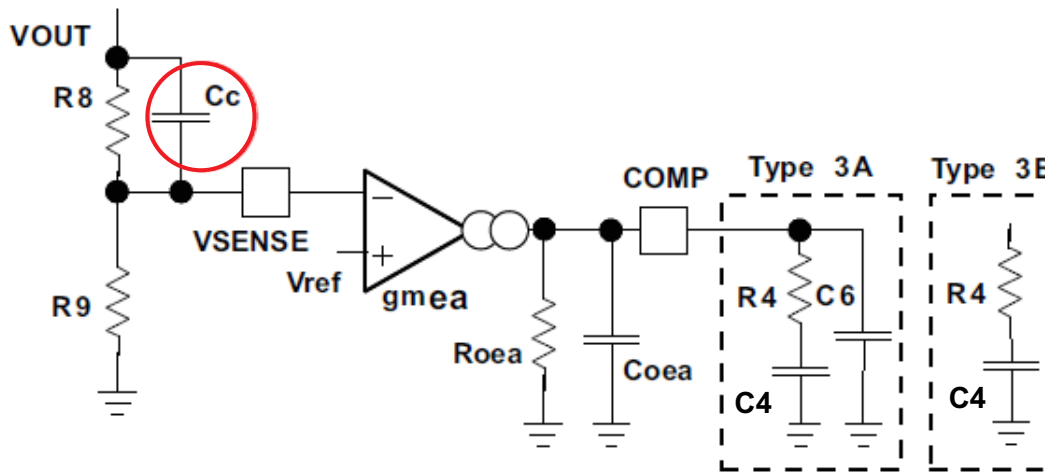


Figure 5. Type III (A and B) Compensation Network for the TPS54120

Figure 6 shows a generic Type III-A compensation gain, and the converter gain with and without compensation. Type III networks use two zeros and two poles to shape the profile of the gain with respect to frequency. The zeros give the compensated converter a 180° phase boost and help counteract the effects of the resonant output filter at the poles of the converter.

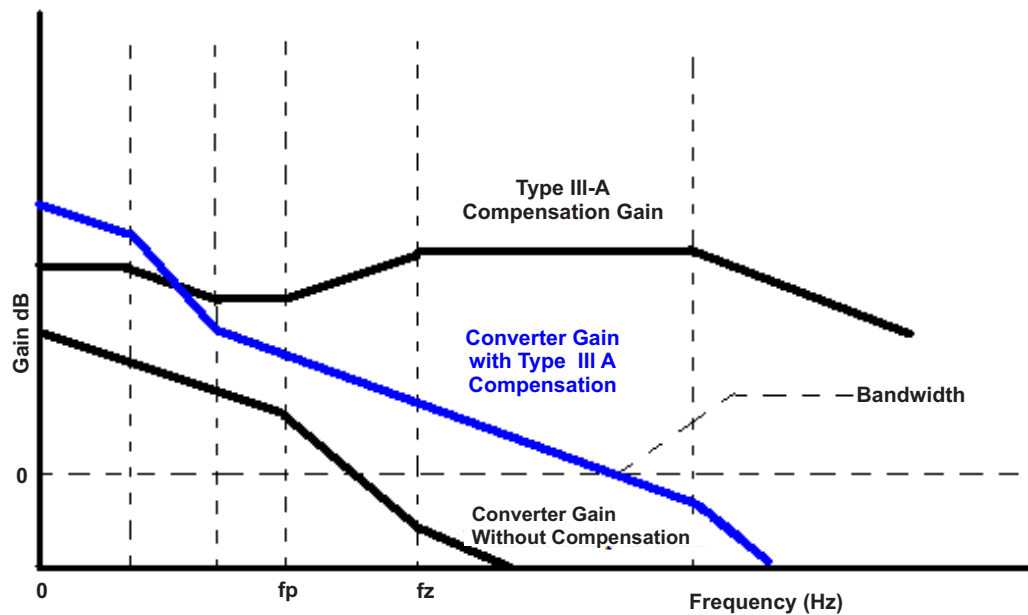
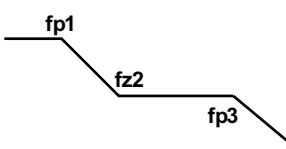
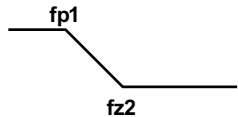
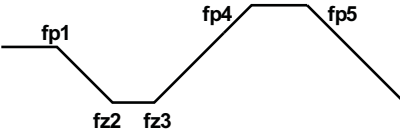
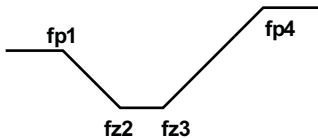


Figure 6. System Gain with Type III-A Compensation

Table 1. Simplified Poles and Zeroes for Type II and Type III Compensation

Compensation	Frequency Responses	Pole/Zero Locations
Type II-A		$f_p1 = \frac{1}{2\pi \times R_{oea} \times C4}$ $f_z2 = \frac{1}{2\pi \times R4 \times C4}$ $f_p3 = \frac{1}{2\pi \times R4 \times C6}$
Type II-B		$f_p1 = \frac{1}{2\pi \times R_{oea} \times C4}$ $f_z2 = \frac{1}{2\pi \times R4 \times C4}$
Type III-A		$f_p1 = \frac{1}{2\pi \times R_{oea} \times C4}$ $f_z2 = \frac{1}{2\pi \times R4 \times C4}$ $f_z3 = \frac{1}{2\pi \times R8 \times Cc}$ $f_p4 = \frac{1}{2\pi \times (R8/R9) \times Cc}$ $f_p5 = \frac{1}{2\pi \times R4 \times C6}$
Type III-B		$f_p1 = \frac{1}{2\pi \times R_{oea} \times C4}$ $f_z2 = \frac{1}{2\pi \times R4 \times C4}$ $f_z3 = \frac{1}{2\pi \times R8 \times Cc}$ $f_p4 = \frac{1}{2\pi \times (R8/R9) \times Cc}$
Where $R_{oea} = \frac{DCgain_{ea}}{gm_{ea}}$, $R8 // R9 = \frac{R8 \times R9}{R8 + R9}$		

4 Conclusion

The TPS54120 has an external compensation network. The designer must compensate this part to ensure the stability of the overall loop response. Additional poles and zeros of the compensation network affect the shape of the phase and gain response of the part. While Type II compensation networks are sufficient for achieving stability, Type III networks can further increase the bandwidth of a system.

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