TPS65142 Loop Compensation Design Consideration

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ABSTRACT

The TPS65142 device provides a compact solution to the bias power and the WLED backlight in note-pc TFT LCD panels. The device features a boost converter, a positive charge pump regulator, and a negative charge pump regulator to power the source drivers and the gate drivers. To be more compatible with TFT LCD system cross-talk requirement, it is necessary to design a required closed-loop performance for the AVDD boost converter. This application report discusses the design consideration.

Contents

FIGURES

1 TPS65142 Boost Converter Introduction

As showed in Figure 1, the TPS65142 AVDD boost regulator is designed for output voltages up to 16.5 V with a minimum switch peak current limit of 1.8 A. The device, which operates in a current-mode scheme with quasi-constant frequency, is internally compensated to minimize the pin and component counts. The switching frequency is selectable between 650 kHz and 1.2 MHz. During the on-time, the current rises in the inductor. When the current reaches a threshold value set by the internal GM amplifier, the power transistor is turned off. The polarity of the inductor voltage changes and forward biases the Schottky diode, which lets the current flow toward the output of the boost regulator. The off-time is fixed for a certain input voltage V_{IN} and output voltage V_S, and therefore maintains the same frequency when varying these parameters.

The fixed off-time maintains a quasi-fixed frequency that provides better stability for the system over a wide range of input and output voltages than conventional boost converters. The topology of the TPS65142 device provides extremely good load and line regulations, and excellent line and load transient responses.

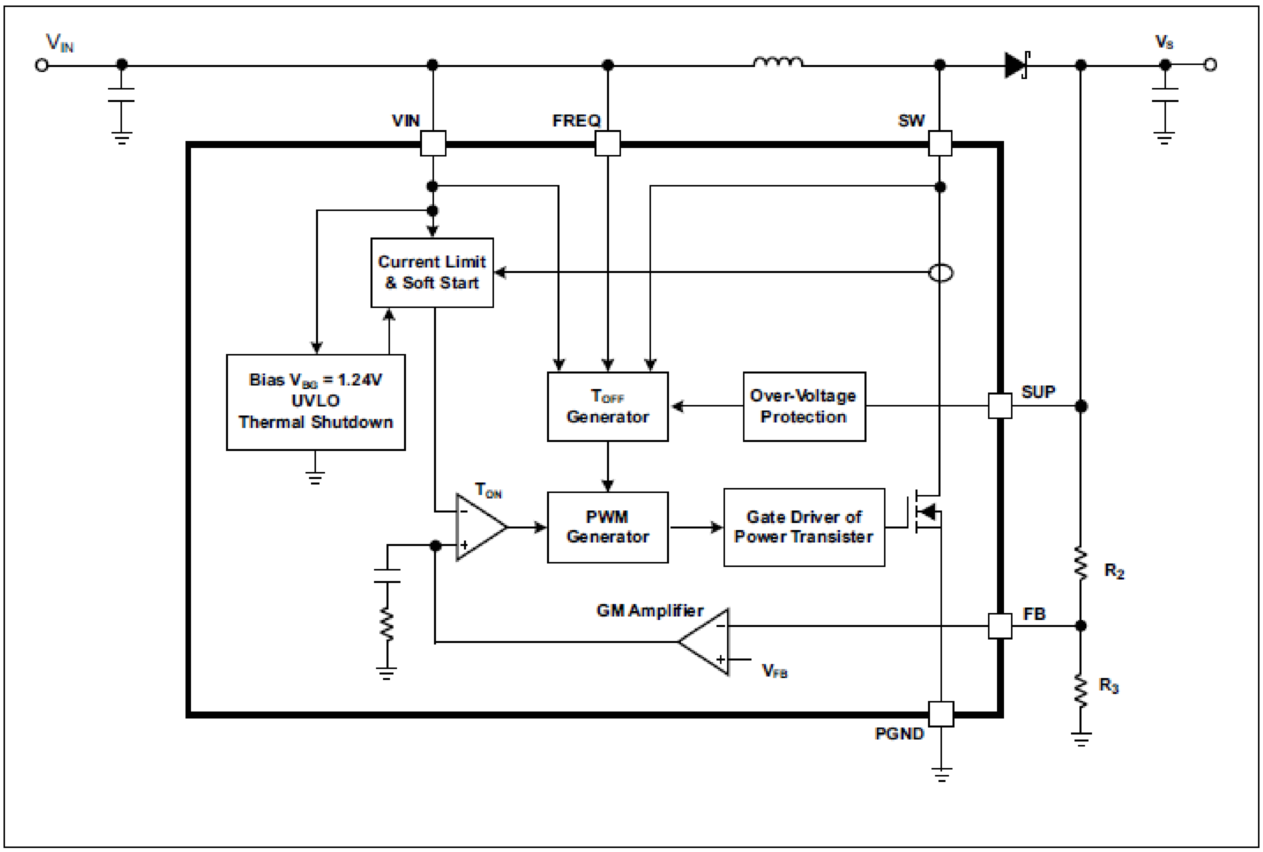

Figure 1. TPS65142 Boost Converter Implementation

2 TPS65142 Fixed Off-time Small Signal Circuitry

For a fixed off-time boost converter, with continuous current mode, the t_{OFF} time can be defined as follows:

$$t_{OFF} = \frac{V_{in}}{V_{out} f_s}; \quad (1)$$

Introducing a sampling-hold functions as follows, to simulate the fixed off-time effect:

$$H_e(s) = \frac{1 - e^{-S \times t_{OFF}}}{s \times t_{OFF}} \approx 1 + \frac{s}{2/t_{OFF}} + \frac{s^2}{\pi^2/t_{OFF}^2}; \tag{2}$$

Then, the gain from the error amplifier output to the inductor current can be obtained:

$$\frac{\hat{i}_L(s)}{\hat{V}_c(s)} = \frac{H_e(s)}{R_s} \tag{3}$$

Define two components as follows:

Resistor: $R_e = \frac{2L_1}{t_{OFF}}$; (4)

Capacitor: $C_e = \frac{t_{OFF}^2}{\pi^2 L_1}$ (5)

The equivalent small signal model from control to inductor current can be obtained as shown in Figure 2.

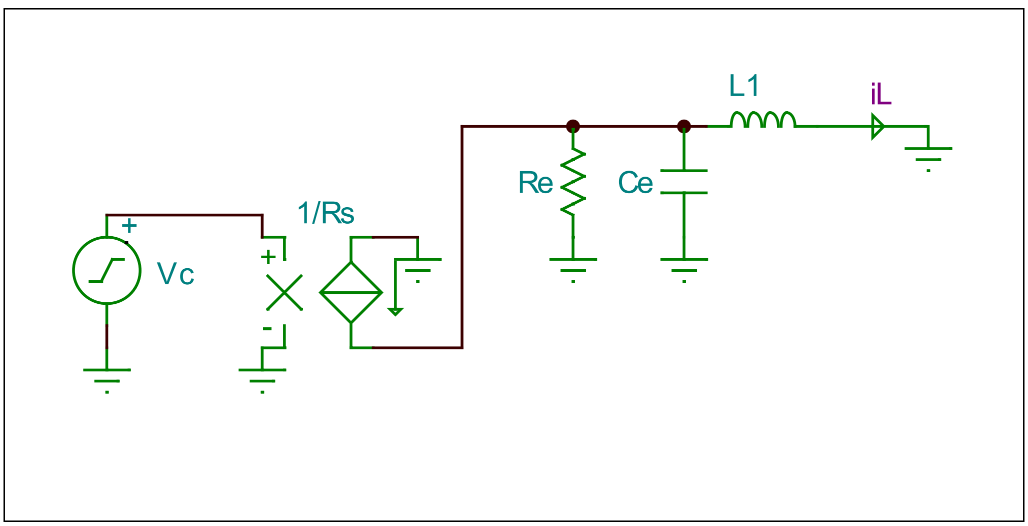

Figure 2. Gain from Control to Inductor Current

Considering average model of the boost converter:

$$< u_{out} > \times (\frac{1}{R_L} + sC_{out}) = (1 - < d >) \times < i_L > \tag{6}$$

$$< u_{out} > - < d > \times < u_{out} > = V_{in} - sL_1 \times < i_L > \tag{7}$$

Here, < > means an average value within a switching cycle.

Separate the small signal distortion from the average value:

$$\hat{u}_{out}\left(\frac{1}{R_L}+sC_{out}\right)=(1-D)\hat{i}_L-\hat{d}\,I_L \tag{8}$$

$$(1-D)\hat{u}_{out}-V_{out}\hat{d}=-sL_1\hat{i}_L \tag{9}$$

As a result:

$$(1-D)\hat{i}_L=\hat{u}_{out}\left(\frac{1}{R_L}+sC_{out}\right)+\frac{(1-D)I_L\hat{u}_{out}}{V_{out}}+\frac{sL_1I_L\hat{i}_L}{V_{out}} \tag{10}$$

From equation 10 and Figure 2, it is possible to deduce the overall small signal circuitry in Figure 3.

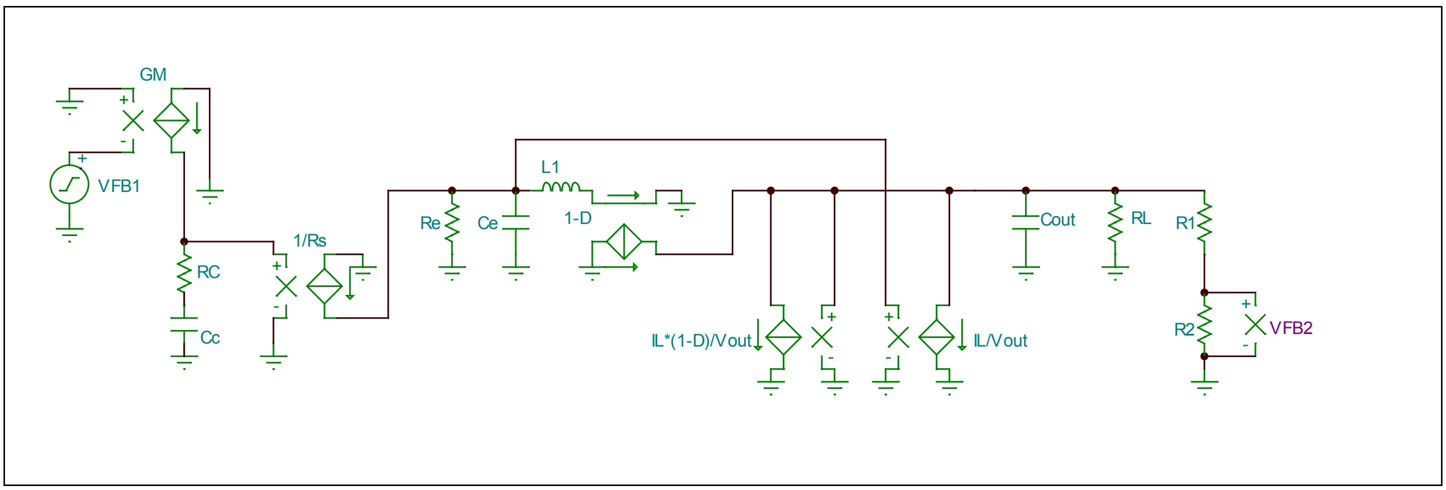

Figure 3. The Overall Small Signal Model for the TPS64142 Boost Converter

According to the data sheet, the parameters in Figure 3 can be obtained:

$$Gm=15u; Rc=120k; Cc=480p; Rs=6.67\Omega \tag{11}$$

3 A Design Example

A design specification follows:

$$Vin = 3.3V; Vout = 8.5V; R1 = 80.6k; R2 = 12.9k; L_1 = 6.8uH; f_s = 1.2MHz; R_L = 64\Omega \tag{12}$$

Based on the results in Figure 3, it is possible to obtain the simulation model shown in Figure 4:

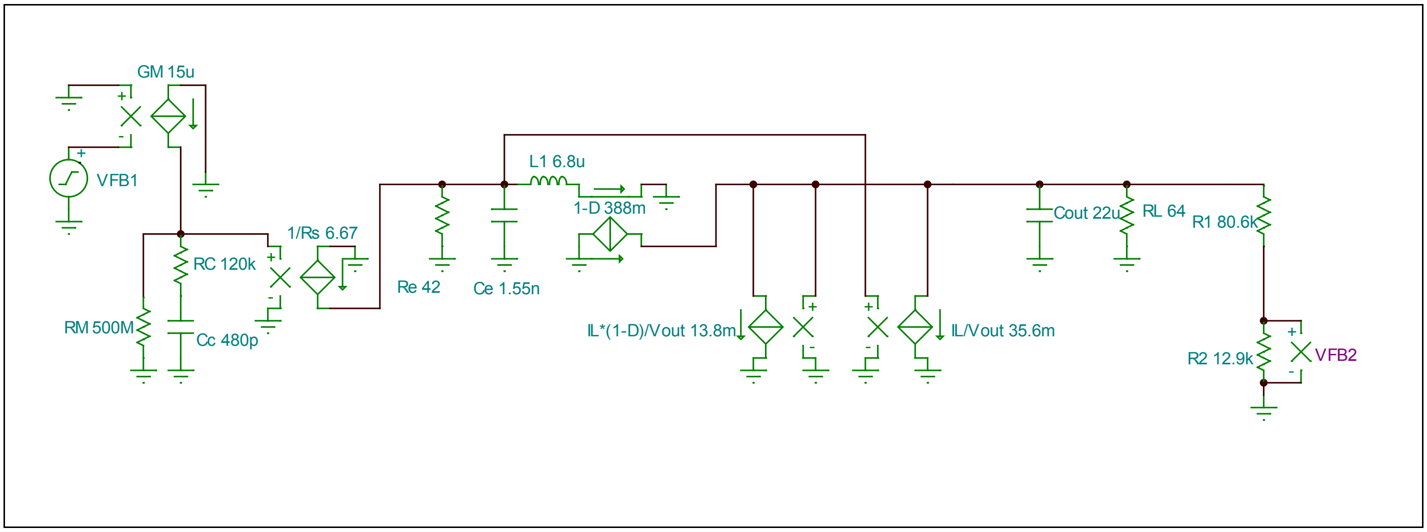

Figure 4. Design Example

The simulation results are seen in Figure 5.

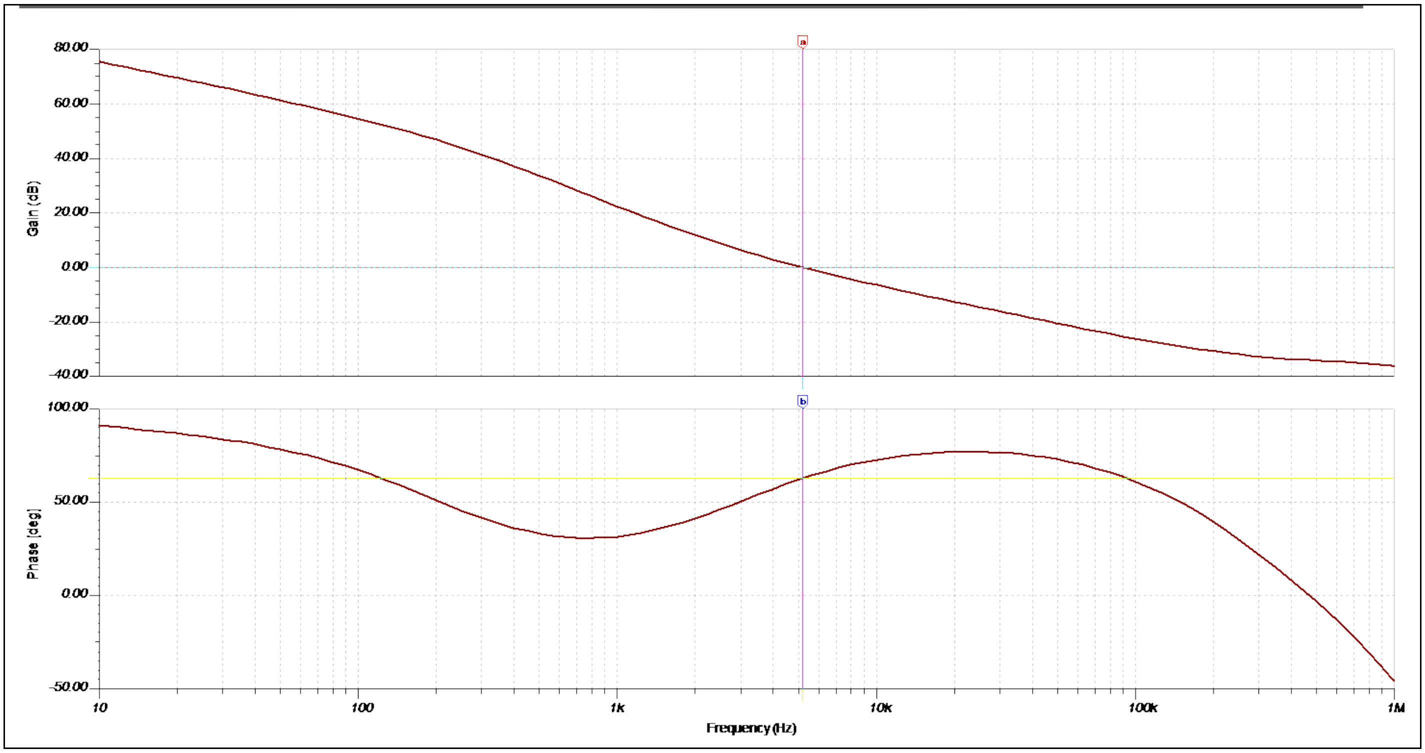

Figure 5. Simulation Results

Figure 5 shows the cross-over frequency is 5.3 kHz and phase margin is 63 degrees.

By lab test results, we can get the results shown in Figure 6.

The test results show the cross-over frequency is 5.5 kHz and phase margin is 66 degrees.

The compared simulation and test results matched fully.

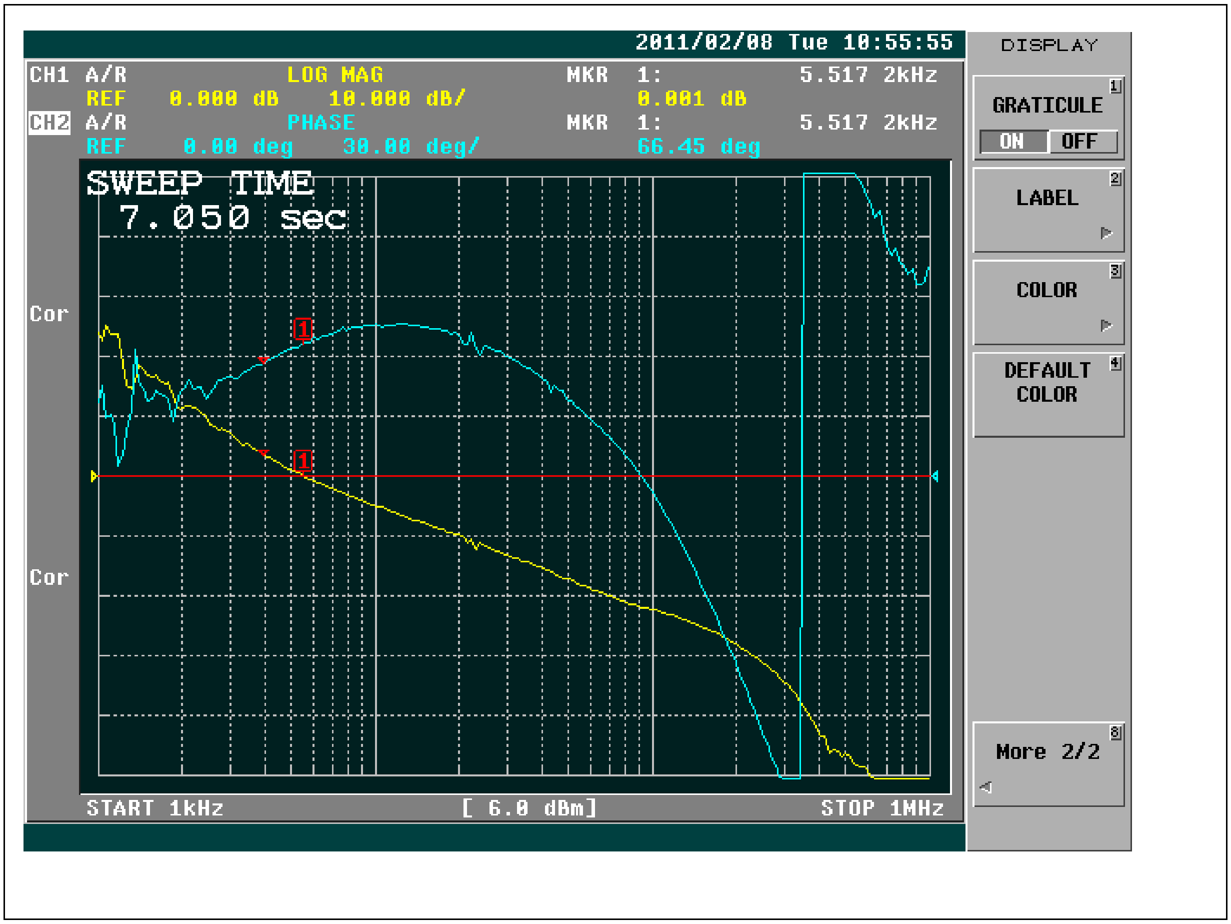

Figure 6. Lab Test Results

4 External Compensation

The TPS65142 device has employed an internal compensation and does not leave any outside dedicated PIN for loop compensation adjustment. However, in some cases, like cross-talk problems, the user must adjust the loop compensation. Two external capacitors (C1 and C2) can be added in parallel with the two divided resistors, as shown in Figure 7.

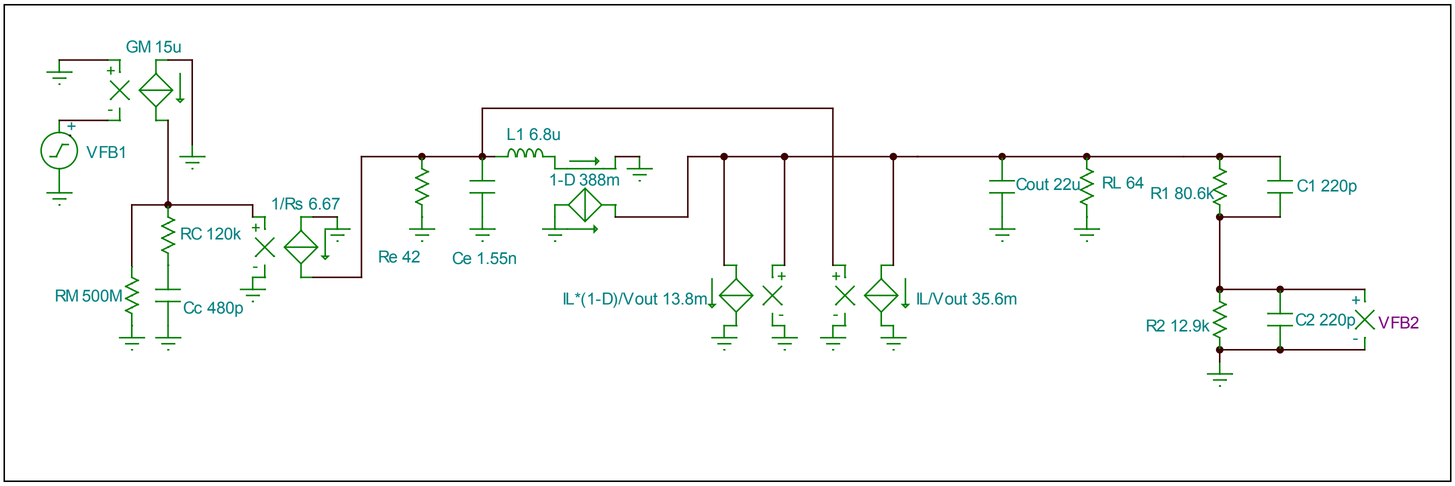

Figure 7. Loop Compensation With the Two External Capacitors C1 and C2

By the simulation, the Bode plot can be obtained in Figure 8.

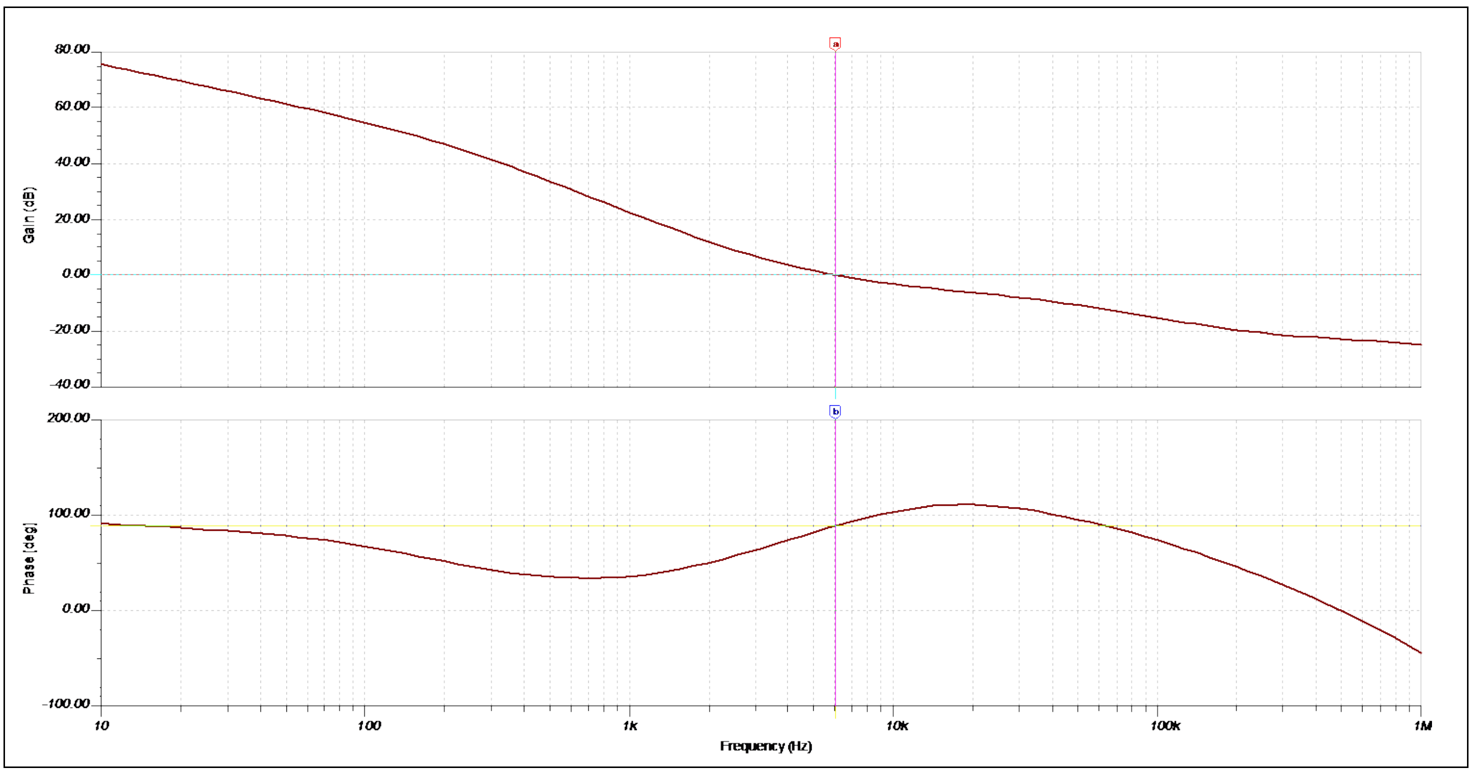

Figure 8. Simulation Results

Figure 8 shows the cross-over frequency is 6.1 kHz and phase margin is 89 degrees. Comparing the simulation results in Figure 5 without the two external capacitors, both cross-over frequency and phase margin can be increased.

Regarding the selection of the external capacitor C1 and C2, the following equations can be provided:

1. Define the additional zero and pole with the two capacitors:

$$f_z = \frac{1}{2\pi R_1 C_1}; f_p = \frac{1}{2\pi (R_1 // R_2)(C_1 + C_2)} \quad (13)$$

2. Assuming the phase gap is θ between test results with the two capacitors and without the two capacitors, and f_c is the targeted cross-over frequency, then:

$$\theta = \tan^{-1}(\frac{f_c}{f_z}) - \tan^{-1}(\frac{f_c}{f_p}) \quad (14)$$

   Also, according to the definition, $\theta = Phase_2(f_c) - Phase_1(f_c)$; (15)

   And, $A = 10^{-\frac{G_1(f_c)}{20}}$ (16)

   As a result, $f_p = f_c \frac{A \times Sin(\theta)}{A \times Cos(\theta) - 1}; f_z = f_c \frac{(1 - \tan(\theta)\frac{f_c}{f_p})}{(\frac{f_c}{f_p} + \tan(\theta))}$ (17)

3. By equations 13 and 17, we can calculate the value of capacitors C1 and C2.

5 Conclusion

This application report provides the small signal analysis about fixed off-time boost converter, and the solution to make the external loop compensation for a TPS65142 device. Meanwhile, a practical design example was implemented to prove that the solution is effective.

6 Reference

Texas instruments, SLVSAX5A, TPS65142 data sheet