Laboratory 9: Stability of the Buck Converter

ELEN: 164L

November 17th, 2021

Fall Quarter

Performed and analyzed by Christian Garcia and Jake Taylor

Materials Supplied by Santa Clara University

Part 1:

Type 2:

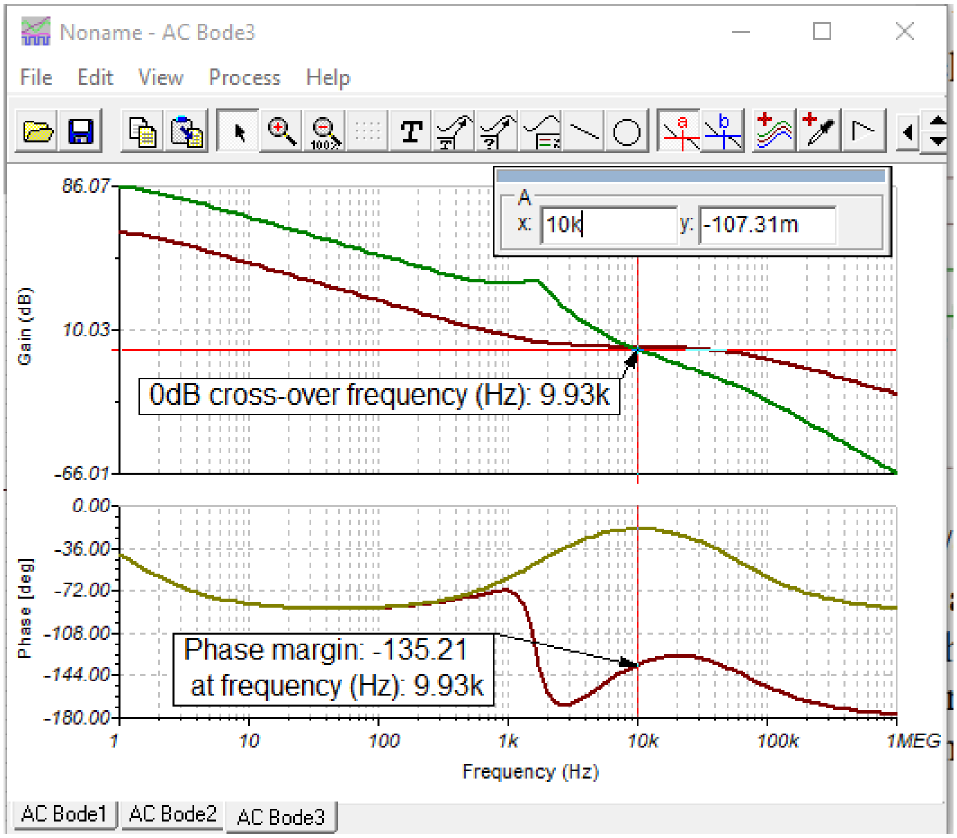

Figure 1: Magnitude and Phase with 100mOhm ESR

Cutoff Frequency: -107.31mdB at 10kHz

Crossover Frequency: 9.93kHz

Magnitude: 0dB

Phase: -135.21°

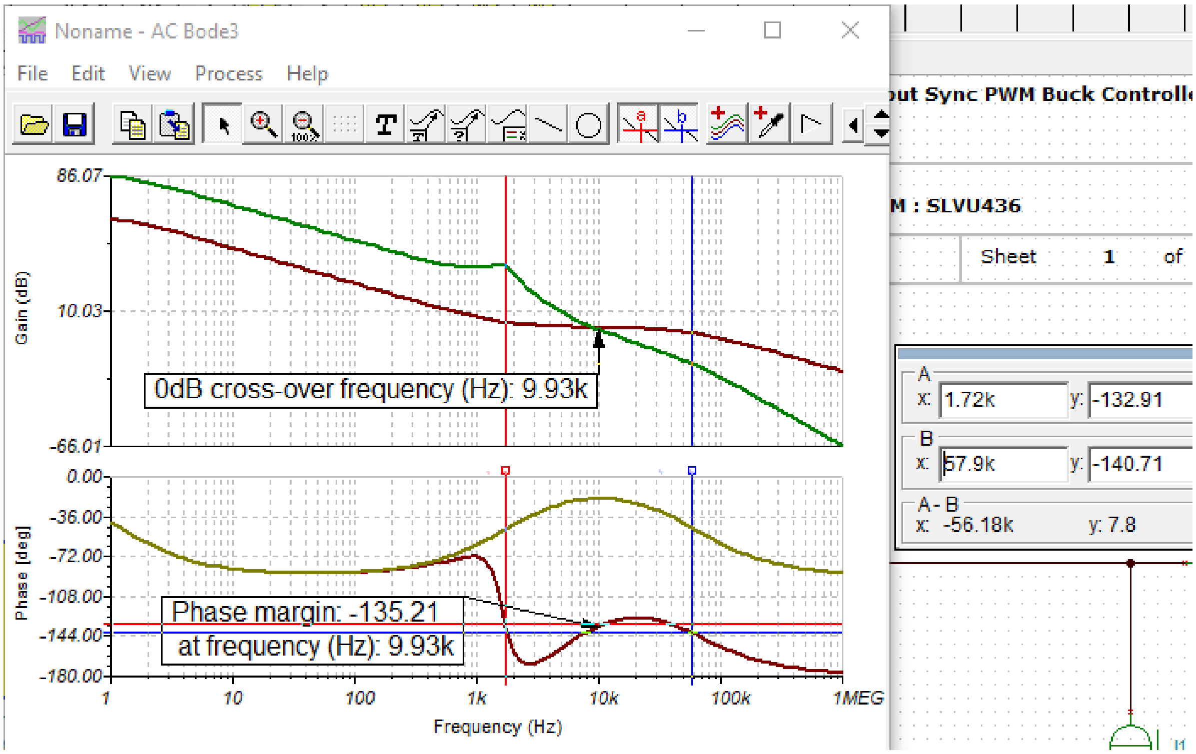

Figure 2:Zeros and Poles

-132.91° & -140.71°

They match our calculated values.

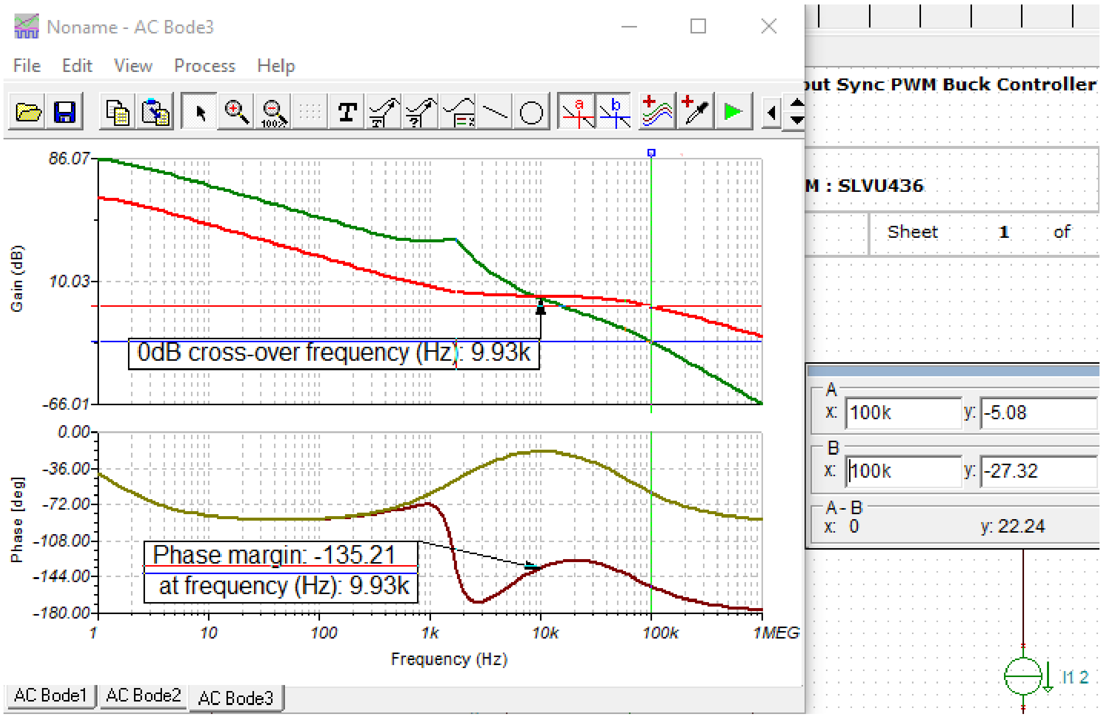

Figure 3:Magnitude and Phase at Switching Frequency

Gain at 100kHz: -5.08dB

Phase Margin: -157°

From the phase margin we can see that this system is underdamped. Since this system is underdamped we know that it is a stable system.

Type 3:

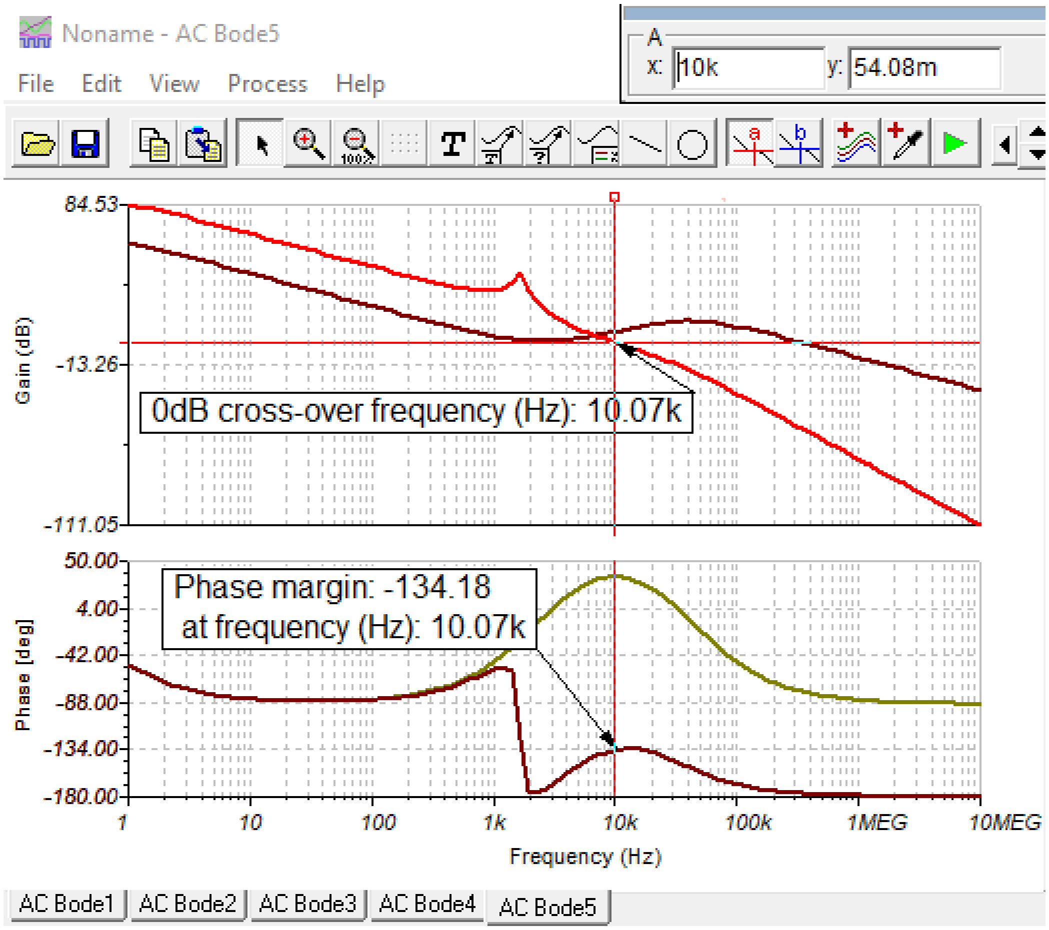

Figure 4: Magnitude and Phase with 10mOhm ESR

Cutoff Frequency: 54.08mdB at 10kHz

Crossover Frequency: 10.07kHz

Magnitude: 0dB

Phase: -134.18°

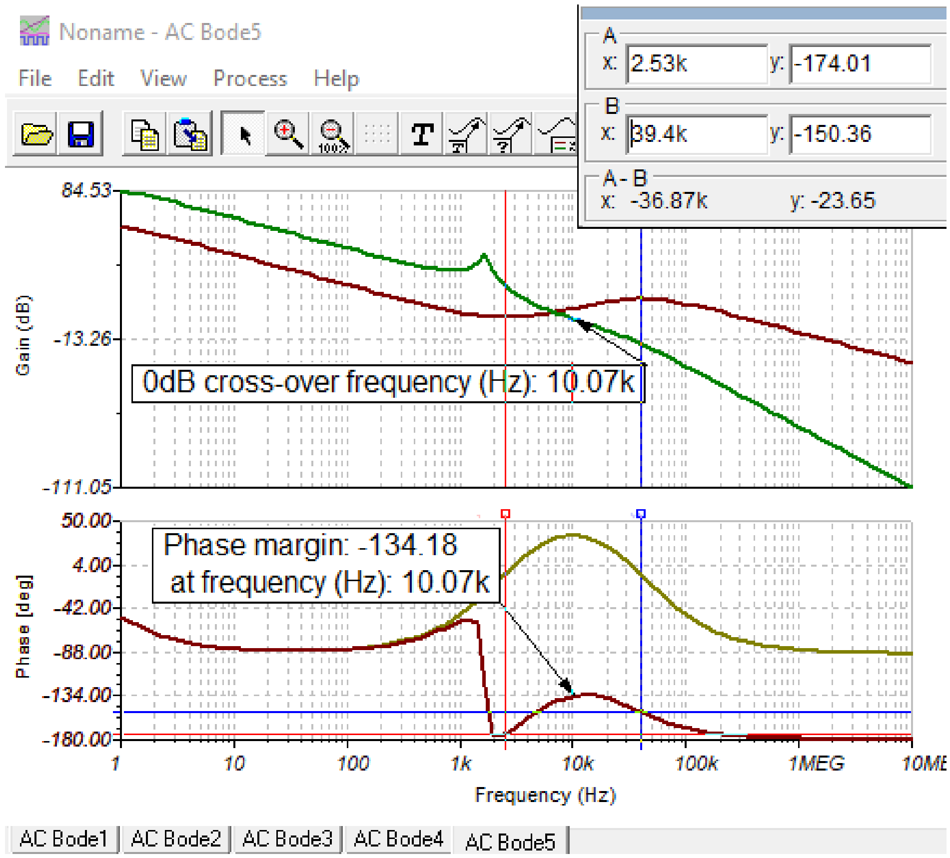

Figure 5:Zeros and Poles

-150.36° & -174.01°

They match our calculated values.

From the phase margin, we can see that this system is overdamped. We know that overdamped systems are slightly unstable so it may be unstable.

Since both our switching frequencies have very low magnitude values meaning we won't have to deal with a high ripple value.

Part 2

Type 2 compensator Transient

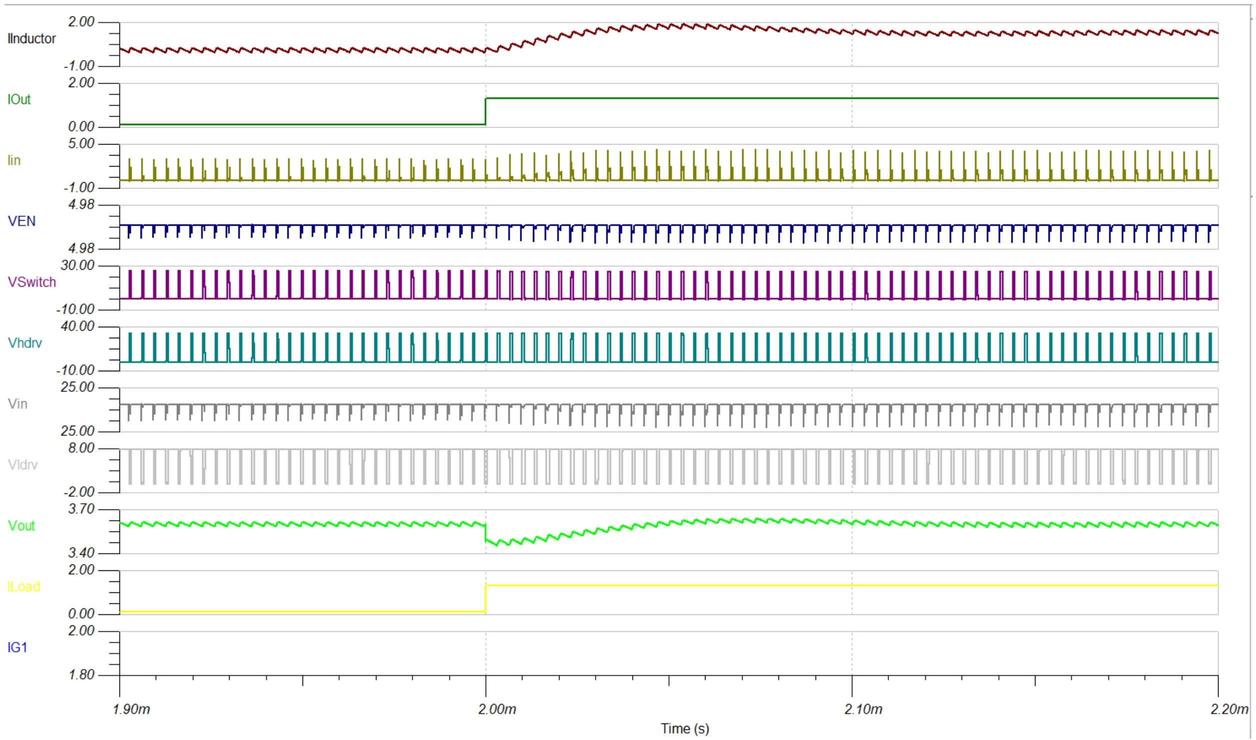

Figure 6: Initial Readings of Input and Output Values with an ESR of 100mOhm

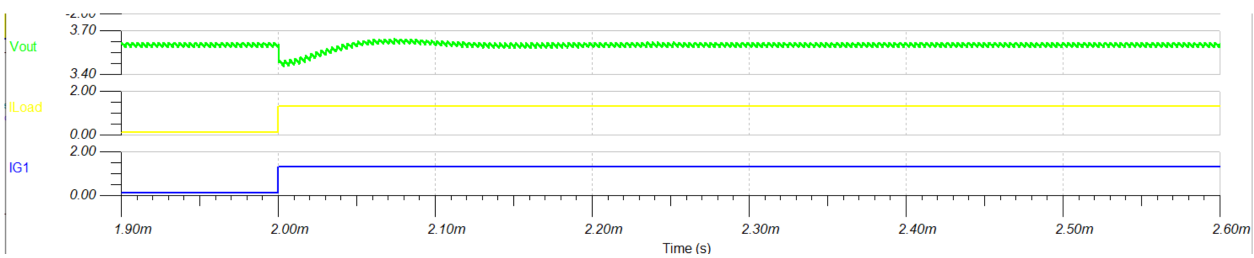

Figure 7: Vout Readjusting as the Load Size Changes with an ESR of 100mOhm

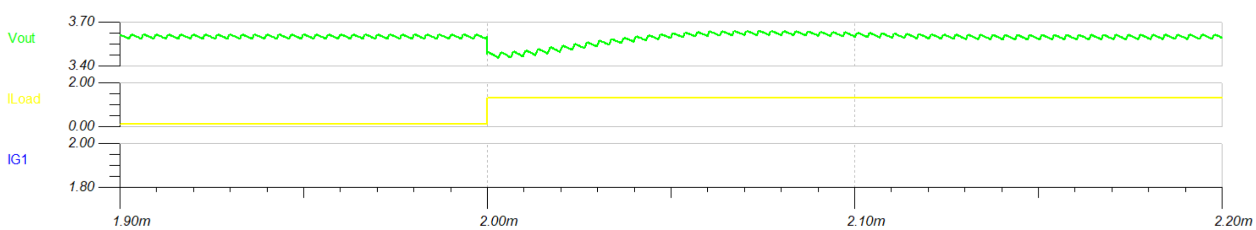

Figure 8: Vout Readjustment More Zoomed In

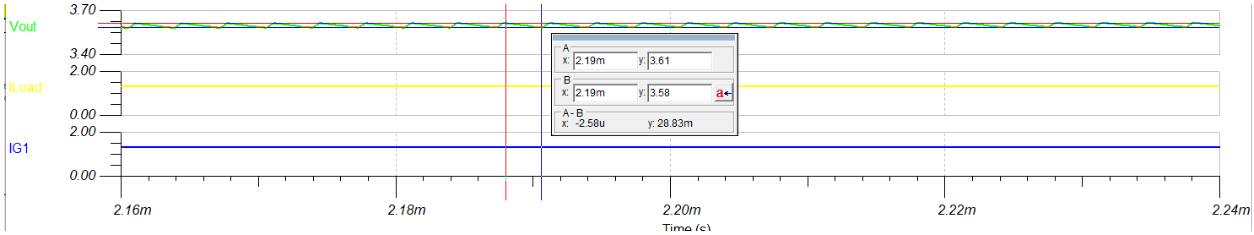

Figure 9: Vout in Steady State with a Different Load and with an ESR of 100mOhm

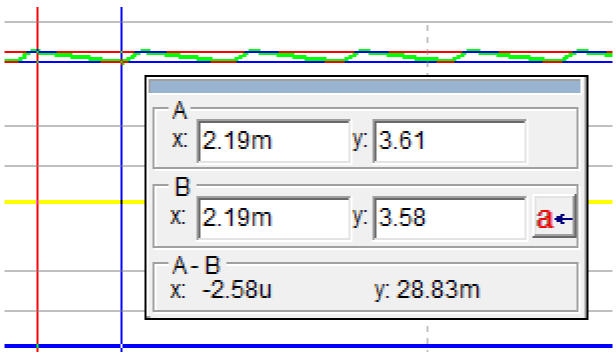

Figure 10: Values for our Vout and Iload

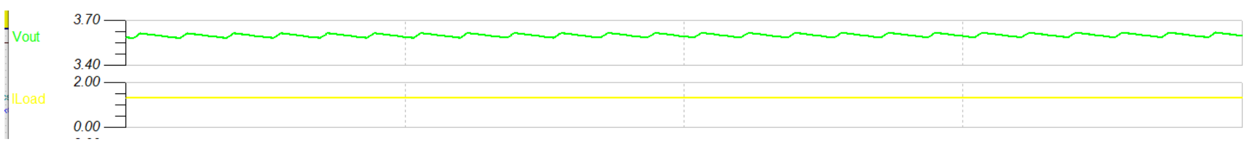

Figure 11: Vout Once It is in Steady State with an ESR of 100mOhm

Type 3 Compensator Transient

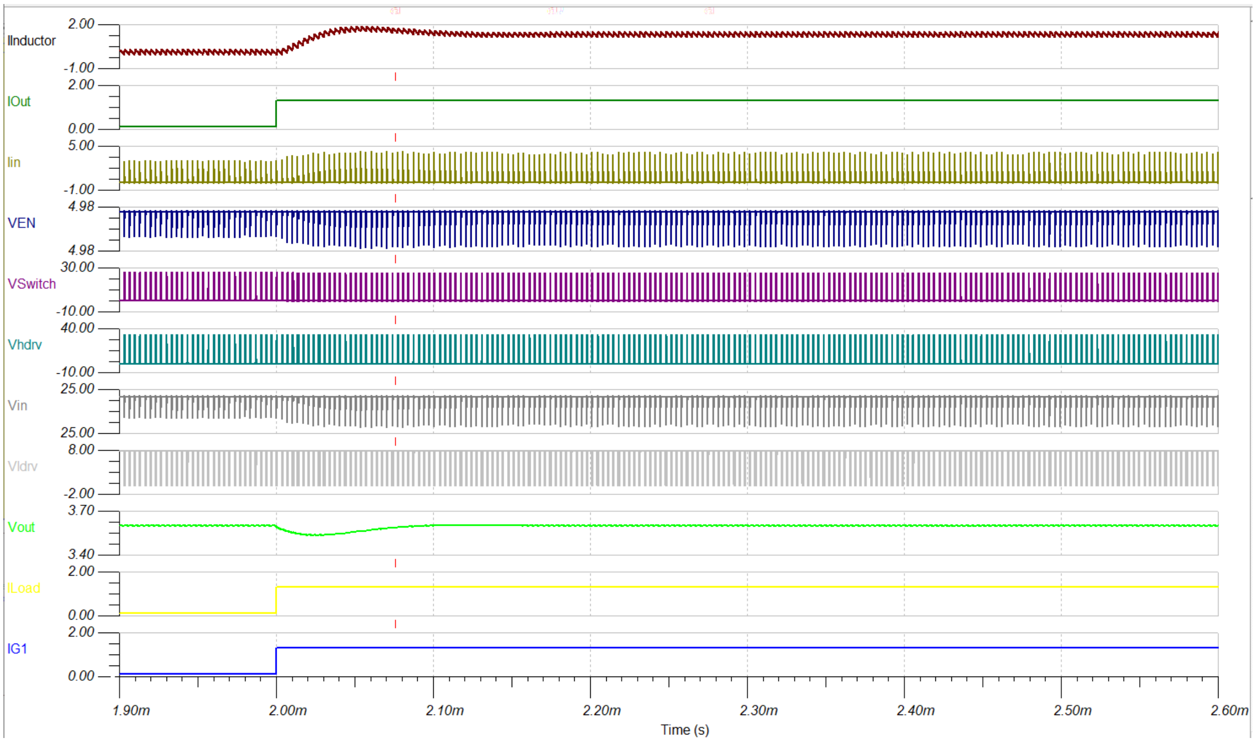

Figure 12: Initial Readings of Input and Output Values with an ESR of 10mOhm

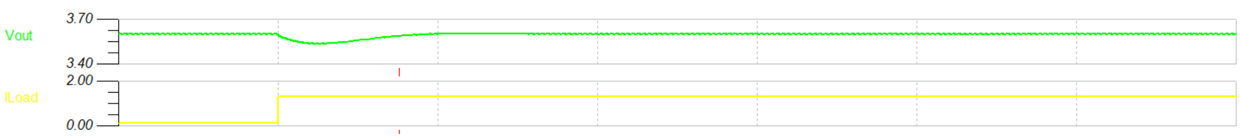

Figure 13: Vout Readjusting as the Load Size Changes with an ESR of 10mOhm

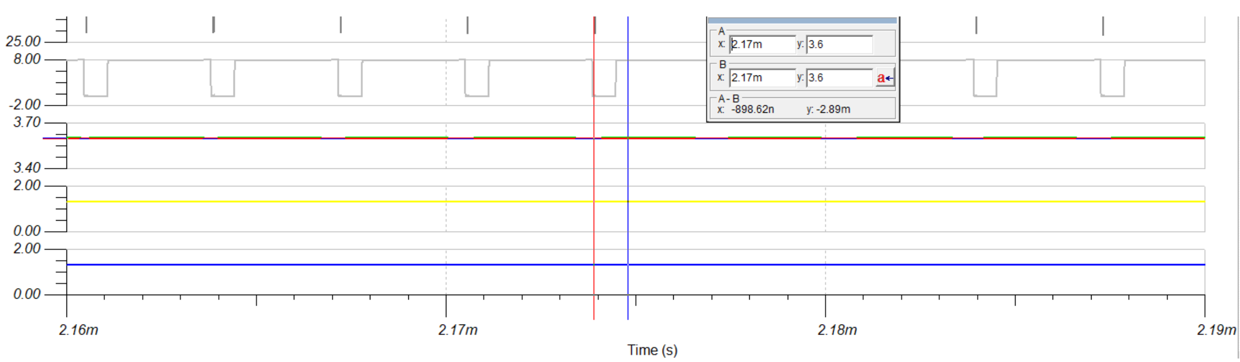

Figure 14: Vout in Steady State with a Different Load and with an ESR of 10mOhm

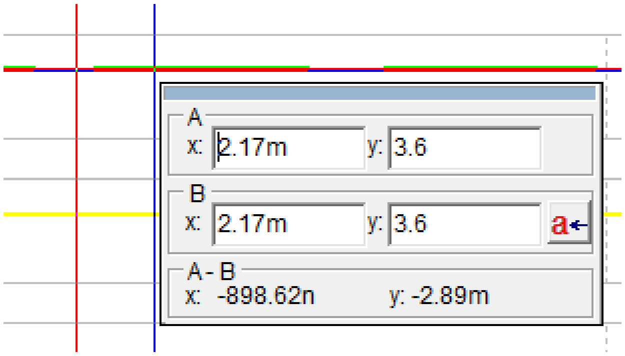

Figure 15: Values for our Vout and Iload

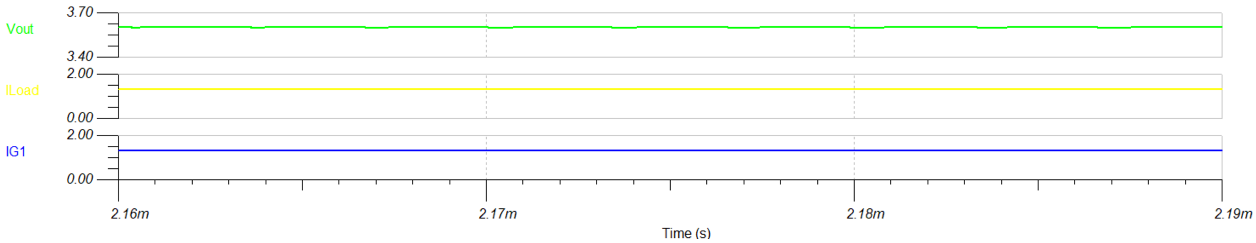

Figure 16: Vout in Steady State with an ESR of 10mOhm

Observations:

1.For each compensator you build, from the Bode plot answer the questions below
(i)What is the DC gain? Explain why?
What is the slope at this point of the magnitude bode plot?
(ii) Where does the gain change and why?
What is the slope at this point of the magnitude bode plot and why?
Give the formula that gives the frequency at which this occurs.
At this frequency what is the phase and why?
(iii)Where does the next change in gain happen and why?
What is the slope at this point of the magnitude bode plot and why?
Give the formula that gives the frequency at which this occurs.
At this frequency what is the phase and why?

1. The DC gain is at around 86.07dB. This is because of the coefficient from our bode plot equation. The slope at this point is -20dB/dec, this is because at this point only one pole is introduced in the graph.
2. The gain is changing right from the DC value, this is because the first pole is introduced at the DC frequency of 0Hz. The slope here is -20dB/dec and this again is because of the single pole that we have. The equation is f=1/2pi*sqrt(LC). The phase here starts at -36deg and makes its way down to -91deg.
3. The next change is introduced at the crossover frequency and this is because of the introduction of a zero in the equation. The slope here is 0, because when you have one pole and one zero there slopes cancel each other out. The equation for this frequency is f=1/2pi*sqrt(LC). The phase here is -135deg.

2.For each compensator you build, from the Bode plot answer the questions below
(i)What is the phase at lower frequencies? Explain why?
(ii)When does the phase change and why?
What is the phase now tending towards?
(iii)Where does the next change in phase happen and why?
What is the phase now tending towards?
(iv)At the crossover frequency, explain if the phase provides a local maxima.

1. The phase at lower frequencies is higher and closer to zero.
2. The phase changes at the crossover frequency when a zero is introduced and here the phase plot has a local max and begins to even out.

3. The next phase change happens at the switching frequency where another pole is introduced and the graph begins to decrease again.
4. Yes the crossover frequency provides a local maxima. This is because this is the part of the graph where a zero is introduced but before the next pole is introduced.

3.Observe the Bode plot of the closed loop and comment on how the open loop systems and the compensators combine to get this Bode plot.

The two plots come together to reveal the overall stability of the circuit. Using the gain and phase values we can determine how stable a system is.

4.Tabulate the below information from the Bode plots and transient response of both the open and closed loop system simulations.

	Open 100mOhm	Open 10mOhm	Closed 100mOhm	Closed 10mOhm
BodePlots	---	---	---	---
Gain at Co	0	0	0	0
Phase at Co	-20	35	-135.21	-134.18
Phase Margin	-20	35	-135.21	-134.18
Gain at Fs	-27.32	5	-5.08	-20
Transient	---	---	---	---
Settling Time	2.1	2.1	2.1	2.1
Damping				
Ripple	0.075	0.075	0.005	0.005

5.Based on the data you have gathered in the table and from your plots, comment on the performance of the filter in the converter and the stability of the system before and after compensation.

The filter in the converter is a good one that is able to block out a lot of noise. We can see that it is slightly overdamped which is shown in the blip on our graph. But that it is overall very stable because of how quickly is is able to return to the desired output voltage.