EE 617 Sensors in Instrumentation
Autumn 2020 - Assignment 03

Aaron John Sabu

1 Problem Statement

Using a circuit simulator of your choice, comment on the performance of the circuit shown in Fig. 1 (simplified block diagram of OPA335).

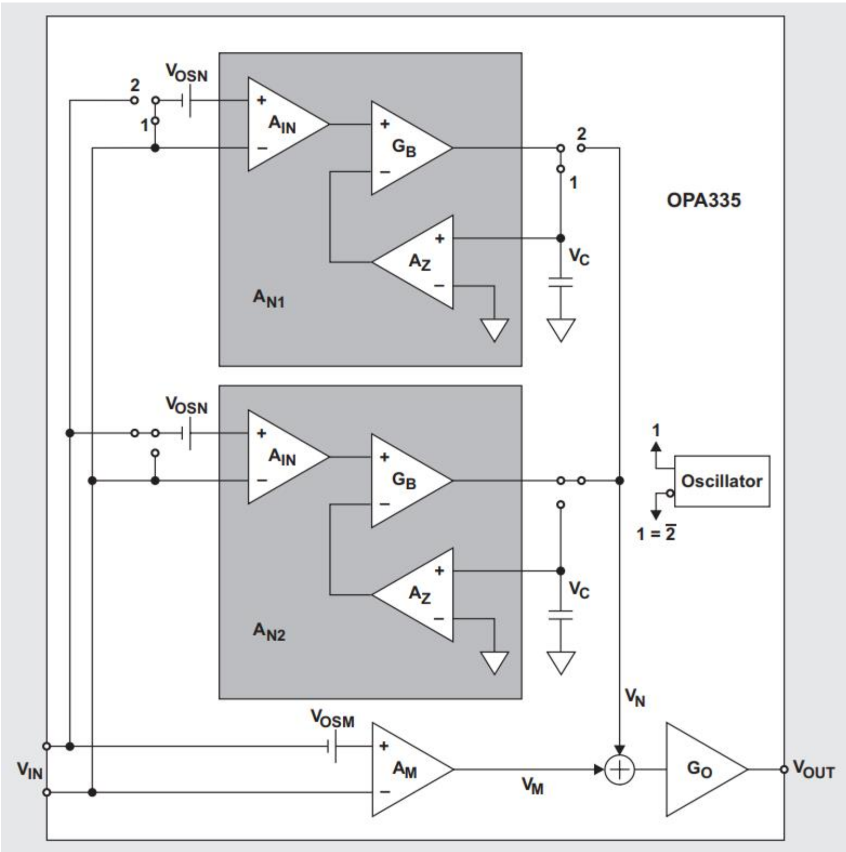


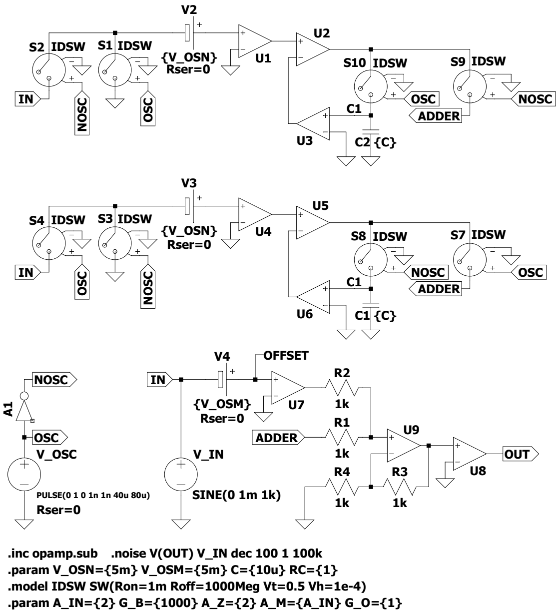
Figure 1: OPA335 Circuit Diagram

2 Simulation Setup

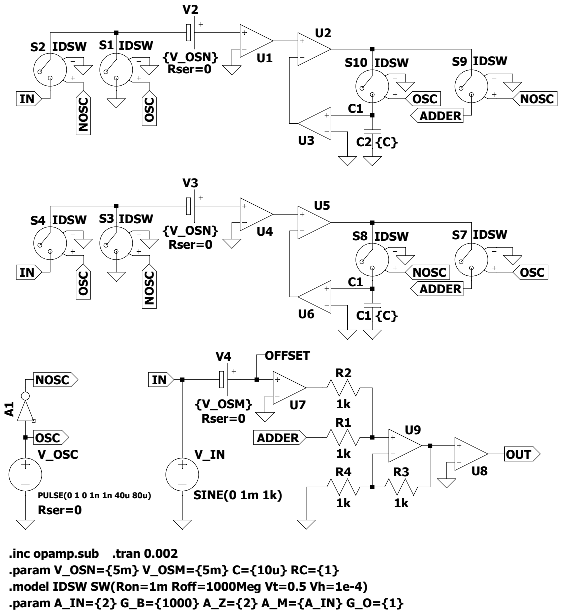
The above demonstrated circuit has been replicated on LTspice as shown in Fig. 2. The following values have been considered for the gains, capacitor values, offsets, etc.:

Constant	Value	Constant	Value
A_{IN}	2	G_B	1000
A_M	2	G_0	1
A_Z	2	V_{OSN}	$0.5V$
C	$10\mu F$	V_{OSM}	$0.5V$

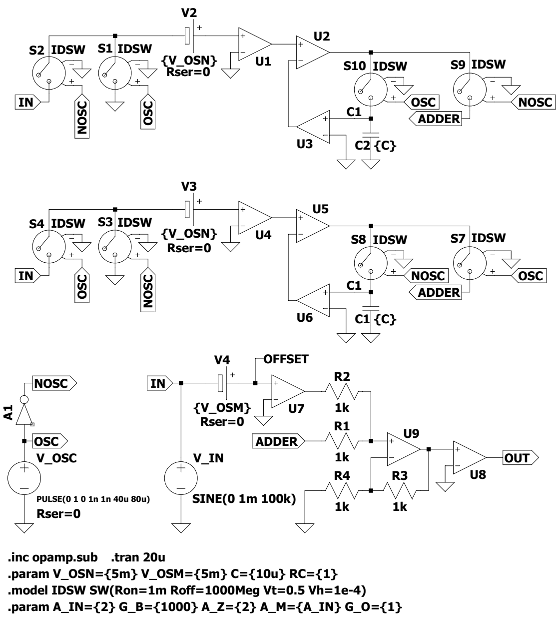
Table 1: Values used in the Simulation



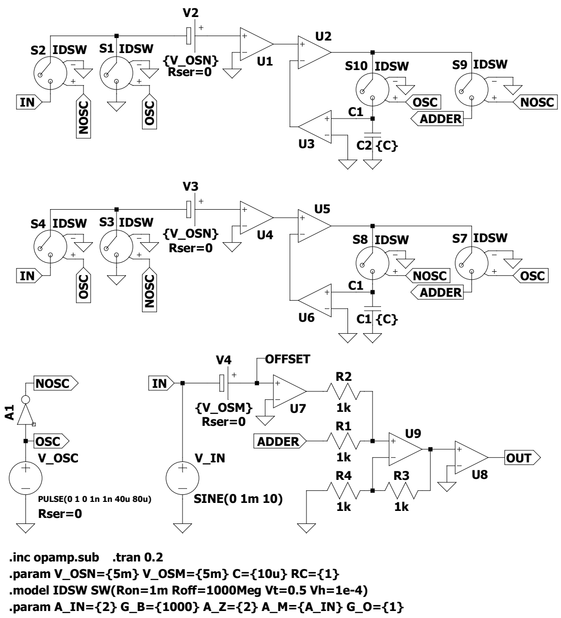
(a) Noise Analysis



(b) Transient Analysis Circuit A (IN: $1kHz$)



(c) Transient Analysis Circuit B (IN: $100kHz$)



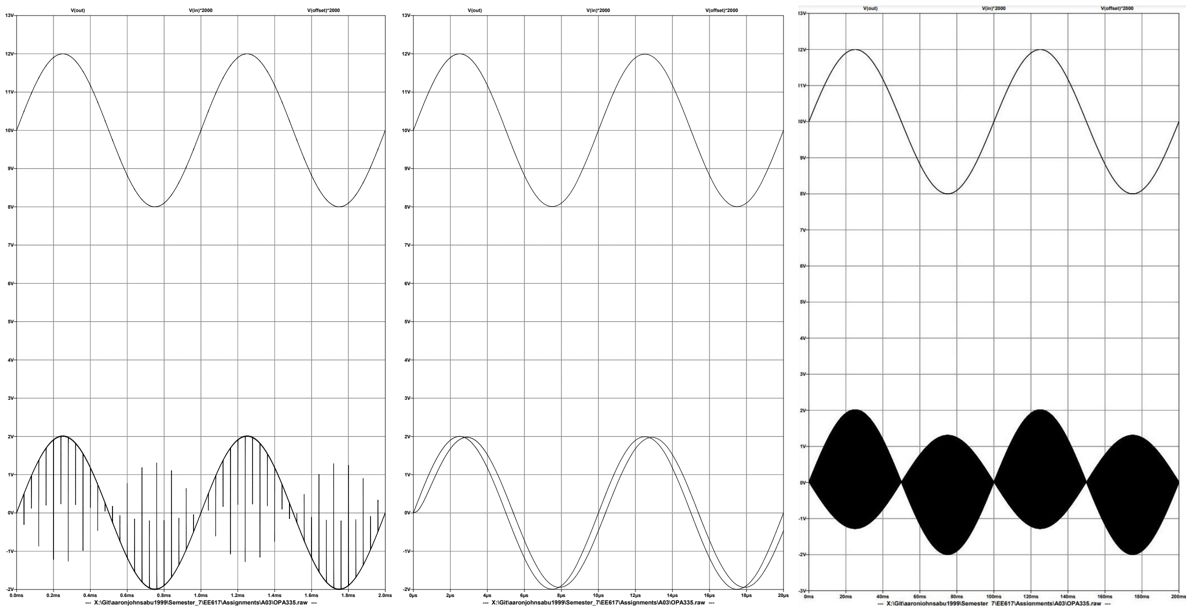
(d) Transient Analysis Circuit C (IN: $10Hz$)

Figure 2: OPA335 Circuit Diagrams

3 Results and Observations

3.1 Offset Minimization

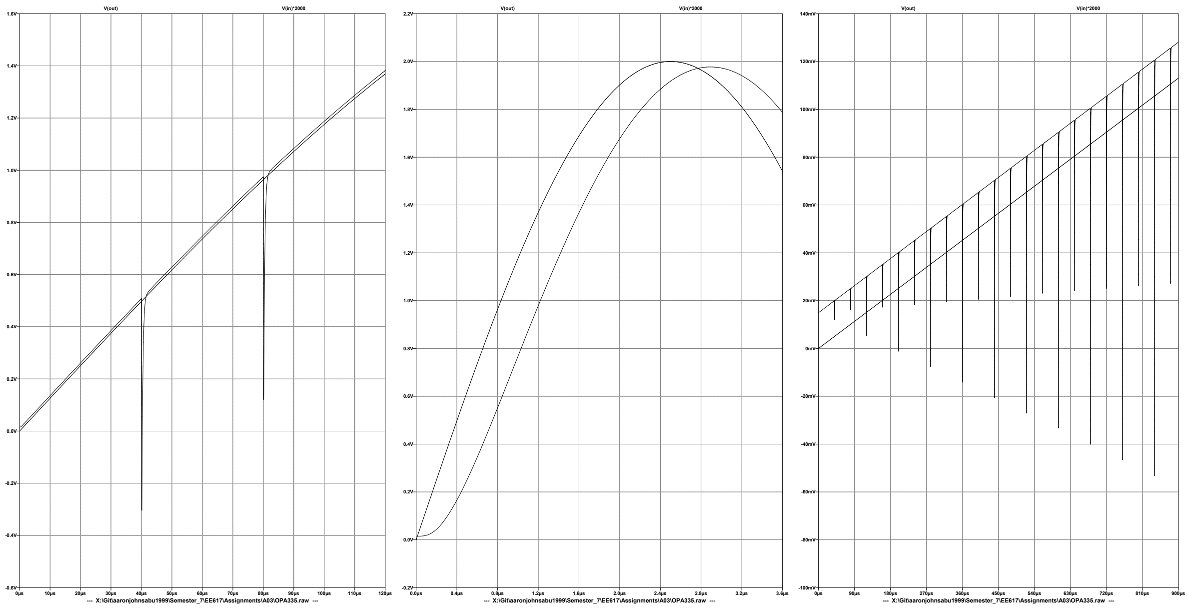
The circuit minimizes offset to a very large extent. This is observed from the transient analysis plots given in Fig. 3. Here, the upper plot represents an artificially amplified (by multiplying by 2000) version of the offsetted (by $V_{OSM} = 5mV$) input. As is visible, the output almost exactly aligns with the input (which is shown here after multiplying by 2000).



(a) $1kHz$ (b) $100kHz$ (c) $10Hz$

Figure 3: Offset removal

The $1kHz$ circuit shows spikes at occasional intervals and the $10Hz$ circuit very frequently as observed in the zoomed versions of the waveforms in Fig. 4.



(a) Spikes in $1kHz$ output (b) Phase Shift in $100kHz$ output (c) Spikes in $10Hz$ output

Figure 4: Zoomed Plots

As expected, there exists a small amount of offset in the output. Moreover, a large amount of phase shift is observed in the $100kHz$ circuit output.

3.2 Noise Characteristics

The circuit gives noise characteristics on the same scale (though larger) as that represented in the document by Texas Instruments. This is shown in Fig. 5. The cutoff frequency of the simulated circuit coincides with the original one. However, the drop is much slower in the simulated circuit. It was also observed that the circuit shows huge variations in the noise levels when the value of G_B was varied.

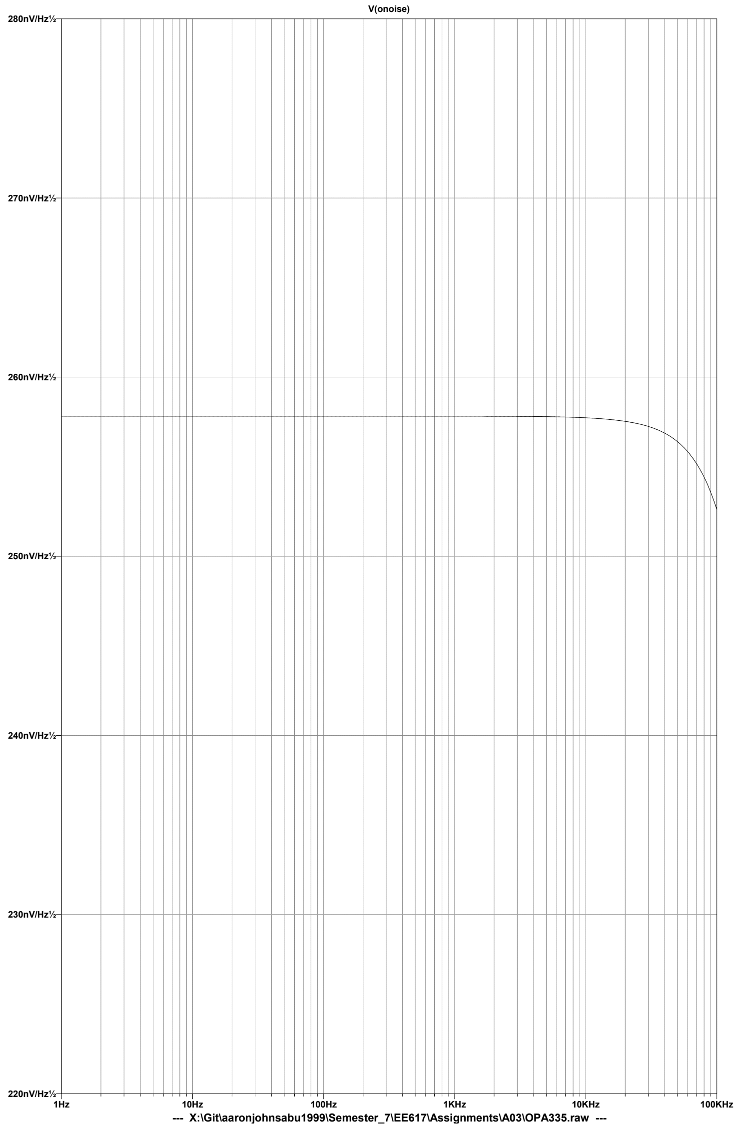
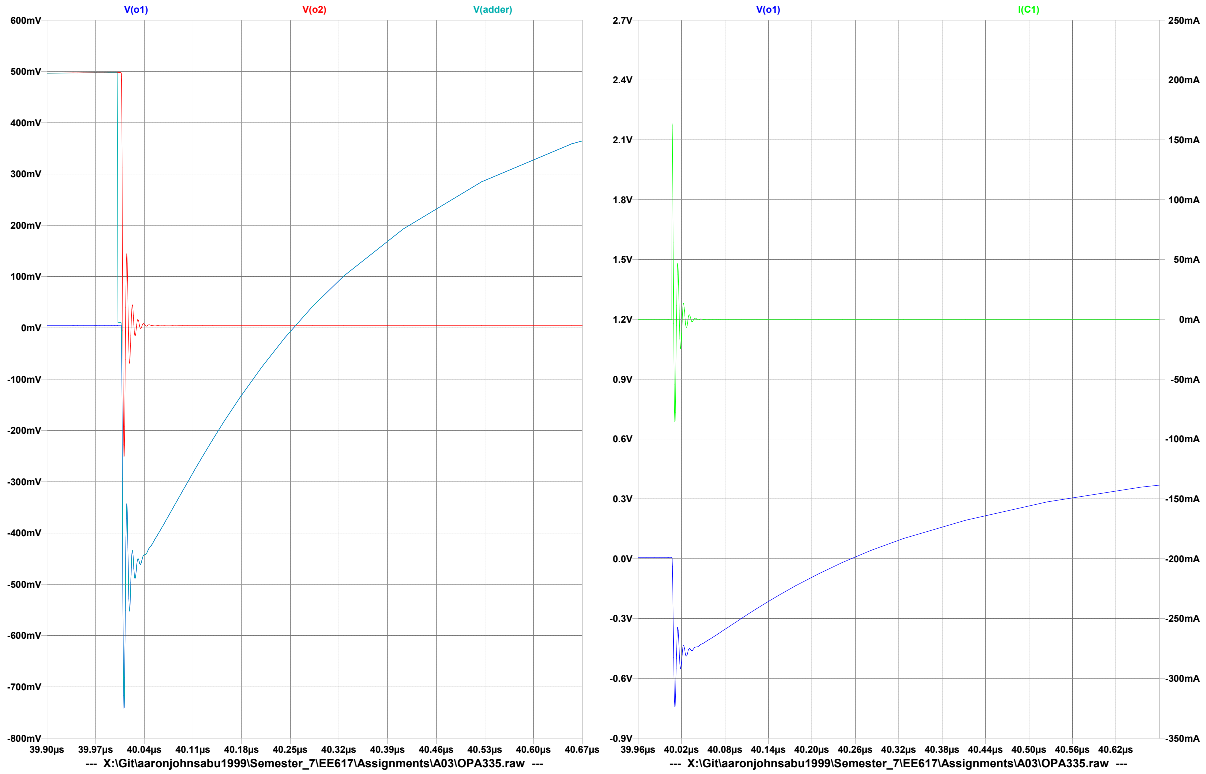


Figure 5: Noise Analysis Plot

4 Analysis and Inferences

While the wideband amplifier amplifies the input signal, the nulling amplifier avoids the offset from being amplified. The only amplification in offset is a result of the main amplifier with gain A_M. In this simulation, small values have been used for A_M, A_{IN}, and A_Z. This is because of the limitation of LTspice to manage cumulatively large gains that occur at the output of the G_B amplifiers. However, even if these values were huge, the offset would not be extensively amplified since the input is further amplified by G_B which makes the input gain much larger when compared to the offset gain.

The spikes in the output occur as a result of multiple reasons. Firstly, the switches utilize a hysteresis curve to avoid chatter. This causes delays that translate to the spikes in the output. Secondly, for a short period of time after switching, both nulling amplifiers simultaneously contribute to the output since both switches conduct against ideal expectations. Moreover, these spikes take a particularly exponential curve due to the capacitances used in the circuit. These effects are depicted in Fig. 6a where the output of each nulling amplifier is compared to the sum of the outputs of both nulling amplifier, and Fig. 6b where the current flowing through capacitor C1 is compared to the output of its corresponding nulling amplifier O1.



(a) Nulling Amplifier Outputs

(b) Capacitor Current vs. Nulling Amplifier Output

Figure 6: Why Spikes?

The phase shift observed in the output of the $100kHz$ circuit may have been caused as a result of the capacitors used in the circuit as well as components such as resistors, inductors and capacitors in the individual amplifiers. Although present in the other circuits, it is more pronounced here due to the high frequency and the subsequently larger influence of the reactance.

A References

1. Voltage-Controlled Switch
2. SPDT in LTspice
3. Using LTspice for Amplifier Noise Measurement
4. Feedback Gain Loop Simulation Problem in LTspice
5. How to comment at the end of a command in LTspice?