ECE 3150 Lab 1

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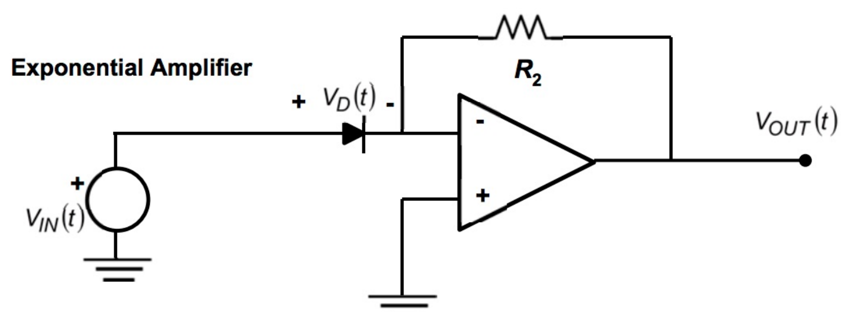
1 Prelab

1.1



$$V_{out}(t) = -Ae^{\frac{qV_{in}(t)}{\eta KT}}$$
$$I = I_o(e^{\frac{qV_{in}(t)}{\eta KT}} - 1)$$
$$-Ae^{\frac{qV_{in}(t)}{\eta KT}} = -V_{in}(t)\frac{R_2}{R_{in}} = I_{in} * R_2$$
$$-Ae^{\frac{qV_{in}(t)}{\eta KT}} = -I_oR_2e^{\frac{qV_{in}(t)}{\eta KT}}$$
$$-A = I_oR_2 \rightarrow A = I - oR_2$$

1.2

$$V_{in}(t) = V_{in-DC} + V_{in-1}cos(n\omega t)$$
$$V_{out}(t) = -Ae^{\frac{qV_{in}(t)}{\eta KT}} = V_{out-DC} + \sum_{\infty}^{n=1} V_{out-n}cos(n\omega t)$$
$$V_{out} = -I_oR_2e^{\frac{q(V_{in-DC}+V_{in-1}cos(n\omega t))}{\eta KT}}$$
$$V_{out} = -I_oR_2e^{\frac{q(V_{in-DC})}{\eta KT}} + e^{\frac{q(V_{in-1}cos(n\omega t))}{\eta KT}}$$
$$V_{out} = -I_oR_2e^{\frac{q(V_{in-DC})}{\eta KT}})(I_o\frac{qV_{in}}{\eta KT} + 2\sum_{\infty}^{n=1} I_n\frac{qV_{in-1}}{\eta KT}cos(n\omega t))$$
$$V_{out-DC} = -I_oR_2(e^{\frac{q(V_{in-DC})}{\eta KT}})(I_o\frac{qV_{in-1}}{\eta KT})$$
$$V_{out-n} = -I_oR_2(e^{\frac{q(V_{in-DC})}{\eta KT}})(2I_n\frac{qV_{in-1}}{\eta KT})$$

$$V_{out-1} = -I_o R_2 (e^{\frac{q(V_{in-DC})}{\eta KT}})(2I_1 \frac{qV_{in-1}}{\eta KT})$$

1.3

$(\frac{V_{out-n}}{V_{out-1}})^2 = (\frac{-I_n(e^{\frac{q(V_{in-n})}{\eta KT}})}{-I_1(e^{\frac{q(V_{in-1})}{\eta KT}})})^2$

After plugging into Matlab the values obtained are:

$n = 2 \rightarrow -6.78dB$

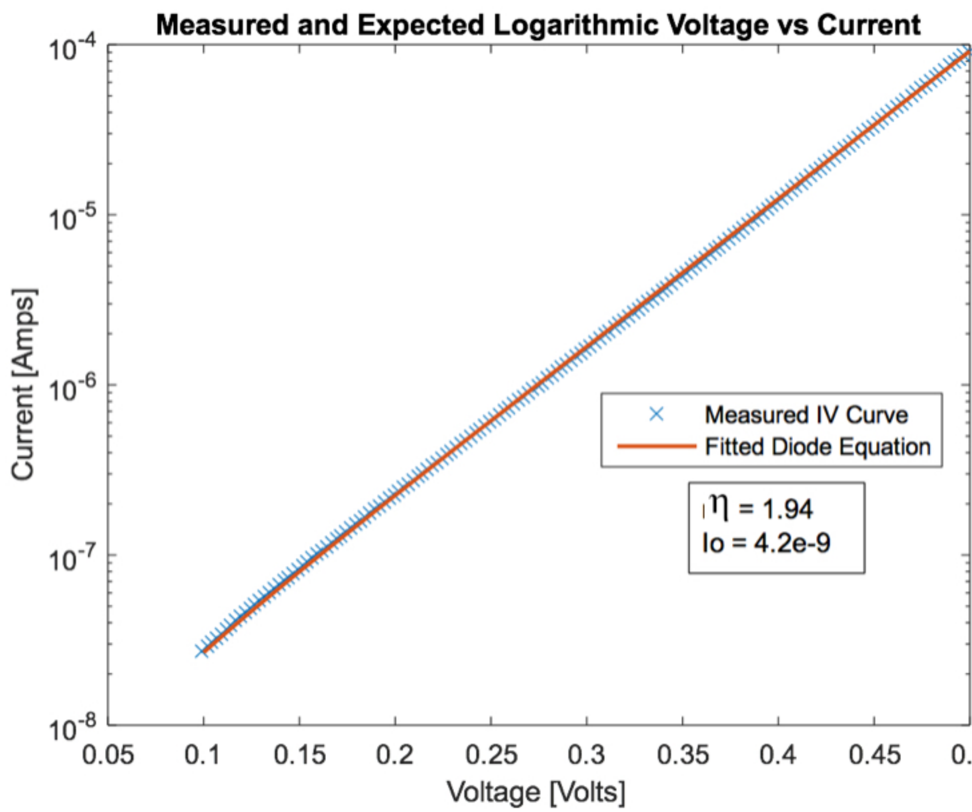
$n = 3 \rightarrow -16.58dB$

$n = 4 \rightarrow -28.39dB$

$n = 5 \rightarrow -44.87dB$

2 Post Lab Work

2.1 Diode Current-vs-Voltage (IV) Curve



The Diode Equation given by: $I = I_o(e^{\frac{qV_{in}(t)}{\eta KT}} - 1)$ fitted very well to the measured data. The fitting values η and I_o were found by varying each one independently till the curve fit. I started with η because it controlled the slope of the line. Once the slope matched the measured value I adjusted the value of I_o till it match the measured slope The values that ended up working were $\eta = 1.94$ and $I_o = 4.2 * 10^-9$ Amps

2.2 Large Signal Input and Output Waveforms

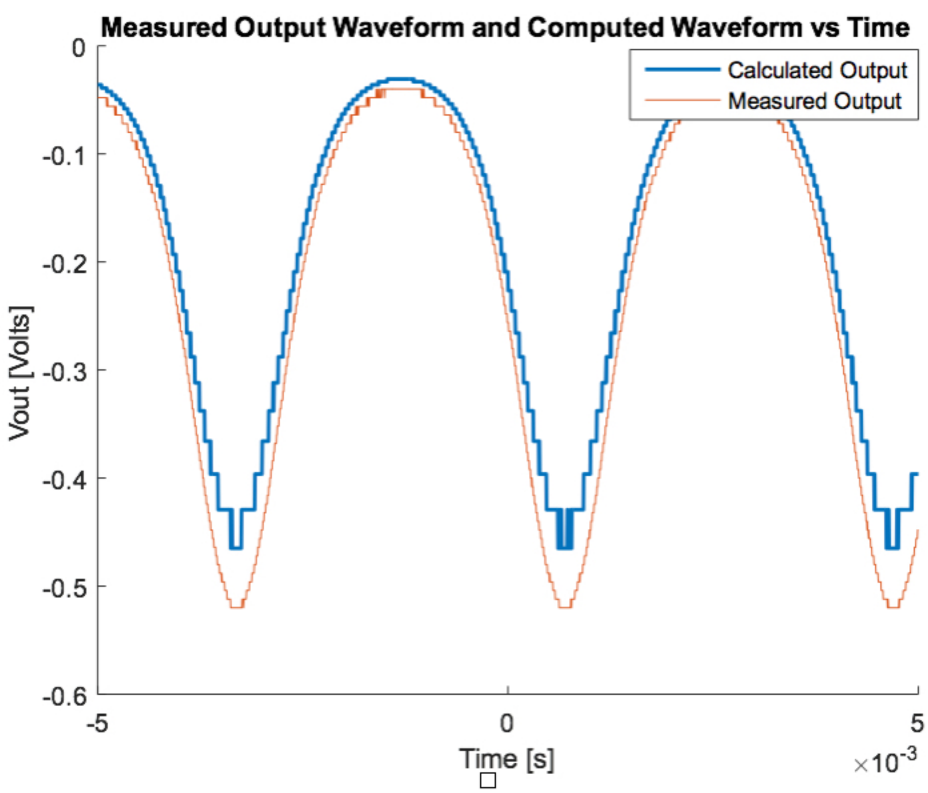
Resistance Values

Resistor	Ideal Ω	Measured Ω
R1	50	47.2
R2	100k	97.7k

The AC amplitude was found by looking at the peak to peak voltage on the oscilloscope and dividing that value by 2 to get the amplitude. The DC offset was found by looking at the oscilloscope.

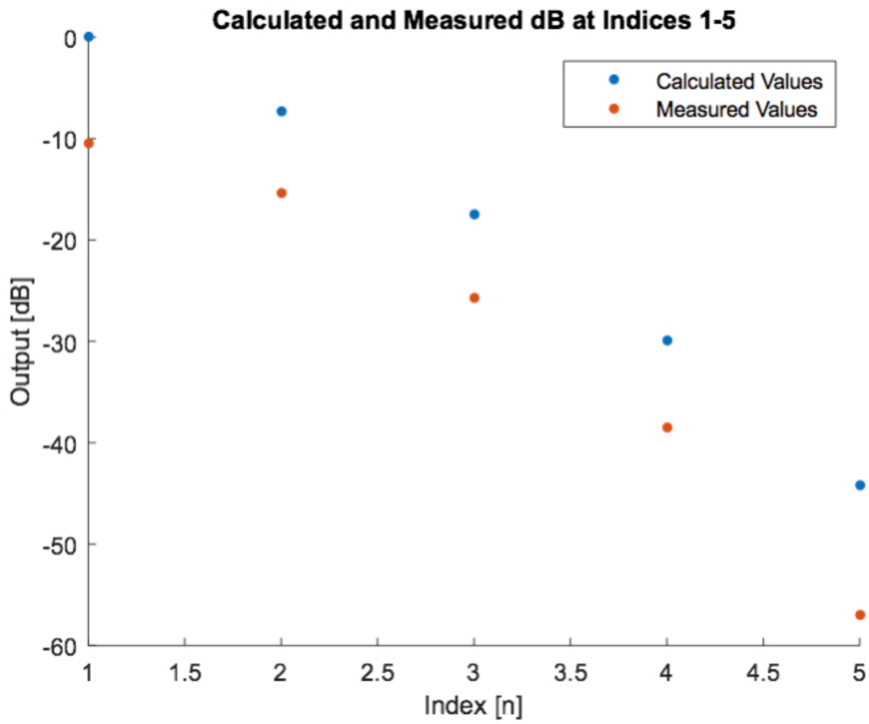
DC offset V_{in} and AC amplitude (v_1)

	Ideal V_{in} (mV)	v_1 (mV)
CH1	290	68
CH2	-222	240



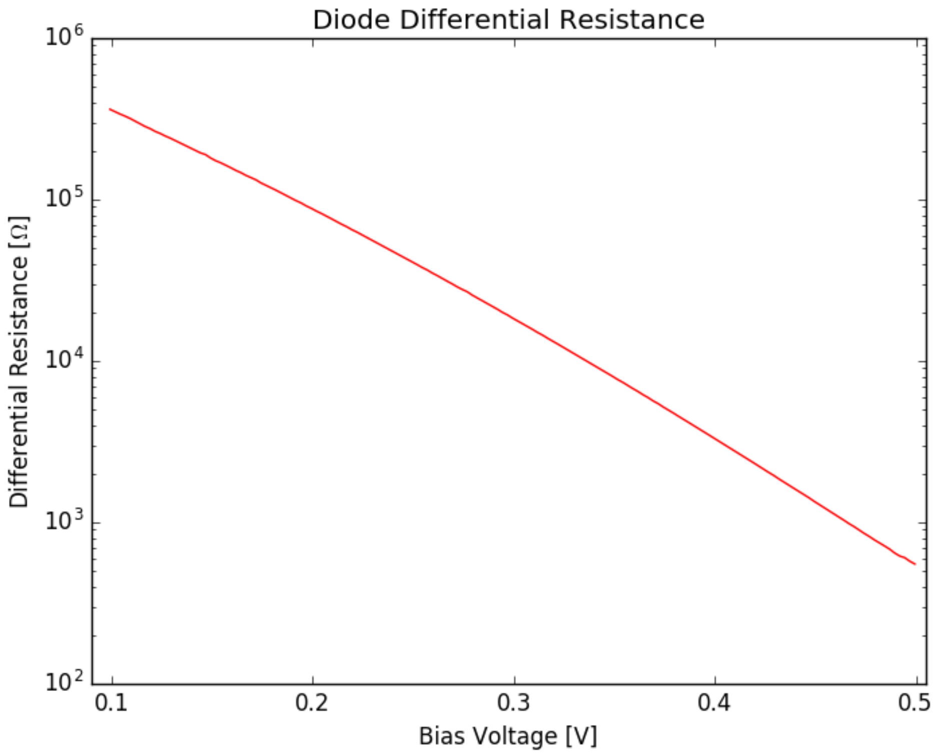
The measured and calculated outputs for the waveform vs. time were very similar. Our calculated output ended up being a bit higher than what we measured, which can be due to outside noise and the fact that the devices we are using are not ideal. We did get the waveforms we wanted with a fairly low margin of error.

2.3 Large Signal Input and Output FFT Spectra



The measured and calculated values for the harmonic peaks were close. They both followed the downward dB as the index n got higher. Our measured values ended up being lower by approximately 10dB than the calculated one. We obtained the calculated values by using the Bessel function. Following what we did in the prelab in order to get the calculated values. We did get a new calculated value of η being 1.94. In the measured data the 5^{th} harmonic ended up being more off than the other harmonics. This is due to the fact that the magnitude of 5^{th} harmonic was very close to the surrounding noise. Thus, the noise messes with the signal more here which contributed to the higher margin of error.

2.4 Small Signal Measurements: Diode Differential Resistance

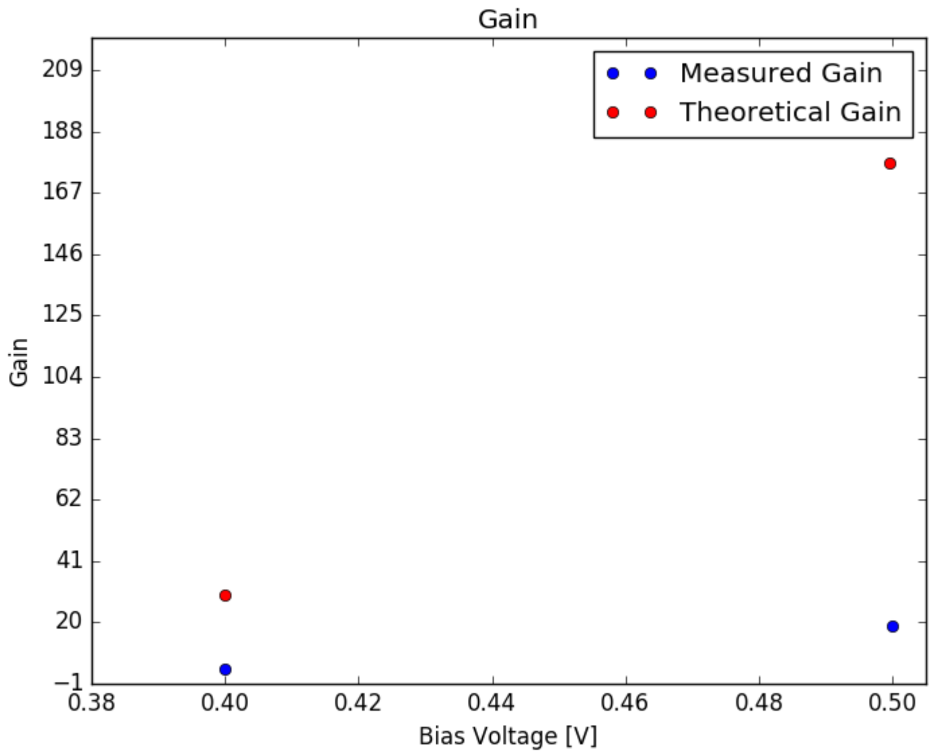


At the input DC bias voltage of 400mv the differential resistance was 3.203kΩ.

2.5 Small Signal Measurements: Circuit Gain

a)

The small circuit model of the op-amp exponential amplifier behaves very similar to an ideal op-amp. Thus we can use the derive the voltage gain using the formula for an ideal op amp. $V_{out} = -V_{in}\frac{R_f}{R_{in}}$. This modified for our op-amp changes the equation to be: $V_{out} = -V_{in}\frac{R_2}{r_d} \rightarrow \frac{V_{out-1}}{V_{in-1}} = \frac{-R_2}{r_d} \rightarrow A_v = \frac{-R_2}{r_d}$ Where r_d is the diode differential resistance.



	Voltage Bias	Gain
Theoretical	400mv	29.2
Theoretical	500mv	176.98
Measured	400mv	4
Measured	500mv	19

400mv	DC Offset [mV]	Pk-to-Pk[mv]
CH1	286	2
CH2	-131	8
500mv		
CH1	312	2
CH2	-236	38

The AC signal amplitude setting on the function generator was 19mV at onset of linear operation

b)

The ideal gain using the measured values would be 4.84 for 400mv and 35.74 for 500mv The measure gain was quite a bit off from the theoretical values. The main reason for this was that because we running at such a small voltage, the outside noise was very noticeable and messed with the measurements. In lab when we first connected the input voltage we got a high gain initially but it then flat lined to the value we ended up using to calculate the gain. However, our gain did increase from the 400mv measurement to the 500mv measurement. This is consistent with the fact that the differential resistance calculated in **2.4** decreases as with an increase in the bias voltage.