Lab 9: BJT Amplifier Design

ECEN 325 - 511

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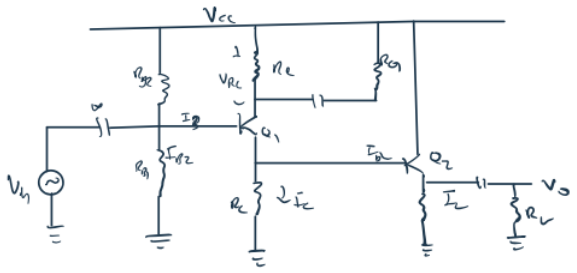
Date Performed: November 9, 2021

Due Date: November 16, 2021

Purpose

The purpose of this lab was to learn how to develop a multi-stage BJT amplifier.

Calculations



$|A_V| = 20$ $\quad \beta = 100$

$V_{D,ON} = 0.9V$ $\quad I_E \approx 10\%$

THD 5% $\quad R_i \geq 1k\Omega$ $\quad R_L = 1k\Omega$

$\Delta i_C = 10\%$

$V_{R_E} \geq 1V$

$|A_V| = |A_{V_1}||A_{V_2}| \cong |A_{V1}|$

$= \dfrac{R_C \| R_{i2}}{r_{e1} + \eta_6 \| R_{E1}} \rightarrow (1)$

$R_{i2} = (1+\beta)(r_{e2} + R_H \| R_2)$

$R_{i2} \geq R_L$

$|A_{V1}| \geq R_L / r_{e1} + \eta_2 \| R_{E1}$

$V_{CB} - V_{DL} \geq 0 \Rightarrow V_{CB} \geq 0.9V$

$V_{CB} + V_{DL} \leq V_{CC} - V_{RE} - V_{CE\,sat}$

$\Rightarrow V_{CB} \leq 3.6V - V_{EE}$

$V_{CB} - 0.7V - V_{DL} \geq 0 \Rightarrow V_{CB} \geq 1.6V$

$V_{CB} - 0.7V + V_{DL} \leq V_{CC} - V_{EE}$

$V_{DL} = 0.9$

$V_{CC} = 5$

$V_{CB,min} = 0.5$

$V_{CB} \leq 4.3V$

$1.6 < V_{CB} < 3.6V - V_{EE}$

$3.0 \rightarrow V_{RC} = 1V$

$V_{CB} = 2.6V$

$\therefore (i_H + i_L)_{min} = \dfrac{V_{CB} - 0.7 - V_{DL}}{R_H} - \dfrac{V_{DL}}{R_L} \geq 0$

$R_H \leq \dfrac{V_{CB} - 0.7V - V_{DL}}{V_{DL}} R_L = \dfrac{2.60 - 0.7 - 0.9}{0.9} 1k\Omega$

$= 111.1k\Omega$

$\boxed{R_H = 110}$

$I_{CQ2} = \dfrac{V_{CQ} - 0.7}{R_H} = \dfrac{0.9 + 0.7}{R_H} = \dfrac{1.8V}{111\Omega}$

$\boxed{I_{CQ2} = 17mA}$

$$R_{i2} = (1+\beta)\left(\frac{25mV}{I_{EQ2}} + R_M \| R_L\right)$$

$$= 100\left(\frac{25}{17} + 110 \| 100\right)$$

$$\boxed{R_{i2} = 5.39k\Omega}$$

$$R_C \ll R_{i2} = 540\Omega$$

$$\boxed{R_C = 540\Omega}$$

now $I_{CQ} = \frac{V_{CQ}}{R_C} = \frac{2.6}{540} = 4.81mA$

$$R_e = \frac{V_{RE}}{I_E} = \frac{1V}{4.81} = 207.9\Omega$$

$$A_V = \frac{R_C}{\frac{25}{4.81} + 207.9 \| R_{C1}} \Rightarrow 20 = \frac{540}{5.197 + \frac{200R_{C1}}{200+R_{C1}}}$$

$$= 5.197 + \frac{200R_{C1}}{200+R_{C1}} = 27$$

$$\Rightarrow \boxed{R_{C1} = 24.467\Omega}$$

now

$$R_i = (R_{B1} \| R_{B2}) \| (1+\beta)(r_{e1} + R_E \| R_{C1})$$

$$= (R_{B1} \| R_{B2}) \| 100\left(\frac{540}{20}\right)$$

$$= 2.7k\Omega$$

$R_i \geq 1k\Omega$ $\rightarrow V_{TH} = \frac{R_{B2}}{R_{B1}+R_{B2}} V_{CC}$

$$V_{TH} = V_{CC} - V_{BE} - 0.7V$$

$$\frac{R_{B2}}{R_{B1}+R_{B2}} 5V = 3.3V$$

$$= 0.66$$

from a $\rightarrow$ $1k\Omega = (R_{B1} \| R_{B2}) \| 2.7k\Omega$

$$1k\Omega = 0.66 \| 2.7k\Omega$$

$$1k\Omega = \frac{0.66R_{B1} \cdot 2.7k\Omega}{0.66R_{B1} + 2.7k\Omega}$$

$$\boxed{R_{B1} = 2.406k\Omega}$$

so $\frac{R_{B2}}{2.4k + R_{B2}} = 0.66$

$$1.58k + 0.66R_{B2} = R_{B2}$$

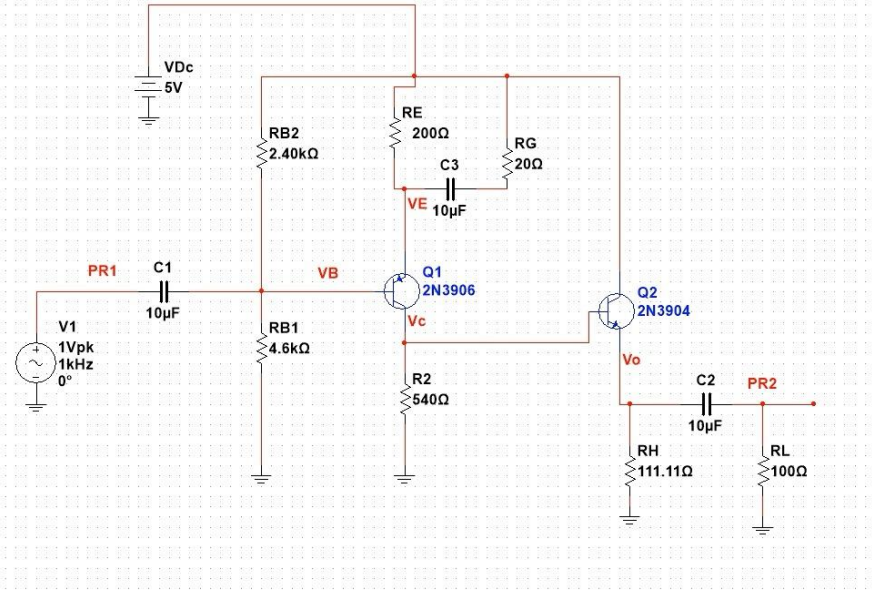
$$\boxed{R_{B2} = 4.67k\Omega}$$

$\therefore$

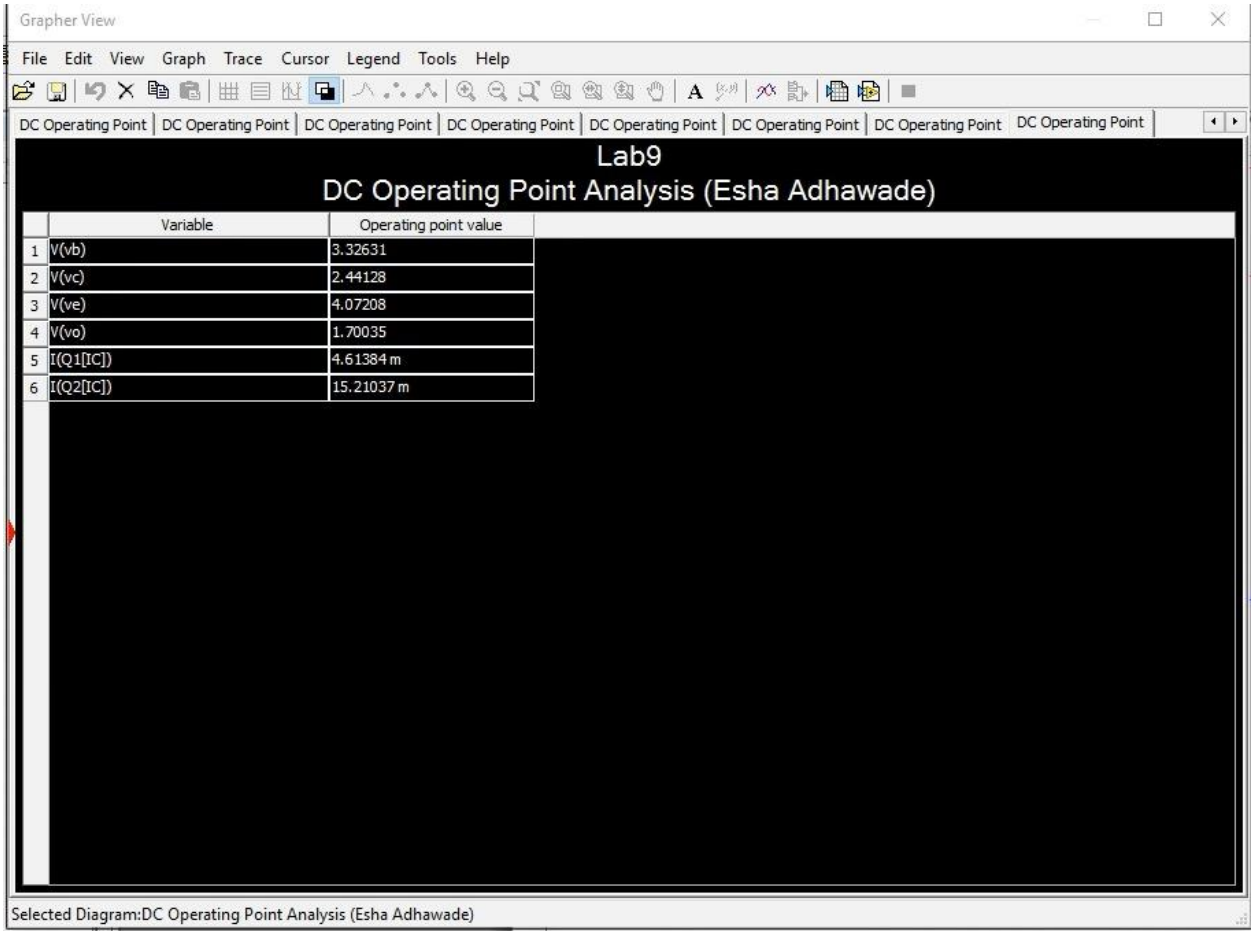
$R_{B1} = 2.406k\Omega$
$R_{B2} = 4.67k\Omega$
$R_{C1} = 24.467\Omega$
$R_L = 540\Omega$
$R_M = 110\Omega$

Simulations (on Multisim)

Schematic

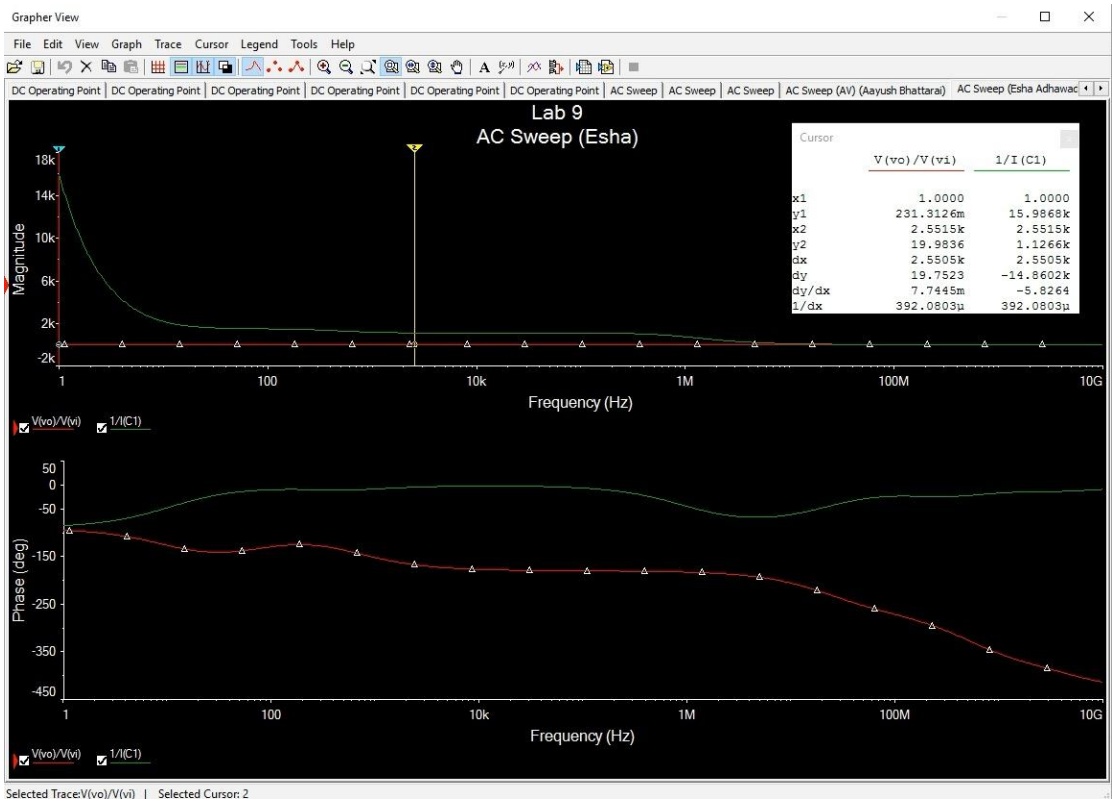


DC Operating Point

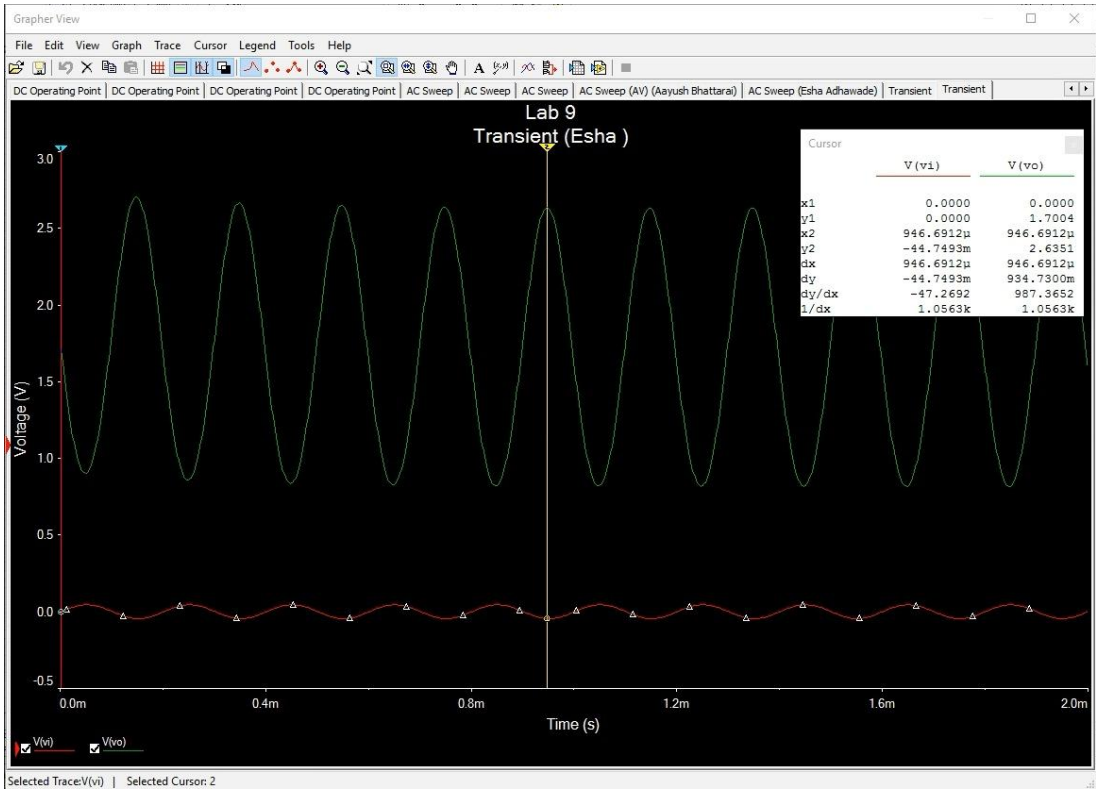


	Variable	Operating point value
1	V(vb)	3.32631
2	V(vc)	2.44128
3	V(ve)	4.07208
4	V(vo)	1.70035
5	I(Q1[IC])	4.61384 m
6	I(Q2[IC])	15.21037 m

A_v / R_i



Transient



Fourier

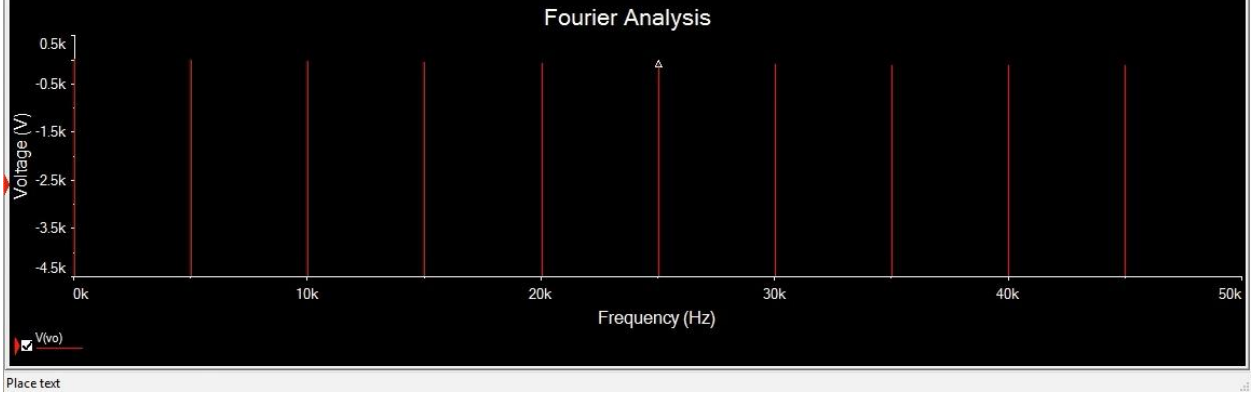
Grapher View

File Edit View Graph Trace Cursor Legend Tools Help

DC Operating Point | DC Operating Point | DC Operating Point | AC Sweep | AC Sweep | AC Sweep | AC Sweep (AV) (Aayush Bhattarai) | AC Sweep (Esha Adhawade) | Transient | Transient | Fourier | Fourier | Fourier | Fourier

Design1

1	Fourier analysis for V(vo):					
2	DC component:	1.70353				
3	No. Harmonics:	9				
4	THD:	2.3239 %				
5	Grid size:	256				
6	Interpolation Degree:	1				
7						
8	Harmonic	Frequency	Magnitude	Phase	Norm. Mag	Norm. Phase
9	0	0	1.70353	0	1.87423	0
10	1	5000	0.908922	-173.86	1	0
11	2	10000	0.021006	-74.857	0.0231108	99.0017
12	3	15000	0.00220587	-160.96	0.00242691	12.8969
13	4	20000	0.000198054	109.871	0.0002179	283.729
14	5	25000	2.42396e-05	23.5988	2.66685e-05	197.458
15	6	30000	5.72983e-06	-15.997	6.30398e-06	157.862
	7	35000	3.5549 1e-06	-0.32252	3.91112e-06	173.536



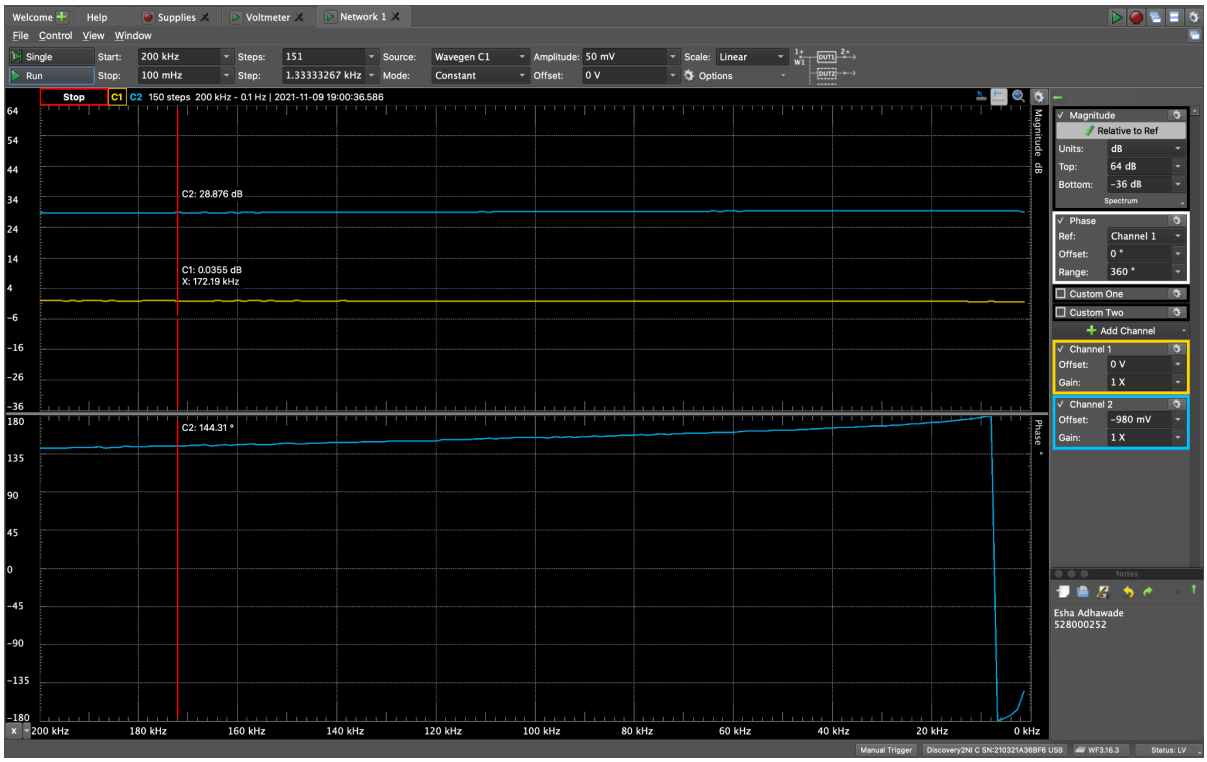
Place text

Measurements

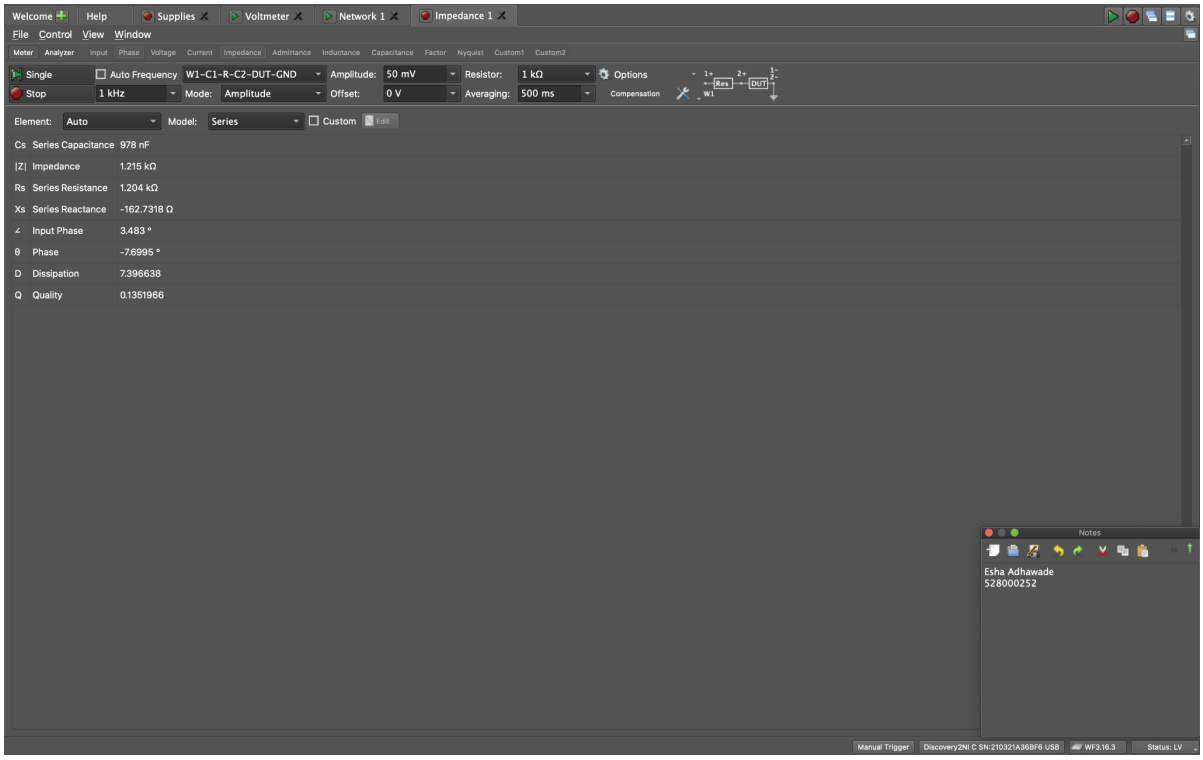
DC Voltages

- DC voltages in Data Tables

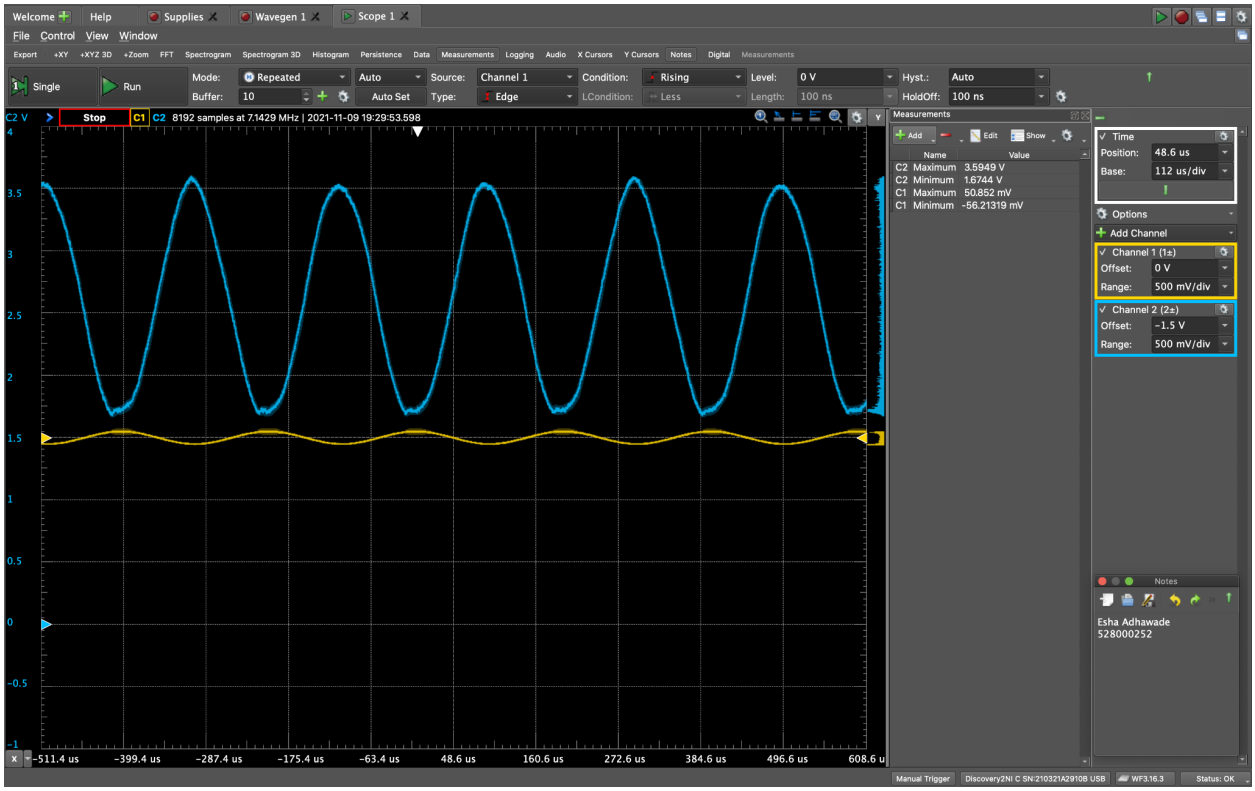
Network Analyzer - A_V



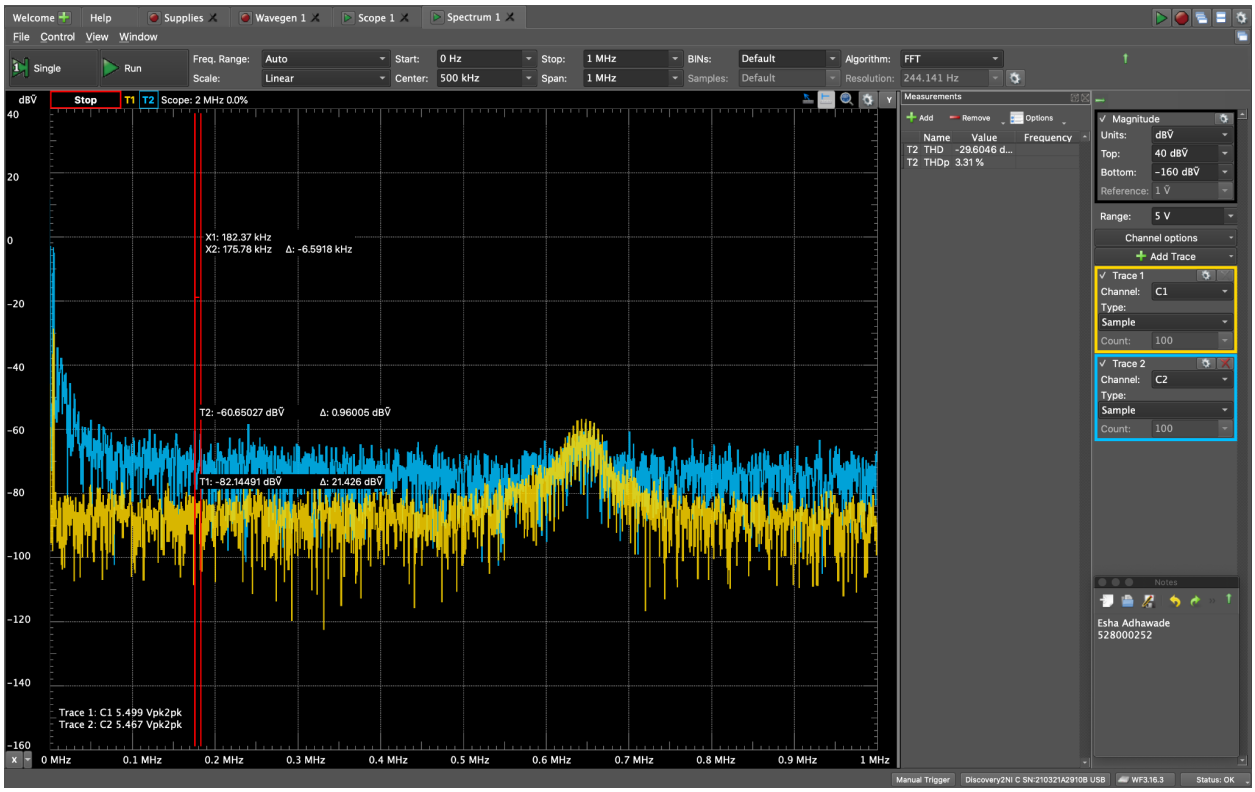
Network Analyzer - R_i



Transient



THD



Data Tables

	Calculations	**Simulations**	**Measurements**
Gain	20 dB	19.98 dB	28.87 dB
R_i	-	1.1266 kΩ	1.1215 kΩ
Transient	N/A	934 mV	1.9205 V
THD	N/A	2.3239%	3.31%

	Simulations	**Measurements**
V_{RB2}	3.32631 V	3.324 V
V_{RE}	4.07208 V	4.001 V
V_{RC}	2.44128 V	2.545 V
V_o	1.70035 V	1.948 V
I_{C1}	4.61384 mA	4.824 mA
I_{C2}	15.21037 mA	16.105 mA

Discussion

For lab 8, students learned to design a multi-stage BJT amplifier. Most of the values between the simulations and measurements were pretty consistent for the circuits. If there were any minor differences, that's probably because of component differences, old breadboards, or loose wires.