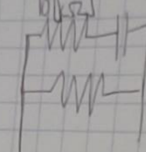
Impedance Spectroscopy

Setup

Cancerous tissue doesn't attach normally and therefore a different impedance.

10 [kΩ]



Input & output frequencies are the same if we have a linear response.

200 Ω is the unlisted resistor.

~1 [kHz] 1 [V] ⇒ rms = $\frac{1}{\sqrt{2}}$

Sensitivity: 50 [mV]

Record: f, phase, $V_{out} = V_{Green}$

current resistor

$\frac{V_{test}}{I}$ = impedance;

we need $Z_{(f)}$

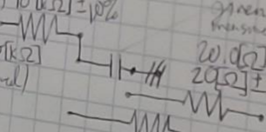
Breadboard:

(given) 10 [kΩ] ± 10%

10.02 ~~9.835~~ [kΩ] (measured)

given: 0.22 [mF]
measured: 238 [nF]

20.0 [Ω] ± (measured)
20 [Ω] ± 5% (given)



200 [Ω] ± 5% (given)
197.7 [Ω] (measured)

f	Phase	V_{out}
1052 [Hz]	18.9 [deg]	13.57 [mV]
10024 [Hz]	14.9 [deg]	13.73 [mV]
~~9/098 [Hz]~~ 0.4	~~15.23 [deg]~~	13.23 [mV]
10 [Hz]	21.3 [deg]	~~13.51 [mV]~~
79 [Hz]	0.1 [deg]	12.59 [mV]

Compare with theoretical
Divide – phase-sensitive measurements

edance Spectroscopy
ve Fitting

general form for a circuit shaped like ours
would be:

$$V = I_0 |Z|, \quad |Z| = \sqrt{Re\{Z\}^2 + Im\{Z\}^2}$$

$$V = I_0 \sqrt{Re\{Z\}^2 + Im\{Z\}^2}$$

$$Z = R_1 \frac{(1 + \omega^2 C^2 R_2 (R_1 + R_2)) - j\omega C R_1}{1 + \omega^2 C^2 (R_1 + R_2)^2}$$

$$Re\{Z\} = R_1 \frac{1 + \omega^2 C^2 R_2 (R_1 + R_2)}{1 + \omega^2 C^2 (R_1 + R_2)^2}$$

$$Im\{Z\} = \frac{-R_1 \omega C}{1 + \omega^2 C^2 (R_1 + R_2)^2}$$

$$Z = \frac{1}{\frac{1}{R_1} + \frac{1}{Z_2}} = \frac{R_1}{1 + \frac{R_1}{Z_2}} = \frac{R_1 (R_2 + \frac{1}{j\omega C})}{R_1 + R_2 + \frac{1}{j\omega C}}$$

$$= R_1 \frac{(R_2 + \frac{1}{j\omega C}) j\omega C}{R_1 j\omega C + R_2 j\omega C + 1} = R_1 \frac{R_2 j\omega C + 1}{1 + (R_1 + R_2) j\omega C}$$

$$= R_1 \frac{(1 + R_2 j\omega C)(1 - (R_1 + R_2) j\omega C)}{1 + (R_1 + R_2)^2 \omega^2 C^2}$$

$$= \frac{R_1}{1 + \omega^2 C^2 (R_1 + R_2)^2} \left(1 - (R_1 + R_2) j\omega C + R_2 j\omega C + R_2 \omega^2 C^2 (R_1 + R_2)\right)$$

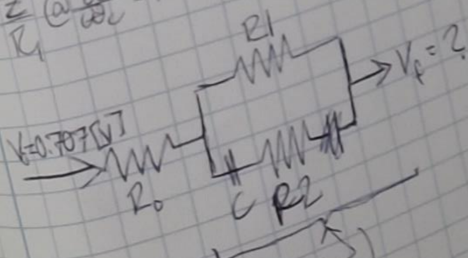
$$= R_1 \frac{1 - R_1 j\omega C + R_2 \omega^2 C^2 (R_1 + R_2)}{1 + \omega^2 C^2 (R_1 + R_2)^2}$$

$$V = I_0 \frac{\sqrt{(1 + (2\pi f)^2 C^2 R_2 (R_1 + R_2))^2 + ((2\pi f) C R_1)^2}}{1 + (2\pi f)^2 C^2 (R_1 + R_2)^2} R_1$$

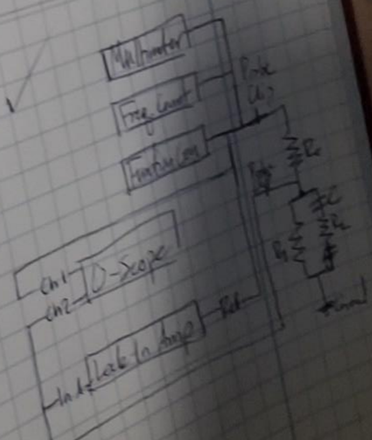
trouble using np.lm / np.Re
b/c it seems to be chasing issues

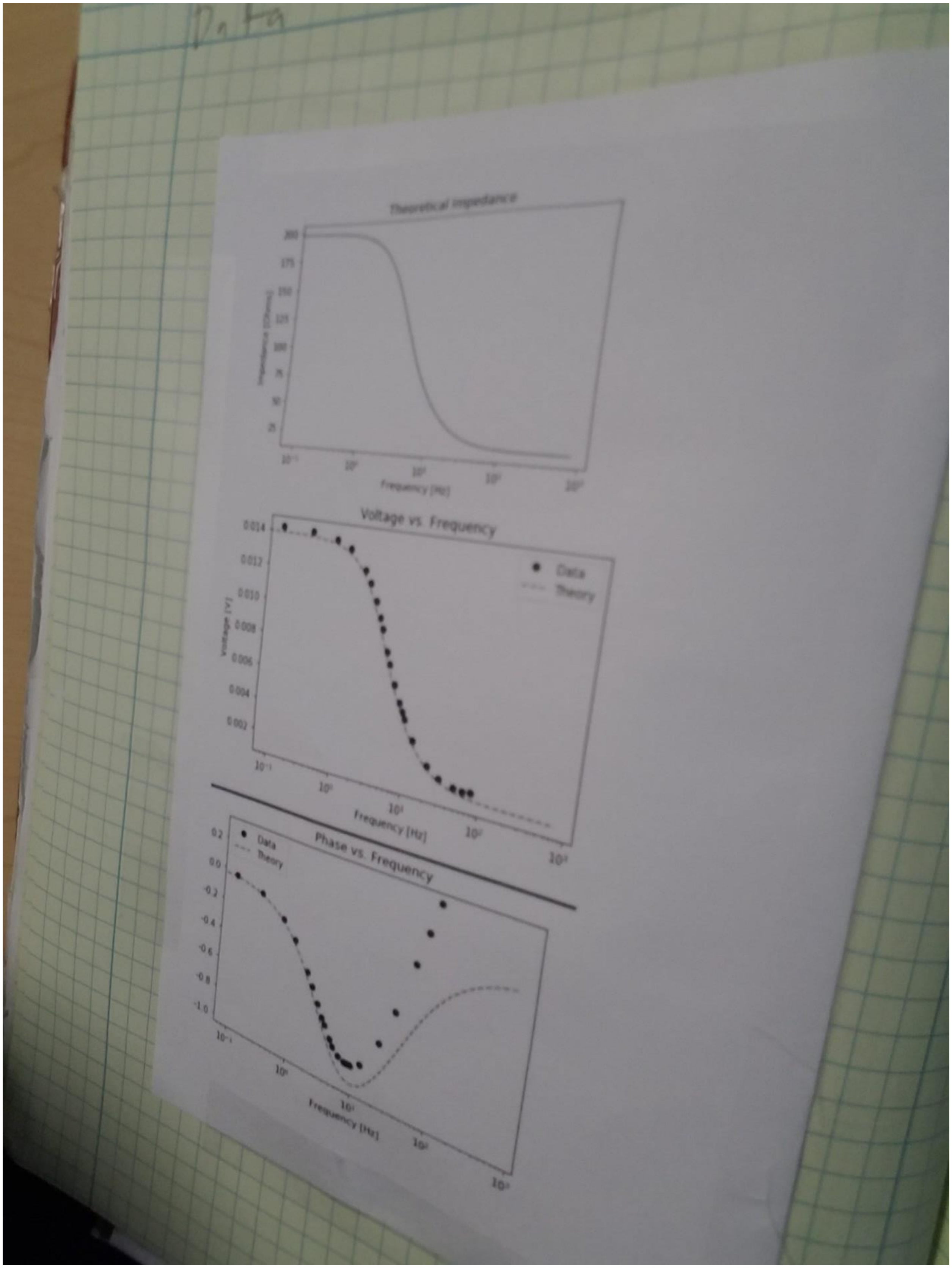
$$\phi = \tan^{-1}\left(\frac{-R_1 \omega C}{1 + (2\pi f)^2 C^2 R_2 (R_1 + R_2)}\right)$$

if $\frac{Z}{R_1}$ @ $\frac{\omega}{\omega_c} = 1$ then everything will ? ✓



Z_{system} (under test!)





Data
Theoretical Impedance
Frequency [Hz]
Voltage vs. Frequency
Data
Theory
Voltage [V]
Frequency [Hz]
Phase vs. Frequency
Data
Theory
Frequency [Hz]