Lab 1

Physics 11A Spring 2026, Jan. 29

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1.1

(a)

Resistor	Resistance ± 0.15 kΩ (1%) from data sheet
1	9.90 → 9.90
2	9.89 → 9.90 repeat
3	9.97
4	9.95
5	9.93

manufacturer spec

all agree w/ 10 kΩ ± 0.1 kΩ

(b)

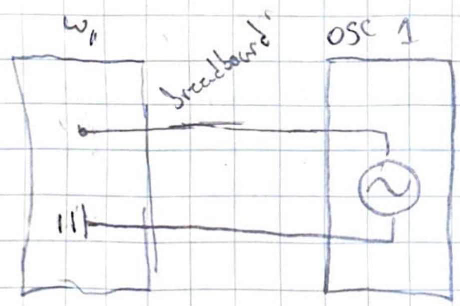
Capacitor	Capacitance
1	9.39 ± 0.43 nF
2	9.90 ± 0.45 nF
3	9.66 ± 0.44 nF
4	8.57 ± 0.39 → does not agree w/ 10 ± 1 nF
5	9.28 ± 0.42 nF

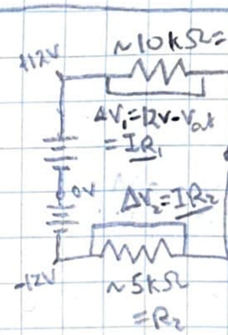
1.2

Voltage Source	Voltage
+12V	12.09 ± 0.17 V
−12V	−12.10 ± 0.17 V
+5V	5.06 ± 0.1 V
+3.3V	3.31 ± 0.08 V

all agree!

1.3





$I = \frac{12V - (-12V)}{R_1 + R_2}$

1.4

(a) total V: 24V, total R: 15.1k → $\Delta V_1 = R_1 I$, $\Delta V_2 = R_2 I$

→ total $\boxed{I = 1.59 \text{ mA}}$ → $\boxed{\Delta V_1 = 15.9 \text{ V}, \ \Delta V_2 = 8.1 \text{ V}}$

$V_{out} = 12V - \Delta V_1 = \boxed{-3.9 V = V_{out}}$

(b) $R_1 = 9.90 \pm 0.15 \text{ k}\Omega$, $R_2 = 5.01 \pm 0.1 \text{ k}\Omega$

↳ $\boxed{I = 1.622 \pm 0.250 \text{ mA}}$, $\boxed{V_1 = 16.06 \pm 0.27 \text{ V}}$ $\boxed{V_2 = 8.128 \pm 0.158 \text{ V}}$

$\boxed{V_{out} = -3.97 \pm 0.27 \text{ V}}$ w/i margin of error, mostly

1.4

(c) measured V_{out} : -3.97 ± 0.087 V relative to ground

(d) measured $\Delta V_1 = 16.05 \pm 0.21$ V , $\Delta V_2 = 8.13 \pm 0.13$ V

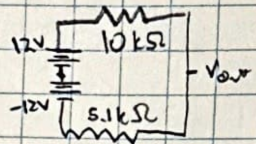
(e) Measured $I = 1.602 \pm 0.032$ mA

wZH
1/26/26

(f) calculated $R_1 = 9.900 \pm 0.150$ kΩ
$R_2 = 5.01 \pm 0.10$ kΩ

1.5

Re-drawing the circuit here:



(a) $P = (\Delta V)^2 / R$

$\hookrightarrow P_1 = (15.89)^2 / 10k = \boxed{0.0253 \text{ W}}$

$\hookrightarrow P_2 = (8.11)^2 / 5.1k = \boxed{0.0129 \text{ W}}$

↓

(b) $R_{min} = (24V)^2 / 0.25W = \boxed{2304\ \Omega}$

(c) R_1/R_2 is the same → V_1, V_2 are the same

for V_1: $R_{1,min} = (15.89)^2 / 0.25 = 1010\ \Omega \approx 0.1 R_1$

for V_2: $R_{2,min} = (8.11)^2 / 0.25 = 262\ \Omega \approx 0.05 R_2$

$\boxed{\text{Resistor } \boxed{1}}$ hits 0.25W first (scaling geometrically) at $\boxed{1010\ \Omega}$

(d) $\left(\frac{1010}{10000}\right)(5100\Omega) = 515\Omega \rightarrow P_2 = (8.11)^2/515 = 0.128$ W

$\rightarrow P_{total} = 0.25W + 0.128W = \boxed{0.378 \text{ W}}$

1.6

$\frac{1}{2}(1+\cos(2\omega x))$

(a) $\int_0^{2\pi/\omega} \sin^2(\omega t)\,dt = \frac{1}{2}x - \frac{1}{4\omega}\sin(2\omega x)\Big|_0^{2\pi/\omega} = \frac{\pi}{\omega} \to \langle \sin^2(x)\rangle = \frac{\omega}{2\pi}\left(\frac{\pi}{\omega}\right) = \frac{1}{2}$

$\to \boxed{V_{RMS} = 2^{-1/2}} \cdot \text{Amplitude}$

(b) $f(x) = \begin{cases} 1-x & x\in(0,2) \\ -3+x & x\in(2,4) \end{cases} \to (f(x))^2 = \begin{cases} (x-1)^2 & 0\le x\le 2 \\ (x-3)^2 & 2\le x\le 4 \end{cases} \to$

$\int_0^4 f(x) = \frac{(x-1)^3}{3}\Big|_0^2 + \frac{(x-3)^3}{3}\Big|_2^4 = \frac{1}{3}(4) \to V_{RMS} = \left(\frac{4}{4}\frac{1}{3}\right)^{1/2} = \boxed{3^{-1/2}} \cdot \text{Amplitude}$

(c) |Square wave| = 1 → average = 1 → $\boxed{V_{RMS} = 1} \cdot$ Amplitude

1.7

(a) 0.708 ± 0.017 V (From DMM)

(b) 707.1 ± 0.05 mV (from ADS Voltmeter)

(c) 0.69858 ± 0.000005 V (from ADS Scope)
↳ this value agrees with the DMM measurement!

(d) Peak2Peak: 2.0021 V ± 5e-5 V
Amplitude: 0.99905 V ± 5e-6 V
$(*2^{-1/2})$ ↳ expected V_{RMS}: 0.70643 ± 4e-6 → does not agree w/ ADS, but does agree with DMM - errors were underestimated

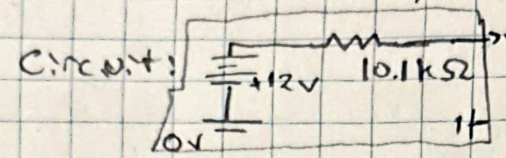
(e)

Frequency	V_{RMS} with: DMM (V)	ADS Voltmeter (mV)	ADS Measurements (V)
10	0.667 ± 0.017	707.3 ± 0.05	0.70706 ± 5e-6
20	0.698 ± 0.017	707.3 ± 0.05	0.70695 ± 5e-6
50	0.707 ± 0.017	707.2 ± 0.05	0.70704 ± 5e-6
100	0.708 ± 0.017	707.1 ± 0.05	0.70696 ± 5e-6
200	0.709 ± 0.017	707.1 ± 0.05	0.70696 ± 5e-6
500	0.708 ± 0.017	703.2 ± 0.05	0.70694 ± 5e-6
1000	0.705 ± 0.017	691 ± 0.05	0.70695 ± 5e-6
2000	0.682 ± 0.017	643.1 ± 0.05	0.70705 ± 5e-6
5000	0.352 ± 0.013	352.9 ± 0.05	0.70733 ± 5e-6
10000	0.039 ± 0.009	120.5 ± 0.05	0.70552 ± 5e-6

1.8

(a) Measured: 6.02 ± 0.09 V, 0.594 ± 0.017 mA → $\boxed{10.1 \pm 0.3 \ k\Omega}$

Circuit:



Predicted: $5.1k + \left(\frac{1}{10k} + \frac{1}{10k}\right)^{-1}$

$= 5.1k + \frac{10k}{2} = 10.1 k\Omega$ ✓

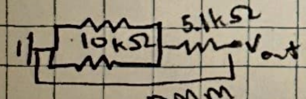
(b)

R_L	V_{out} (V)	I_{out} (mA)
330Ω	0.193 ± 0.011	0.58 ± 0.01
1kΩ	0.538 ± 0.015	0.54 ± 0.01
3kΩ	1.364 ± 0.026	0.45 ± 0.01
10kΩ	3.00 ± 0.05	0.3 ± 0.01
33kΩ	4.60 ± 0.07	0.14 ± 0.003
100kΩ	5.46 ± 0.08	0.055 ± 0.001

full plot in pdf

all values agree!

(c)



measured resistance = 9.94 ± 0.10 kΩ

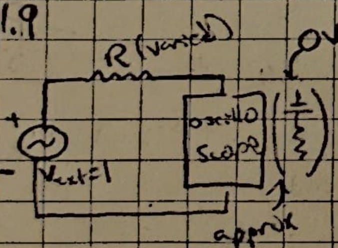
it agrees with theory but only w/i 0.5σ

1.9

$I = \frac{V_{ext}}{R + Z_{th}}$

$V_{in}(R + Z_{th}) = V_{ext}(Z_{th})$

↳ $Z_{th} = R(V_{in}) / (V_{ext} - V_{in})$

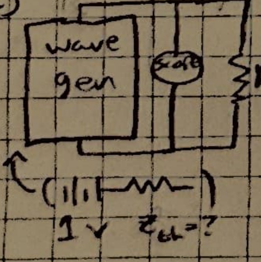


R	measured V_{in}	Predicted Z_{th}
0Ω	0.999 ± 5e-4	0 ± ∞ Ω → discounted
100kΩ	0.91 ± 5e-3	1.01 ± 0.07 MΩ
1MΩ	0.51 ± 5e-3	1.041 ± 0.033 MΩ
5.6MΩ	0.1 ± 5e-2	1.0 ± 0.4 MΩ

↳ $\boxed{\text{Avg: } 1.01 \pm 0.13 \ M\Omega}$

1.10

(a)



$R_L = \infty$ ↓ $V_s = 1V$ (0.999 ± 5e-4) ↓ ✓

$R = (R_{scope}^{-1} + R_L^{-1})^{-1} \approx R_L$.

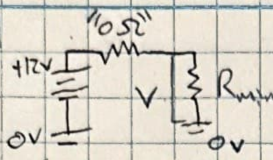
(b)

R (Ω)	V (V)	$Z_{waveform}$
33	0.39 ± 5e-3	51.6 ± 1.6 Ω
100	0.66 ± 5e-3	51.5 ± 1.7 Ω
330	0.86 ± 5e-3	53.7 ± 2.5 Ω
1k	0.95 ± 5e-3	53 ± 6 Ω

$V_{out} = \underbrace{V_{th}}_{1V}\left(\frac{R}{R + Z_{th}}\right) \to Z_{th} = R\left(\frac{1}{V_{out}} - 1\right)$

Final: $\boxed{52.4 \pm 1.7 \ \Omega}$

1.11



$P = V^2/R = 0.25\,W \rightarrow R_{min} = \text{"}12V\text{"}^2/0.25 = 576\,\Omega$

DMM measured 11.93 ± 0.12 V with $680\,\Omega \pm 7$

vs $12.09 \pm 0.17\,\Omega$ from earlier

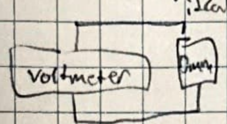
$(12.09)\frac{R_{min}}{R_{min}+Z} = 11.93 \rightarrow Z_{min} = R_{min}\left(\frac{12.09}{11.93} - 1\right) = 680\left(\frac{12.09}{11.93} - 1\right) = \boxed{9 \pm 14\,\Omega}$

$\boxed{\text{vs } 01/29}$

12

$V_{ideal} \approx 1V$

for voltage:



for resistance:

Setting	V_0 open voltage	R_L	V_L load voltage
200	$1.09 \pm 5e{-3}$	100	$0.990 \pm 5e{-4}$
2k	$1.09 \pm 5e{-3}$	1k	$0.266 \pm 5e{-4}$
20k	$1.08 \pm 5e{-3}$	10k	$0.473 \pm 5e{-4}$
200k	$1.03 \pm 5e{-3}$	100k	$0.504 \pm 5e{-4}$
2M	$0.709 \pm 5e{-4}$	1M	$0.415 \pm 5e{-4}$

$V_D \equiv V_{Th}$

$\sim V_{th}$? only if $R_{voltmeter} \gg R_{DMM} = R_D \equiv R_{Th}$

$Z_V \gtrsim 1M\Omega,\ V_V = 0$

$V_0 = V_D\left(\frac{Z_V}{Z_V + R_D}\right) \overset{?}{\approx} V_D, \quad R_C = (Z_V^{-1} + R_L^{-1})^{-1}, \quad V_L = V_D\left(\frac{R_C}{R_C + R_D}\right) \rightarrow$

$R_D = R_C\left(\frac{V_D}{V_L} - 1\right)$

$\downarrow$

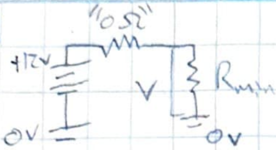
$V_0\left(\frac{Z_V + R_D}{Z_V}\right) = V_L\left(\frac{R_C + R_D}{R_C}\right)$

$\hookrightarrow R_D = \frac{(R_C V_0 Z_V - R_C V_L Z_V)}{(Z_V V_L - R_C V_0)} \rightarrow V_D = V_0\left(\frac{Z_V + R_D}{Z_V}\right)$

Calculations:

Setting	R_C (Ω)	R_D (Ω)	V_D (V)
200	~100	10.1 ± 0.8	$1.09 \pm 5e{-3}$
2k	~1k	3.11 ± 0.09 e3	$1.093 \pm 5e{-3}$
20k	~9.9k	1.300 ± 0.034 e4	$1.094 \pm 5e{-3}$
200k	~91k	1.16 ± 0.04 e5	1.148 ± 0.019
2M	~500k	2.4 ± 0.8 e6	2.4 ± 0.7

1.11



$P = V^2/R = 0.25\,W \rightarrow R_{min} = \text{"}12V\text{"}^2/0.25 = 576\,\Omega$

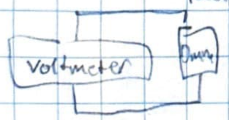
DMM measured $11.93 \pm 0.12\,V$ with $680\,\Omega \pm 7$
vs $12.09 \pm 0.17\,\Omega$ from earlier

$$(12.09)\frac{R_{min}}{R_{min}+Z} = 11.93 \rightarrow Z_{min} = R_{min}\left(\frac{12.09}{11.93} - 1\right) = 680\left(\frac{12.09}{11.93} - 1\right) = \boxed{9 \pm 14\,\Omega}$$

1.12 $\boxed{\text{vs } 01/29}$

$V_{ideal} \approx 1V$

for voltage:



for resistance:

Setting	V_o open voltage	R_L	V_L load voltage
200	$1.09 \pm 5e{-3}$	100	$0.990 \pm 5e{-4}$
2k	$1.09 \pm 5e{-3}$	1k	$0.266 \pm 5e{-4}$
20k	$1.08 \pm 5e{-3}$	10k	$0.473 \pm 5e{-4}$
200k	$1.03 \pm 5e{-3}$	100k	$0.504 \pm 5e{-4}$
2M	$0.709 \pm 5e{-4}$	1M	$0.415 \pm 5e{-4}$

$V_D \equiv V_{Th}$

$\sim V_{th}$? only if $R_{voltmeter} >> R_{DMM} = R_D \equiv R_{Th}$

$Z_v \approx 1M\Omega$, $V_v = 0$

$$V_o = V_D\left(\frac{Z_v}{Z_v+R_D}\right) \overset{?}{\approx} V_D, \quad R_c = (Z_v^{-1} + R_L^{-1})^{-1}, \quad V_L = V_D\left(\frac{R_c}{R_c+R_D}\right) \rightarrow$$

$$R_D = R_c\left(\frac{V_D}{V_L} - 1\right)$$

$\downarrow$

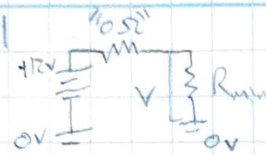
$$V_o\left(\frac{Z_v+R_D}{Z_v}\right) = V_L\left(\frac{R_c+R_D}{R_c}\right)$$

$$\hookrightarrow R_D = \frac{(R_cV_oZ_v - R_cV_LZ_v)}{(Z_vV_L - R_cV_o)} \rightarrow V_D = V_o\left(\frac{Z_v+R_D}{Z_v}\right)$$

Calculations:

Setting	R_c (Ω)	R_D (Ω)	V_D (V)
200	~100	10.1 ± 0.8	$1.09 \pm 5e{-3}$
2k	~1k	3.11 ± 0.09 e3	$1.093 \pm 5e{-3}$
20k	~9.9k	1.300 ± 0.034 e4	$1.094 \pm 5e{-3}$
200k	~91k	1.16 ± 0.04 e5	1.148 ± 0.019
2M	~500k	2.4 ± 0.8 e6	2.4 ± 0.7

1.11



$P = V^2/R = 0.25\text{ W} \rightarrow R_{min} = \text{"}12\text{V"}^2/0.25 = 576\,\Omega$

DMM measured $11.93 \pm 0.1/2$ V with $680\,\Omega \pm 7$

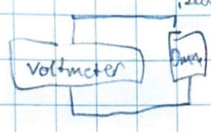
vs $12.09 \pm 0.17\,\Omega$ from earlier

$$(12.09)\frac{R_{min}}{R_{min}+Z} = 11.93 \rightarrow Z_{min} = R_{min}\left(\frac{12.09}{11.93} - 1\right) = 680\left(\frac{12.09}{11.93} - 1\right) = \boxed{9 \pm 14\,\Omega}$$

$\boxed{\text{vs } 01/2\Omega}$

1.12

for voltage:



for resistance:

$V_{ideal} \approx 1\text{V}$

Setting	V_0 open voltage	R_L	V_L load voltage
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$V_D \equiv V_{Th}$

$\sim V_{Th}$? only if $R_{voltmeter} \gg R_{DMM} = R_D \equiv R_{Th}$

$Z_v \approx 1\text{M}\Omega,\ V_v = 0$

$$V_0 = V_D\left(\frac{Z_v}{Z_v + R_D}\right) \overset{?}{\approx} V_D, \quad R_c = (Z_v^{-1} + R_L^{-1})^{-1}, \quad V_L = V_D\left(\frac{R_c}{R_c + R_D}\right) \rightarrow$$

$$R_D = R_c\left(\frac{V_D}{V_L} - 1\right)$$

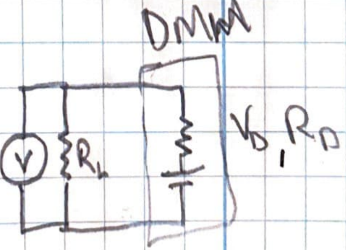
$$\downarrow$$

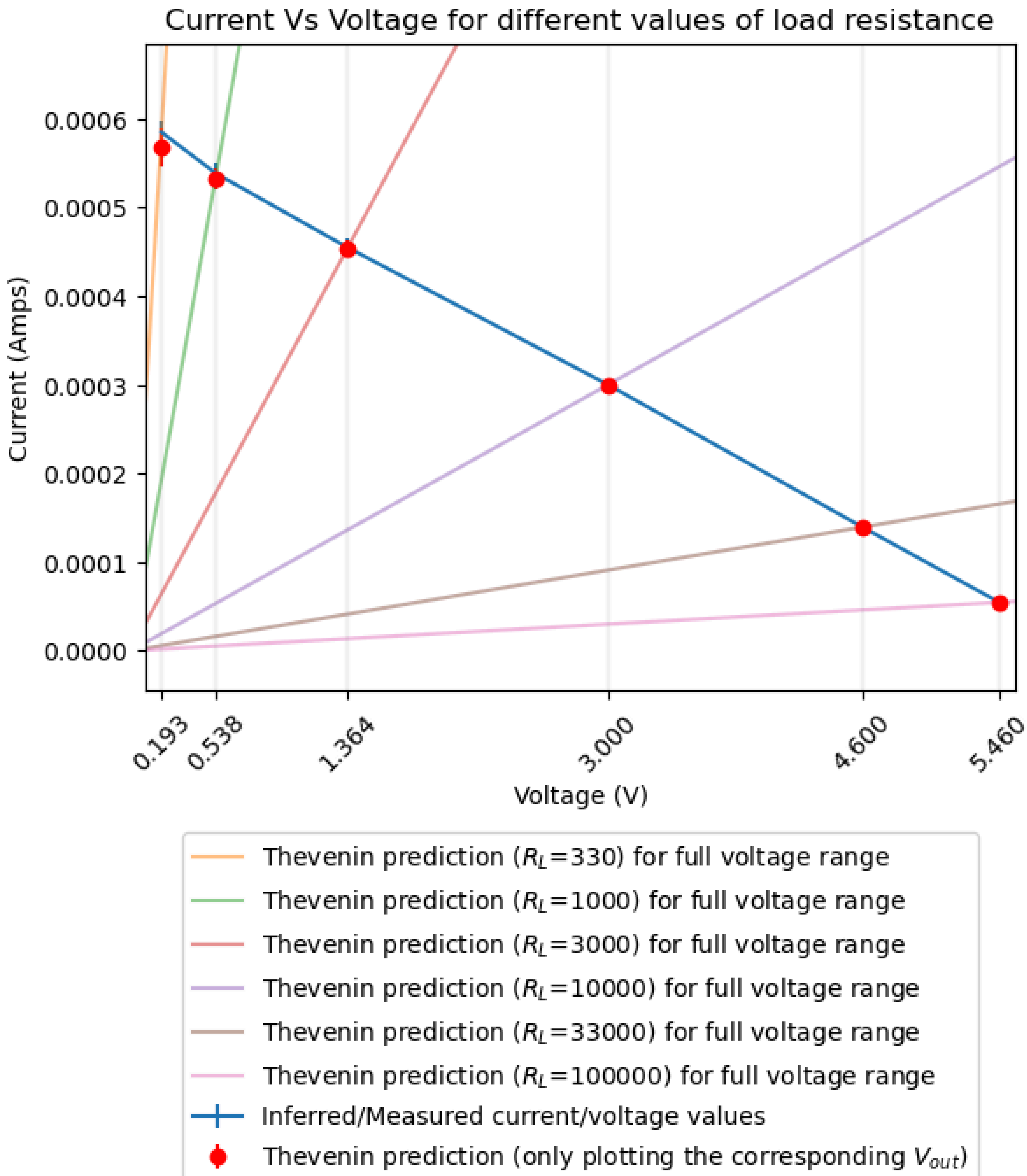
$$V_0\left(\frac{Z_v + R_D}{Z_v}\right) = V_L\left(\frac{R_c + R_D}{R_c}\right)$$

$$\hookrightarrow R_D = \frac{(R_c V_0 Z_v - R_c V_L Z_v)}{(Z_v V_L - R_c V_0)} \rightarrow V_D = V_0\left(\frac{Z_v + R_D}{Z_v}\right)$$

Calculations:

Setting	R_c (Ω)	R_D (Ω)	V_D (V)
200	~100	10.1 ± 0.8	1.09 ± 5e-3
2k	~1k	3.11 ± 0.09 e3	1.093 ± 5e-3
20k	~9.9k	1.300 ± 0.034 e4	1.094 ± 5e-3
200k	~91k	1.16 ± 0.04 e5	1.148 ± 0.019
2M	~500k	2.4 ± 0.8 e6	2.4 ± 0.7




Current Vs Voltage for different values of load resistance
Current (Amps)
0.0006
0.0005
0.0004
0.0003
0.0002
0.0001
0.0000
0.193
0.538
1.364
3.000
4.600
5.460
Voltage (V)
Thevenin prediction (R_L=330) for full voltage range
Thevenin prediction (R_L=1000) for full voltage range
Thevenin prediction (R_L=3000) for full voltage range
Thevenin prediction (R_L=10000) for full voltage range
Thevenin prediction (R_L=33000) for full voltage range
Thevenin prediction (R_L=100000) for full voltage range
Inferred/Measured current/voltage values
Thevenin prediction (only plotting the corresponding V_{out})