Brac University

Department of Electrical & Electronic Engineering

Semester Spring-25

Course Number: EEE203L

Course Title: Electrical Circuits II Laboratory

Section: 06

Final Project

Prepared by:

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Group Number: 03

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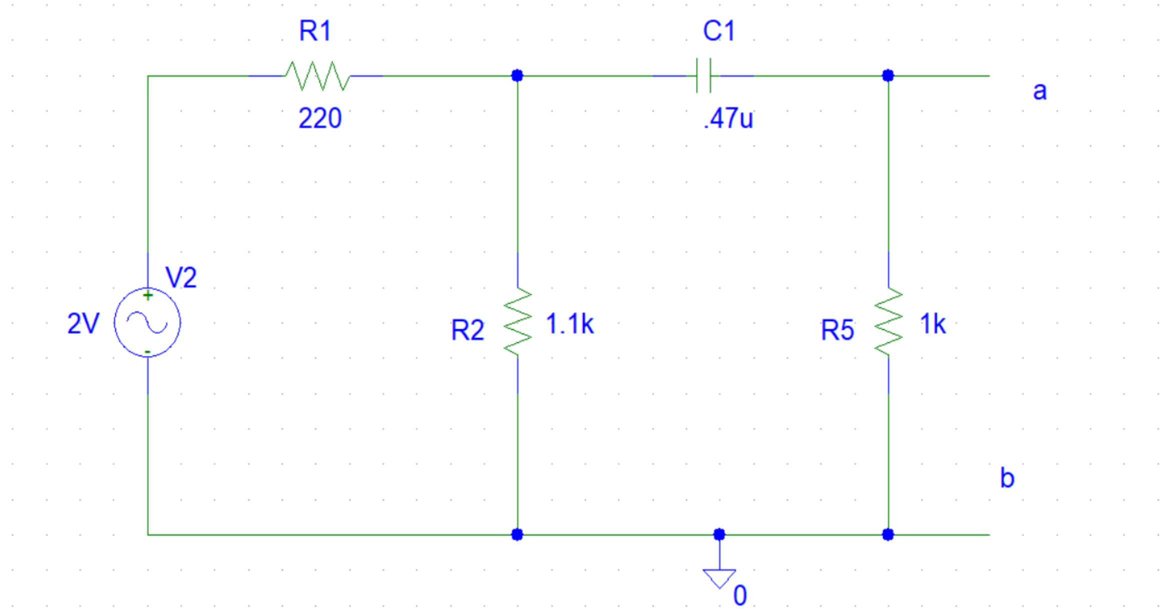
4.	24321022	Sumya Zaman

EEE203L Spring-2025 Project

Objective: This software and hardware project combination will be performed to evaluate all the steps learned in the EEE203L course.

Problem: Choose a load comprising appropriate passive elements to be connected in terminals a-b, so that the output current experiences a resonance for an input frequency of 1kHz. At the same time, ensure maximum average power is transferred to the load at the resonant frequency.

Problem circuit:



Components used:
- Resistors: 220, 1.1k, 1k - ohm
- Capacitor .47uF
- AC source with SINE wave at 2Vamp
- Ground

Circuit explanation:

The circuit has a capacitor so the net impedance of the circuit across the unused terminal a-b would be a negative complex number. To achieve resonance at 1KHz frequency with 2V input, an inductor is necessary to cancel the capacitor's negative impedance.

So, for resonant condition:

$X_c = X_L$

- ➔ $1 / 2\pi fC = 2\pi fL$
- ➔ $1 / \{ 2 \times 3.1416 \times (1 \times 10^3) \times (0.47 \times 10^{-6}) \} = 2 \times 3.1416 \times (1 \times 10^3) \times L$
- ➔ $338.627 = 6283.2 \times L$
- ➔ $L = 338.627 / 6283.2 = 0.05389\ H = 53.89mH$

According to the calculations, to achieve resonance at 1Khz frequency we need to use an inductor set to 53.89mH in the point a-b.

Now, we need to verify that the component or load placed in a-b achieves maximum average power. To achieve this state, we need to attach a resistor with the inductor in series. A resistor is necessary because it will complement the impedance of the inductor to provide and verify maximum average power transferred in a real scenario.

Applying Thevenin's theorem:

Considering a-b as Zth so the impedances of the components:

$Z1 = R1 = 220\ \Omega$
$Z2 = R2 = 1.1\ K\Omega = (1.1 \times 10^3)\ \Omega = 1100\ \Omega$
$Z3 = X_c = 1 / 2\pi fC = 1 / 2 \times 3.1416 \times (1 \times 10^3) \times (0.47 \times 10^{-6}) = 338.627\ \Omega$
$Z4 = R3 = 1\ K\Omega = 1000\ \Omega$

Turning off the voltage source:

$Zp = Z1 \parallel Z2 = (Z1 \times Z2) / (Z1 + Z2) = (220 \times 1100) / (220 + 1100) = 183.333\ \Omega$
$Zs = Zp + Z3 = 183.333 - j\ 338.627\ \Omega$
$ZTh = Zs \parallel Z4 = (Zs \times Z4) / (Zs + Z4)$
$= \{ (183.333 - j\ 338.627) \times 1000 \} / \{ (183.333 - j\ 338.627) + 1000 \}$
$= 218.89 - j\ 223.53\ \Omega$
where, $RTh = 218.89\ \Omega$ and $XTh = - 223.53\ \Omega$

Now, $X_L = 2\pi fL$
$= 2 \times 3.1416 \times (1 \times 10^3) \times (0.05)$
$= 314.16\ \Omega$
For maximum average power, the resistor should be~
$RL = \sqrt{} \{ RTh^2 + (XTh + XL)^2 \}$
$RL = \sqrt{} [\{(218.89)^2\} + (-223.53 + 314.16)^2 \}$

= 236.91 Ω

So, maximum average power transfer can be proven when the resistor will be 236.91Ω

Simulation for Resonance :

Equipments required:

1. Pspice software (Schematics)
2. Suitable PC or Laptop

Components required in software for resonance:

- VAC voltage source
- Resistor (R)
- Capacitor (C)
- Inductor (L)
- Ground (GND-Analog)

Circuit diagram (Resonance):

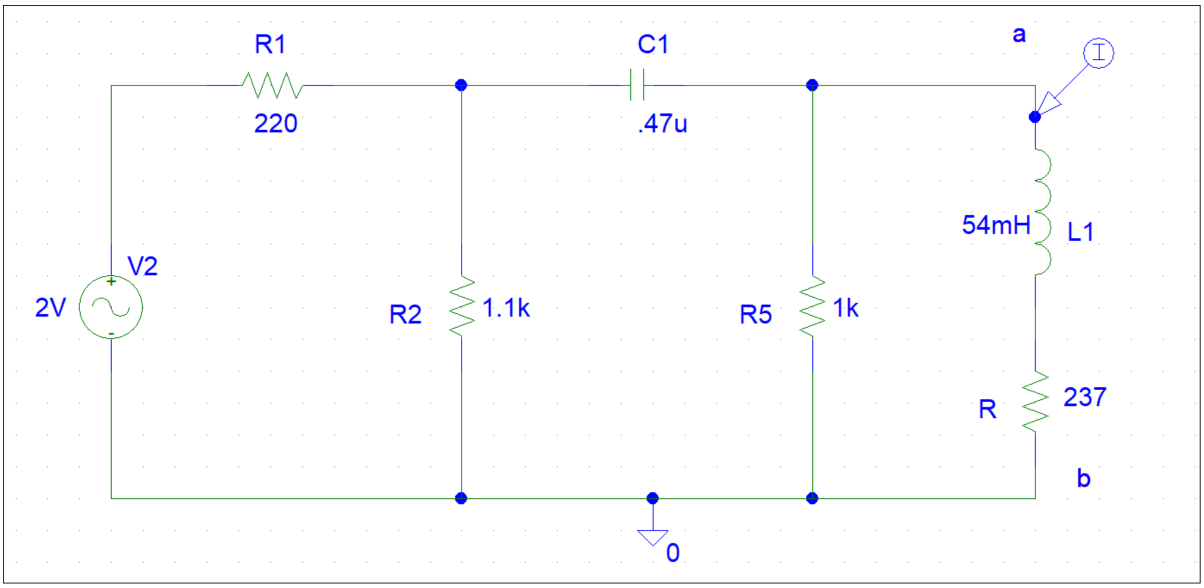
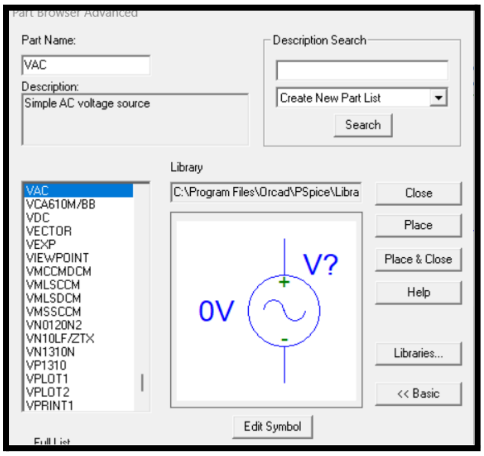
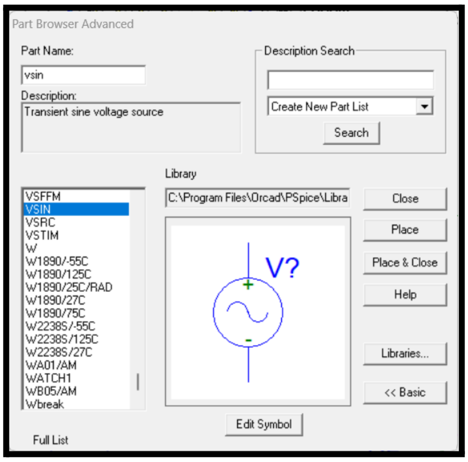


Figure: Circuit diagram for determining resonance. L1=54mH and R=237 used for easier simulation points

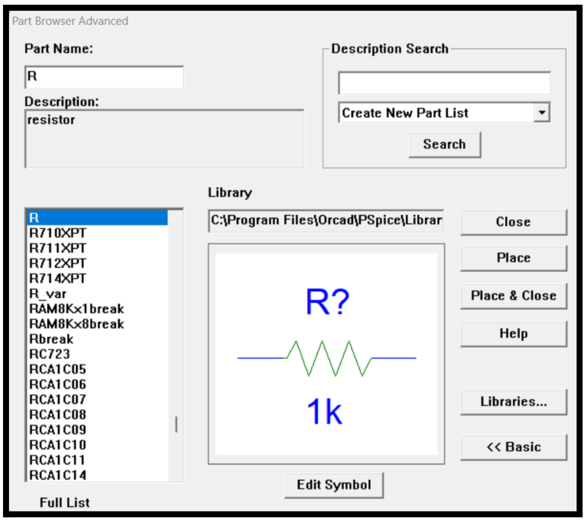
Tools, values and parameter setup menu:



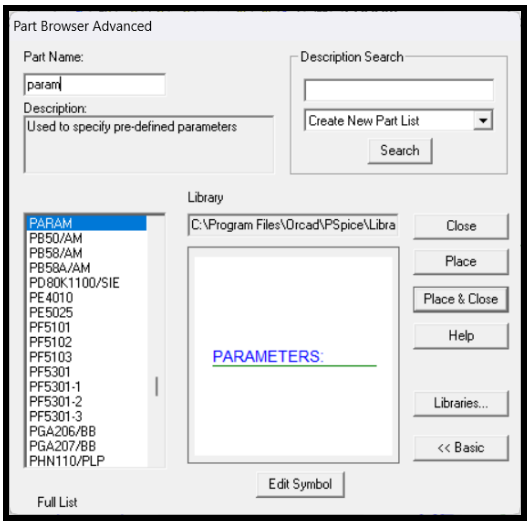
Voltage Source (VAC)



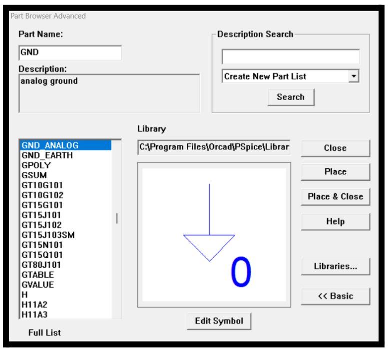
Voltage source (VSIN)



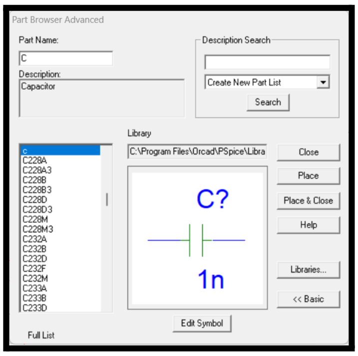
Selection of Resistor



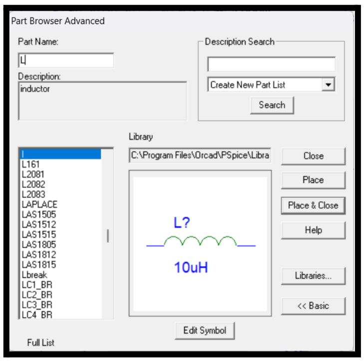
PARAMETERS in parts menu



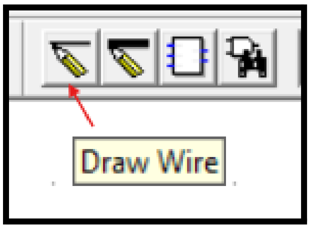
Selection of Ground



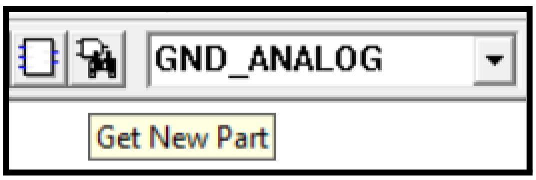
Selection of Capacitor



Inductor

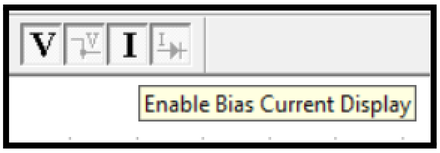


Wire tool

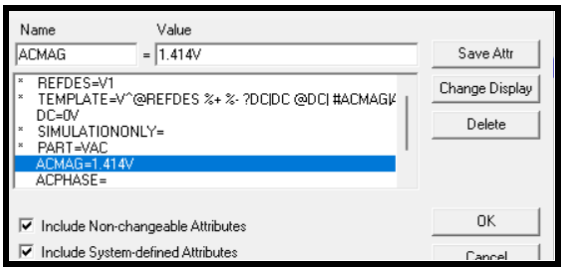


Parts menu

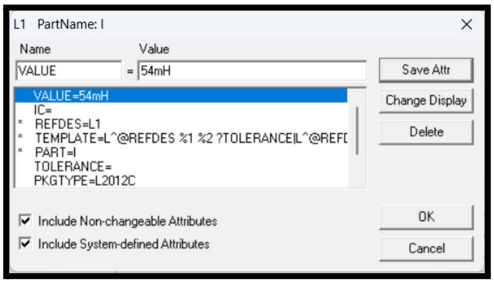
Bias Voltage



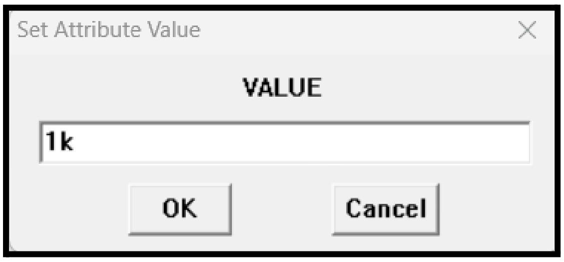
Bias Current



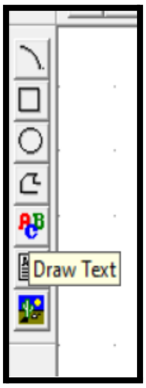
Values set in VAC



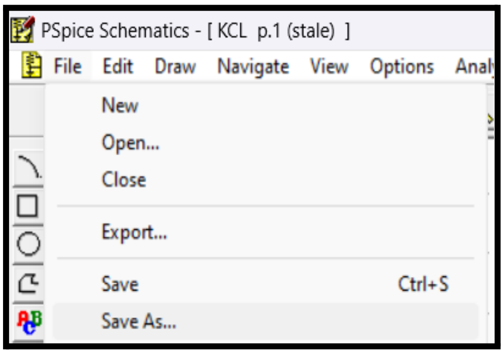
Inductor value menu



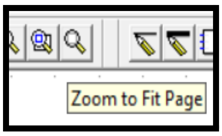
Resistor set (R value set)



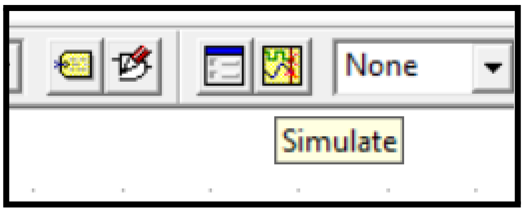
Text tools



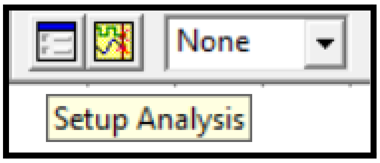
File saving

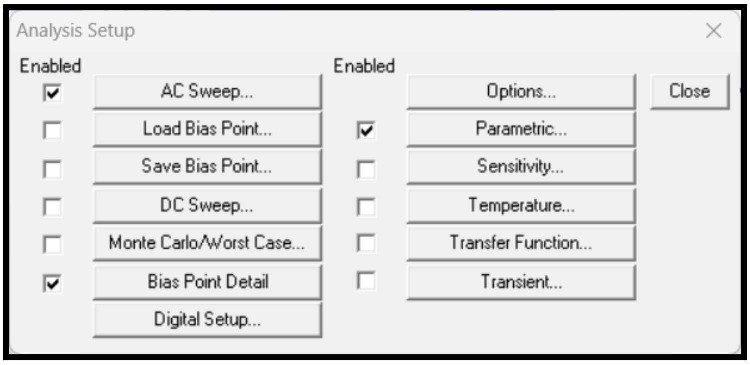


Zoom



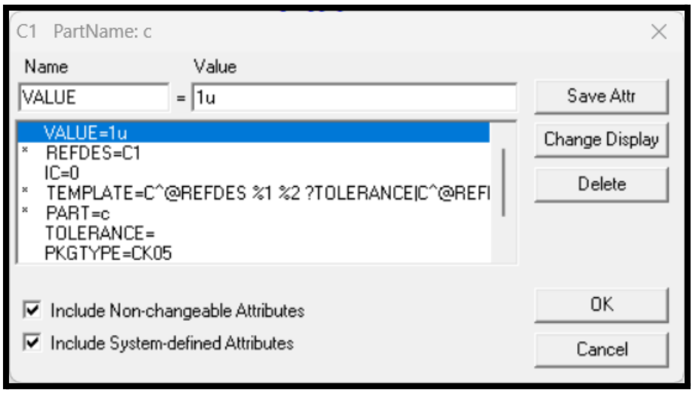
Begin Simulation

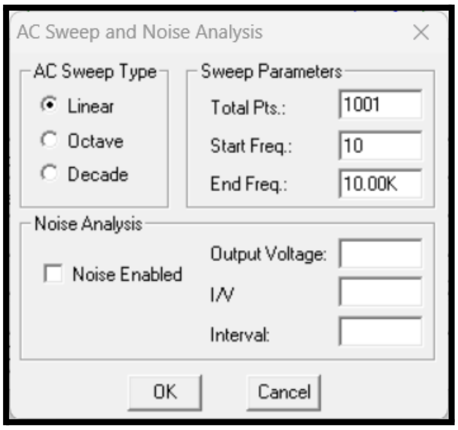




Setup Analysis Icon

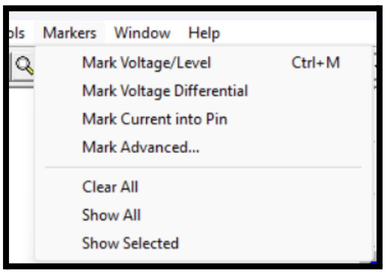
Analysis Setup Menu (AC Sweep, Parametric, Transient)

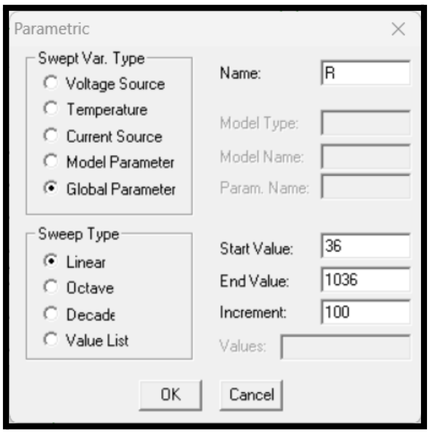


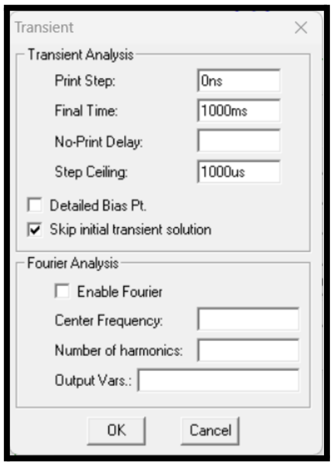


Values set in Capacitor

AC Sweep value menu



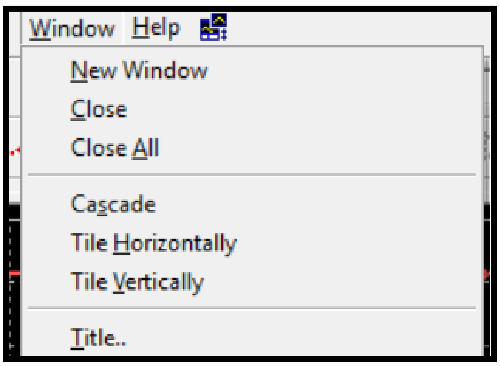


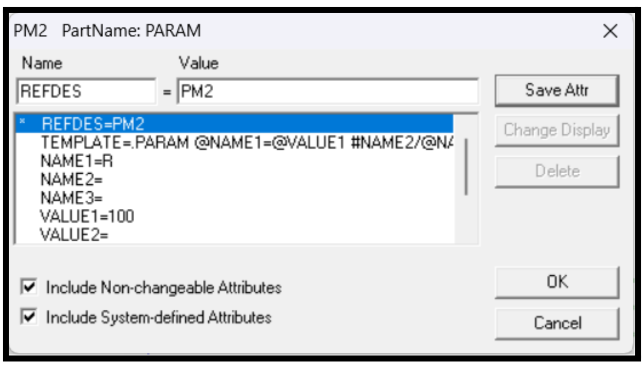


Marker Menu

Parametric value menu

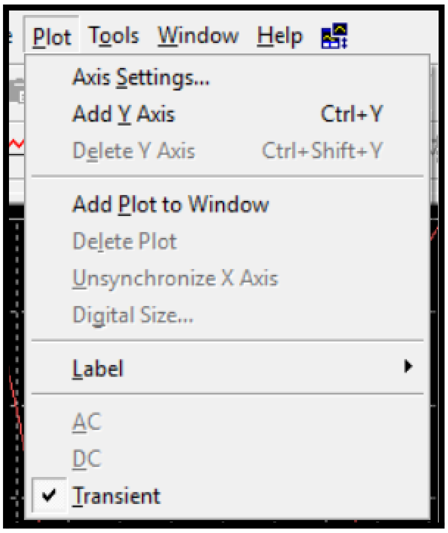
Transient value menu



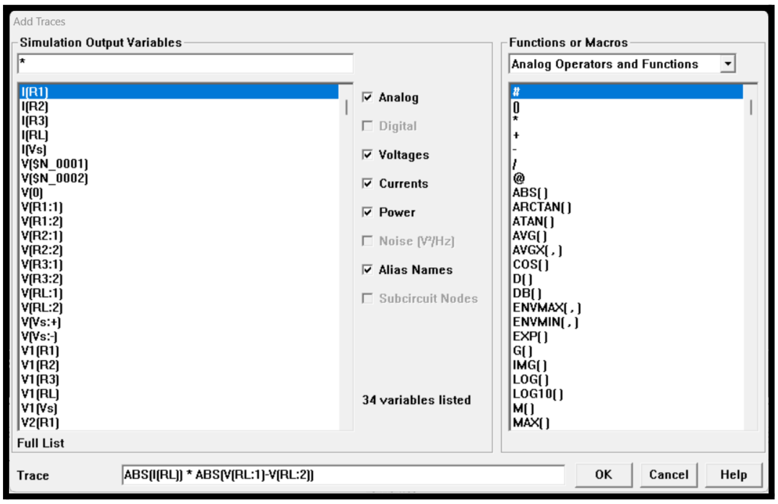


New Window Menu

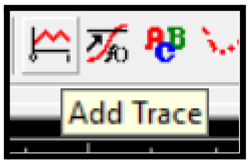
Parameter part value menu



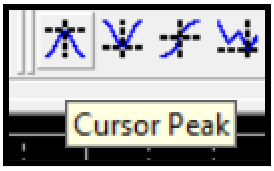
Adding new plot



Add trace value

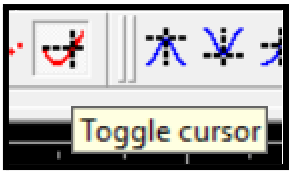


Add trace tool

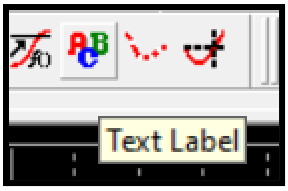


Cursor Peak tool

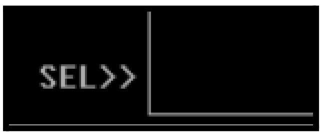
Mark Label Tool



Toggle Cursor Tool



Text Label tool



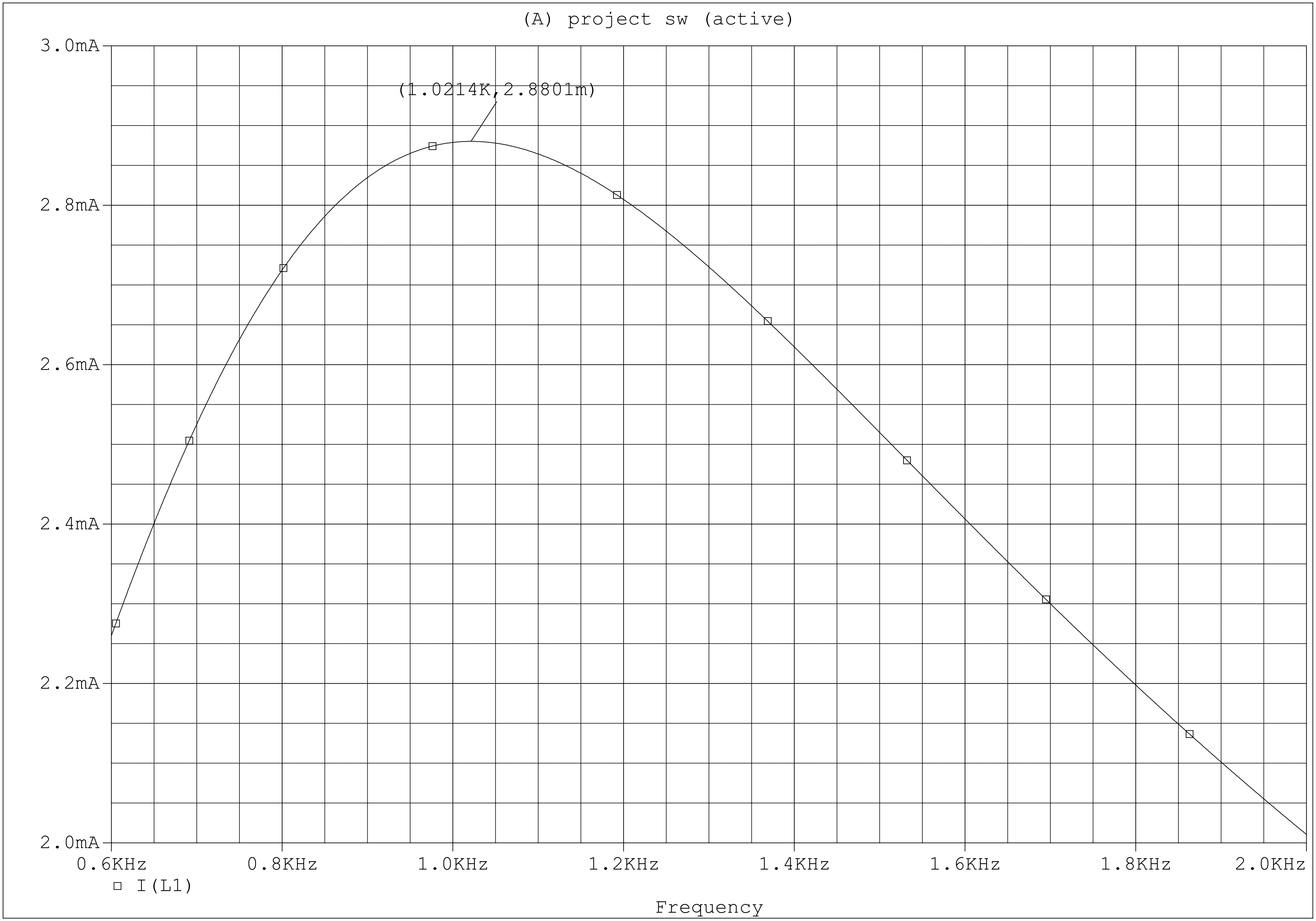
Selected Plot

After enabling cursor peak (Probe Cursor Window)

Experiment Procedure (Resonance):

1. Open Pspice Schematics software
2. Open the parts menu
3. Search the necessary parts and place them according to the diagram
4. Using the wire tool connect all the parts in the circuit
5. Rename all the parts for easier identification
6. Use the draw text and text box tool to mark necessary information
7. Set the value of resistor and capacitor.
8. Double click on VAC and set ACMAG=2V.
9. Open setup analysis and select AC Sweep.
10. In AC Sweep, set type Linear, Total Pts. 1001, Start Freq, 600 and End 2K.
11. Double click on the capacitor and Inductor to set IC=0V.
12. Add Mark Voltage/Level and Current into Pin on the circuit.
13. Begin circuit simulation.
14. Shift to the graph interface menu
15. Use toggle cursor to mark peak graphs
16. Calculate the necessary information.

* D:\BracU\4. Fourth Semester (SP-25)\EEE203\Lab\Simulations\final project\project sw.sch
Date/Time run: 05/13/25 15:19:19 Temperature: 27.0



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Graph for determining resonance when f=1Khz and vamp= 2V

Result:

From the graph we can see that the peak point is (1.0241K, 2.8801). Since the graph is showing current through the inductor IL1 vs frequency (F), the X line shows peak frequency which is 1.0241KHz and Y line shows the value of current I which is 2.8801mA. So from the simulation it can be seen that the maximum frequency is close to the value of 1KHz. Only a small margin of error has been considered.

Now in order to get the resonant frequency of this circuit, the net impedance of the inductor has to be equal to the net impedance of the used capacitor. So Xc = XL

This will indicate that both elements cancel each other keeping the real part in hand and according to Ohm's law- V=I*Zeq so I=V/Zeq

From the graph it can be seen that current is maximum at the given frequency because Zeq = R + j (XL ± XC) and XL ± XC = 0 in resonant frequency. So, Zeq=R

Now R << R + j (XL ± XC) so the value of Zeq is lower. For this, the current is maximum.

So, it can be concluded that at resonant frequency current through the circuit faces least resistance and maximum current is achieved.

Simulation for Maximum Average Power :

Components required in software:

- VSIN voltage source
- Resistor (R)
- Capacitor (C)
- Inductor (L)
- PARAMETER
- Ground (GND-Analog)

Circuit diagram (Maximum average power):

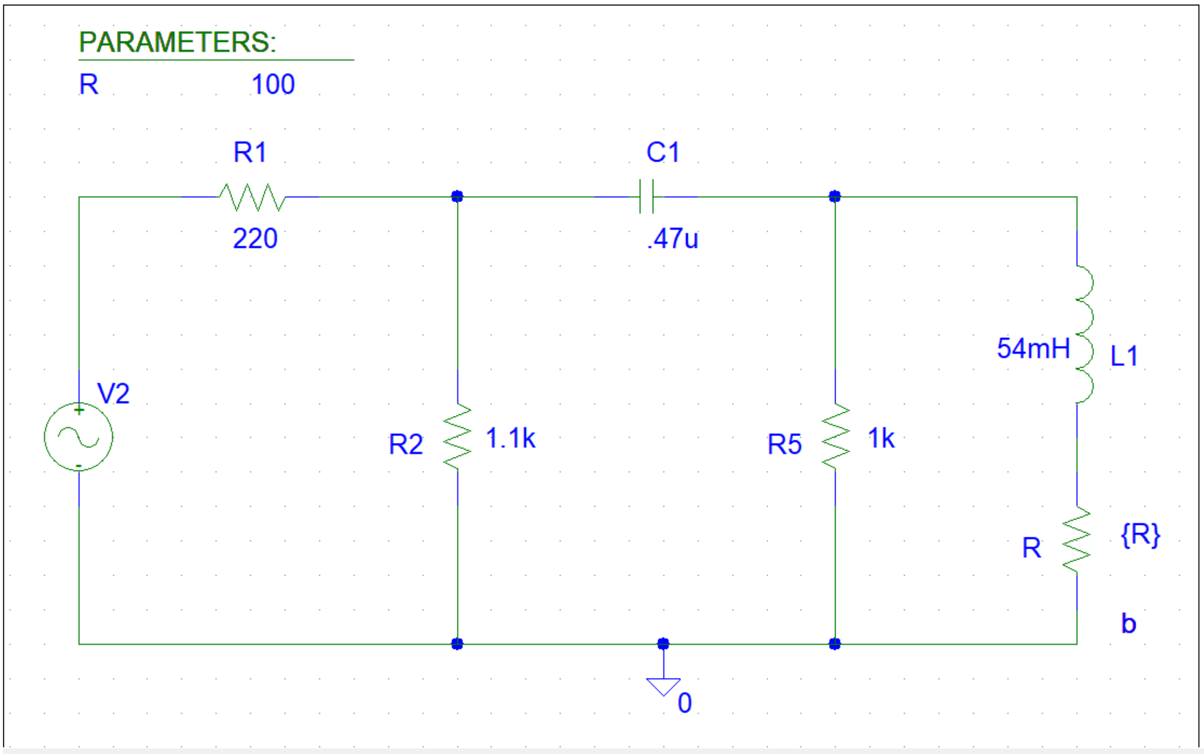
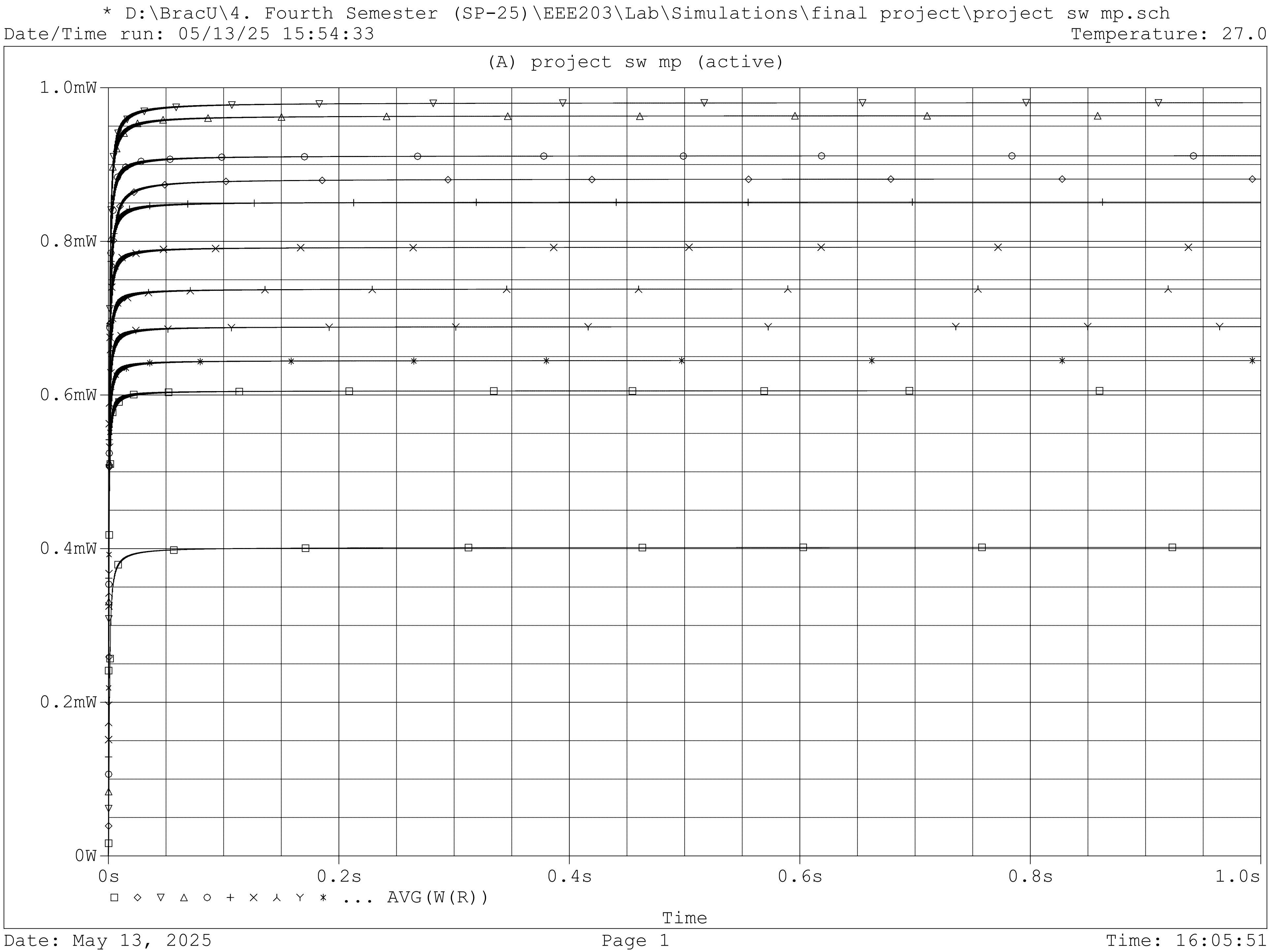


Figure: Circuit diagram for determining maximum average power transfer. L1=54mH is used for easier simulation points

Experiment Procedure (Maximum power):

1. Open Pspice Schematics software
2. Open the parts menu
3. Search the necessary parts and place them according to the diagram
4. Using the wire tool connect all the parts in the circuit
5. Rename all the parts for easier identification
6. Use the draw text and text box tool to mark necessary information
7. Set the value of resistor and capacitor.

8. Double click on VSIN and set VOFF=0V, AMPL=2V, FREQ=1K
9. Open setup analysis and select Parametric.
10. In Parametric, set Global Parameter, Name R, start value 36, End 1036, Increment 100 and sweep type linear.
11. Double click on the capacitor and Inductor to set IC=0V.
12. Double click on the PARAMETERS part. Set NAME1=R and VALUE1=100.
13. Open setup analysis and select Transient.
14. In transient, set final time 1000ms, step ceiling 1000us and skip initial transient solution.
15. Add Mark Voltage/Level and Current into Pin on the circuit.
16. Begin circuit simulation.
17. Shift to the graph interface menu
18. In trace, use AVG(W(R))
19. Use toggle cursor to mark peak graphs
20. Calculate the necessary information.



Graph with multiple current points simulated through R from 36 to 1036-ohm

Explanation of used parts in determining maximum average power:

A load resistor has been simulated which has a starting value of 36-ohm and finishing at 1036-ohm with an increment of 100-phm. The generated graph shows time on the X axis and power used by the load resistor on Y axis.

VSIN has been used instead of VAC in transient because it is easier to visualize current, voltage waveforms and calculate real average power over time using VSIN. The only drawback is we cannot change the variable time so as to prove maximum average power, random graphs have been created from a low resistor value to peak. PARAMETERS must be removed along with its settings for these simulations.

R=37-ohm

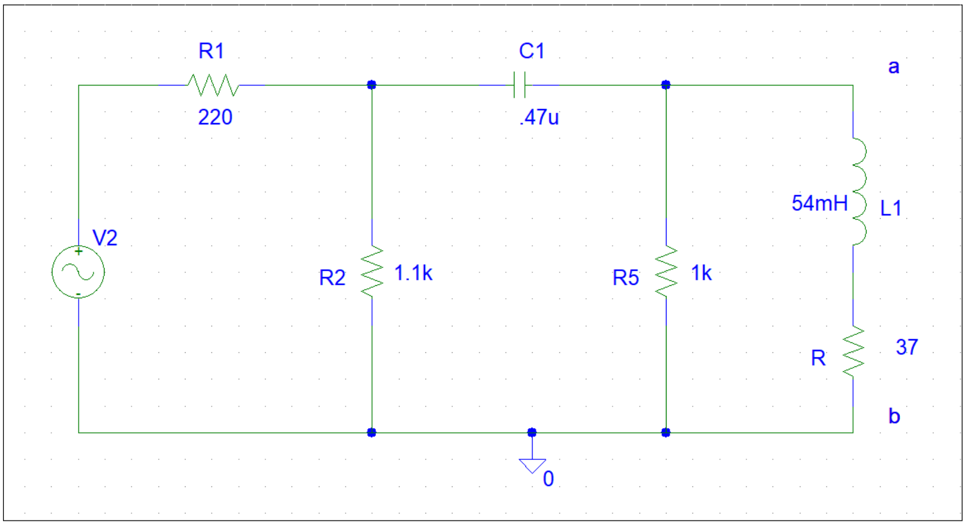


Figure: Circuit with a resistor value of 37-ohm

R=137-ohm

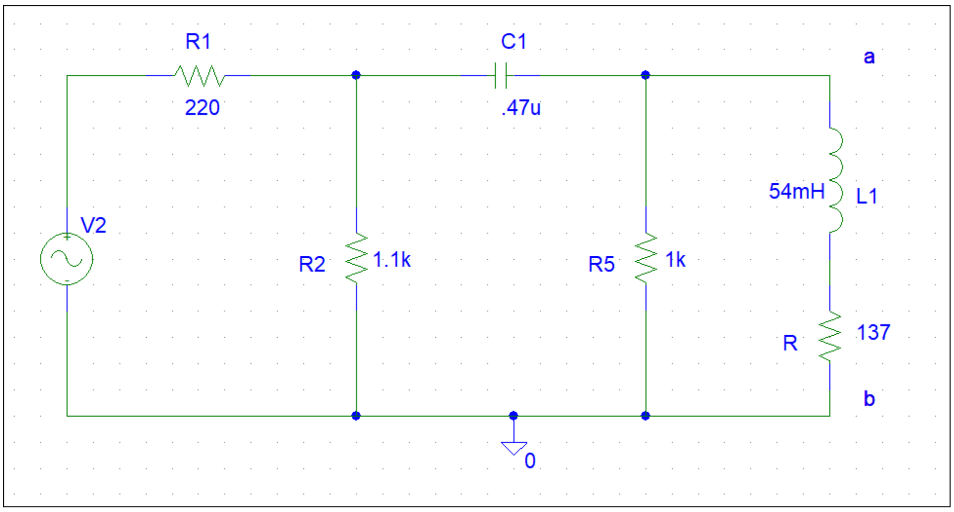


Figure: Circuit with a resistor value of 137-ohm

R=237-ohm (Maximum power resistor)

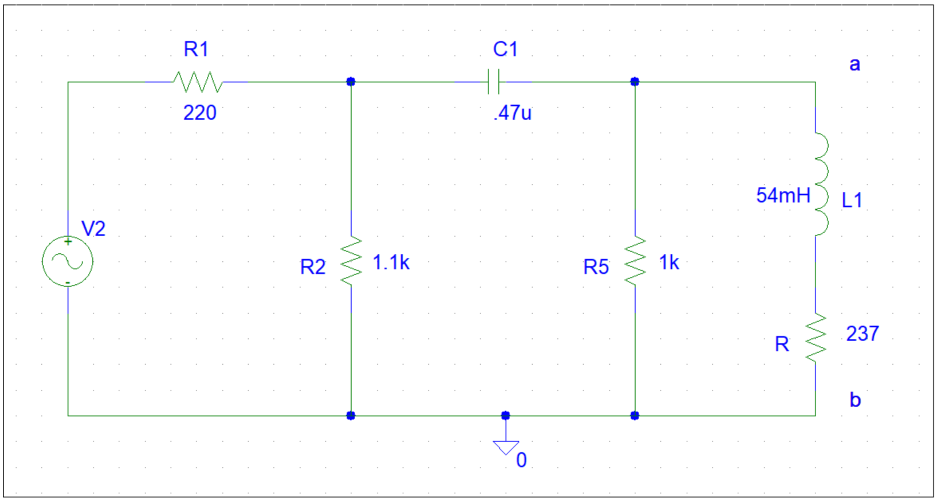


Figure: Circuit with a resistor value of 237-ohm

R=337-ohm

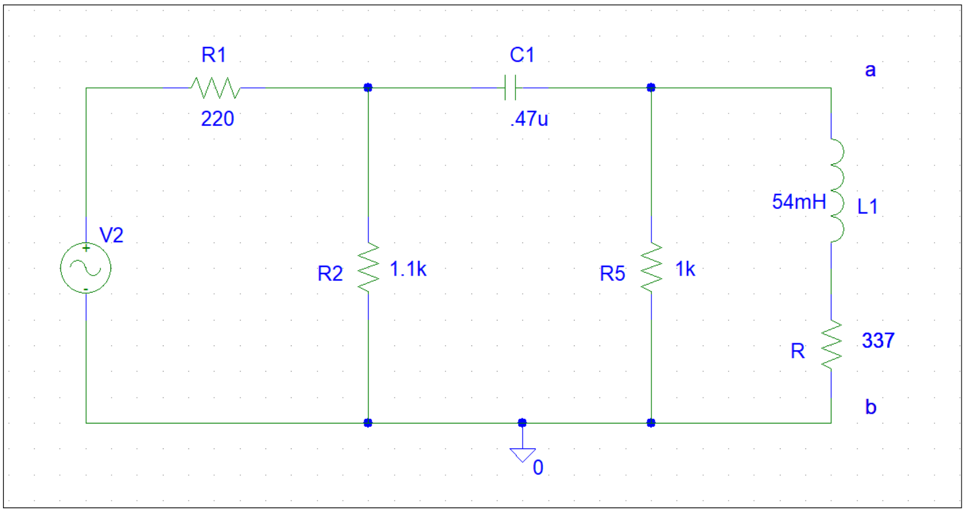


Figure: Circuit with a resistor value of 337-ohm

437-ohm

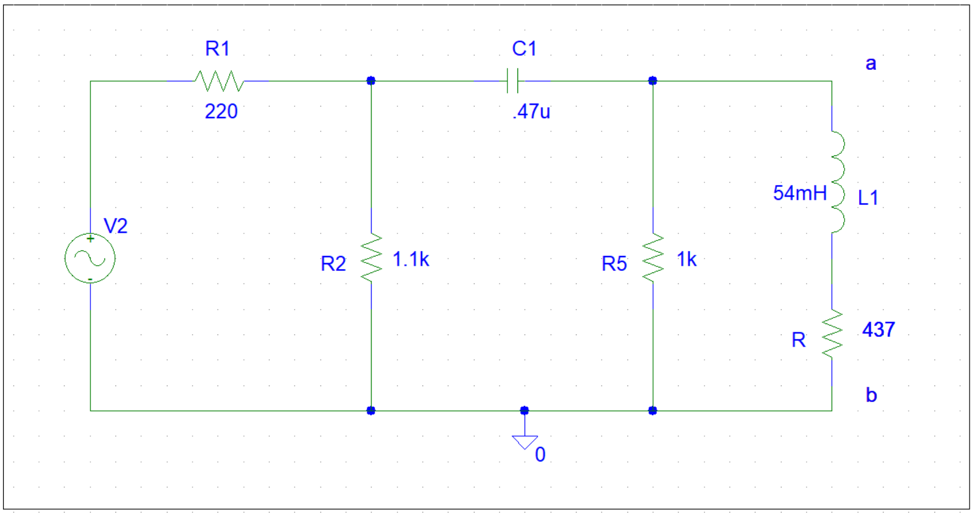


Figure: Circuit with a resistor value of 437-ohm

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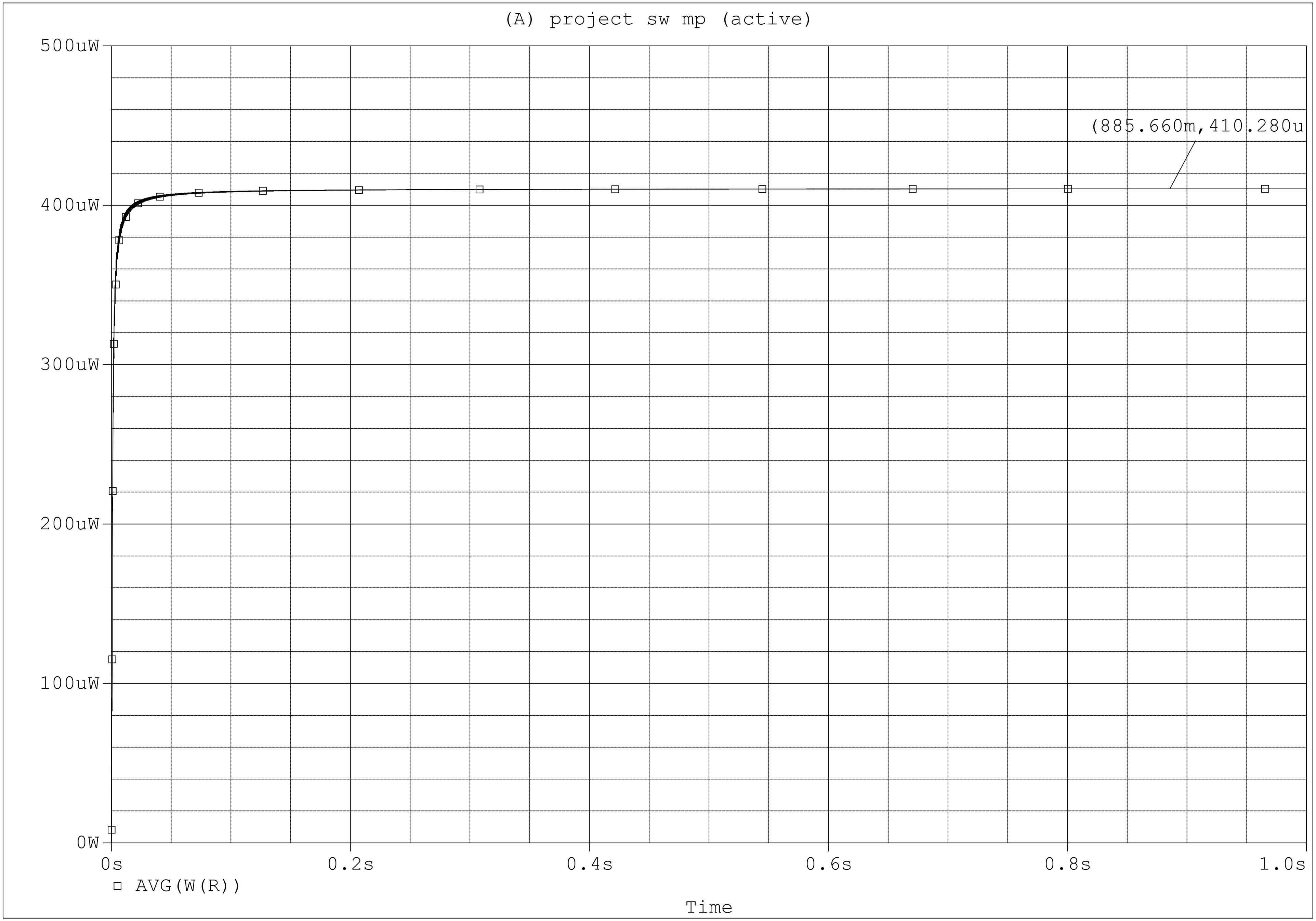

Date: May 13, 2025 Page 1 Time: 16:22:05

Graph when R=37 ohm

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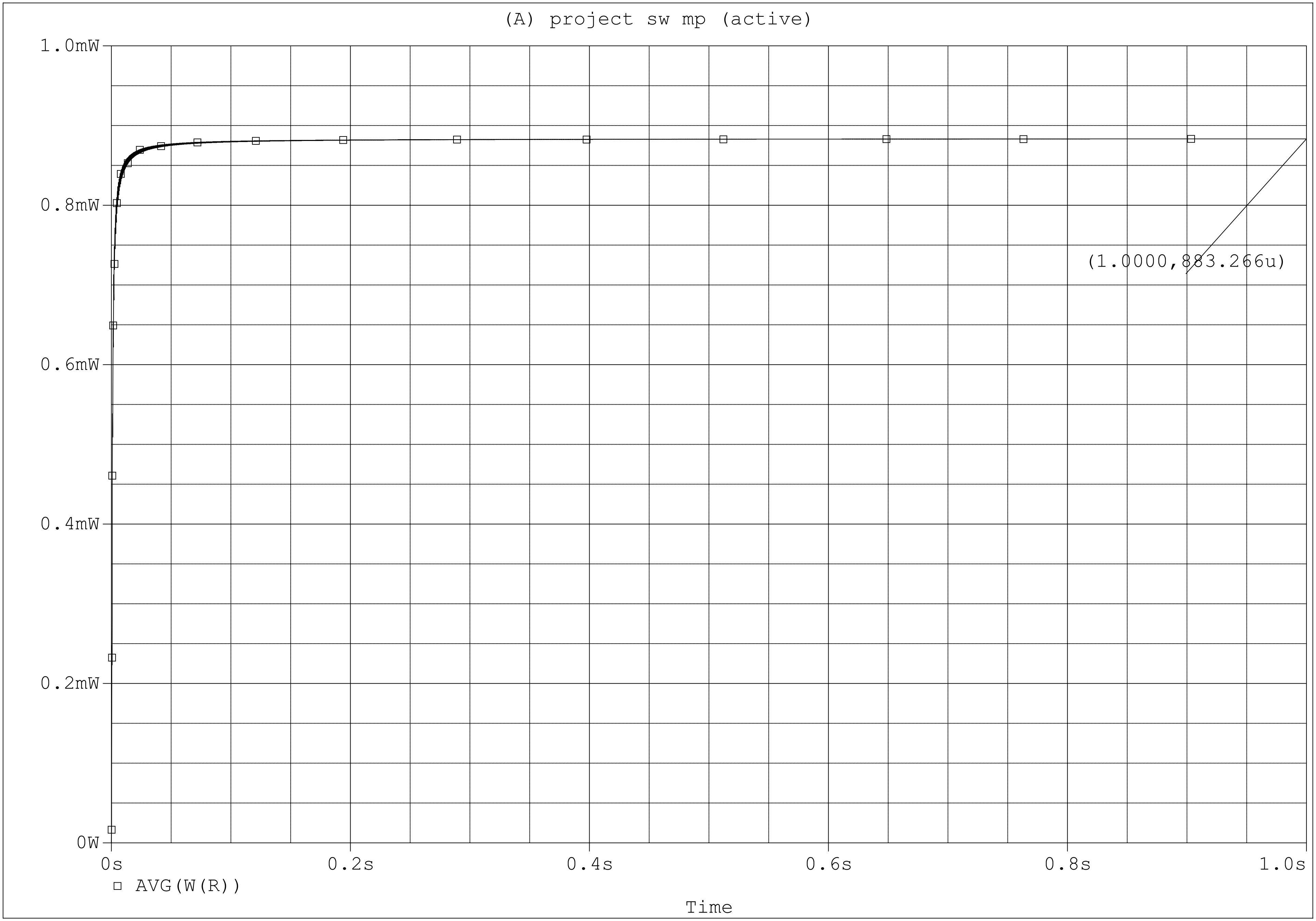

Date: May 13, 2025 Page 1 Time: 16:26:05

Graph when R=137 ohm

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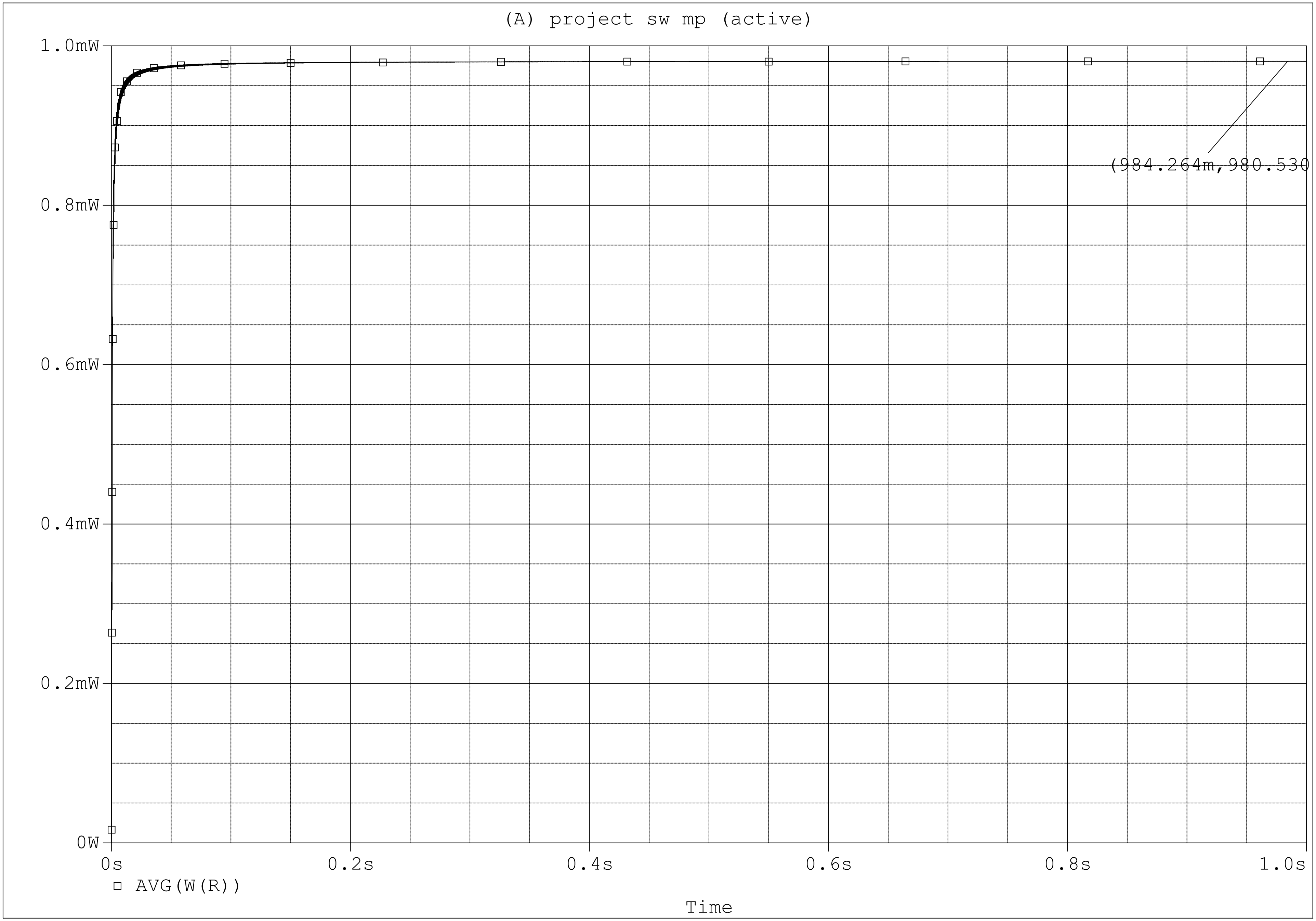

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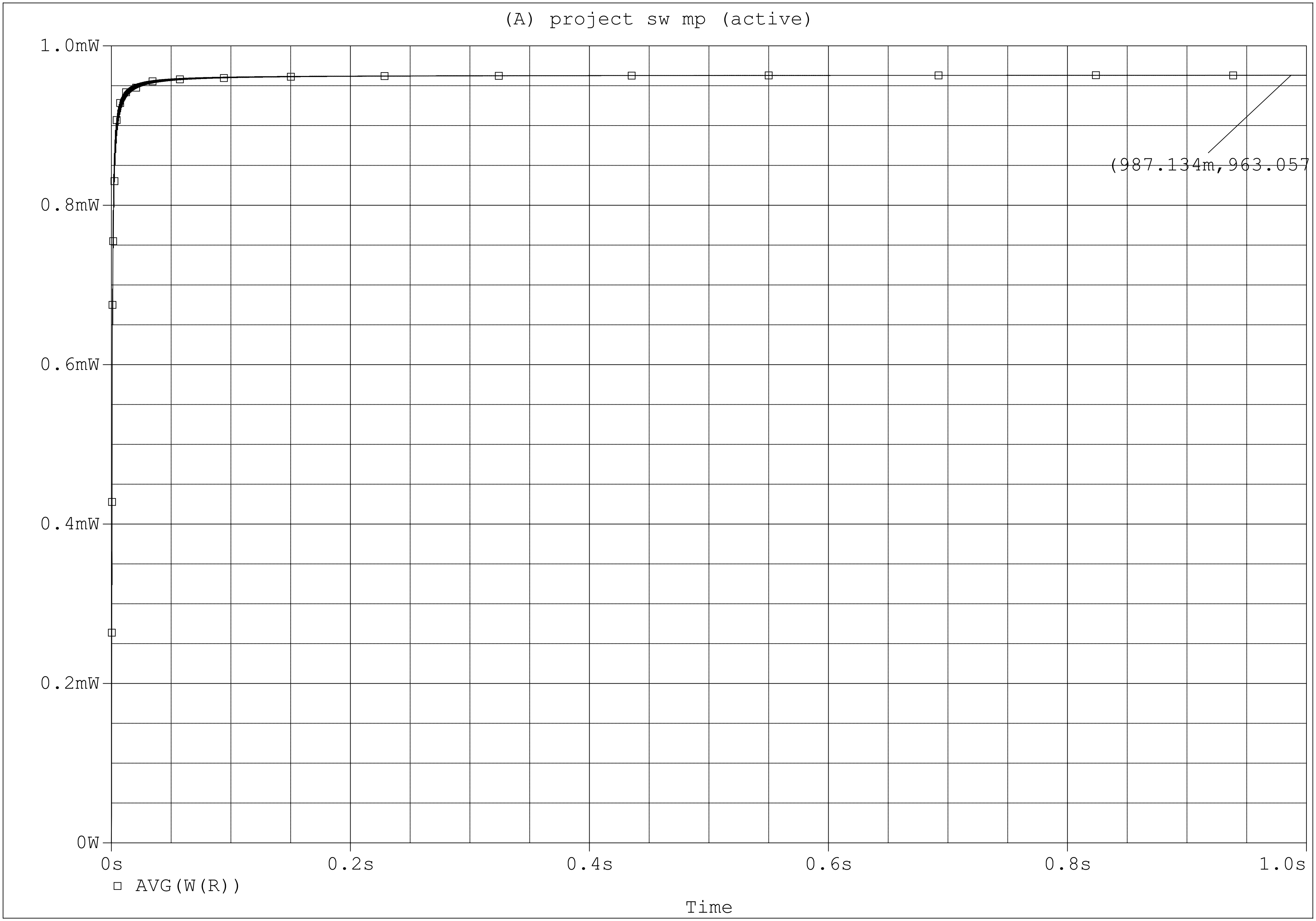
Graph when R=237 ohm (maximum average power)



Graph when R=337 ohm

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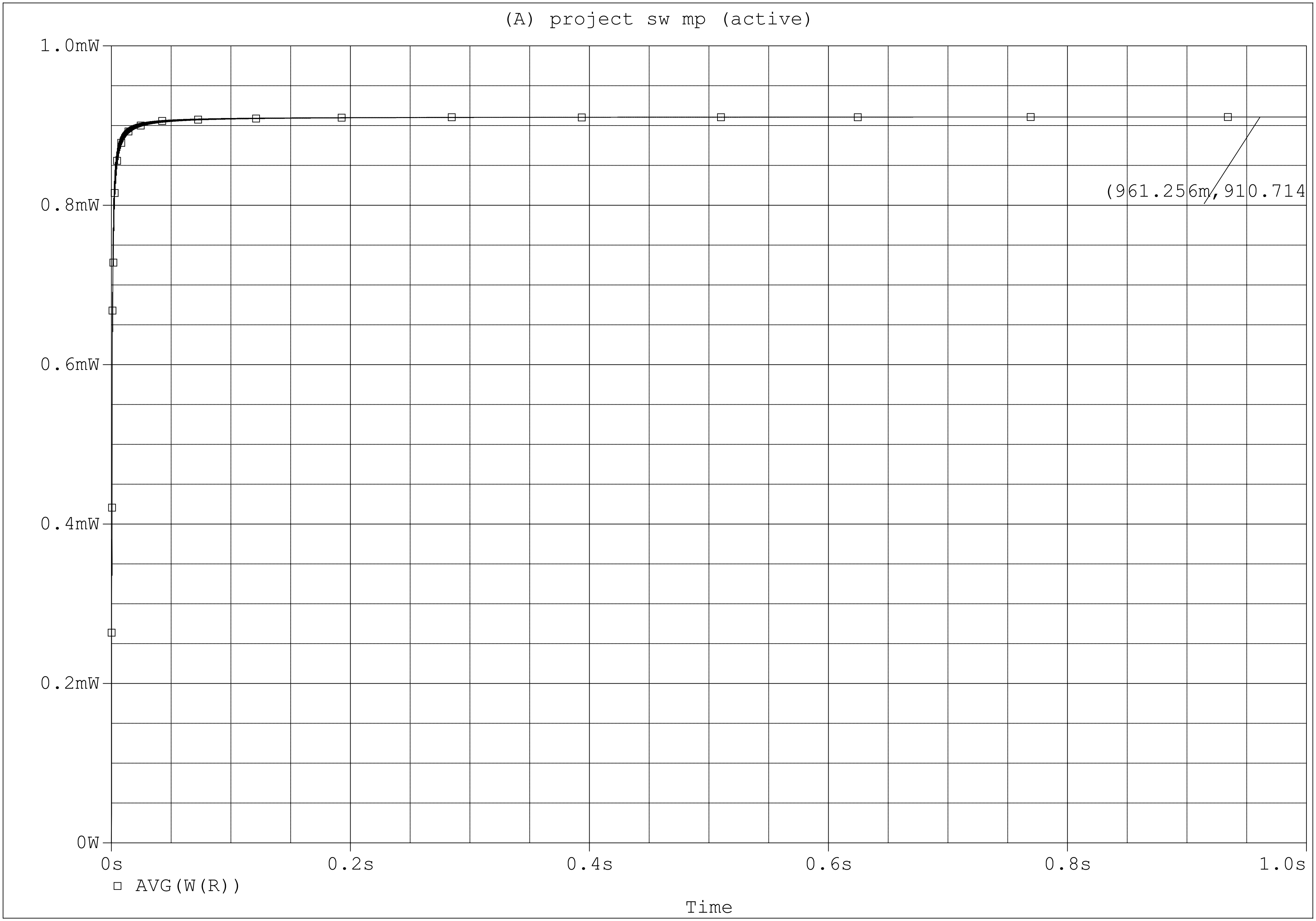
Date/Time run: 05/13/25 16:35:18 Temperature: 27.0



Date: May 13, 2025 Page 1 Time: 16:36:10

Graph when R=447 ohm

Result:

Value of resistor (Ohm)	Value of current
37	410.280 uW
137	883.266 mw
237	***980.530 mW***
337	963.057 mW
437	910.714 mW

According to the maximum points marked on the graphs all above, it is noticeable that the maximum average power output is 980.530mW, which is achieved by the load when the value of the resistor is 237-ohm. This value is close to our theoretically predicted value of 236.91 ohm. So only a small margin of error has been simulated.

<u>Hardware experiment for resonance:</u>

In the hardware lab, the same problem circuit was constructed to prove resonance can be achieved at 1Khz frequency but due to real world problems such as heat resistance and equipment failure, there was some amount of error in getting a perfect resonating graph from the oscilloscope. A potentiometer was used to easily get the required resistor value.

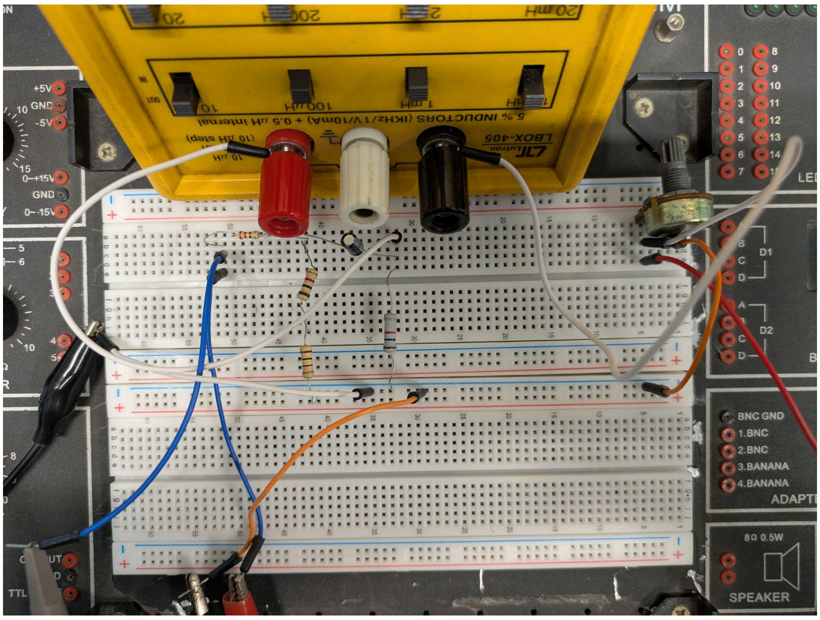


Figure: Completed circuit (Top view)

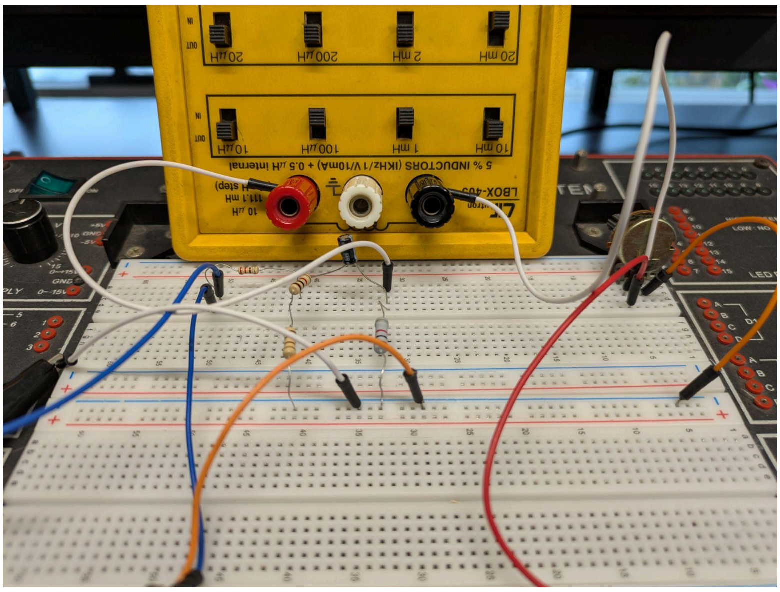


Figure: Completed circuit (Front view)

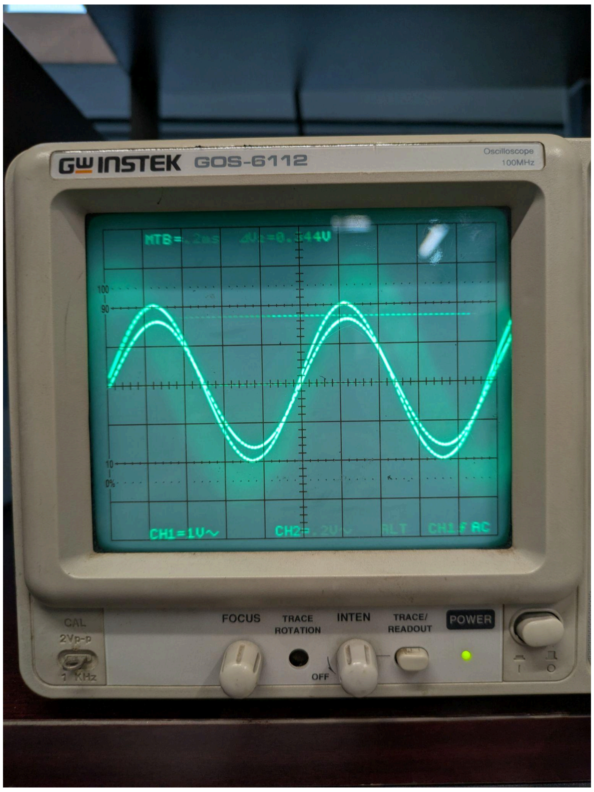


Figure: Resonance achieved at 1Khz frequency with 2Vamp

<u>Discussion:</u>

We were able to build and observe a parallel circuit which had an alternating current (AC) source using the Pspice Schematics software. Sinusoidal waveform was generated after the simulation was completed and after calculations, we correlated with practically measurable values such as frequency, current and voltage. From the simulation graph and theoretical calculation, we successfully determined that it is possible to complete the project if an inductor and resistor are used in series on point a-b. Resonance and maximum average power was achieved. All steps necessary to complete the circuit and experiment were written above. In conclusion, we were able to successfully solve the problem with a small acceptable amount of percentage error.

Schematics Drive Link:

Resonance experiment

Maximum average power experiment