EE203 - Electrical Circuits Laboratory

Experiment - 4 Laboratory Report
Linearity and Superposition

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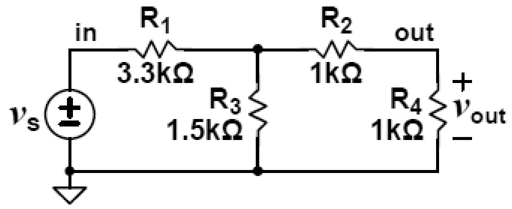
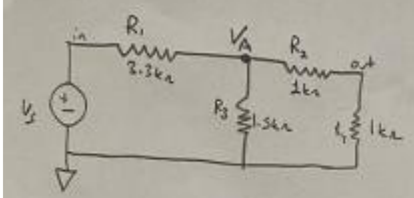
Preliminary Work

1. Calculate a proportionality factor **K** that gives the v_{out}/v_s ratio in the following circuit.





$$\frac{V_A}{2} = V_{out}$$

$$\frac{V_A - V_s}{3.3k} + \frac{V_A}{1.5k} + \frac{V_A}{2k} = 0$$

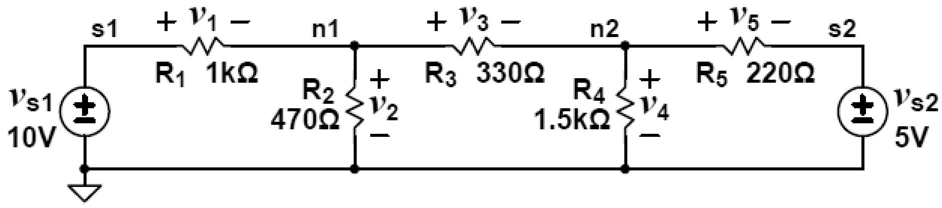
$$2V_A - 2V_s + 4.4V_A + 3.3V_A = 0$$

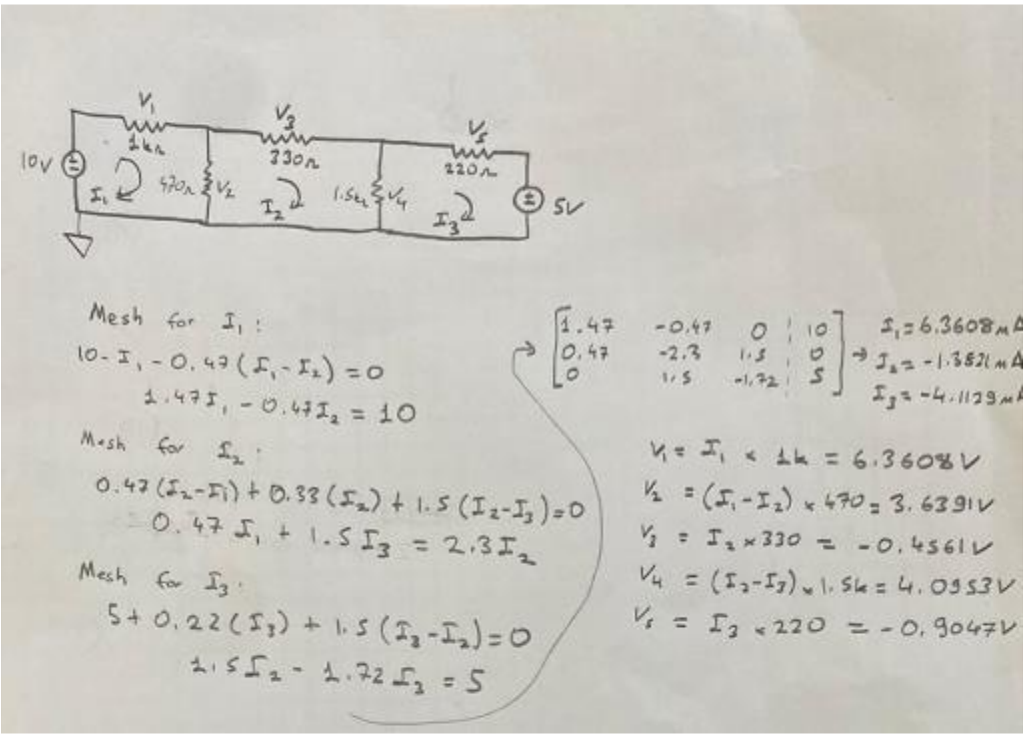
$$2V_s = 9.7\,V_A$$

$$2V_s = 9.7 \times 2V_{out}$$

$$\Rightarrow k = \frac{V_{out}}{V_s} = \frac{1}{9.7} = 0.10303$$

2.1 Calculate v_1, v_2, v_3, v_4, and v_5 for the circuit shown below using nodal or mesh analysis. Enter the results in the table given below.





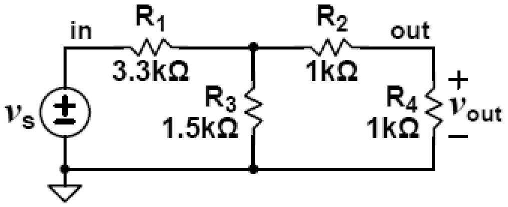
	v_1	v_2	v_3	v_4	v_5
Calculated value (**V**):	6.3608V	3.6392V	-0.4561V	4.0953V	-0.9047V
Simulation result (**V**):	6.3608V	3.6392V	-0.4561V	4.0953V	-0.9047V
%error	0.0	0.0	0.0	0.0	0.0

We do not have any error because simulation is ideal so we get same values for calculation and simulation.

2.2 Draw the same circuit schematic in LTspice, and enter the simulation results in the table given above. Save the schematic file since it will be used in the procedure section. If there is any significant difference between your calculations and the simulation results, then make the necessary corrections to obtain consistent results.

Procedure

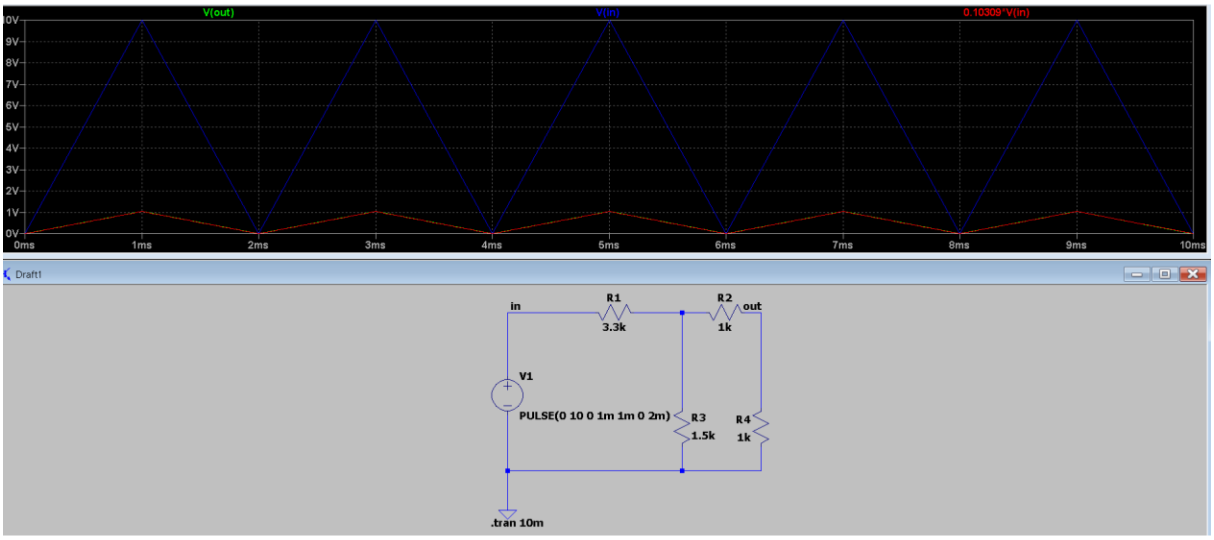
1.1 Make the following circuit schematic on LTspice.

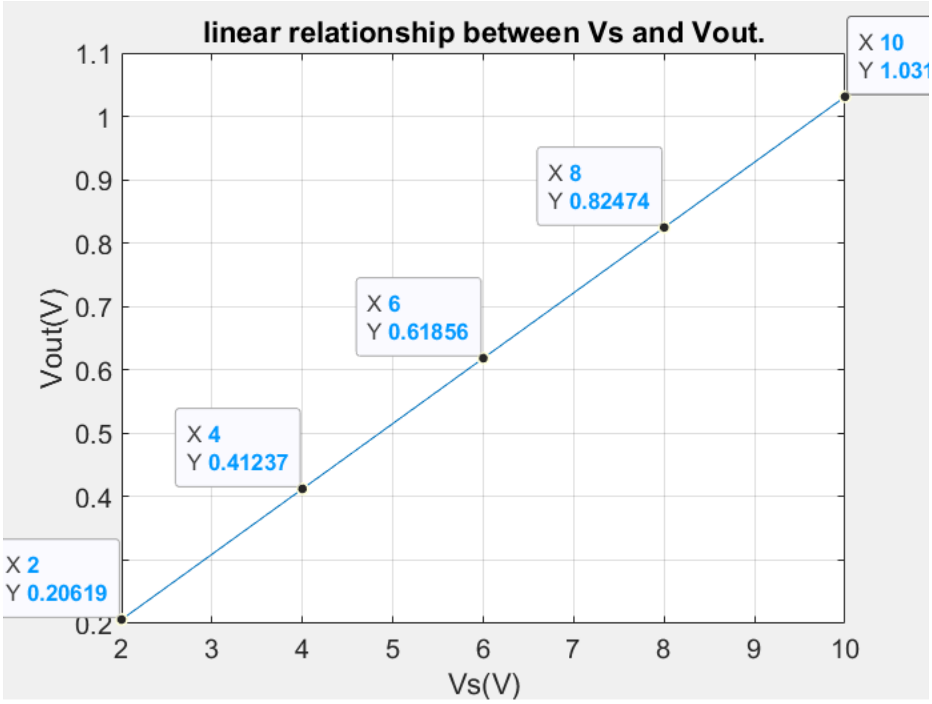


1.2 Set v_S source to obtain DC outputs from **2 V** to **10 V** in **~2 V** steps and measure v_{out} at each v_S setting. Enter the measured voltages and v_{out}/v_S, ratio in the following table.

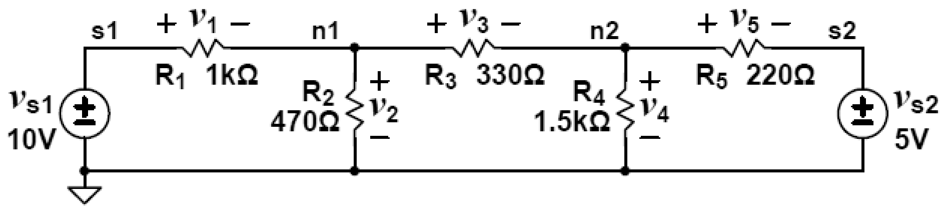
Input v_S (V)	Output v_{out} (V)	v_{out}/v_S ratio
2V	206.19mV	103.09×10^{-3}
4V	412.37mV	103.09×10^{-3}
6V	618.56mV	103.09×10^{-3}
8V	824.74mV	103.09×10^{-3}
10V	1.0309V	103.09×10^{-3}

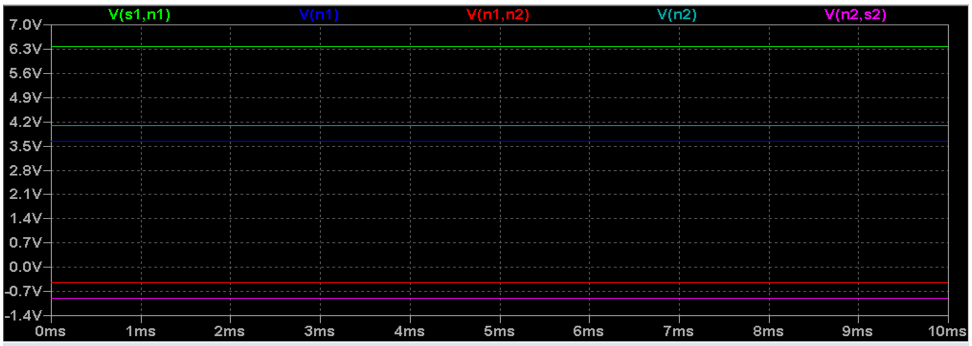
1.3 Set v_S source to obtain **500 Hz** triangular signal with **10 Vp-p** amplitude and **0 V** DC offset. Set simulation time to **10 ms**. Display the v_S and v_{out} waveforms. Add another trace in the form of "`K * V(in)`" where `K` is the v_{out}/v_S ratio found in the preliminary work. Check if there is a perfect match between v_{out} and the "`K * V(in)`" waveform and verify the linear relationship between v_S and v_{out}.

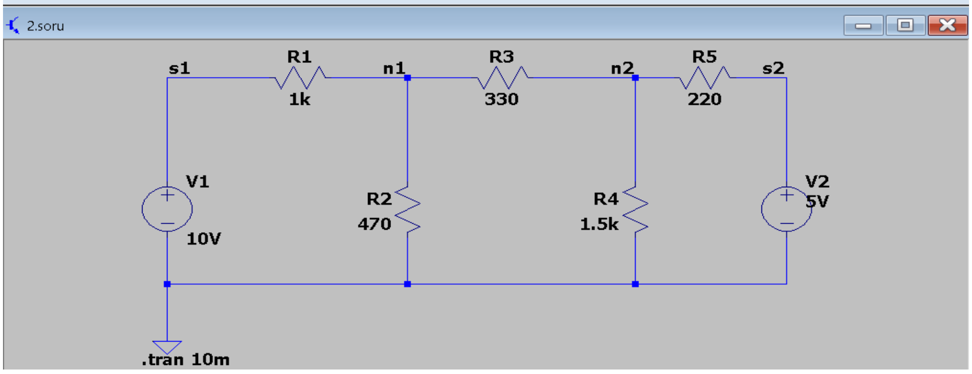




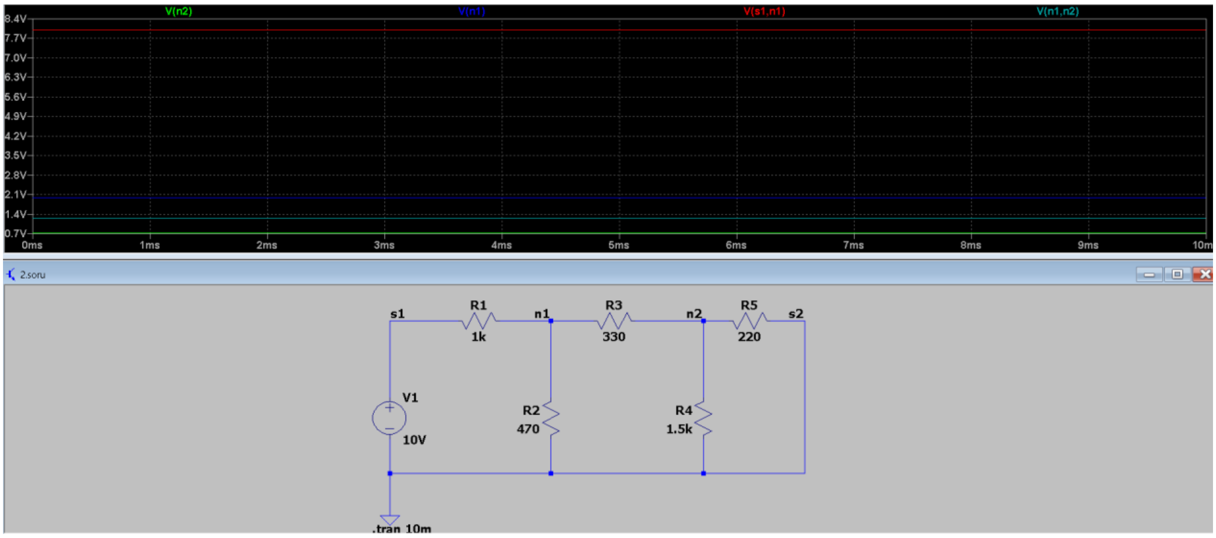
2.1 Build the following circuit and set v_{s1} **= 10 V** and v_{s2} **= 5 V**. Make sure that you enter the proper node labels (i.e. **s1**, **s2**, **n1**, **n2**) that will help you easily identify all voltages marked on the schematic. Measure the voltages, v_1, v_2, v_3, v_4, and v_5, shown on the schematic and record their values in the first row of the table given below.



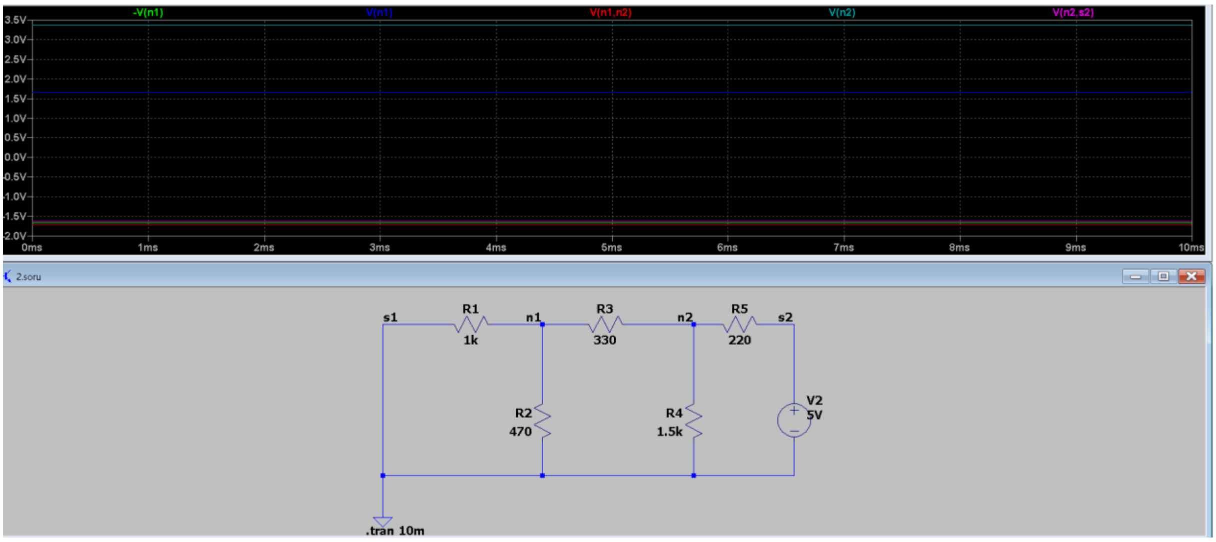




2.2 Disconnect $\boldsymbol{v_{s2}}$, and replace it with a short circuit. Record the measured voltages in the second row of the table.



2.3 Disconnect $\boldsymbol{v_{s1}}$, replacing it with a short circuit, and connect $\boldsymbol{v_{s2}}$ **= 5 V** source again. Record the measured voltages in the third row of the table.



Step	Source settings	v_1 (V)	v_2 (V)	v_3 (V)	v_4 (V)	v_5 (V)
2.1	$\boldsymbol{v_{s1} = 10\,V}$, $\boldsymbol{v_{s2} = 5\,V}$	6.3608V	3.6392V	-0.4561V	4.0953V	-0.9047V
2.2	$\boldsymbol{v_{s1} = 10\,V}$, $\boldsymbol{v_{s2}}$ is disabled	8.0174V	1.9826V	1.2537V	0.7289V	0.7289V
2.3	$\boldsymbol{v_{s1}}$ is disabled, $\boldsymbol{v_{s2} = 5\,V}$	-1.6566V	1.6566V	-1.7098V	3.3664V	-1.6336V
2.4	Sum of voltages measured in steps **2.2** and **2.3**	6.3608V	3.6392V	-0.4561V	4.0953V	-0.9047

2.4. Calculate the sum of voltages measured in steps **2.2** and **2.3** and write the results in the last row of the table. Compare these results with the voltages measured in step **2.1**.

Because of we apply superposition theorem we must get same result between measurement we use 2 Voltage source at same time(2.1) and sum of when one by one results(2.4). We do not have any error between step 2.1 and 2 because we measured on simulation and everything is ideal.

2.5. Connect v_{S1} **= 10 V** again and set v_{S2} source to obtain **500 Hz** sinusoidal signal with **10 Vp-p** amplitude and **0 V** DC offset. Measure DC offset and peak-to-peak amplitude of v_1, v_2, v_3, v_4, and v_5 on the displayed waveforms and record the results in the following table.

	v_1	v_2	v_3	v_4	v_5
DC offset (**V**):	8.017V	1.983V	1.254V	729.19mV	728.76mV
AC amplitude (**Vp-p**):	3.310V	3.311V	3.418V	6.728V	3.265V

Questions

Q1. Compare the proportionality factor calculated in the preliminary work with the v_{out}/v_S ratios found in step **1.2** of the procedure.

Calculated v_{out}/v_S ratios	Measured v_{out}/v_S ratios	%error
$103.09\text{x}10^{-3}$	$103.09\text{x}10^{-3}$	0.0

Because of simulation is ideal, our measured and calculated proportionality are same. Because of ratio is constant when Vin increase, Vout increase so that we see linear graph.

Q2. Consider the following cases where one of the voltage supplies is changed by **1 V** in the circuit built for step **2** of the procedure.

Case 1: v_{S1} is reduced to **9 V** or raised to **11 V**, while v_{S2} remains at **5 V**.

Case 2: v_{S2} is reduced to **4 V** or raised to **6 V**, while v_{S1} remains at **10 V**.

Which of these changes has in a bigger effect in v_1, v_2, v_3, v_4, and v_5? How can you make a decision looking at the voltage measurements made in steps **2.2** and **2.3** of the procedure?

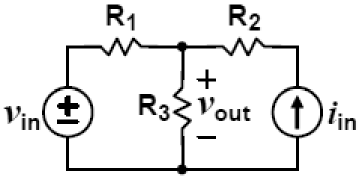
	V1	V2	V3	V4	V5
In step 2	6.3608V	3.6392V	-0.4561V	4.0953V	-0.9047V
Case1	5.5591V	3.4409V	-0.58147V	4.0224V	-0.9776V
Case1 change %	12.6	5.45	27.49	1.78	8.06
Case 2	6.6921V	3.3079V	-0.11414V	3.422V	-0.578V
Case 2 change %	5.2	9.1	74.9	16.4	36.2

When we look table, we saw that case 1 change is more effective on V1, case 2 change is more effective on V2,V3,V4 and V5. So we can say the change on VS2 has greater effect on voltage. When we compare table 2.2 and 2.3 we see when VS1 open VS2 closed only on V1 much effective on the other side when VS1 closed and VS1 open we see on V2,V3,V4,V5 more effective so that we can say VS2 is more effective.

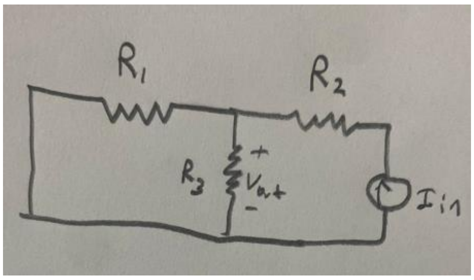
Q3. How can you relate the DC offset and peak-to-peak AC voltage measurements made in step **2.5** to the voltage measurements made in steps **2.2** and **2.3** of the procedure?

In step 2.5 we just have $\boldsymbol{v_{S1} = 10\ V}$ offset and we do not have off set for Vs2 and in step 2.2 we have just Vs1=10V so that their DC offset values are same. In step 2.3 we have Vs2=5V is half of previous voltage. So that it's ac amplitude is half of the 2.5 ac amplitude.

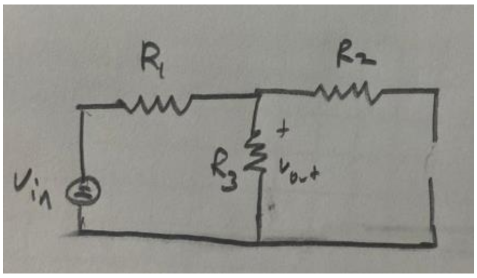
Q4. The output voltage calculated for the following circuit (example given in the Background section) is independent of $\mathbf{R_2}$. Explain why $\mathbf{R_2}$ has no effect on $\boldsymbol{v_{out}}$, considering its function when one of the sources is active and the other source is disabled.



$$v_{out} = \frac{R_3}{R_1 + R_3} v_{in} + \frac{R_1 R_3}{R_1 + R_3} i_{in}$$



When Vin short circuit, the voltage source is not in circuit, the current flowing through R3 depends on resistor R1. Therefore R2 does not affect voltage.



When open circuit, current source disabled. No current flows through on resistor R2, so Vout is not affected. Because of both cases the Vout independent from R2.

Q5. How can you apply the superposition principle to calculate the power dissipated in a resistor, when the circuit contains independent DC and AC sources?

When the circuit contains independent DC and AC sources, to calculate the power dissipated in a resistor, we can apply superposition. We find power values using superposition for each resource and we sum them step by step.

Conclusion

In this experiment, in preliminary work in first part, we found Vout/Vs ratio using node analysis, in second part we calculated V_1,V_2,V_3,V_4,V_5 values for given circuit using mesh analysis. In first part, we set given circuit using 1kΩ,3.3kΩ, 1.5kΩ resistors and we measured Vs, Vout and ratio them for different voltage source(2V-4V-6V-8V-10V) step by step. Then we added another trace for displayed K*V_{in} and we verified linear relationship between Vs and Vout. In second step, we built given circuit using 1kΩ, 470Ω, 330Ω, 1.5kΩ, 220Ω resistors with two voltage sources(5V and 10V). We measured V_1,V_2,V_3,V_4,V_5 values. After that we disconnected 5V voltage source and we repeated same measurements. Then, we disconnected 10V voltage source and we did same measurement. After that we see sum of this results equal to first calculation because of superposition theorem. In next step, we changed Vs2(5V). We obtain 500Hz sinusoidal signal with 10Vp-p amplitude and 0V DC offset. Then we measured DC offset and AC amplitude(Vp-p) values for V_1,V_2,V_3,V_4,V_5.

To sum up, in this experiment we observed linear response of resistive circuits. We learnt calculation and measuring of superposition theorem. We observed applications of superpositions theorem.