Lab 1 – First and Second Order Passive Circuits

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***Abstract-* In this lab, we learned about first and second order passive circuits. For the first order circuits, we determined the rise and fall times based off simulations LTSpice, verified time constant values, and determined the best pulse to provide to the circuit to get the correct waveform. For second order circuits, we found the inductance, determined the rise and fall times, and determined the roots.**

***Keywords: First Order Passive Circuit Analysis, Second Order Passive Circuit Analysis, LTSpice, Rise and Fall Time*, time constant**

I. Introduction

First order passive circuits are simple circuits with a resistor connected to an energy source like a conductor (capacitor) or an inductor. Second order passive circuits are described as a circuit in series with a resistor, capacitor, and an inductor.

II. First Order Passive Circuit

1. RC Circuits

Calculating Capacitance given Resistance and Time Constant (τ) as 1us. The equation used to calculate the Capacitance for Resistances 1 KOhm, 10 KOhm, 100 KOhm, and 1 MOhm is τ = RC.

The work below is a sample calculation for 1Kohm :

1 \* 10^-6 = C \* 1000

C = 10^-9 F = 1 nF

|  |  |  |
| --- | --- | --- |
| Resistance (Ohm) | Time Constant (τ) | Capacitance (F) |
| 1000 | 0.000001 | 0.000000001 |
| 10000 | 0.000001 | 1E-10 |
| 100000 | 0.000001 | 1E-11 |
| 1000000 | 0.000001 | 1E-12 |

Table 1 – Calculations for Capacitance given different Resistance values.

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Fig 1 – RC Circuit for 1 KOhms and 1 nF.

Diagram

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Fig 2 – Waveform for the RC Circuit in Fig 1

To find the rise and fall times, the equation:

Vout = V(1-(e^(-t/RC)) is used for charging (rise) and Vout = V(V(e^(-t/RC)) is used for discharging (fall).

A sample calculation is shown below:

Rise Time

0.2(5) = 5(1-e^(t/10^-6))

0.2 = 1-e^(t/10^-6)

-0.8 = - e^(t/10^-6)

t = ln(0.8) / 10 ^6

t = 2.2 \* 10^-7 seconds

Fall Time

0.2(5) = 5(e^(-t/10^-6))

0.2 =e^(-t/10^-6)

ln(0.2) = -t/10^-6

t = -ln(0.2) / 10^6

t = 1.6 \* 10 ^ -6 seconds

Diagram

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Fig 3 – Representation of the rise and fall times at 20 and 80%.

1. RL Circuits

Calculating Inductance given Resistance and Time Constant (τ) as 1ns. The equation used to calculate the Capacitance for Resistances 1 KOhm, 10 KOhm, 100 KOhm, and 1 MOhm is τ = L / R.

The work below is a sample calculation for 1Kohm :

1 \* 10^-9 = L / 1000

L = 10 ^-6 H

|  |  |  |
| --- | --- | --- |
| Resistance (Ohm) | Time Constant (τ) | Inductance (H) |
| 1000 | 0.000000001 | 0.000001 |
| 10000 | 0.000000001 | 0.00001 |
| 100000 | 0.000000001 | 0.0001 |
| 1000000 | 0.000000001 | 0.001 |

Table 2 – Inductance values for different resistances

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Fig 3 – RL Circuit for 1KOhm and 0.000001 H

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Fig 4 – Waveform for the RL Circuit in Fig 3

To find the rise and fall times, the equation:

Vout = V(1 - e^(-Rt/L)) is used for charging (rise) and Vout = V(e^(-Rt/L) is used for discharging (fall).

A sample calculation is shown below:

Rise Time

0.2(5) = 5(1-e^(-10^9t))

0.2 = 1-e^(-10^9t)

-0.8 = -e^(-10^9t)

ln(0.8) = 10^9t

t = 2.23 \* 10 ^-10 seconds

Fall Time

0.2(5) = 5(e^(-10^9t))

0.2 = e^(-10^9t)

ln(0.2) = -10^9t

t = 1.61 \* 10^-9 seconds

Graphical user interface, diagram

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Fig 5 – Representation of the rise and fall times

II. Second Order Passive Circuits

1. Calculating Inductance (L) give w0 as 10^7 rad/sec and C as 100pf.

w0 = 1 / sqrt(LC)

10^7 = 1 / sqrt(L(100 \* 10^-12))

10^14 = 1/L(100\*10^-12)

10^14 \* (100\*10^-12)L = 1

L = 1 \* 10 ^-4 H

1. Calculating s1 and s2, roots for the output voltage.

Sample calculation for R = 0 Ohms , I = 1 ^ 10^-4 H :

 α = R / 2L

α = 0 / 2(1\*10^-4)

α = 0

s1 = 0 – sqrt(0^2 – 10^14)

s1 = -10^7i

s2 = 0 + sqrt(0^2-10^14)

s2 = 10^7i

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Resistance (Ohms) | Inductance (H) | Alpha | w0 | s1 | s2 |
| 0 | 0.0001 | 0 | 10000000 | -10^-7i | 10^7i |
| 10 | 0.0001 | 50000 | 10000000 | -5\*10^4 - 9.99\*10^6i | -5\*10^4 + 9.99\*10^6i |
| 100 | 0.0001 | 500000 | 10000000 | -5\*10^5 - 9.98\*10^6i | -5\*10^5 + 9.98\*10^6i |
| 1000 | 0.0001 | 5000000 | 10000000 | -5\*10^6 - 8.66\*10^6i | -5\*10^6 + 8.66\*10^6i |
| 10000 | 0.0001 | 50000000 | 10000000 | -5\*10^7 - 4.89\*10^7i | -5\*10^7 + 4.89\*10^7i |

Table 3 – Calculating Roots for s1 and s2

1. Waveforms to find Rise and Fall Times

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Fig 6 – Waveform for RLC Circuit with 0 Ohm Resistance

Calendar

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Fig 7 - Waveform for RLC Circuit with 10 Ohm Resistance

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Fig 8 - Waveform for RLC Circuit with 100 Ohm Resistance

Diagram

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Fig 9 - Waveform for RLC Circuit with 1K Ohm Resistance

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Fig 10 - Waveform for RLC Circuit with 10K Ohm Resistance

1. Time Constant

Formula to find the time constant of an RLC circuit:

τ = (T1 – T2) / ln(V1-V2)

Sample Calculation for resistance as 0 Ohms:

τ = (226.904 – 97.244) / ln(7.88 / 2.06)

= 96.644

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Resistance (Ohms) | Inductance (H) | T1 | T2 | V1 | V2 | Tau |
| 0 | 0.0001 | 226.904 | 97.244 | 7.88 | 2.06 | 96.64421695 |
| 10 | 0.0001 | 226.904 | 97.244 | 7.88 | 2.06 | 96.64421695 |
| 100 | 0.0001 | 226.904 | 96.205 | 7.39 | 1.95 | 98.1003983 |
| 1000 | 0.0001 | 225.443 | 80.515 | 4.59 | 1.1 | 101.4497125 |
| 10000 | 0.0001 | 224.959 | 1.622 | 0.953 | 4.01 | 155.4263247 |

1. Oscillation Frequency

|  |  |
| --- | --- |
| w0 | frequency |
| 10000000 | 1592356.688 |

w0 = 10000000 / 2pi

w0 = 1592356.688

III. Conclusion

After doing this lab, I learned a lot about the behaviors of depending on the components that are attached to it. For example, when we had RC and RL circuits, the waves were consistent from 0 V, but as we added the Capacitor and Inductor in the same circuit, the waveform took more time to become consistent.