

Faculty of Engineering and Technology

Electrical and Computer Engineering Department

Circuits LAB (ENEE2102)

Pre-LAB of Experiment #5

First and Second Order Circuits

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Date:

8/10/2020

Section: #1

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# Part A: Step Response of First-order RC circuit:



Figure (5.1)

1. Calculate VC (t) using the general solution formula, show calculation of time constant (τ).

|  |  |  |
| --- | --- | --- |
|  | V(0) = 0VC(∞) = 6volts |  |
|  | * Toe = Rth \* C

= 10k \* 0.1u = 1ms | (1) |
|  | VC(t) = VC(∞) + [VC(0) - VC(∞)]$e^{\frac{-t}{toe}}$ | (2) |
|  | * VC(t) = 6 + [0-6]$ e^{\frac{-t}{1ms}}$

= 6[1-$e^{-1000t}$] |  |

1. Use PSPICE to do transient analysis of the circuit. Show VC(t) and use cursors to measure time constant (𝛕).



Figure (5.1): PSPICE simulation



VC(t)

|  |  |  |
| --- | --- | --- |
|  | 0.63\*Vo = 3.78 |  |
|  | Toe $≈0.998m ≈ $1ms |  |

1. For the same circuit show VR(t) using a differential voltage marker, and use cursors to measure time constant (𝛕).



VR(t)

|  |  |  |
| --- | --- | --- |
|  | 0.37\*Vo = 2.22 |  |
|  | * Toe $≈0.976m ≈$ 1ms
 |  |

# Part B: Step response of First-order RL circuit:



Figure (5.2)

1. Calculate VL (t) using the general solution formula, show calculation of time constant (τ).

|  |  |  |
| --- | --- | --- |
|  | VL(∞) = 0VL(0) = Vin max = 6v |  |
|  | * Toe = $\frac{L}{R}=1ms$
 | (3) |
|  | VL(t) = VL(∞) + [VL(0) – VL(∞)]$e^{\frac{-t}{toe}}$ |  |
|  | * VL(t) = 6\*$e^{1000t}$
 |  |

1. Use PSPICE to do transient analysis of the circuit. Show VL(t) and use cursors to measure time constant (𝛕)



Figure (5.2): PSPICE simulation



VL(t)

0.37\*Vo = 2.22

* Toe $≈0.941m ≈$ 1ms
1. For the same circuit show VR(t) using a differential voltage marker, and use cursors to measure time constant (𝛕).



VR(t)

0.63\*Vo = 3.78

* Toe $≈1.0394m ≈$ 1ms

# Part C: Step response of second-order Series RLC circuit:



Figure (5.3)

1. For R = 10 kΩ, calculate the roots of the characteristic equation and write an expression for VC(t). Use PSPICE to do transient analysis of the circuit, and show VC(t).



Figure (5.3): PSPICE simulation

|  |  |  |
| --- | --- | --- |
|  | α = $\frac{R}{2L}=\frac{10k}{500m }=20000 rad/s$ | (4) |
|  | ω0 = $\frac{1}{\sqrt{LC}}= \frac{1}{\sqrt{2.5\*10^{-8}}}=6324.5$ | (5) |

The system is over damped:

|  |  |  |
| --- | --- | --- |
|  | S1,2 = - α $\pm $ $\sqrt{α^{2}- ω0^{2} }= -$20000 $\pm $ $\sqrt{20000^{2}- 6324.5^{2} }$ |  (6) |
|  | * S1 = -1026.3
* S2 = -38973.68
 |  |
|  | Vc(∞) = 3 |  |
|  |  VC(t) = A1 t \* $e^{S1t }$+ A2 t \* $e^{S2t }$+ VF |  (7) |
|  | * VC(t) = A1 \* $e^{-1026.3t }$+ A2 \* $e^{-38973.68t }$+ 3
 |  |



VC(t)

1. Calculate the critical resistance RC that will result in equal roots (S1 = S2 = - α) and write an expression for VC(t). Use PSPICE to do transient analysis of the circuit and show VC(t).

S1 = S2 = - α means that the response will be critically damped, so:

|  |  |  |
| --- | --- | --- |
|  | $α^{2}$ = $ω0 ^{2}$ |  |
|  | $$\left(\frac{Rc}{2L}\right)^{2}= \left(\frac{1}{\sqrt{LC}}\right)^{2}$$ | (8) |
|  | R2 = $\frac{4L}{C}=10000000$R = 3.162k ohm |  |
|  | * S1 = S2 = - $\frac{Rc}{2L}= - 6324$
 |  |
|  | VC(t) = D1 t \* $e^{-αt }$+ D2 t \* $e^{-αt }$+ VF | (9) |
|  | * VC(t) = A1 t \* $e^{-6324t }$+ A2 t \* $e^{-6324t }$+ 3
 |  |



VC(t)

1. For R = 500 Ω, calculate the roots of the characteristic equation, showing the value of 𝛂 𝐚𝐧𝐝 𝛚𝐝 and write an expression for VC(t). Use PSPICE to do transient analysis of the circuit, show VC(t), and measure 𝛂 𝐚𝐧𝐝 𝛚𝐝 using cursors.

α = $\frac{R}{2L}=\frac{500}{500m }=1000 rad/s$

ω0 = $\frac{1}{\sqrt{LC}}= \frac{1}{\sqrt{2.5\*10^{-8}}}=6324.5$

 ω0 > α so the response is under-damped:

|  |  |  |
| --- | --- | --- |
|  | * $ωd=(\sqrt{ω0^{2}- α^{2}})$ $=\left(\sqrt{6324.5^{2}- 1000^{2}}\right)=6244.94$
 | (10) |
|  | Vc(t) = VF + e-α (A cos ω0t + B sin ω0t) | (11) |
|  | * Vc(t) =3 + $e^{-1000t}$(A cos 6244.94t + B sin 6244.94t)
 |  |



VC(t)

|  |  |  |
| --- | --- | --- |
|  | $τ= \frac{tb-ta}{ln⁡(\frac{Va-Vo\left(\infty \right)}{Vb- Vo\left(\infty \right)})}$ = $\frac{1.5m-0.5m}{ln⁡(\frac{4.7227-3 }{3.5627-3)})}$ =0.894ms | (12) |
|  | * α = $\frac{1}{τ}$ = 1118.56 ohm
 | (13) |
|  | * $ωd= \frac{2π}{tb-ta}= \frac{2π}{1.5m-0.5m}= 6283.2$
 | (14) |

# Part D: Step response of second-order parallel RLC circuit:



Figure (5.4)

1. For R = 4 kΩ, calculate the roots of the characteristic equation showing the value of 𝛂 𝐚𝐧𝐝 𝛚𝐝. Write an expression of VC(t). Use PSPICE to do transient analysis of the circuit, show VC(t), and measure 𝛂 𝐚𝐧𝐝 𝛚𝐝 using cursors.



α = $\frac{1}{2RC}= \frac{1}{2\*4k\*0.1u}=1250$

ω0 = $\frac{1}{\sqrt{LC}}= \frac{1}{\sqrt{10^{-8}}}=10000$

ω0 > α so the response is under-damped:

* $ωd=(\sqrt{ω0^{2}- α^{2}})$ $=\left(\sqrt{10000^{2}- 1250^{2}}\right)=9921.56$

 Vc(t) = VF + e-α (A cos ω0t + B sin ω0t)

* VC (t) = $e^{-1000t}$(A cos 9921.56t + B sin 9921.56t)



VC(t)

$τ= \frac{tb-ta}{ln⁡(\frac{Va-Vo\left(\infty \right)}{Vb- Vo\left(\infty \right)})}$ = $\frac{0.79m-0.146m}{ln⁡(\frac{0.62m-0 }{0.28m-0)})}$ = 0.810ms

* α = $\frac{1}{τ}$ = 1234.56 ohm
* $ωd= \frac{2π}{tb-ta}= \frac{2π}{0.79m-0.146m}= 9756.49$
1. Calculate the critical resistance RC that will result in equal roots (S1 = S2 = - α) and write an expression for VC(t). Use PSPICE to do transient analysis of the circuit and show VC(t).

S1 = S2 = - α means that the response will be critically damped, so:

$α^{2}$ = $ω0 ^{2}$

$$\left(\frac{1}{2RC}\right)^{2}= \left(\frac{1}{\sqrt{LC}}\right)^{2}$$

RC= $\sqrt{\frac{L}{4C}}=500$ ohm

* S1 = S2 = - $\frac{1}{2RC}= - 10000$

VC(t) = D1 t \* $e^{-αt }$+ D2 t \* $e^{-αt }$+ VF

* VC(t) = A1 t \* $e^{-10000t }$+ A2 t \* $e^{-10000t }$



VC(t)

1. For R = 150 Ω, calculate the roots of the characteristic equation and write an expression for VC(t). Use PSPICE to do transient analysis of the circuit, and show VC(t).

α = $\frac{1}{2RC}= \frac{1}{2\*150\*0.1u}=33333.3$

ω0 = $\frac{1}{\sqrt{LC}}= \frac{1}{\sqrt{10^{-8}}}=10000$

ω0 < α so the system is over damped:

S1,2 = - α $\pm $ $\sqrt{α^{2}- ω0^{2} }= $- 33333.3 $\pm $ $\sqrt{33333.3^{2}- 10000^{2} }$

* S1 = -1535.36
* S2 = -65131.24

 VC(t) = A1 t \* $e^{S1t }$+ A2 t \* $e^{S2t }$+ VF

* VC(t) = A1 \* $e^{-1535.36t }$+ A2  \* $e^{-65131.24t }$



VC(t)