Queensland University of Technology

EGB120
Foundations of Electrical Engineering

Profressor Geoff Walker

Dinal Atapattu

November 6, 2023

Contents

Chapter 1

Circuits and Sources

1.1 Fundamental Electrical Quantities

1.2 Power and Energy

1.3 Circuits and Sources

1.4 Resistors and Ohm's Law

Chapter 2

Filters and Rectifiers

Chapter 3

Source Transformation

3.1 Thevenin Equivalent Circuits

3.2 Norton Equivalent Circuits

3.3 Superposition

3.4 Maximum Power Transfer

Chapter 4

Ohm's Law, Kirchoff's Laws, and Resistive Circuits

4.1 Kirchoff's Laws

4.2 Series and Parallel Elements

4.3 Voltage and Current Dividers

4.4 Measuring Voltages and Currents

Chapter 5

Diodes

5.1 Introduction to Diodes

5.2 Voltage and Current Characteristics

5.3 Operating Points and Load Lines

5.4 Practical Diodes

Chapter 6

Mesh Analysis

6.1 Nodes, Loops, and Meshes

6.2 Mesh Analysis

6.3 Current Source Mesh Analysis

6.4 Dependant Source Mesh Analysis

Chapter 7

Inductors and Capacitors

7.1 Capacitors

7.2 Inductors

7.3 Inductors and Capacitors in Steady State

Chapter 8

RL and RC circuits and Time Response

8.1 Switches

8.2 Natural Response

8.2.1 Capacitors and Inductors

Capacitors store energy as voltage

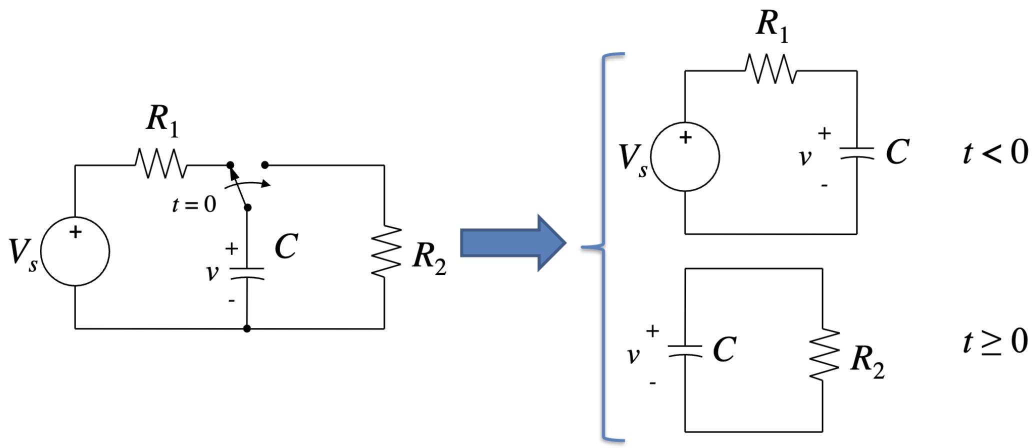
$$i = C\frac{\mathrm{d}v}{\mathrm{d}t}$$

Inductors store energy as current

$$v = L\frac{\mathrm{d}i}{\mathrm{d}t}$$

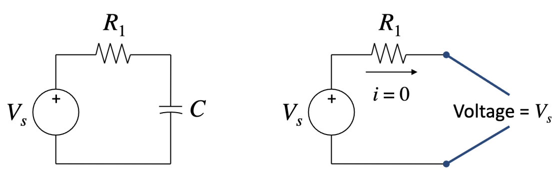
8.2.2 Switched RC Circuit

Assuming that the switch has been in the first position for a long time (till reached steady state). Find the voltage right before $t = 0$.



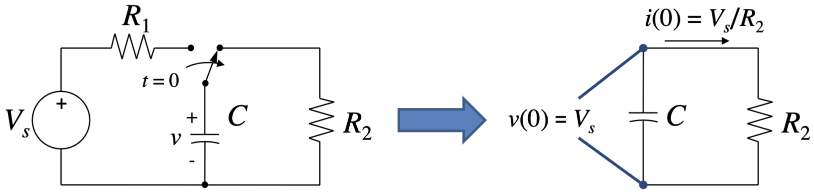
For the initial condition

- Perform steady state analysis by treating the capacitor as an open circuit



The voltage across the capacitor right before $t = 0$ is the same as source voltage V_s

Natural Response of an RC Circuit



Using KCL we get

$$-C\frac{\mathrm{d}v}{\mathrm{d}t} = \frac{v}{R_2}$$

Rearranging and solving the differential equation

$$\frac{\mathrm{d}v}{\mathrm{d}t} = -\frac{v}{R_2C}$$
$$\frac{1}{v}\frac{\mathrm{d}v}{\mathrm{d}t} = -\frac{1}{R_2C}$$

Integrate both sides

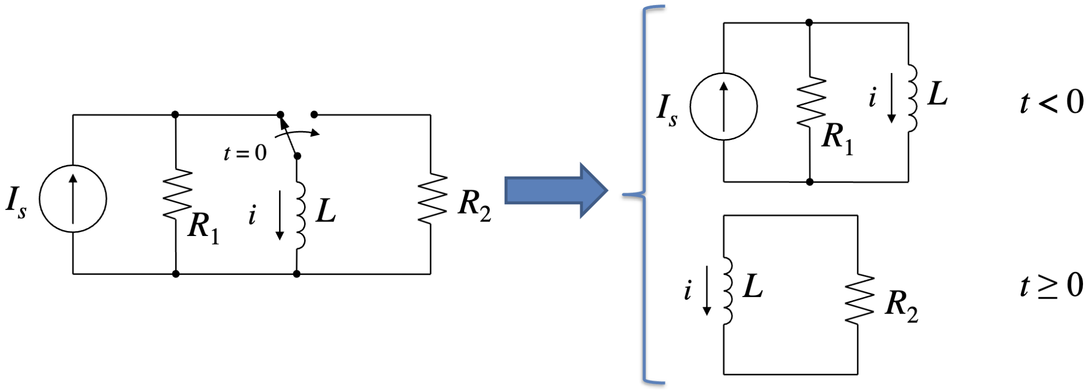
$$\int \frac{1}{v}\frac{\mathrm{d}v}{\mathrm{d}t}\,dt = \int -\frac{1}{R_2C}\,dt$$
$$\ln v = -\frac{t}{R_2C} + k$$
$$v = e^{-\frac{t}{R_2C}+k}$$
$$v = Ae^{-\frac{t}{R_2C}}$$

Noting that $A = v(0) = V_s$ we get

$$v = V_s e^{-\frac{t}{R_2C}}$$

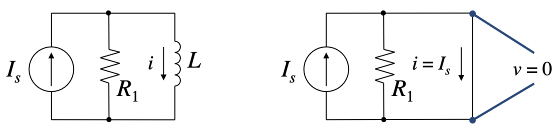
8.2.3 Switched RL Circuit

Assuming that the switch has been in the first position for a long time (till reached steady state). Find the current right before $t = 0$.



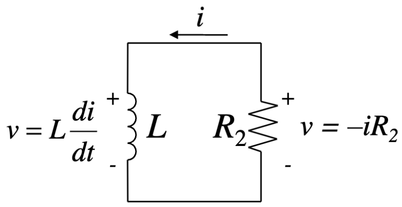
For the initial condition

- Perform steady state analysis by treating the inductor as a short circuit



The current through the inductor right before $t = 0$ is the same as source current I_s

Natural Response of an RL Circuit



Using KVL we get

$$-L\frac{\mathrm{d}i}{\mathrm{d}t} = R_2 i$$

Rearranging and solving the differential equation

$$\frac{\mathrm{d}i}{\mathrm{d}t} = -\frac{R_2}{L}i$$

Using the integrating factor method

$$\frac{\mathrm{d}i}{\mathrm{d}t} + \frac{R_2}{L}i = 0$$

Multiplying both sides by $e^{\frac{R_2}{L}t}$

$$e^{\frac{R_2}{L}t}\frac{\mathrm{d}i}{\mathrm{d}t} + \frac{R_2}{L}e^{\frac{R_2}{L}t}i = 0$$

Noting that $\frac{\mathrm{d}}{\mathrm{d}t}\left(e^{\frac{R_2}{L}t}i\right) = e^{\frac{R_2}{L}t}\frac{\mathrm{d}i}{\mathrm{d}t} + \frac{R_2}{L}e^{\frac{R_2}{L}t}i$

$$\frac{\mathrm{d}}{\mathrm{d}t}\left(e^{\frac{R_2}{L}t}i\right) = 0$$

Integrating both sides

$$\int \frac{\mathrm{d}}{\mathrm{d}t}\left(e^{\frac{R_2}{L}t}i\right)\,dt = \int 0\,dt$$
$$e^{\frac{R_2}{L}t}i = k$$
$$i = ke^{-\frac{R_2}{L}t}$$

Noting that $k = i(0) = I_s$ we get

$$i = I_s e^{-\frac{R_2}{L}t}$$

8.2.4 Natural Response

$$v(t) = v(0)e^{-\frac{t}{R_2C}}$$ (Where $\tau = RC$ is the time constant)

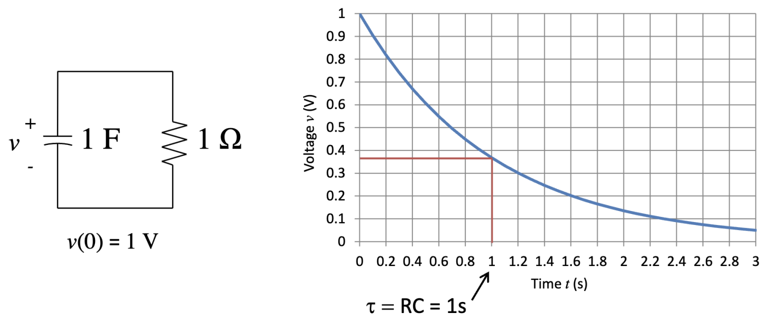


Figure 8.1: Natural Response of RC Circuit for $v(t) = v(0)e^{-\frac{t}{R_2C}}$ where $v(0) = 1V$, $R_2C = 1\Omega$, and $C = 1F$

$$i(t) = i(0)e^{-\frac{t}{R_2 C}} \qquad \text{(Where } \tau = \frac{L}{R_2} \text{ is the time constant)}$$

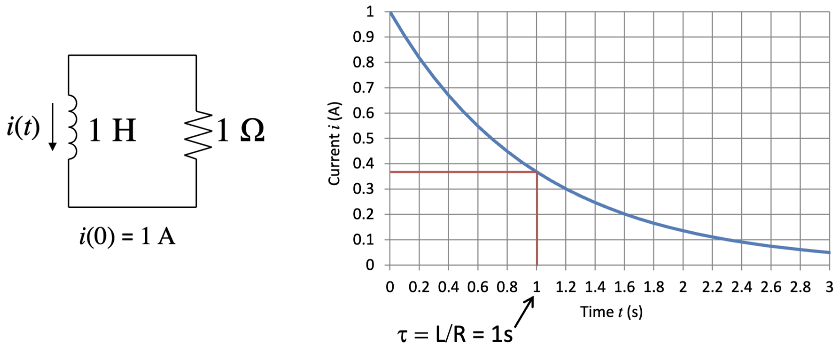


Figure 8.2: Natural Response of RL Circuit for $i(t) = i(0)e^{-\frac{t}{R_2 C}}$ where $i(0) = 1A$, $R_2 C = 1\Omega$, and $L = 1H$

8.3 Step Response

Chapter 9

Operational Amplifiers

9.1 Introduction to Operational Amplifiers

9.2 Op Amp Analysis

9.3 Practical Op Amps

Chapter 10

Sinusoidal State Analysis

10.1 Sinusoidal Signals

10.2 RMS

10.3 Phasors

10.4 Circuit Analysis with Phasors

Chapter 11

Frequency Response of RL and RC Circuits

11.1 AC Circuit Analysis

11.2 Frequency Response and Transfer Functions

11.3 Bode Plots

Chapter 12

Filters and Rectifiers

12.1 Filter Introduction

12.2 Passive Filters

12.3 Active Filters

Chapter 13

Zener Diodes and Voltage Regulators

13.1 Rectifiers and Regulators

13.2 Zener Diode Regulators

13.3 Series Regulators

13.4 Op Amps as Regulators