Facilitator's Guide to Module 11:
The First Order Step Response

Introduction

In this series of lectures capacitors and inductors are introduced as circuit elements and then the natural and step response of first order circuits are studied. The module has been organized to first provide an introduction to inductors and capacitors as circuit elements. This section can be omitted, if it is adequately covered elsewhere. The second part covers the natural and step response of simple resistor-capacitor (RC) and resistor-inductor (RL) circuits and extends the results to general first order RC and RL circuits, by exploiting the student's knowledge of Thévenin and Norton equivalent circuits and superposition.

Prerequisites

Before starting this module, one should be familiar with;

- circuit elements such as resistors, switches, voltage sources and current sources,
- Kirchhoff's Voltage and Current Laws, along with voltage and current division,
- Thévenin and Norton equivalent networks and superposition
- and finding the derivative and the integral of common functions, especially piecewise constant functions and the exponential function[1].

Outcomes

With careful study, by the end of this module, one should be able to;

- describe the behaviour of inductors and capacitors as circuit elements,
- calculate the equivalent value of parallel and series combinations of inductors and of capacitors.
- analyze circuits containing inductors, resistors and capacitors driven by dc sources and determine the energy stored in the reactive elements,
- evaluate the response of first order circuits to some initial stored energy,
- and evaluate the response of first order circuits to step changes in their input voltage or current.

Module Overview

This module consists of a sequence of 26 videos with self-assessment questions keyed to specific videos. The videos provide an alternative to in-class lectures and reading the textbook. The videos can be assigned in place of regularly scheduled lectures or as additional material. It is expected that the course instructor, will supplement the module with additional questions and perhaps some problem solving tutorials and one or two laboratory exercises.

1. We have specifically avoided introducing the unit step function (also known as the Heaviside function).

Module Contents for Capacitors and Inductors as Circuit Elements

Introduction to the Capacitor

1. LC1a Introduction: An introduction to the capacitor's basic structure and operation.
2. LC1b Symbol I-V: Using capacitors as circuit elements, their symbol and I-V relationship.
3. LC1c Example: An example to illustrate finding a capacitor's voltage from its current.
4. LC1d Power: Power and energy relationships for the capacitor.

Introduction to the Inductor

5. LC2a Introduction: An introduction to the inductor's basic structure and operation.
6. LC1b Symbol I-V: Using inductors as circuit elements, their symbol and I-V relationship.
7. LC2c Power: Power and energy relationships for the inductor.
8. LC2d Example: Determining the energy stored in passive elements in dc circuits.

Parallel and Series Combinations of Capacitors and Inductors

9. LC3a Introduction: A quick review of the I-V relationships for capacitors and inductors.
10. LC3b Inductors in Series: The equivalent inductance of inductors connected in series.
11. LC3c Capacitors in Series: The equivalent capacitance of capacitors connected in series.
12. LC3d Inductors in Parallel: The equivalent inductance of inductors connected in parallel.
13. LC3e Capacitors in Parallel: The equivalent capacitance of capacitors connected in parallel.
14. LC3f Summary: The series and parallel relationships for capacitors and inductors.
15. LC3g Example: Simplification of a circuit containing multiple inductors and capacitors.
    - Followed by 15 problems.

Module Contents for The Natural and Step Response of First Order Circuits

Natural Response of a First Order RC Circuit

1. Step1a Introduction: Introduction to first order RC circuits and their natural response.
2. Step1b Time Constant: A discussion of the significance of, and how to find the time constant.
3. Step1c Example: A worked example of determining the natural response of an RC circuit.

Step Response of a First Order RC Circuit

4. Step 2a RC Step: Analysis of the step response of a first order RC circuit.
5. Step2b RC Observations: A discussion of the step response and how to determine it quickly.
6. Step2c RC Step Example: A numerical example of the step response for an RC circuit.

Natural and Step Response of a First Order RL Circuit

7. Step3a RL Natural: Analysis of the natural response of an RL circuit.
8. Step3b RL Step1: Analysis of the step response of an RL circuit's inductor current using basic circuit analysis and using the Norton equivalent circuit to provide insight.
9. Step3c RL Step2: The above analysis continued, determining all the other circuit variables. This video can be omitted if the students understand the significance of superposition.
10. Step3d RL Summary: A review and generalization of the first order step response.
11. Step3e RL Example: An example of a step response problem with multiple steps.
    - Followed by 10 problems.