Synthesis Lectures on Electrical Engineering

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Farzin Asadi

Electric Circuits Laboratory Manual

Springer

Synthesis Lectures on Electrical Engineering

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Preface

This is a book for a lab course meant to accompany, or follow, any first course in electric circuit analysis. It has been written for sophomore or junior electrical and computer engineering students who are taking their first lab, either concurrently with their first electric circuit analysis class or following that class. This book is appropriate for non-majors, such as students in other branches of engineering and in physics, for which electric circuits is a required course or elective and for whom a working knowledge of electric circuits is desirable.

This book has the following objectives:

1. To support, verify, and supplement the theory; to show the relations and differences between theory and practice.
2. To teach measurement techniques.
3. To convince students that what they are taught in their lecture classes is real and useful.
4. To help make students tinkerers and make them used to asking "what if" questions.

This book contains 33 experiments which help the reader to explore the concepts studied in the classroom. Here is a brief summary of the chapters and appendixes:

Chapter 1 introduces the commonly used measurement devices that are used during the experiments and breadboard to the reader.

Chapter 2 studies the resistors. This chapter contains 9 experiments.

Chapter 3 studies the details of measurement with Digital Multi Meters (DMM). This chapter contains 7 experiments.

Chapter 4 studies some of the important circuit theorems like Kirchhoff's Voltage Law (KVL), Kirchhoff's Current Law (KCL), nodal analysis, mesh analysis, and Thevenin equivalent circuit. This chapter contains 5 experiments.

Chapter 5 studies the first order (RC and RL) and second order (series and parallel RLC) circuits. This chapter contains 4 experiments.

Chapter 6 studies the DC and AC steady state behavior of electric circuits. Frequency response of filters are studied in this chapter as well. This chapter contains 5 experiments.

Chapter 7 studies magnetic coupling and transformers. This chapter contains 3 experiments.

Appendix A shows how to draw different types of graphs with MATLAB®.

Appendix B reviews the concept of Root Mean Square (RMS).

I hope that this book will be useful to the readers, and I welcome comments on the book.

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Contents

Commonly Used Labaratory Equipmentes

1

1.1 Introduction

This chapter studies the most commonly used devices in the laboratory. Measurement devices that are used in different laboratories are made by different companies. Working with each device has its own details. Therefore, you are encouraged to read the user manual of devices that you will use during the experiments. Another good reference is your laboratory instructor. Studying the reference [1] is highly recommended as well.

1.2 Digital Multi Meter (DMM)

Digital multimeters are measuring instruments that can measure quantities such as voltage, current, and resistance. Measured values are shown on a digital display, allowing them to be read easily and directly, even by first-time users.

Study the user manual of the DMM that you will use in the experiments. Ensure that you are able to do the followings:

(a) Measurement of resistance.
(b) Measurement of AC/DC voltages.
(c) Measurement of AC/DC currents in the range of Amps.
(d) Measurement of AC/DC currents in the range of milli/micro Amps.

Ask your laboratory instructor to make an explanation to you if you are not able to do one or more of the above tasks.

F. Asadi, *Electric Circuits Laboratory Manual*, Synthesis Lectures
on Electrical Engineering, https://doi.org/10.1007/978-3-031-24552-7_1

1.3 Function Generator (Signal Generator)

A function generator (sometime is called signal generator) is used to generate different types of electrical waveforms over a wide range of frequencies. Some of the most common waveforms produced by the function generator are the sine wave, square wave, triangular wave and saw tooth shapes.

The FG's are divided into two groups: Analog FG's and Direct Digital Synthesis (DDS) FG's. As the name suggests, the analog FG's, uses the analog circuits in order to produce the output waveform. DDS FG's use digital circuits (i.e. a microprocessor) in order to produce the output waveforms. Accuracy of DDS signal generators is better than analog signal generators.

Beside the standard waveforms (i.e. sinusoidal, square, triangular and saw tooth), some DDS FG's are able to produce arbitrary waveforms. These type of FG's are called Arbitrary Waveform Generator (AWG). They have software which permits you to draw the waveform that you want. After drawing the waveform in the software environment, the hardware of AWG produces the waveform for you.

Output of function generator is connected to the circuit under test with the aid of a cable (Fig. 1.1). Black wire is connected to the ground of the signal generator as shown in Fig. 1.2. R1 shows the output resistance of the signal generator which is generally 50 Ω.

Fig. 1.1 Signal generator cable

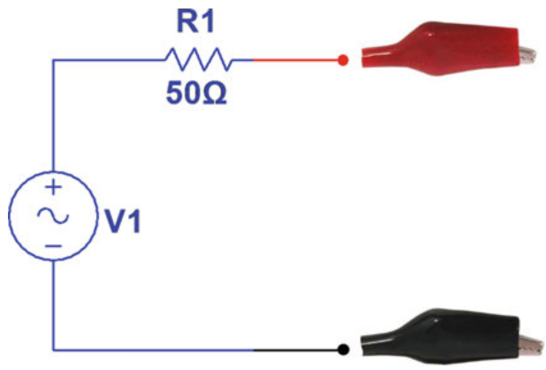

Fig. 1.2 Simple model for signal generator

Study the user manual of the function generator that you will use in the experiments. Ensure that you are able to do the followings:

(a) Generation of a sinusoidal signal with amplitude of 5 V and frequency of 50 Hz, i.e., $v(t) = 5 \times \sin(2\pi \times 50 \times t)V$.
(b) Generation of a sinusoidal signal with amplitude of 5 V, frequency of 50 Hz and average value of 3 V, i.e., $v(t) = 3 + 5 \times \sin(2\pi \times 50 \times t)V$.
(c) Generation of a sinusoidal signal with peak value of 50 mV, i.e., $\mathrm{v}(t) = 0.05 \times \sin(2\pi \times 50 \times t)V$.
(d) Generation of a triangular wave with frequency of 50 Hz and peak value of 5 V (Fig. 1.3).

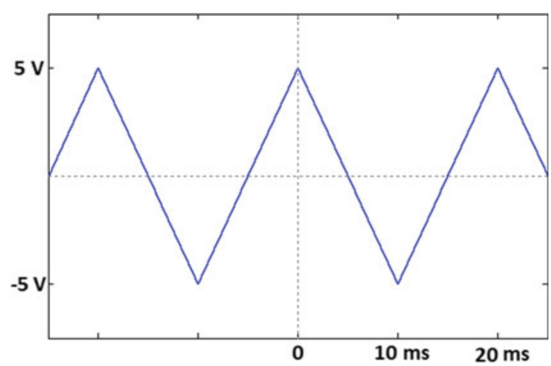

Fig. 1.3 Sample triangular wave

(e) Generation of a pulse with frequency of 50 Hz and duty cycle of 25% (Fig. 1.4).

Ask your laboratory instructor to make an explanation to you if you are not able to do one or more of the above tasks.

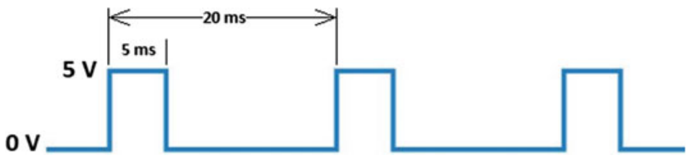

Fig. 1.4 Sample pulse

1.4 Oscilloscope

An oscilloscope is an instrument that graphically displays electrical signals and shows how those signals change over time. Scientists, engineers, physicists, repair technicians and educators use oscilloscopes to see signals change over time. These days generally digital scopes are used in laboratory.

Study the user manual of the oscilloscope that you will use in the experiments. Ensure that you are able to do the followings:

(a) Measurement of peak value of a signal.
(b) Measurement of period and frequency of a periodic signal.
(c) Use the cursors to read voltage or time difference between two points.
(d) Observing two waveforms simultaneously.
(e) Measurement of phase difference between two waveforms. Remember that you can measure the phase difference between two waveform easily with the aid of $\Delta\varphi = \frac{\Delta t}{T} \times 360°$ formula (Fig. 1.5).

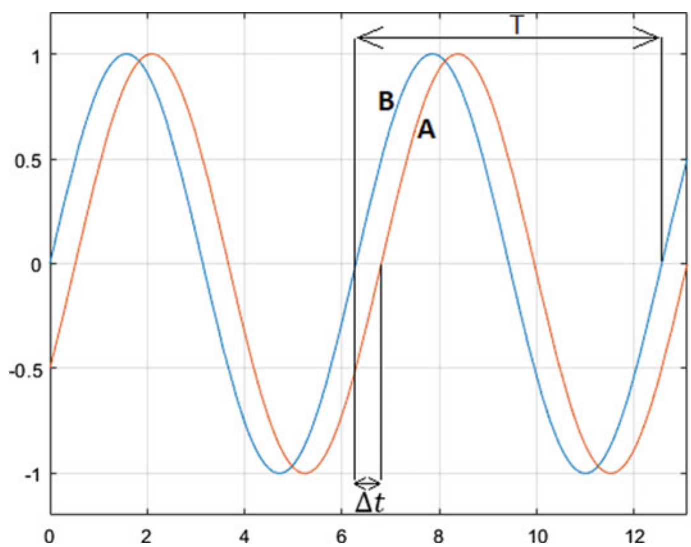

Fig. 1.5 Measurement of phase difference. B leads A by $\Delta\varphi = \frac{\Delta t}{T} \times 360°$

(f) Explain the difference between AC and DC coupling.
(g) Explain the functionality of X1/X10 switch on the probe.

Ask your laboratory instructor to make an explanation to you if you are not able to do one or more of the above tasks.

1.5 Power Supply

All the circuits require an energy source in order to work. The power supply (PS) is responsible for providing the required energy for the circuit. The power supply takes the AC electric energy from the grid and converts it into a DC voltage. Generally, they provide the voltages in the 0–30 V range. Generally, the output current could be up to 3 A. The outputs of a PS are called a "Channel". So, when we speak about a 3 channel PS, we mean a PS with three outputs. Generally, the outputs are variable and the user could set them to the desired value he/she wants. Generally, PS's have one regulated output with voltage of 5 V. This output is used to supply digital circuits. Remember that traditional digital circuits work with 5 V (However this voltage decreased to 3.3 V and even 1.1 V these days!). So, it is a good idea to use this fixed 5 V when you work with traditional digital circuits. You can connect a digital circuit to variable outputs of a PS. However, if you increase the voltage of that variable channel by mistake, then your circuit may be damaged. So, always use this fixed 5 V when you are working with traditional digital circuits.

Study the user manual of the power supply that you will use in the experiments. Ensure that you are able to do the followings:

(a) Generation of 12 V with maximum output current of 0.5 A.
(b) Generation of 12 V with maximum output current of 5 A (Use parallel mode).
(c) Generation of 40 V with maximum output current of 1 A (Use series mode).
(d) Generation of a symmetric voltage for instance +12 V and −12 V with maximum output current of 0.5 A.

Ask your laboratory instructor to make an explanation to you if you are not able to do one or more of the above tasks.

1.6 Breadboard

A breadboard is used to build and test circuits quickly. The breadboard has many holes into which circuit components like ICs and resistors can be inserted. A typical breadboard is shown in Fig. 1.6.

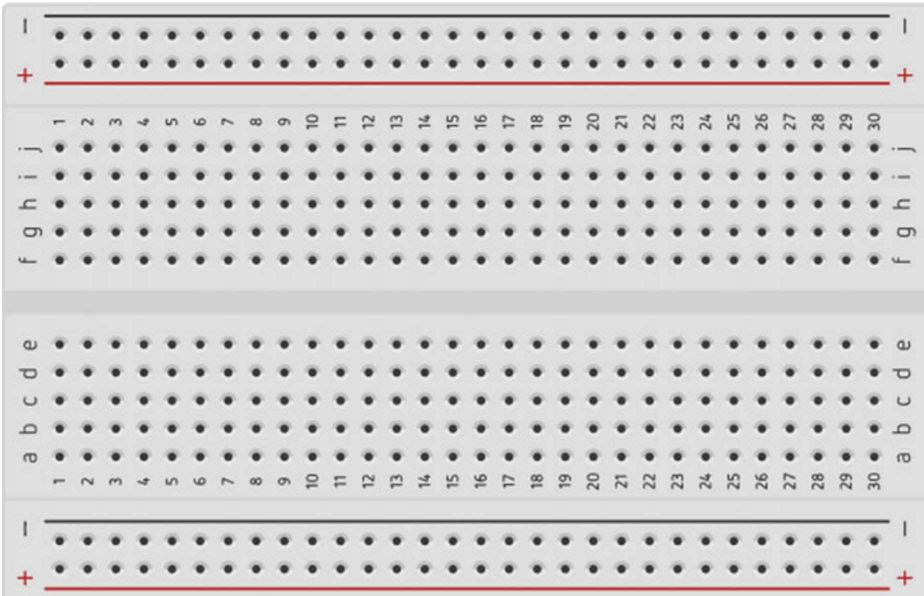

Fig. 1.6 Bread board

The breadboard has strips of metal which run underneath the board and connect the holes on the top of the board. The metal strips are laid out as shown below. Note that the top and bottom rows of holes are connected horizontally while the remaining holes are connected vertically (Figs. 1.7 and 1.8).