

**Laboratory 1: Familiarization**

## 1 Introduction:

**Laboratory Objectives:** This first laboratory session is to introduce to the instruments and components that make up the lab-stations that you will be using throughout the term. In particular you should become familiar with

- (i) The various laboratory hardware components at your lab-station.
- (ii) The “Virtual Bench” computer-based laboratory instruments (oscilloscope, function generator, digital voltmeter, digital signal analyzer).
- (iii) The use of Virtual Bench to make dynamic response measurements on a simple R-C electrical circuit.

**Preparation:** Before you came to the laboratory you did a written preparation exercise. Keep this on hand for reference during the lab and hand it in as part of the report.

**The Lab Bench:** On your bench you have the following pieces of equipment:

- (1) A permanent-magnet dc electric servo motor with an inertial load (a ‘plant’) about the size of a starter motor for a car.
- (2) A power amplifier (a ‘servo-amp’) to drive the motor.
- (3) An input/output interface box connected to your computer. The input BNC connectors on this box allow you to measure and record voltages through an A-to-D (analog to digital) converter. Similarly the computer is able to generate voltages through a pair of D-to-A (digital to analog) converters connected to the BNC connectors marked ‘output.’ You will make connections between your equipment and the computer through this box.
- (4) The computer contains software packages such as Matlab and Simulink to help you process information, simulate electronic and physical systems, and design controllers. In addition, it contains a program called “Virtual Bench.” Virtual Bench provides a set of five “virtual” instruments: an oscilloscope, function generator, digital voltmeter, digital signal analyzer, and data logger. You will use this package extensively throughout the term to generate commands and monitor system response.

- (5) An electronic breadboard. Each lab group will have its own breadboard on which you will build electronic controllers.

Detailed specifications for your lab equipment are given in the accompanying handout.

**Further equipment:** In the drawer of the bench you have a digital multimeter, a set of BNC cables, a breadboard for constructing circuits, wire clippers, connectors, etc.

## 2 Explore your equipment

- (1) Turn on your computer, and log on as instructed by the lab instructor. You will notice a set of icons on the screen for the major lab software components (Vbench, Matlab, Maple). Double click on the Vbench icon to open Virtual Bench (Vbench): the Virtual Bench toolbox menu will appear.
- (2) Click on the function generator (FG) icon. The panel of the virtual function generator will appear. The function generator generates voltage signals with different amplitudes, frequencies, and waveforms, and sends them via the D-to-A (digital-to-analog) converter to the output connector on the interface box. Use the mouse to “turn” the knobs and “press” the buttons. Use the Configuration menu to set the function generator to use a specific output channel.
- (3) Click on the oscilloscope icon in the Vbench menu. The oscilloscope will appear. You may switch between the function generator and the oscilloscope by clicking on its window. To display the signal generated by the function generator, use a BNC cable to connect Channel 1 of the output connectors on the interface box to Channel 1 of the input connectors, and open the oscilloscope (Scope). The virtual oscilloscope mimics a 4 channel real oscilloscope, and has many features found only in expensive digital oscilloscopes.

The main use of the oscilloscope is to show a trace of the voltage of the input signal as a function of time. To get a signal, you may need to change the input channel of the oscilloscope, the trigger, and the output voltage on the function generator. The oscilloscope also measures a variety of properties of the signal. Click on *Configure* on the oscilloscope menu, then click on *Scope* and go to the section marked *Measurements*. You can then select the measurements that you want to see.

- (4) Experiment with the function generator and the oscilloscope to view a variety of waveforms, and to try out different features of the equipment. For example, what does the *Duty Cycle* knob on the function generator control? What happens when you change the *Averaging* feature of the oscilloscope (controlled in the *Configure* menu)?

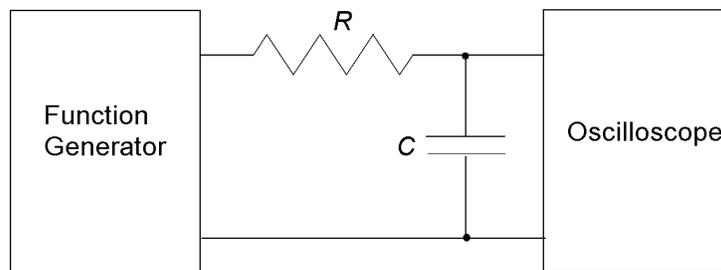
A problem that occurs with all digital instrumentation is “aliasing”. If you sample a sinusoidal waveform too slowly it will appear to have a frequency much lower than its true frequency. Sampling theory states that you must sample fast enough to capture

more than two samples per cycle of the highest frequency present in the input waveform. This means that if you have a 100 Hz sinusoid, in order to reconstruct it unambiguously your sampling rate must be more than 200 samples/second. Experiment with aliasing by setting a sampling rate on the oscilloscope and using an input of different frequencies.

- (5) Open the digital voltmeter on the Virtual Bench menu. Use the voltmeter to measure the RMS (root-mean-square) voltage of the input signal. Vary the amplitude and waveform of the signal and see how the voltage changes. Is the RMS voltage of a sine wave the same as the RMS voltage of a square wave of the same amplitude? If not, by what factor do they differ?

### 3 Build and test a simple circuit

Using the supplied electronic breadboard, resistors and capacitors, construct the simple R-C circuit shown below from part (a) of the laboratory preparation exercise 1 homework.



Use a capacitor with capacitance between 0.5 and 5  $\mu\text{F}$ , and a 1 k $\Omega$  resistor. Note the resistors and capacitors used on your lab answer sheet. Using the BNC connectors on the board, supply  $V_{\text{in}}$  to the circuit from an output of the input/output box, and take  $V_{\text{out}}$  from the circuit to an input on the input/output box. Test the circuit as follows:

- (1) Calculate the time constant of the circuit, and note it down on your lab answer sheet.
- (2) Using the function generator, generate a step input for the circuit by selecting a square wave with a period longer than twice the circuit's time constant.
- (3) Drive the circuit with the square wave. Sketch or print the output waveform.
- (4) Use the measurement feature of the oscilloscope to measure the rise time and steady-state voltage of the output trace. Record the result on your answer sheet and discuss how this result compares with the answer you calculated in step (1), and with the step response you sketched in the preparation exercise.
- (5) Change the amplitude and frequency of the square wave and record and compare the resulting rise times. How does the fall time compare with the rise time? Discuss what the results of these measurements imply about your circuit.

- (6) Now substitute a  $20\text{ k}\Omega$  resistor in your circuit and perform steps (1-4) again. Is there a problem?
- (7) Explain the results of step (6) in terms of a circuit of the form given in part (d) of the preparation exercise. What would  $R_2$  have to be to explain the results of your measurements? response.

Repeat the procedure with the capacitor and resistor interchanged as shown below:

