LABORATORY NUMBER 10

EFFECT OF SAMPLING RATE ON RECORDING OF A TIME VARYING SIGNAL

1.0 INTRODUCTION

Computer data acquisition systems may in some cases be used for single point measurements in which each sensor only supplies a single value. In the more general case, however, the sensor output will produce a time-varying analog signal. The computer will sample this signal with a certain sample rate – for example 5 samples per second. The recorded data will thus not be a complete record but only discrete values corresponding to the times the signal was sampled. Compact discs for audio recording use this method (with a sampling rate of over 40 kHz). If the sensor output changes significantly between samples, the data acquisition system may not provide a meaningful recording of the time varying experimental signal. For example, if the sensor output has a frequency of 5 kHz and the sampling rate is 10 samples per second, the recorded data may be worthless. In fact, the recorded data can be very misleading, leaving out information of importance and also introducing false information. If, for instance, the signal frequency is an exact integer multiple of the sampling rate, the sample will occur at the same position of each signal cycle and the recorded data will appear to have a constant (DC) value. If the sampling rate is close to the signal frequency (but greater than the signal frequency), the recorded data will have a frequency which is the difference between the signal and the sampling rate. This latter effect produces false frequencies which do not actually exist in the data. The effect is called aliasing. Aliasing is a major problem for data acquisition.

A simple sine wave – $Asin(2\pi ft)$ – is made up of a single frequency. Most periodic (repeating) time varying waves are much more complicated. They consist of a fundamental or lowest frequency and other higher frequencies. For periodic waveforms, it is possible to perform a Fourier Analysis to find these higher frequencies or harmonics as they are called. A square wave, for example, consists of the fundamental frequency plus an infinite series of odd-integer (3, 5, etc.) multiples of the fundamental frequency. Even non-repeating time varying signals can be broken up into Fourier components over a defined time span. Thus, to determine the maximum frequency in a signal, the experimenter must look beyond the lowest frequency and examine the other, higher frequency, components.

In some cases, the maximum frequencies in the sensor output are not of interest to the experimenter. In analog (continuous) recording methods, this is not a problem because these higher frequencies can be filtered out using low pass filters before the data is displayed. For discretely sampled signals however, this filtering must be performed before the signal is recorded. Otherwise, alias signals will be generated which may well fall into the frequency range of the data of interest.
A fundamental sampling-rate theorem provides that aliasing problems can be avoided if the sampling rate is at least twice the maximum frequency component of the sensor output. A frequency which is half the sampling rate is called the Nyquist frequency and is the maximum frequency that can be successfully sampled. A sampling rate of twice the Nyquist frequency may not, however, result in recorded data which accurately reproduces the actual wave shape. There are, however, methods that can recover the original wave shape if the sampling rate is at least twice Nyquist frequency. Often, the signal is sampled at a rate significantly higher than twice the Nyquist frequency. In this case, more sophisticated methods to recover the original wave shape may not be required.

2.0 THE EXPERIMENT

2.1 EXPERIMENTAL APPARATUS

The experimental apparatus (schematic shown in Figure 10.1) consists of the computer data acquisition system (with a 12-bit A/D converter), a function generator, and an oscilloscope. The transformer produces a single-frequency sinusoidal signal that can be displayed on the oscilloscope. This same signal is then sampled by the computer data-acquisition system. The data-acquisition system is capable of sampling an analog input signal at up to 200,000 samples per second. In this experiment, however, the sampling will be done at much lower rates to investigate the issue of aliasing.

2.2 TEST PROCEDURE

Connect the apparatus as shown in Figure 10.1. Use a BNC-connector splitter to feed the signal from the function generator to both the oscilloscope and the data acquisition input box. Turn on the function generator and, using oscilloscope measurements as a guide, adjust the function generator (frequency and amplitude) such that the output signal is nominally a 60 Hz sinusoid with a peak-to-peak voltage of 6 V. Record the actual values of the frequency and peak-to-peak voltage as determined by the oscilloscope.

Open the VI entitled Lab10 from the folder on the Desktop labeled “ENGR 300 Labs”. For each run, enter the run number, the sampling rate, and the number of samples (as indicated in the table below). Press the run button ( giỏi) on the LabVIEW toolbar to record the data. The data will be saved to the Desktop in a file entitled Lab10_Runx.xls, where x is the run number (an individual file is created for each run). The first column in the data file represents the time in seconds; the second
column represents the corresponding measured voltage in volts.

You should complete the following runs:

<table>
<thead>
<tr>
<th>RUN</th>
<th>SAMPLE RATE (Hz)</th>
<th>NO. SAMPLES</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>30</td>
<td>100</td>
</tr>
<tr>
<td>2</td>
<td>35</td>
<td>100</td>
</tr>
<tr>
<td>3</td>
<td>60</td>
<td>100</td>
</tr>
<tr>
<td>4</td>
<td>65</td>
<td>100</td>
</tr>
<tr>
<td>5</td>
<td>110</td>
<td>50</td>
</tr>
<tr>
<td>6</td>
<td>120</td>
<td>50</td>
</tr>
<tr>
<td>7</td>
<td>300</td>
<td>50</td>
</tr>
</tbody>
</table>

To assist in your analysis, you may also wish to conduct an eighth run with higher sampling rate (e.g., 100 samples at 1000 Hz). You may then use this eighth run as a representation of the true signal (rather than recalling from memory the nature of the true signal as displayed on the oscilloscope).

This completes the data taking for this experiment.

3.0 REQUIRED RESULTS

You can view, print and plot the results by accessing the files using Excel or use an alternate software application of your choice.

Prepare a separate plot of each run in the form of voltage on the \( y \)-axis and time on the \( x \)-axis.

For each graph, using only that graph, make your best estimate of the frequency and amplitude of the results.

3.1 DISCUSSION

You are to submit your results in a form requested by the instructor.

You should consider the following when writing your discussion. What can you say about the frequency and amplitude of the signals as compared to the oscilloscope results for each run. What sampling rate might be considered to produce an adequate representation of the actual signal? What might happen if the actual signal were a 60 Hz sawtooth wave of the same amplitude and it were sampled at a rate of 130 samples/sec? If you give some thought to the matter, you can give a good explanation as to why the results look the way they do.