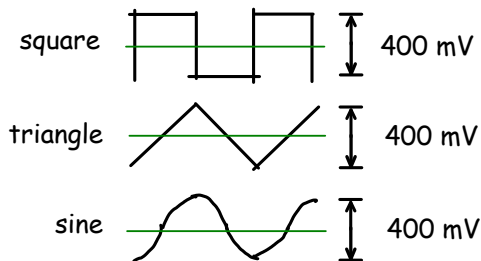


Lab 4 - Signal Capture and Analysis

Introduction

The purpose of this lab is to capture waveforms with a digital oscilloscope and analyze the captured signals using numerical analysis software and spreadsheets.

You will measure the statistics of the three waveforms that can be generated by the lab's function generator: square, triangle and sine waves:



You will capture these waveforms with a digital oscilloscope. Then you will use Matlab to compute histograms that estimate the probability density functions of the waveforms. The histograms will be imported into a spreadsheet and you will use the spreadsheet to plot the probability distributions, compute the RMS powers from the distributions and compare them to the powers measured using an RMS voltmeter and the oscilloscope's measurement function.

Waveform capture records a "snapshot" of a signal so that it can be analyzed with software later. In this lab we will use a digital oscilloscope to sample the signal voltage and save the sample values to a file.

Software

Numerical Analysis Software

Numerical analysis software such as Matlab, has many signal-processing and statistics libraries and support for high-level data structures such as complex vectors and matrices. This makes it possible to perform complex analyses with relatively little programming.

For this lab you can use Matlab or the free and largely compatible alternatives FreeMat or Octave. Many other software packages, both commercial and open-source, are also available. Some of the most popular include Mathematica, Maple, MathCAD, R, Octave, and Sage.

Spreadsheets

You should already be familiar with spreadsheets from previous courses. They are useful for manipulating and presenting limited amounts of data and for formatting numerical data for reports.

For this lab you can use Excel or OpenOffice/LibreOffice Calc.

CSV Files

Text files contain characters and can be read by people. For example, you can print a text file containing numbers and read the values directly.

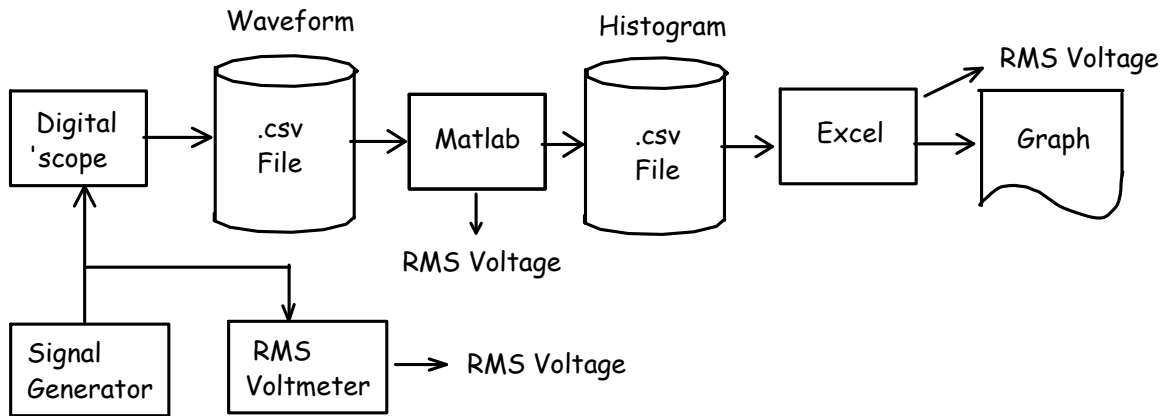
A common text file format for exchanging numerical data between programs uses comma-separated values (CSV). Each line of the file corresponds to one row of a table and the values for each column are separated by commas.

Strings can also be included in CSV files by quoting them although in this lab we will restrict ourselves to CSV files with numerical values.

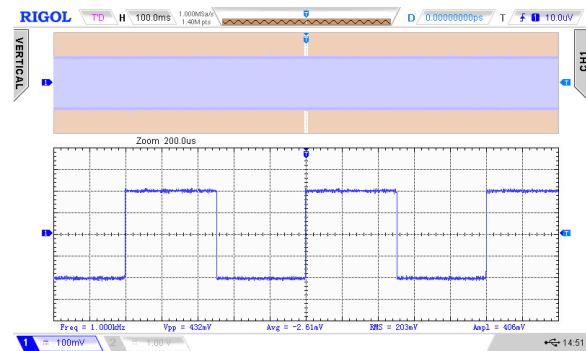
Procedure

Waveform Capture

As shown below, connect the output of the function generator to both Channel 1 of the 'scope and the voltmeter so you can view the waveform and measure its voltage on the DMM simultaneously. The 'scope will sample the input signal and digitize it (convert it to a number). The RMS voltmeter will allow you to measure the RMS voltage independently of the 'scope.



can view a few cycles of the square wave:



Note that the Fluke multimeters in the lab are unusual in that they are RMS-responding. Most DMMs are average-responding and only measure the average value of a signal. For these DMMs the voltage reading only corresponds to the RMS voltage when the signal is a sine wave.

Adjust the signal generator output for a square-wave output at a 1 kHz frequency with a 200mV amplitude (400 mV peak-to-peak) and less than a few mV DC (average) value. You may have to enable the -20dB output level range and enable and adjust the DC offset to get these values.

Use the 'scope's Measurement menu to add frequency and RMS, Avg (average) and Ampl (amplitude $\times 2$) voltage measurements to the display.

Use the Acquire menu to set the memory Depth to 140 kSamples. Use the Scale control in the Horizontal controls section for a sampling rate of 1 MHz. These values will be visible in the status line at the top of the display.

Press the Horizontal scale knob to switch to delayed trigger mode. This will show a portion of the captured samples. Adjust the horizontal scale so you

Use the DMM to measure the RMS value of the waveform. It should match the 'scope measurement value.

Plug a flash drive into the connector on the front of the 'scope. Press the printer icon on the top right of the panel to capture an image of the display. The image file name will be displayed briefly. Write down the file name in your lab book.

Use the Storage menu to save the captured data to your flash drive. Under "Storage" select CSV for the file type, Channel 1 for the source, "Maximum" for the Data Depth and enable Parameter Save.

Press Save to select the folder (directory) and file name under which to save the file. You can create a new folder on the flash drive and a new file name.

Record the following: the data and time, the type of waveform, the frequency shown on the signal generator, the voltage shown on the DMM, the measurement values on the 'scope and the names of the image and waveform capture files.

Change the signal generator to a triangle-wave output and check with the 'scope that the amplitude

(peak-to-peak) voltage is still 400 mV. Check that the average (DC) voltage is zero.

Repeat the steps above, saving image and waveform capture files and recording the various instrument readings.

Repeat the above steps using a sine wave signal.

You should now have three sets of voltage readings, three display files and three waveform files.

The rest of the lab can be done without test equipment but you should try to do as much of it as possible during the lab session in case you need to repeat some of your measurements.

Waveform Analysis

Run Matlab or Freemat. Use the `cd` command to change to the directory where you have copied the files for this lab (e.g. a folder on your H: network drive). Read the waveform data from the CSV waveform sample file using the command:

```
s=csvread('Newfile3.csv',2,1,[2 1 140001 1]);
```

which will skip the first two rows and read only second column. You may have to prefix the file name with the drive letter and folder name.

Plot the first 2000 samples of the waveform to make sure you captured and have read the waveform correctly:

```
plot(s(1:2000))
```

Use the File->Save As menu item in the plot window to save this plot to an image file (.png format) so that you can include it your report later.

Compute the mean and RMS values of the captured waveform:

```
mean(s)
std(s)
```

Compute a histogram of the voltage waveform using the `hist()` function:

```
[n,v]=hist(s,100);
```

which will return a vector `n` with the number of samples values in each histogram 'bin' and a vector `v` with the voltages at the midpoints of each bin.

We can then export the histogram to a CSV file by opening a file for writing:

```
fo=fopen('lab4square.csv','w')
```

and writing the values to the file as strings separated by commas, two per line:

```
fprintf(fo,'%d, %f\n',[n;v])
```

and closing the file:

```
fclose(fo)
```

Repeat for the triangle and sine wave capture files. You can use the cursor keys and the command history window to save typing.

RMS Calculation and Report

The RMS (root mean square) voltage of a signal is defined as the square root of the mean (average) of the square of the voltage. In cases where different voltages have different probabilities we must scale each voltage (or its corresponding power) by the probability of that power and then compute the sum. For example, if 20% of the values had a power of 0.3W and 80% had a power of 0.2W then the average power would be $0.2 \times 0.3 + 0.8 \times 0.2 = 0.06 + 0.16 = 0.22$.

We can use a spreadsheet to do this calculation on the histogram values stored in the CSV file.

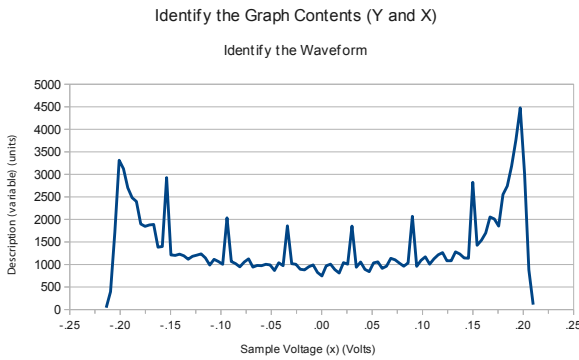
Run Excel or OpenOffice Calc. Open the CSV file (File->Open) which will result in a spreadsheet with two columns, the first with the bin counts and the second with the bin voltages.

Enter a formula at the bottom of the first column to compute the total number of samples. Add additional formulas to divide by this value to normalize the bin counts to probabilities¹. Then compute the square of each bin voltage and scale it by the probability of that voltage. Compute the sum of the scaled squared voltages. This is the mean square voltage. Finally, compute the square root of the sum. This is the RMS voltage of the waveform.

Repeat using the histograms for the triangle and sine waves (Data->Get External Data or Import->Sheet from File). Compare your results to the values read from the DMM.

Create a line graph (chart) with curves showing the normalized values of the sine and triangle wave histograms. Use Insert->Chart, set the chart type to an XY Line graph and use the voltages as the X values and the histogram sample counts as the Y values. Add a title and label the X and Y axis. Adjust the chart properties so it looks approximately as follows:

¹To insert a reference to an absolute rather than relative cell, prefix the cell and/or row with a dollar sign (\$). For example, `=$A$101`.



- graphs showing the three histograms as created by your spreadsheet,
- a table comparing the RMS voltages measured by the DMM and computed from the histogram for each of the three waveforms

Pre-Lab Report

Submit a report containing a title, the lab number, your name, your student number, and the answers to the following questions:

- What are the average and RMS voltages of a square, triangle and sine wave as a function of the waveform's amplitude A ?
- A signal switches randomly between two levels, +1V and +3V. The level is +1V 30% of time and +3V 70% of the time. What is the RMS voltage?
- If the 'scope has an 8-bit A/D converter, how many different voltage levels can it resolve? If some histogram bins included one of those voltage levels and other bins included two, what effect would you expect to see?

Lab Report

Upload three files to the dropbox folder for this lab:

1. the histogram CSV file for the sine wave input in CSV (.csv) format
2. the Excel (or OpenOffice Calc) spreadsheet file in Excel (.xls) format (any version)
3. your report in PDF (.pdf) format

Your report should include:

- student and lab identification as described in the first lab,
- plots of the first 2000 samples of each of the three sampled waveforms,