

Creating a Waveform for the WGM-101 Waveform Generator

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1 Introduction

The WGM-101 Waveform Generator can produce an arbitrary waveform. The waveform consists of 256 8-bit values. The waveform is output at the frequency and amplitude settings of the generator.

As an example, this application note describes how to use various software tools and the Syscomp WGM-101 Waveform Generator to create an ECG (ElectroCardioGram) waveform.

The ECG (ElectroCardioGram), or EKG, as it is sometimes known, is an electrical signal generated by the muscles of a human heart. It is a common medical diagnostic procedure to record and analyse the ECG of a patient to identify injuries and diseases associated with the heart.

Generating an artificial ECG signal is useful in the testing and debugging of an ECG recording device. For example, the



Figure 1: Typical ECG Signal

artificial ECG signal could be contaminated with various noise signals to check the performance of filters in the ECG recording instrument.

In this application note, a drawing program is used to trace the image of the original waveform. Then the original image is discarded and the trace data used as the waveform information. This method has the advantage that it can cope with any shape of waveform. However, it is labour intensive and inflexible. A change to the digitized waveform is likely to require drawing the entire waveform.

An alternate approach is a *waveform generator* program. One such is available for download at the Web site of reference [1].

2 The ECG Waveform

The ECG waveform is described in the excellent Wikipedia entry, reference [2].

A typical ECG signal is shown in figure 1 (ref [3]).

One cycle of the ECG waveform is shown in figure 2 (ref [4]).

3 Creating the Waveform Data

In general, there are two methods of creating the waveform data.

- **Mathematical Model** For a simple waveform - such as a sine wave - the data file may be created using a mathematical formula.
- **Graphical Construction** In this approach, the waveform is built up from straight line and curve segments. A program of this type is described in [1].
- **Digitization** For a complex waveform - such as the ECG - a mathematical description is not straightforward. Then the waveform must be converted to a datafile by *digitization*. The waveform is divided into 256 points. The vertical value of the waveform at each point becomes a data value in the file.

This process is much more labour intensive than a mathematical model, but it can cope with any shape of waveform.

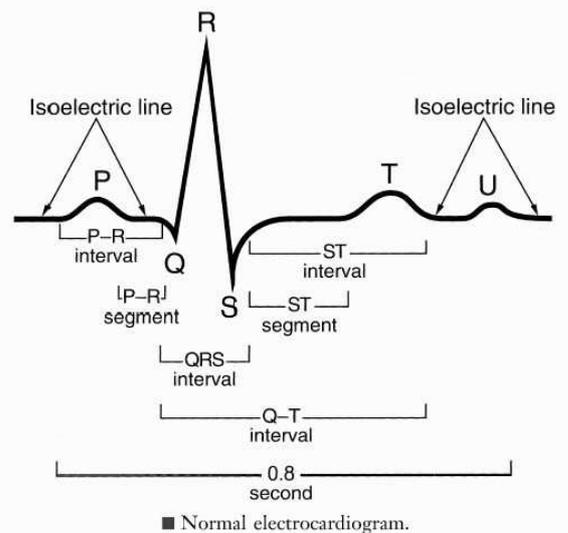


Figure 2: ECG, One Cycle

4 Digitization

You will need a drawing program that can import a picture, draw lines, and export the line data. I used `xfig` on a Linux system. The program `jfig` is an open-source clone of `xfig` for Windows computers and seems to function in an identical fashion for this application. See reference [5].

For those not familiar with `xfig`, there is a manual here: [6]. This manual should help with `jfig` as well.

You will also need a spreadsheet program. I used `calc`, which is part of `Open Office`, a freely available office suite for Linux and Windows. `Excel` should work equally well on Windows systems.

The basic idea

1. Import an image of the waveform into the drawing program.
2. Trace the drawing with 256 line segments.
3. Erase the image, leaving the 256 line segments.
4. Save this line drawing. The format of an `xfig` or `jfig` data file is coordinate pairs, so there will be 256 coordinate pairs in the file.
5. Reformat this data so there is one coordinate pair per line.
6. Import this data into a spreadsheet. Now you have all the horizontal X data in one column, the vertical Y data in another column.
7. Shift and scale the vertical data so that all values are between 0 and 255.
8. Save the vertical data. This is the waveform file.

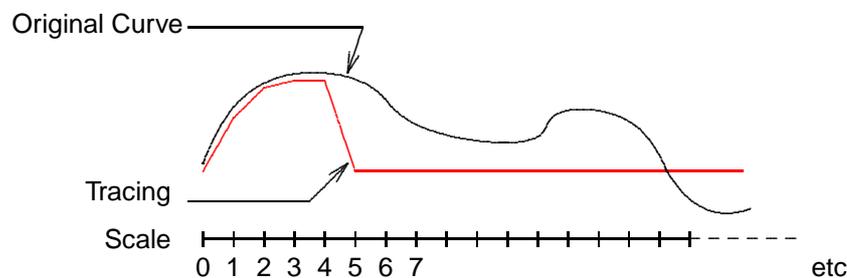


Figure 3: Tracing Method Illustrated

Figure 3 illustrates the method. The upper trace is the original curve which was imported as an image and will eventually be discarded. The next curve is the tracing, offset slightly for clarity. Points 0 through 4 have been moved into position over the original image. The horizontal scale is at the bottom, running from 0 to 255.

In Greater Detail

1. Obtain a drawing of the waveform. This could be a freehand drawing that has been scanned or from some literature source.
2. Using Xfig, set up a horizontal scale of 256 points by the 'double-double' method.
 - (a) Create a short horizontal line, 2 units long. Put vertical tick marks at the beginning and middle.
 - (b) Copy that line and append it to the original.
 - (c) Repeat the previous step 6 more times, and the line will be 256 units long.
 - (d) Put one final vertical tick mark on the line.

Don't worry if the line is one or two points longer or shorter than 256, we can fix that later.

3. Import the waveform diagram into the drawing program and scale it until the horizontal axis is the same size as the 256 point scale. Ensure that the position of the scale and waveform are completely on one side of the zero axis. (This avoids negative numbers, which is a complication.)
4. The drawing canvas in Xfig has zero in the upper left corner. Positive units are down the screen. Flip the drawing vertically so that positive on the waveform corresponds to positive on the drawing canvas.
5. Trace the waveform with 255 line segments (256 points). This is very tedious. Try to get each point lined up correctly with each division on the time scale.

You should start with one long line and then divide it up and move each point to the right place. (There is a drawing tool that adds another point to a line, which can then be moved.) That is easier than adding a new line segment each time and results in a cleaner data file.

You can copy and paste line segments, but be aware that *the data will appear in the file in the order in which it was created*. This is not a show-stopper, because you can use the X values to order the data, but it does complicate interpretation of the file.
6. Save the composite drawing (the waveform picture, the scale, and your tracing) for safety.
7. Delete the scale and the picture so that only the tracing is left. Save this as a file with different name, say 'complete.fig'.
8. Use a text editor to examine 'complete.fig'. There is some preamble and then the line coordinate pairs, 256 of them if you did it correctly. Erase the preamble. Edit the file so that each coordinate pair is on its own line. Again, this is tedious. The unix program 'sed' can do this automatically, but I didn't bother.
9. Create a copy of this file with a .csv suffix. The suffix .csv stands for *comma separated values*. In fact, these values are separated by a space, but that's not critical.
10. Load this file into a spreadsheet. The horizontal coordinates should appear in one column, the vertical in a second column.
11. Create a column that contains the difference between each horizontal value. Every difference value should be the same, which is a good check that your data points are evenly spaced.
12. Now you can massage the vertical values so that the minimum value is 0 and the maximum 255. First, create a new column that makes the minimum value 0 by subtracting (or adding) the minimum vertical data value. Then create another column that scales the vertical data so that the maximum value is 255. Use the spreadsheet round function to create integer values.

13. Copy this final column to another spreadsheet. Check that there are exactly 256 entries. If not, trim the file or pad the file with extra values.
14. Save the data as a '.csv' file. Examine the file with a text editor. It should consist of 256 data points, each with an integer value between 0 and 255, each on its own line. (Technically speaking, each data value is delimited by a *newline* character.) This is the waveform data for the generator.
15. You should now be able to load this file into the WGM-101 waveform generator and produce the waveform - at any frequency between 0.1Hz and 100kHz.

5 In Operation

Figure 4 shows the WGM-101 waveform generator (right panel) producing the ECG waveform, which is displayed on the DSO-101 oscilloscope screen (left panel).

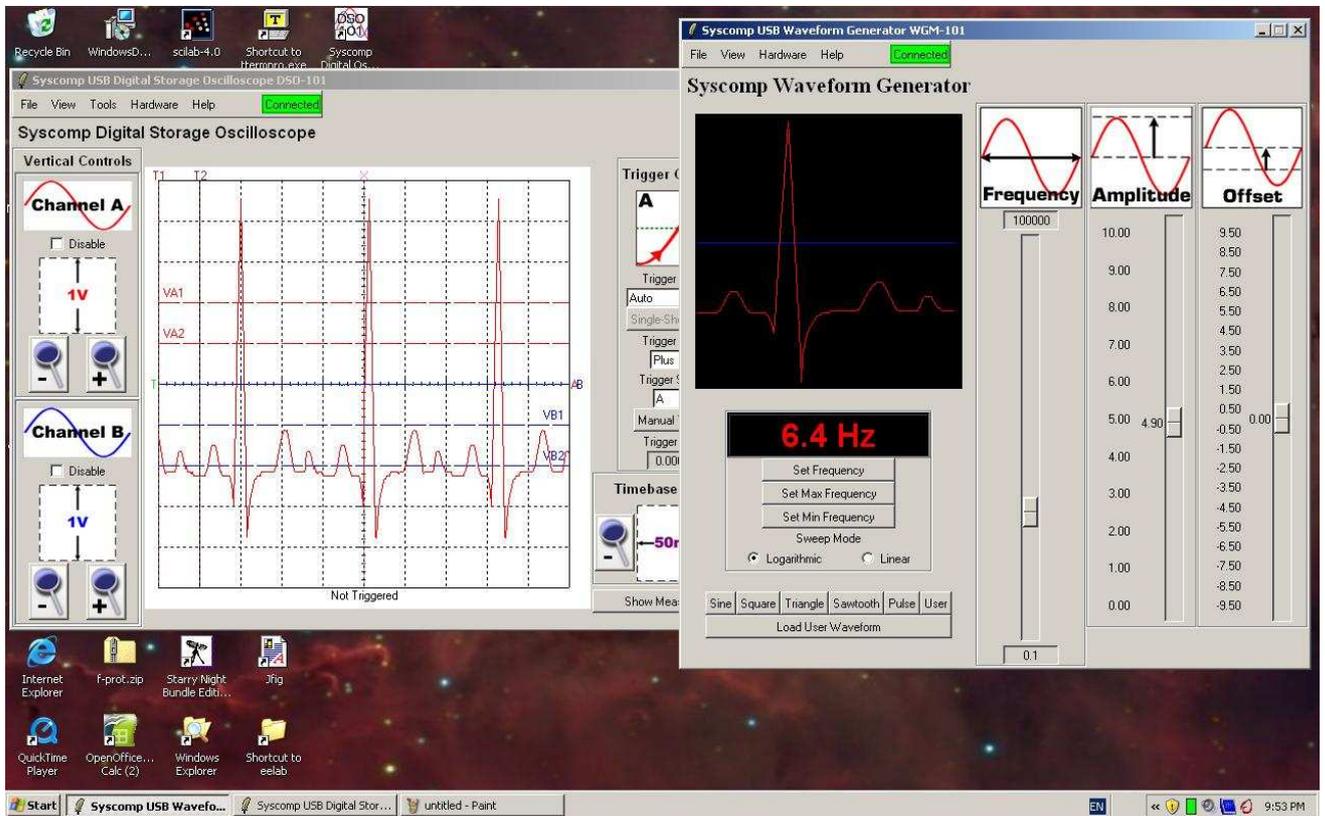


Figure 4: ECG In Operation

6 Acknowledgement

A thank-you to John Foster for his proofreading and comments.

References

- [1] <http://alvinyeung.com/waveformeditor/>.
- [2] <http://http://en.wikipedia.org/wiki/Ecg>
- [3] http://uimc.discoveryhospital.com/shared/enc/img_htm/CV-30.htm
- [4] <http://medical-dictionary.thefreedictionary.com/electrocardiogram>
- [5] <http://tams-www.informatik.uni-hamburg.de/applets/jfig/>
- [6] <http://www.ee.ryerson.ca/~phiscock/papers/xfig-howto.pdf>