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A Signal Analyzer for Teaching Signals and Systems

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Abstract

Music and computers continue to fascinate today's students. This powerful and sometimes addicting combination can also provide for a tremendous opportunity to enhance the understanding of the time and frequency domain relationships routinely discussed in a *Signals and Systems* course. This paper discusses a MATLAB-based program that allows for simultaneous signal analysis in the time and frequency domains. The program is menu-driven and very easy to learn and use.

1 Introduction

The curriculum for most electrical engineering (EE) programs contains at least one course on *Signals and Systems*. While the majority of the concepts taught in a traditional first course on *Signals and Systems* date back more than a hundred years, today's students still struggle with the relationship between the time and frequency domains. Any teaching technique that permits increased student insight into this complex relationship is of great value to both the professor and the student alike. Several tools exist to display signals in the time or frequency domain, but few offer the capability to rapidly, simultaneously, and accurately display the signal information in both domains.

2 Discussion

Solving this problem with hardware would require, at a minimum, an oscilloscope and a dynamic signal analyzer. It can easily cost several thousand dollars just to equip a single lab station. System cost may only allow for a single demonstration system with which a professor or teaching assistant would demonstrate the time and frequency domain relationships between selected signals. These signals may be pre-recorded or generated in real-time.

But what is the level of student involvement in such a demonstration? Do we really expect our students to understand such a complex relationship without the opportunity to spend time exploring other signals on their own? We want our students to explore these relationships in depth and at their own pace.

A software solution to this problem could involve MATLAB[1] or some other computational software package. The relative ease with which MATLAB can be used to perform complex calculations has revolutionized the way we teach electrical engineering. Additionally, MATLAB ships with the ability to perform the basic operations that are required to simultaneously display signal characteristics in both the time and frequency domains. These operations include (**bold text** represent MATLAB commands),

Signal acquisition – data acquisition toolbox, **wavread, auread**, etc …

Time domain display – **plot**, **subplot, semilogx, semilogy, loglog**, etc …

Frequency domain display – **psd**, **psdplot, spectrum**, **specgram**, etc …

Signal playback – **sound**, **soundsc**, **wavwrite, auwrite**, etc …

With all of the necessary software commands available, all that is needed is to provide an easy to use graphical user interface (GUI) that allows for file selection and the desired display of the time and frequency representation of the input signal. Individual needs and display requirements will vary, but our MATLAB-based m-file can easily be modified to suit various needs.

Our signal analyzer GUI, displaying a sinusoid is shown in Figure 1. The signal plotted is a 1000 Hz sinusoid that extends for more than 5 seconds. To allow for a meaningful time domain display, only a few milliseconds of the signal is displayed. This is easily accomplished within the time domain subplot by using the **zoom** or **axis** commands. Even though this signal was created in MATLAB, a close inspection of Figure 1 (bottom subplot) reveals that the 3rd through 19th harmonics are all present. The Hanning window used in the power spectral density (PSD) estimate obscures the 2nd harmonic from view. Measurements using the **ginput** command reveal a signal dynamic range in excess of 90 dB even though harmonic content is at least 70 dB down (from the fundamental value).

This sinusoid was created in MATLAB and stored as a .wav file using the **wavwrite** command. This standard file format (*.wav) allows for easy file manipulation using any of the dozens of commercially available wav-editors on the market. File editing is routinely necessary to remove the beginning and ending portions of a recording that do not include a useful part of the signal. This editing also increases the effectiveness of the scaling that automatically takes place in commands such as **specgram**.

Windows based operating system programs such as the sound recorder or the media player can also be used in conjunction with the wav-files. Therefore, numerous methods are available to make short sound files accessible to MATLAB.

The computers we use in our EE labs have hundreds of operating system .wav files preinstalled on their hard drives. Since most of these signals are of little use from a *Signals and Systems* perspective, we created a separate directory in which we put the files we are most interested in processing. This separate directory allows for an easily navigated pull-down menu for file selection and subsequent analysis. An example of such a menu is shown in Figure 2. Figure 3 shows the signal analyzer GUI displaying a ringing bell. Harmonic content can be easily identified.

All of the recorded files can be heard by pushing the play button. Additionally, since this button is not modal, rapid replay sound effects can be generated.

Given this type of tool, several students have chosen to continue their exploration of the time and frequency domain relationships after class or lab in their rooms using their own computers and software (MATLAB). An unlimited number of files can easily be created or recorded and stored in a separate directory for subsequent analysis in a classroom, laboratory, or dormitory setting.

3 Conclusions

This paper discusses a signal analyzer program and how we use it in our *Signals and Systems* courses. The authors freely distribute this software for educational, non-profit use. The URL for downloading the signal analyzer program is http://www.usna.edu/EE/links/ee_links.htm.

Bibliography

1. The MathWorks, Inc., Natick, MA, *MATLAB: The Language of Technical Computing,* 2000.

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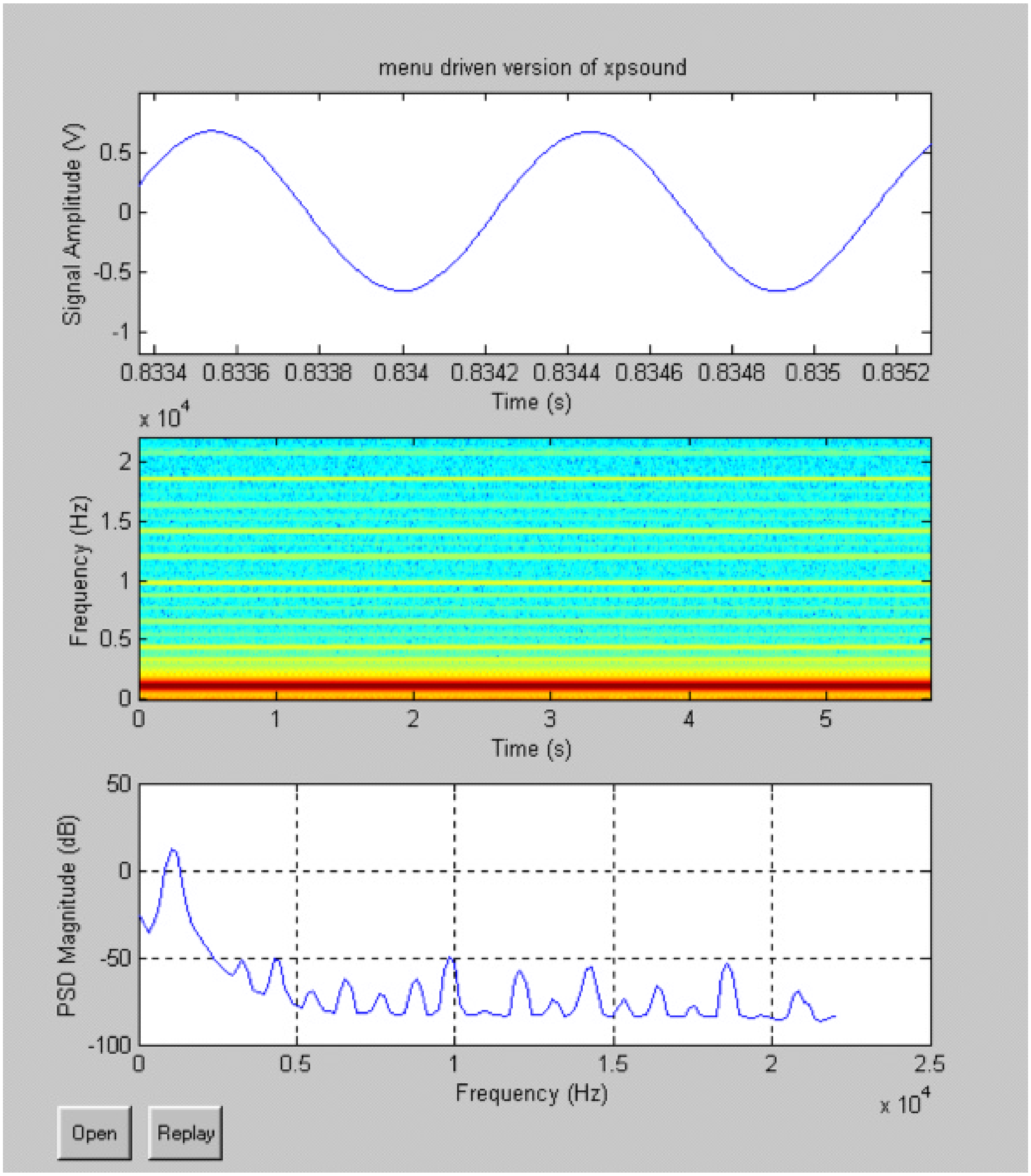

Figure 1. Signal analyzer displaying a sinusoid.

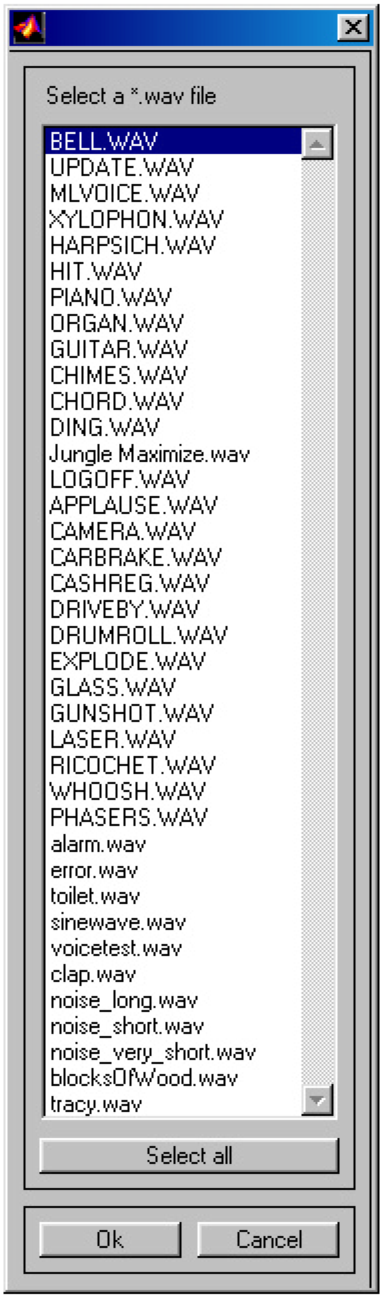

Figure 2. Signal analyzer file selection pull down menu.

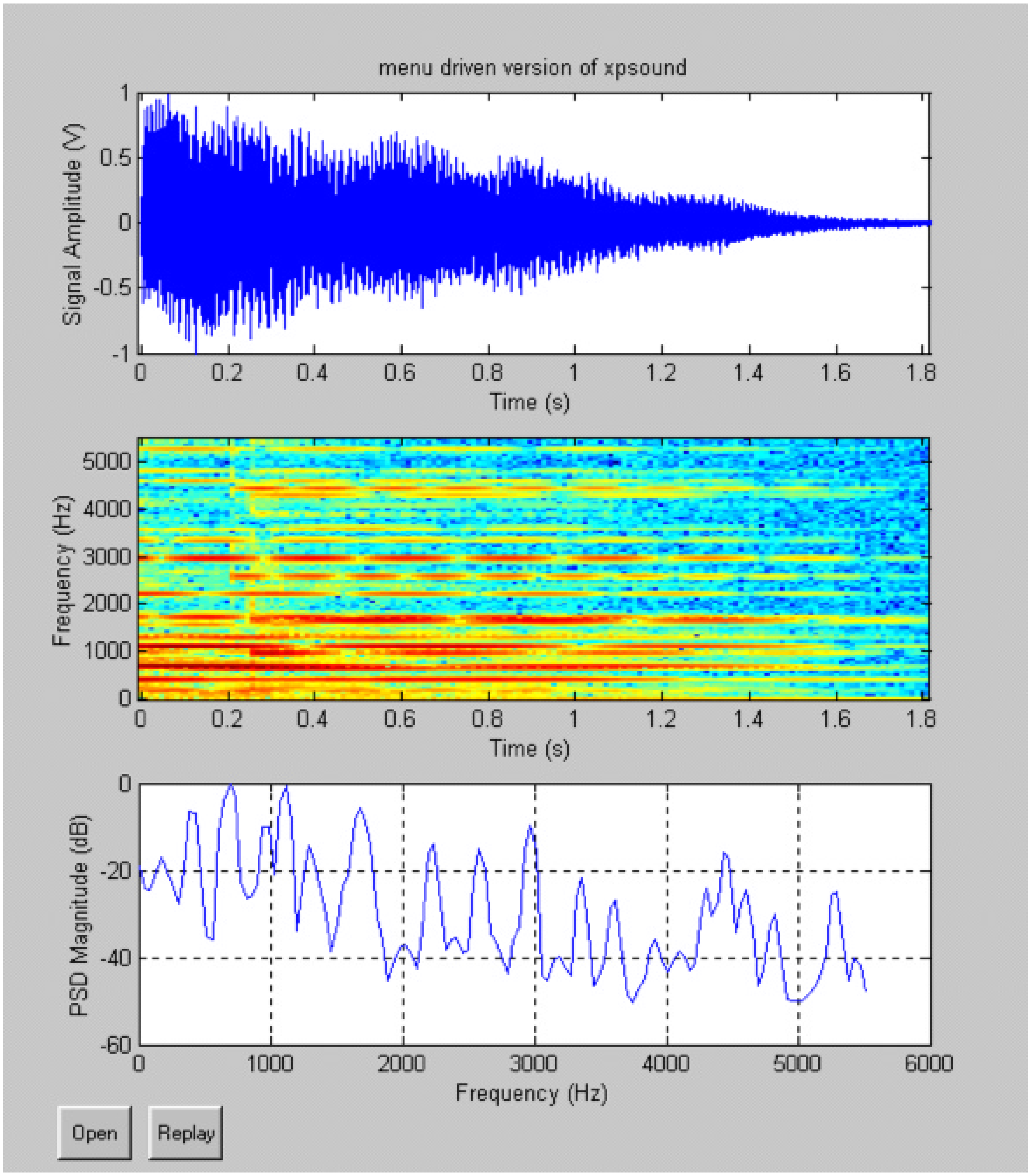

Figure 3. Signal analyzer displaying a ringing bell.