

# Signal Modulation, Chirps, and Pulsations

Aidan Sharpe & Elise Heim

**Abstract**—Through MATLAB, this lab helps in the understanding of combined signals. This is accomplished by generating the signals and viewing the results of their combination. This lab also takes a look at more complex signals such as chirps and pulsation, and how to create them.

## I. INTRODUCTION & OBJECTIVES

Signals can be altered in several fundamental ways. They can be scaled, shifted, or reflected in order to change one signal into another. Signals can also be added, subtracted, or multiplied by other signals in order to generate a new signal that combines their properties. This lab explores what changes can be seen when combining multiple signals. A visual representation aids in the understanding of how signals combine together.

## II. BACKGROUND

The simplest signal used in this lab is the unit step. It is defined as 0 when time is less than 0, and 1 when time is greater than 0. It looks like a single, infinitely long step, hence the name. A slightly more complex signal used is the square wave, which is a non-sinusoidal periodic waveform in which the sign of the output alternates at a steady rate. The duration at minimum and maximum is the same, and ideally the change occurs instantaneously. More complex signals within this lab include chirps and pulsations. Chirps are sinusoids with time-varying frequency, which means that they make interesting sounds. Pulsations are rapid changes in the amplitude of a signal.

## III. RESULTS & DISCUSSION

The first step in this lab included generating a signal by advancing and delaying a unit step. The signal was  $x(t) = u(t+20) - u(t-20)$ . As shown in figure 1, the amplitude of this unit step is 1, and the signal is on between the times of -20 and 20. This displays how simple it is to turn a unit step into a square pulse.

A square wave can be generated using modular arithmetic. Figure 2 shows such a wave. The square wave has an amplitude of 1 and alternates between 1 and 0 every 5 seconds.

The signal  $x(t) = 2 \sin(250\pi * t - \frac{\pi}{5})$  is shown in figure 3. It is a simple, slightly modified sine wave. These modifications consist of only fundamental changes, meaning no signal combination.

However, when sine waves are combined with other signals, the result can be fascinating. In figure 4, a sine wave is combined with a quadratic, causing the frequency to increase proportionally to the square of  $t$ . Analytically, the combined signal is  $x(t) = \cos(2t + \frac{t^2}{4})$ . While technically a cosine, the signal is still considered sinusoidal. Importantly, changing

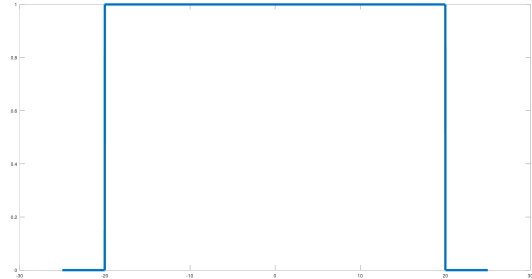


Fig. 1. The difference of two unit steps with different delays

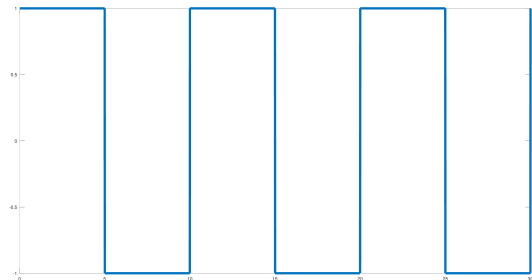


Fig. 2. A square wave

the frequency has no effect on other properties of the signal such as amplitude and phase shift.

Frequency modulation does not have to be limited to simple signals, it can also be modulated with a periodic signal. In figure 5, the frequency changes sinusoidally. The signal shown is  $x(t) = \cos(2t - 2 \sin(t))$ . This concept is used in the real world in FM radio transmissions. In this way, radio receiver can be tuned to the baseline frequency, and the desired signal can be recovered.

## IV. CONCLUSION

Analytically combining signals can be challenging, especially when attempting to acquire a better intuition about emergent behaviors. For example, combining a sine wave with a ramp can be achieved in a handful of ways. If the sine wave is added to the ramp, it is analogous to adding an ever increasing voltage offset to an AC input. Alternatively, the product of a ramp and a sine wave yields a sine wave with constant frequency but ever increasing amplitude. Another option, the one used in this lab, is the chirp. The chirp seen in figure 4 has a quadratically increasing frequency. If instead, a ramp was used, the chirp would have a linearly increasing frequency.

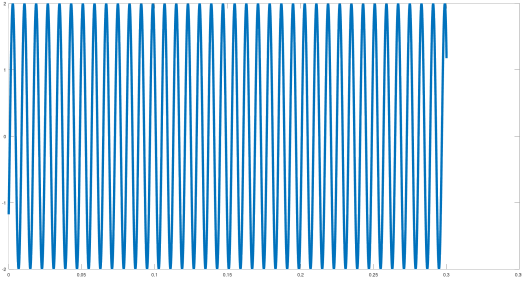


Fig. 3. A high frequency sine wave

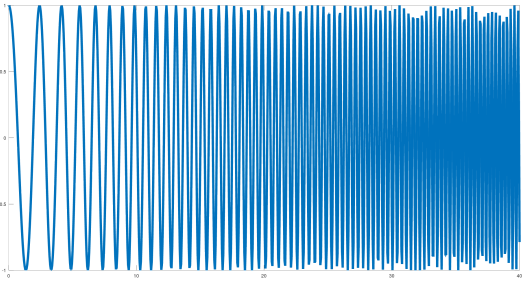


Fig. 4. A sinusoidal wave with increasing frequency

Clearly, there are a lot of ways to combine just two signals together. For this reason, it can be difficult to have a deep understanding without a visualization. In the real world, ideal signals do not exist, so by understanding more complex signals in the first place, real-world signals become more accessible.

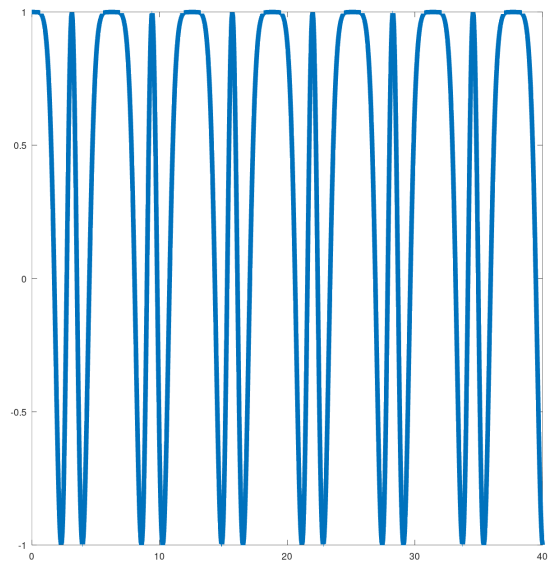


Fig. 5. Taking the cosine of a sine wave