Digital Signal Processing SS 2024 – Exercise 3
Digital Signal Processing Tutorial

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Exercise 1

We have the analog signal

$$x(t) = x_1(t) + x_2(t) = \sin(2\pi f_1 t) + \sin(2\pi f_2 t)$$

with $f_1 = 4\text{kHz}$ and $f_2 = 6\text{kHz}$. The signal is sampled with a sampling frequency of $f_s = 10\text{kHz}$.

a) In Figure **??** we draw the spectrum of $x(t)$. This was derived analytically by observing that $x(t)$ is composed of two separate sinusoidal signals.

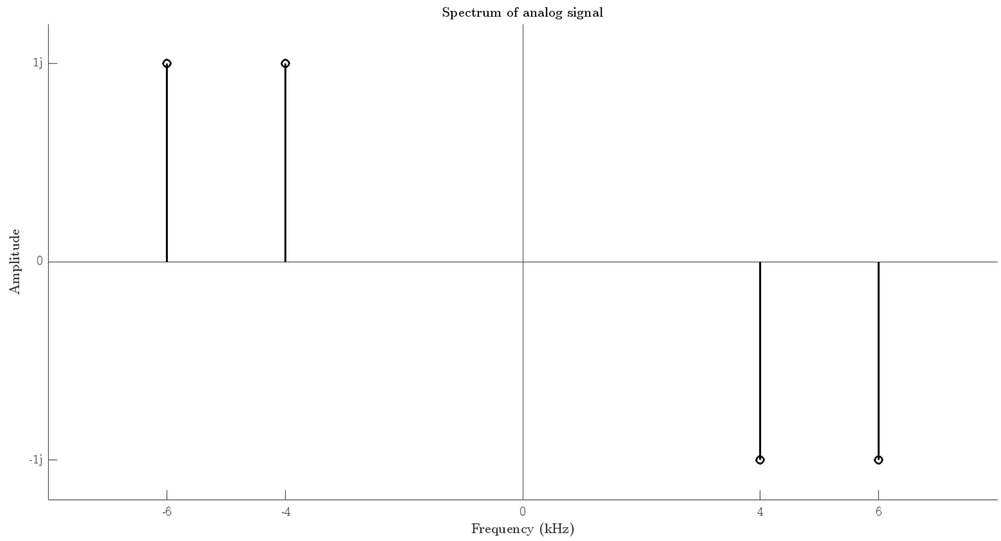

Figure 1: Spectrum of $x(t)$

b) In Figure **??** we draw the spectrum of $x(t)$ shifted by $-f_s$, 0, and $+f_s$, as well as the result of adding up the shifted spectra.

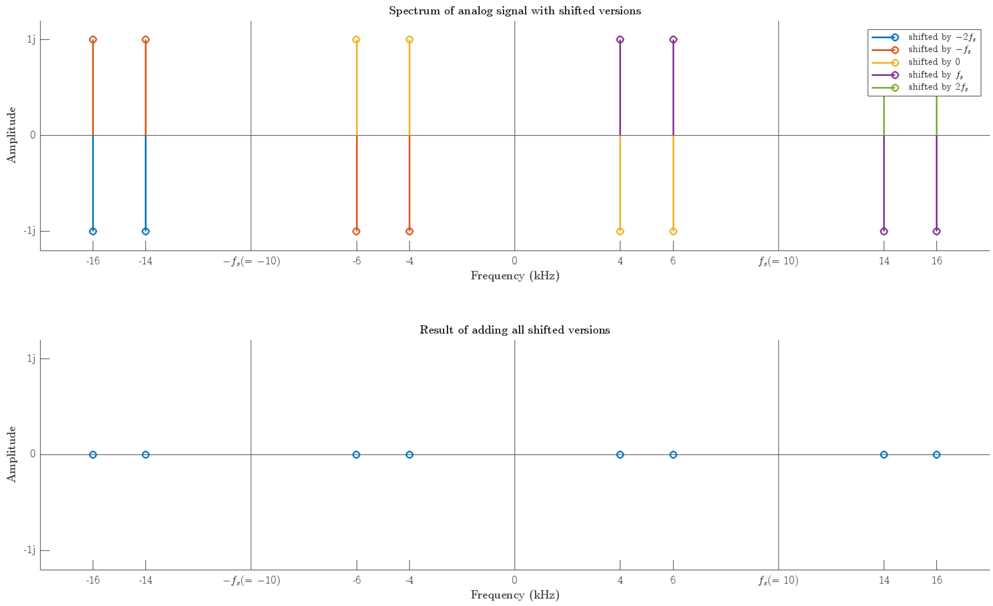

Figure 2: Spectrum of $x(t)$ shifted

c) In Figure **??** we draw the first 2ms of the signal $x(t)$ and the resulting signal after sampling with $f_s = 10$kHz. As we can see, $x[t] = 0$, and therefore the spectrum will also be constant 0.

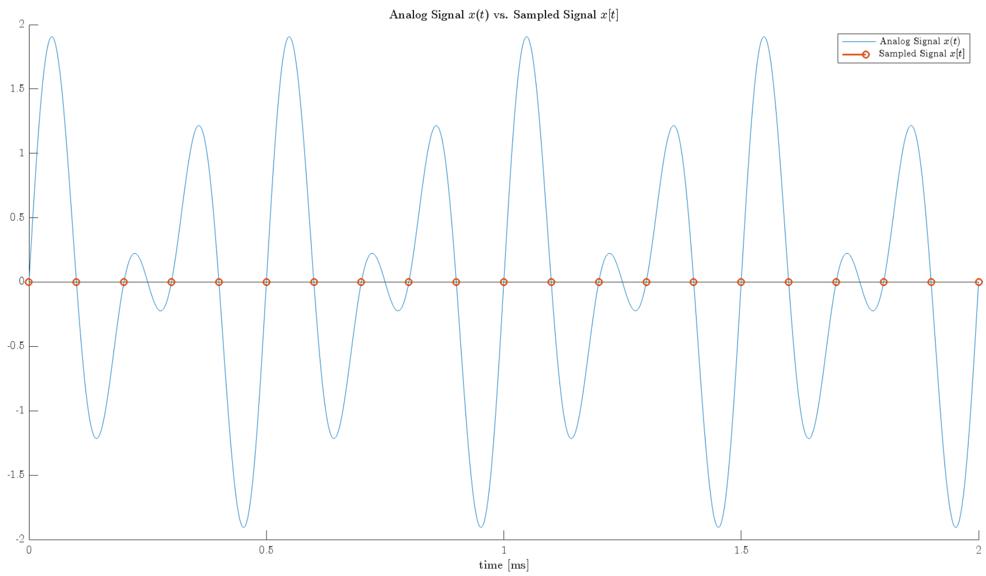

Figure 3: $x(t)$ and $x[t]$

Exercise 2

We are given the spectrum $X(f)$ of an analogue signal $x(t)$:

a) Draw the real and imaginary parts of the spectrum $X(f)$

We have 2 Impulses with Magnitude $\frac{\pi}{2}$ at -5 & 5kHz
We use that $X(f) = |X(f)| \cdot e^{j\phi_x(f)} = |X(f)| \cdot (\cos(\phi_x(f)) + j\sin(\phi_x(f))$

Since we have $\phi_x(f) = \pm\frac{\pi}{2}$ we get that $\cos(\phi_x(f)) = \cos\left(\pm\frac{\pi}{2}\right) = 0$
$\Rightarrow$ The real parts of the spectrum are 0

And we get that $\sin(\phi_x(r)) = \sin\left(\pm\frac{\pi}{2}\right) = \pm 1$
$\Rightarrow$ The imaginary part is $-|X(f)|$ for the first part and $+|X(f)|$ for the second part

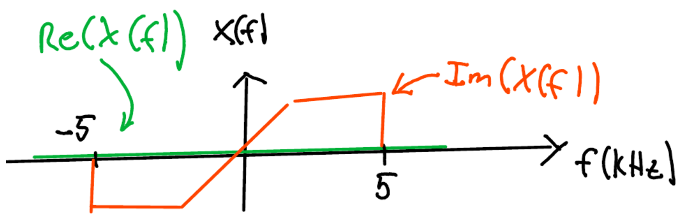

Figure 4: real and imaginary parts

b) $x(t)$ is sampled with 8kHz to yield the discrete time signal $x[n]$ Draw the spectrum of $x[n]$ from $-f_s$ to f_s and indicate the baseband.

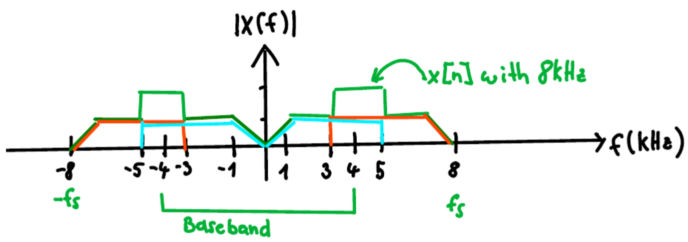

Figure 5: Spectrum of $x[n]$