Practical Assignment

Answer in no more than 5 pages total
Minimum 10pt font size

October 16, 2013

1. (**Loopback test**) Obtain a audio cable with 3.5mm stereo jacks on either end. Connect one end to the audio output of your soundcard, and the other end to the audio input. Using the software available on the course website (see folder called "loopback"), or your own software, play a sinusoidal signal of frequency 100Hz for a finite duration of time (atleast 2 seconds). Assert that you can hear the tone when the cable is not plugged in and the audio is played through internal computer speakers, or a set of connected headphones. Obtain samples at rate $F_s = 44100$Hz,

$$x_1, \dots, x_L, \qquad y_1, \dots, y_L$$

from the left and right channels of the soundcard input, where L is the number of samples obtained. Reconstruct the signals as

$$\tilde{x}(t) = \sum_{\ell=1}^{L} x_\ell \operatorname{sinc}(F_s t - \ell), \qquad \tilde{y}(t) = \sum_{\ell=1}^{L} y_\ell \operatorname{sinc}(F_s t - \ell)$$

where

$$\operatorname{sinc}(t) = \frac{\sin(\pi t)}{\pi t}. \tag{1}$$

Plot these reconstructed signals for a 20ms window from $t = 1$s to 1.02s.

2. (**Multiplier**) Consider the operational amplifier circuit in Figure 1. Analyse this circuit to obtain a relationship between the input voltage x and the output voltage y. Build the circuit on a breadboard and, using the soundcard, input the signal

$$x(t) = \tfrac{1}{3}\sin(2\pi f_1 t) + \tfrac{1}{3}\sin(2\pi f_2 t)$$

with $f_1 = 100$ and $f_2 = 233$. Using the (stereo) soundcard simultaneously record the input signal x directly from the soundcard ouput and also the output voltage signal y. Build reconstructed approximate signals $\tilde{x}$ and $\tilde{y}$ from the samples obtained and hypothesise a relationship between $\tilde{x}$ and $\tilde{y}$. Plot $\tilde{x}$, $\tilde{y}$ and the hypothesised signal over a 20ms duration and comment on the validity of your hypothesis. List the components that you used in constructing the circuit.

3. (**Band-pass filter**) Consider the operational amplifier circuit in Figure 2. Assuming the operational amplifier is ideal, find a differential equation relating the input voltage signal x with the output voltage

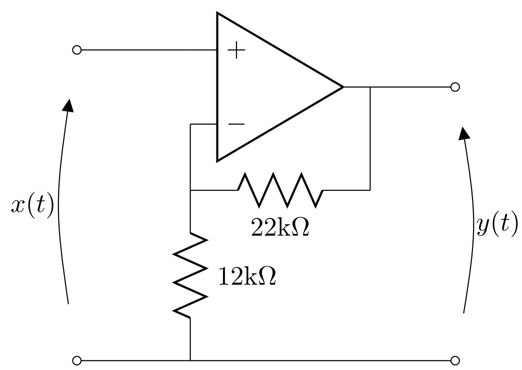

Figure 1: Operational amplifier circuit configured as a multiplier

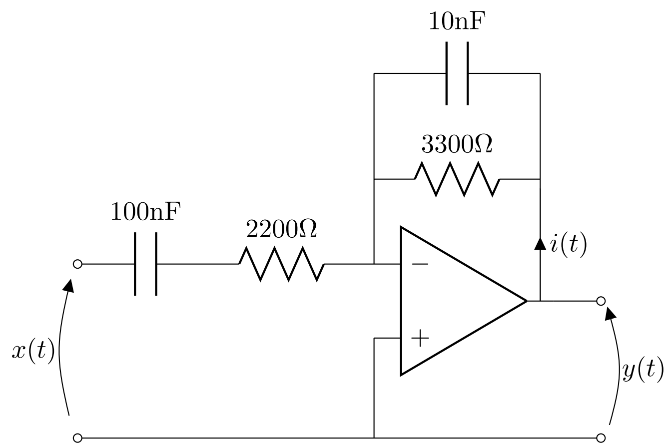

Figure 2: Operational amplifier configured as a band-pass filter with two capacitors and two resistors.

signal y. Find the transfer function of the system H mapping x to y. Find the poles and zeros of the system and construct a pole-zero plot. Assert that H is stable and regular and find its impulse response h.

Build the circuit on a breadboard and, using a computer soundcard, input the signal

$$x(t) = \tfrac{1}{3}\sin(2\pi f_1 t) + \tfrac{1}{3}\sin(2\pi f_2 t)$$

with $f_1 = 500$ and $f_2 = 1333$. Using the (stereo) soundcard simultaneously record the input signal x and also the output voltage signal y. Build reconstructed approximate signals $\tilde{x}$ and $\tilde{y}$ from the samples obtained. Plot $\tilde{x}$, $\tilde{y}$ and $H(\tilde{x}) = h * \tilde{x}$ over a 4ms duration. Assert that $h * \tilde{x}$ is close to $\tilde{y}$. To compute $h * \tilde{x}$ you may wish to use the trapezoidal integration method used in Test 5 of the lecture notes.

Now measure the spectrum of the circuit by using the soundcard to input sinusoidal signals of the form

$$x_k(t) = \sin(2\pi f_k t), \qquad f_k = 110 \times 2^{k/2}, \;\; k = 0, 1, \dots, 12.$$

For each $k = 0, 1, \dots, 12$ obtain an estimate of the spectrum $\Lambda(H, f_k)$ by measuring the square root of the ratio of the energy of the reconstructed output signal $\tilde{y}_k$ to the energy of the reconstructed input signal $\tilde{x}_k$. This ratio can be computed using the method described in Test 4 of the lecture notes. Find an analytical expression for the spectrum of the system $\Lambda(H, f)$ and plot this over the interval $f \in [0, 7500]$. On the same plot draw the measurements of the spectrum taken using the sound card. Assert that the measurements are close to the hypothesised spectrum $\Lambda(H, f)$. List the components used in constructing the circuit.

4. **(Butterworth filter)** Design a lowpass second order Butterworth filter with cuttoff frequency in the range 1800Hz to 2200Hz. Draw a diagram of the electrical circuit you have designed and list the components. Derive the transfer function and the spectrum of your filter. Construct the circuit and, using the computer soundcard, measure its spectrum over frequencies in the range 100Hz to 7000Hz. Plot your measurements alongside the hypothesised spectrum that you derived.