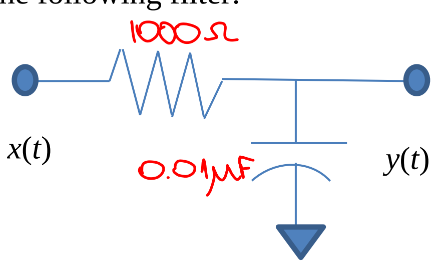
UNIVERSITY OF MANITOBA

Department of Electrical and Computer Engineering

ECE 4830 Signal Processing II. **Laboratory 3**

Lets start with the following filter:



1) Find the differential equation for the input $x(t)$ and output $y(t)$ relationship of the voltages. Express it in discrete time by substituting for example $\frac{dy(t)}{dt}$ for $\frac{y[n]-y[n-1]}{T_s}$ where T_s will be the sample period.

2) Calculate its z transform and solve for $H[z] = Y[z]/X[z]$. Use R = 1000 Ω and C = 0.01 μF, and fs = 40 000 Hz.

3) By using the help command in Matlab, familiarize with the command *freqz*
Plot its frequency response using the following:

```
[h,w]=freqz(b,a);
plot(40000*w/(2*pi),abs(h))
```
(angular freq to Hz)

Your parameters a and b in the command above come from your derivation of $H[z]$.

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h(n)

4) In general, in order to obtain the impulse response of a system, we would set up an experiment in the lab where we would generate an impulse and measure the response of the system. This is not feasible in most cases. Think of $\delta(t)$ in the frequency domain. Would noise be a good choice as a testing signal?

Use the following type of noise `X = normrnd(0,1,512,30);`
That is 30 realizations of 512 Gaussian distributed samples. Instead of building an RC circuit, we will let Matlab compute the output as

```
y = filter(b,a,X);
```

fft(y);

what result before?

5) You will be using 30 examples. Average them and see if you obtain a similar result as before.
[h,w]

6) What if you use more than 30 examples, is the result better?

Another choice of testing signal is the chirp, given that name because its "resemblance" to the sound of some birds

$x(t) = \sin(2\pi f_0(t + Kt^2))$, where f_0 is the initial frequency and K is a real constant.

For these type of signals the concept of Instantaneous Frequency *IF* is very helpful:

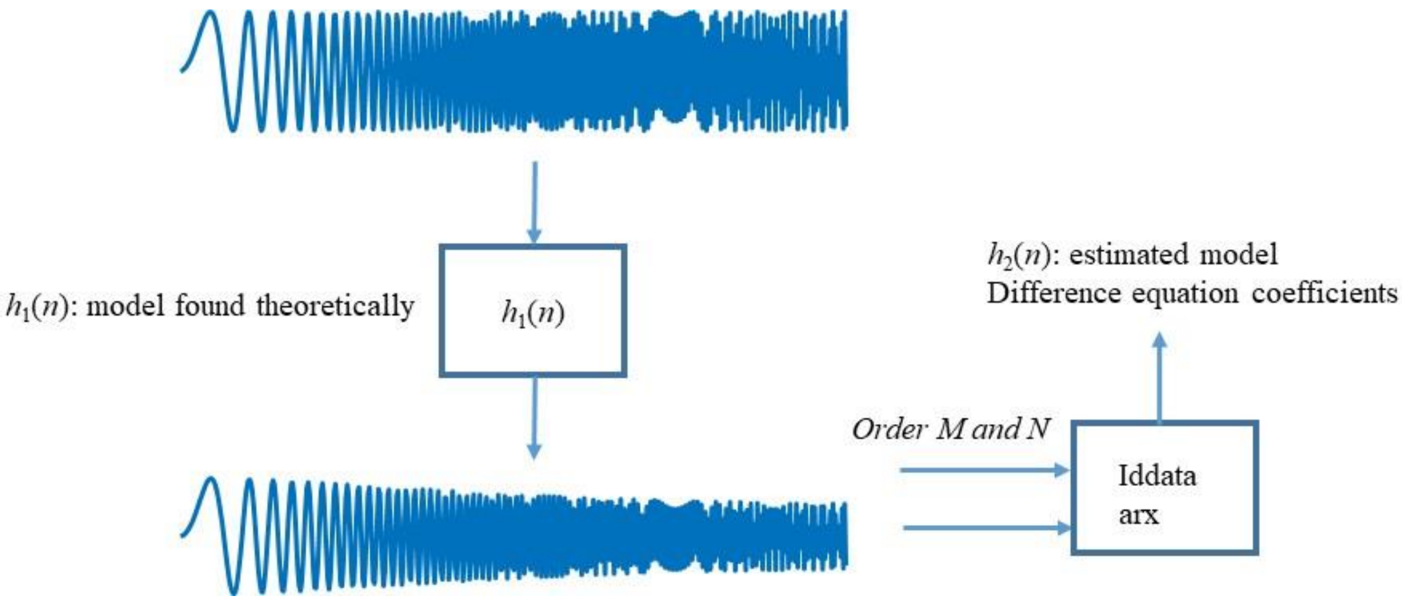
$$IF = \frac{1}{2\pi}\frac{d}{dt}\{\Psi(t)\}, \text{ where } x(t) = \sin(\Psi(t))$$

f0 = some value > 0

512 signals

7) Sample a chirp ($t = nT_s$) and use the same amount of samples N for n = 0,2, …, N-1 as before in order to compare it with the noise input example. Choose the parameters f_0 and K as to obtain the best identification of your system. Look at the chirp in the frequency domain first and experiment with different values, although you can derive these values theoretically from the expression of the chirp, *IF*.

You can identify the system using the commands iddata and arx. Use the command help in Matlab and familiarize with these commands. Use the chirp you created and use it as an input to obtain the output using the results you obtained from the difference equation you found that described the system. Afterwards, these two system identification commands should give you similar parameters of the difference equation coefficients that you calculated theoretically. Think of how useful it is to have input and output signals from a circuit you have no idea what it is and that you can describe the system as easily as this. But, there is always a but, you do need the parameters M and N and if you do not know the order of the model you may end up with identifying a system that can give you trouble.



Problems

5.3.4 5.3.6 5.3.7 5.4.3 part (a)

5.4.10 5.5.4 5.6.5 5.8.14

5.3-4 Consider a DT system with transfer function $H[z] = \frac{2z-2}{z-0.5}$. Assuming the system is both controllable and observable, determine the ZIR $y_{zir}[n]$ given $y[-1] = 1$.

5.3-6 Consider a LTID system that is described by the difference equation $y[n] - \frac{1}{4}y[n-2] = x[n-1]$.

(a) Use transform-domain techniques to determine the zero-state response $y_{zsr}[n]$ to input $x[n] = 3u[n-5]$.

(b) Use transform-domain techniques to determine the zero-input response $y_{zir}[n]$ given $y_{zir}[-2] = y_{zir}[-1] = 1$.

5.3-7 (a) Find the output $y[n]$ of an LTID system specified by the equation

$$2y[n+2] - 3y[n+1] + y[n] = 4x[n+2] - 3x[n+1]$$

for input $x[n] = (4)^{-n}u[n]$ and initial conditions $y[-1] = 0$ and $y[-2] = 1$.

(b) Find the zero-input and the zero-state components of the response.

(c) Find the transient and the steady-state components of the response.

5.4-3 Repeat Prob. 5.4-2 for

$$H[z] = \frac{5z+2.2}{z^2+z+0.16}$$

(a) Show the canonic direct form, a cascade, and a parallel realization of

5.4-10 Consider the LTID system shown in Fig. P5.4-10, where parameter c is an arbitrary, real constant.

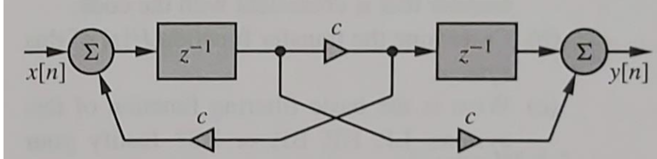


Figure P5.4-10

5.5-4 A causal LTID system $H(z) = \frac{-7(z+1)}{32(z-j\frac{3}{4})(z+j\frac{3}{4})}$ has a periodic input $x[n]$ that cycles through the 4 values 3, 2, 1, and 2. That is, $x[n] = [\ldots, 3, 2, 1, 2, \overset{\downarrow}{3}, 2, 1, 2, \ldots]$, where $x[0] = 3$.

(a) Plot the magnitude response $|H(e^{j\Omega})|$ over $-2\pi \le \Omega \le 2\pi$.

(b) Plot the phase response $\angle H(e^{j\Omega})$ over $-2\pi \le \Omega \le 2\pi$.

(c) Determine the system output $y[n]$ in response to the periodic input $x[n]$.

5.6-5 Figure P5.6-5 displays the pole-zero plot of a second-order real, causal LTID system that has $H[1] = -1$.

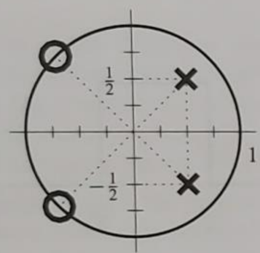


Figure P5.6-5

(a) Determine the five constants k, b_1, b_2, a_1, and a_2 that specify the transfer function $H[z] = k\frac{z^2+b_1z+b_2}{z^2+a_1z+a_2}$.

(b) Using the techniques of Sec. 5.6, accurately hand-sketch the system magnitude response $|H[e^{j\Omega}]|$ over the range $(-\pi \leq \Omega \leq \pi)$.

(c) A signal $x(t) = \cos(2\pi f t)$ is sampled at a rate $F_s = 1$ kHz and then input into the above LTID system to produce DT output $y[n]$. Determine, if possible, the frequency or frequencies f that will produce zero output, $y[n] = 0$.

5.8-14 Use partial fraction expansions, z-transform tables, and a region of convergence $(0.5 < |z| < 2)$ to determine the inverse z-transform of

(a) $X_1[z] = \dfrac{1}{1 + \frac{13}{6}z^{-1} + \frac{1}{6}z^{-2} - \frac{1}{3}z^{-3}}$

(b) $X_2[z] = \dfrac{1}{z^{-3}(2 - z^{-1})(1 + 2z^{-1})}$