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Assignment 1

```
clear all; clc;
fs = 44; % Hz
dt = 1/fs;
t_gen = 0:dt:8-dt; % Need different t vector for u because U gives
 different length y.
u =7*uGen(t_gen, "step",1,0); % unit step input for system analysis

% Persistently exciting input signal (generated from unit step ut)
U = genU(u); % works only for unit step input

yraw = exciteSystem(5360188, U, fs);
t = 0:dt/(countZeros(u)+1):(8)-dt/(countZeros(u)+1); % time vector for
 U

% The peak time is at .87 seconds and the signal starts rising after a
% delay of .45 seconds. This means that the rise time is about .42
 seconds.
% An appropriate sample rate would be to have 8 or 9 samples in this
 time period.
% So the sample time interval shoud be .42/9=.0467 seconds. i.e. a
 sampling
% frequency of 22Hz when rounded up. In hindsight, an announcement was
 made
% that the signal generation process is correllated to the sampling
% frequency and the we were allowed to eyeball a good frequency.
 Double the
% found frequency (44Hz) gives a nice workable result.

% the peak of the rise after a time delay was determined to be ca. .8
% seconds. This time was multiplied by 10 and taken as an appropriate
% duation for the simulation.

% figure(1);
% clf; hold on; grid on;
% plot(t,yraw)
% legend("y_{raw}")

y = despike(yraw,10000,fs); % Desipike output
```

```
% The signal was despiked by means of, first, flatlining the spikes,
 and
% then intepolating between the beginning of the flatline and the
 first
% value after the flatline. The decision to first flatline the spike
 was
% made beucause this process determines the width of the spike (it is
 not
% nescicarily 1 extreme measurement). Then this flatline was an easy
% criterion to determine the area that needs to be interpolated over.
 The
% interpolation was done linearly.

% figure(2)
% clf; grid on;
% plot(t,y)
```

Timeshift

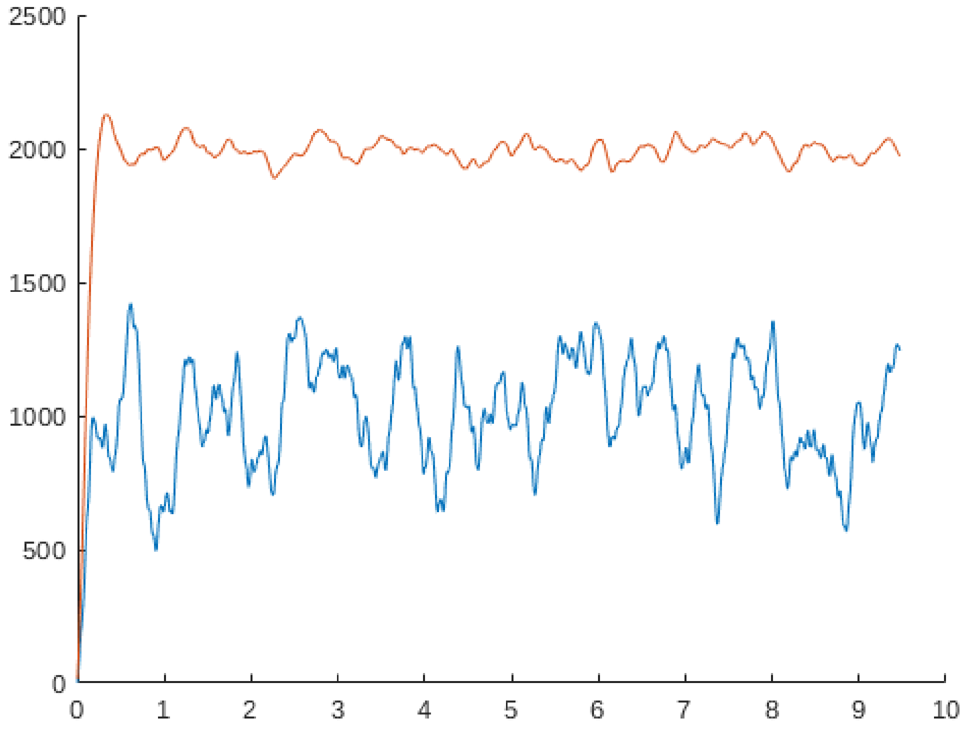
```
y = timeshift(y,500,fs);

cutoff = length(yraw)-length(y);
t_shifted = t(cutoff+1:end);
clear cutoff;

% The time shifting was performed looking at the slope of the output
% signal. This cuts off any part of the signal where the slope reaches
 500,
% but only is the signal value at that point is equal or greater than
 0.

% figure(3)
% clf; hold on;
% plot(t_shifted,y)

y = DCoffset(y); % removes DC Offset

% figure(4)
% clf; hold on;
% plot(t_shifted,y)

% Linearity Check

% table = [];
% fprintf("%0s | %10s \n","Input gain","IO gain")
% for i = 1:10 % determine io gain for input gain 1 till 20
%  ut =i*uGen(t_gen, "step",1,9);
%
% % Persistently exciting input signal
%  Ut = genU(ut); % works only for unit step input
%  yt = exciteSystem(5360188, Ut, fs);
%  iogain = IOgain(ut,yt,fs);
%  fprintf("%-10.0i | %2.3f \n", ut(end), iogain)
```

```
% end
% clear ut Ut table;

% The table below shows IO gains for a varyety of input gains. The IO
 gains
% seems constant by aproximation, which indicates linearit of the
 system.
% The system roughly behaves as: y*Igain=IOgain*u*Igain -->
 y=IOgain*u. I.E
% scaling the input gain scales the output gain with the same factor,
% resulting in a roughly constant IO gain of ca. 58.
```

Generating training and validation data for assignment 2

```
clc; close all;

% completely new data will be generated and pre-processed for the
% identification and validation of the system.

% Now in order to do system identification we need training data and
% validation data. We will generate these using different types of
 signals.
% The training data will be generated using a Pseudo Random Binary
 Sequence (prbs). The
% validation data will the data generated with a step function, like
% before.

fs = 100; %Hz
dur = 10;

t = 0:(1/fs):dur-(1/fs); % same time verctor for generating both sets

u_v = uGen(t,'step',35,0); % validation data is step input mag=35
y_v = exciteSystem(5360188,u_v,fs);

% preprocess validation data
y_v = despike(y_v,80000,fs);
y_v = timeshift(y_v,4000,fs);
% y_v = DCoffset(y_v);

b = length(u_v)-length(y_v);
u_v = u_v(1:end-b); % shorten u_v for reasons explained in assignment
 1


u_t = 35*prbs(length(t),0.5); % training data is PRBS mag=35
y_t = exciteSystem(5360188,u_t,fs);

y_t = despike(y_t,80000,fs);
y_t = timeshift(y_t,4000,fs);
% y_t = DCoffset(y_t);
```

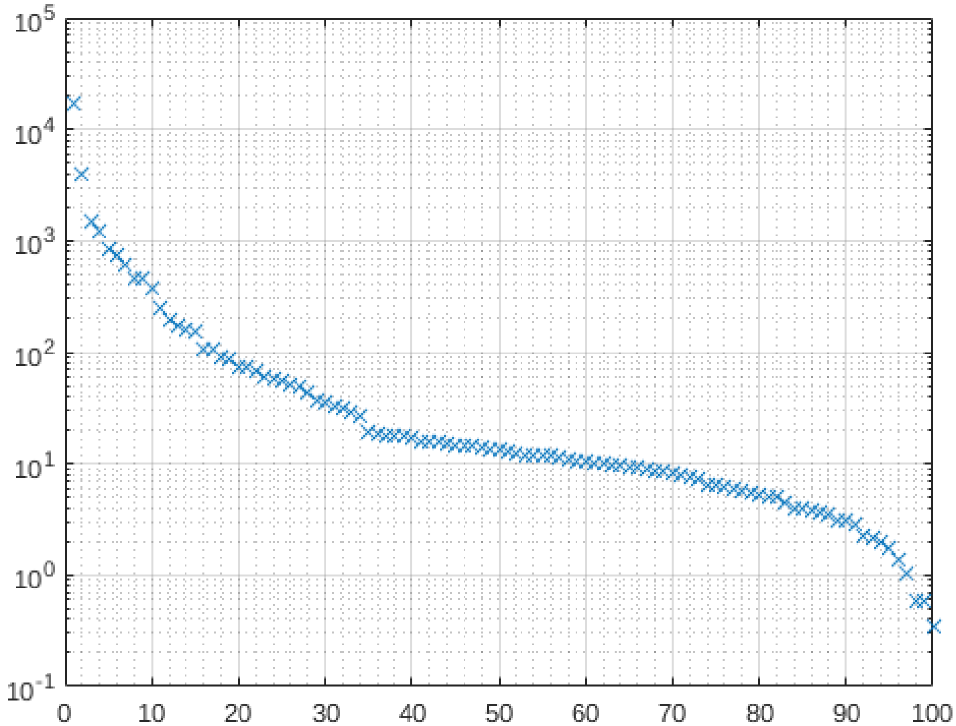
```
a = length(u_t)-length(y_t);
u_t = u_t(1:end-a); % shorten input like before

% shorten time to fit with either data set (for identification script
 to work)
t_t = t(1:length(u_t))';
t_v = t(1:length(u_v))';

clear a b;

clear; % nicedata.mat was used to have cosistent data, for consistency
 and streamlining of the process
load('nicedata.mat')

figure(12)
clf; hold on;
plot(t_t,y_t)
plot(t_v,y_v)
```



Assignment 2

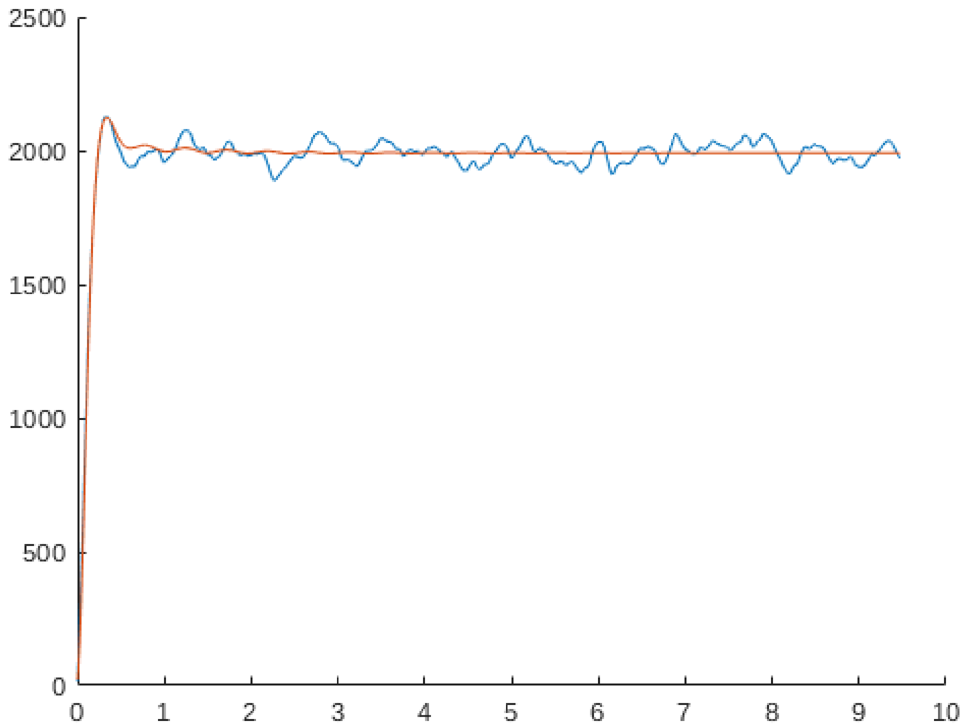
```
%Since we cannot use a white-noise sequence as an input signal, the
%identification methods that can be used are PI-MOESP and PI-MOESP. We
 will
```

```
%use PI-MOESP here, because we do not know if we are dealing with
 white
%measurement noise.
method = 'pi-moesp';

%To determine the order, we look for a gap between a set of dominant
 sin-
%gular values that correspond to the dynamics of the system and a set
%of small singular values due to the noise.

n = 5;%non-zero singular values
s = 100;

% subspaceID runs into a problem, because the timeshifted output is no
% longer the same length as the input. Even though there is a delayed
% response, the output signal was originally the same length as the
 input
% signal. This means that the end of the input signal was partially
 not
% accounted for in the output. to solve this, the amount of
 measurements
% that were cut off at the beginning of the output will also be cut
 off at
% the end of the input.

[A,B,C,D,x0,sv] = subspaceID(u_t,y_t,s,n,method);

figure(6)
semilogy(sv,'x')
grid on; grid minor;

y_hat_t = simsystem(A,B,C,D,x0,u_t,fs,t_t);
%identification VAF
dy = y_t - y_hat_t;
VAF_id = max(0, 1 - ((1/length(y_t))*sum(dy.^2))/((1/
length(y_t))*sum(y_t.^2)));
```



Assignment 3

```
y_hat_val = simsystem(A,B,C,D,x0,u_v, fs,t_v);
%identification VAF
dy = y_v - y_hat_val;
VAF_val = max(0, 1 - ((1/length(y_v))*sum(dy.^2))/((1/
length(y_v))*sum(y_v.^2)));

figure(13)
clf; hold on;
plot(t_v,y_v)
plot(t_v,y_hat_val)
```



Functions

```
function u = uGen(time,type, amp, periods) % generate inputs
 dt = time(2)-time(1);
 if type=="step" % gen step with periods as prior zeros
  u = [zeros(periods,1) ; ones(length(time)-periods,1)]*amp;
 elseif type == "pulse"
  u = [1 ; zeros(length(time)-1,1)];
    elseif type == "sine"
  u = amp*sin(periods*time*2*pi/(dt*length(time)));
 else
  u = "Unknown input type";
 end
end

function u = prbs(N,rate)
    % wrote own prbs because not allowed to use SI toolbox
    if rate>0 && rate<1
        du = floor(rand(N,1)+rate);
        u = rem(cumsum(du),2);
    else
        u = 'prbs(N,rate) | Error: Pick a rate between 0 and 1 \n';
        fprintf(u);
    end
end
```

```
function z = countZeros(u) % counts zeros before unit step
    z = 0;
    while u(z+1)==0
        z=z+1;
    end
end

function U = genU(u)
    % Generates Persistently exciting unit step
    z = countZeros(u);
    rank = z+1; % for unit step input
    gain = max(u); % same input gain as 1D signal
    U = gain*ones(rank,length(u));
    U(1,:) = u'; % first row equals 1D signal
    for i=2:rank
  % Do bitshift operation (1 to the left) for all other rows with
  % respect to previous row.
       U(i,:) = [u(i:end)' gain*ones(1,i-1)];
    end
end

function y = interp(sig)
 % Interpolates flatlines signal until not flatlined anymore and
 appends
 % anything that comes after it. Start at flatline, will not influence
 % other flatlines
 done = false;
 i = 2;
 while ~done
  if ~(sig(i) == sig(1)) % if no longer flatlined
   dy = sig(i)-sig(1); % determine slope
   dx = i;
   for j=2:i-1 % for flatline
    sig(j) = sig(j-1)+dy/dx; % linear interpolation
   end
   done = true;
  end
  i = i+1; % look further if still at flatline
 end
 y = sig; % return
end

function y = despike(sig,slope,fs)
 % removes spikes by flatlining and then interpolating over flatline
 spikes = []; % to stare spike starts
    for i = 2:length(sig)

        if fs*(sig(i)-sig(i-1))>slope % check slope criterion

            sig(i) = sig(i-1); % flatline spike

   % only save start of identified spike
   if  ~(ismember(i-3,spikes)) && ~(ismember(i-2,spikes))
    spikes = [spikes i-1];
```

```
   end
        end
 end

 for i = 1:length(spikes) % interpolate over spikes and prepend prior
 data
  sig = [sig(1:spikes(i)-1) ; interp(sig(spikes(i):end))];
 end
    y =sig; % return
end

function y = timeshift(sig,slope,fs)
 % removes any data before certain slope is achieved at y>=0
    i = 2;
 done = false;
 while ~done % while no delayed respones identified
        if fs*(sig(i)-sig(i-1))>slope && sig(i-1)>=0 % if high and
 steep enough
            sig = sig(i-1:end); % remove prior data
   done = true; % don't run while loop again
  end
  i = i+1;
 end
    y =sig; % return
end

function y = DCoffset(y)
 % removes constant offset to (ignores signal rise)
 done = false;
 i=2;
 while ~done
  % find fitst peak after rise
  if y(i) > y(i-1) && y(i) > y(i+1) && y(i) >400
   sig = y(i:end); % look only after this peak
   done = true;
  end
  i = i+1;
 end
 DC = mean(sig); % remove mean after this peak from signal
 y = y-DC;
end

function g = IOgain(u,y,fs)
 % determines IO gain
 y = despike(y,10000,fs);
 y = timeshift(y,500,fs);
 g = mean(y)/mean(u);
end
```

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