Cairo University
Faculty of Engineering
Aerospace Engineering Department

Digital Control Project: Liquid Level Control-Part II

AER 4410 Digital Control Applications
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Liquid Level Control Question: 6

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```
clc; clear; close all;
```

Requirements

$$O.S. = 5\%, T_s = 5s, e_{\mathrm{ss}} = 5\%$$

```
OS=0.05;        T_Settle=5;       Ess=0.05;
zeta=fzero(@(x) OS-exp(-pi*x/sqrt(1-x^2)),0.5);
w_n=4/T_Settle/zeta;
```

System definition

$$\text{For } G_p = \frac{K_{\mathrm{amp}}}{\tau\ s+1}$$

```
s=tf('s');
tau=4.35;        K_amp=4;        H=0.1;
Gp=K_amp/(tau*s+1);
```

Controller

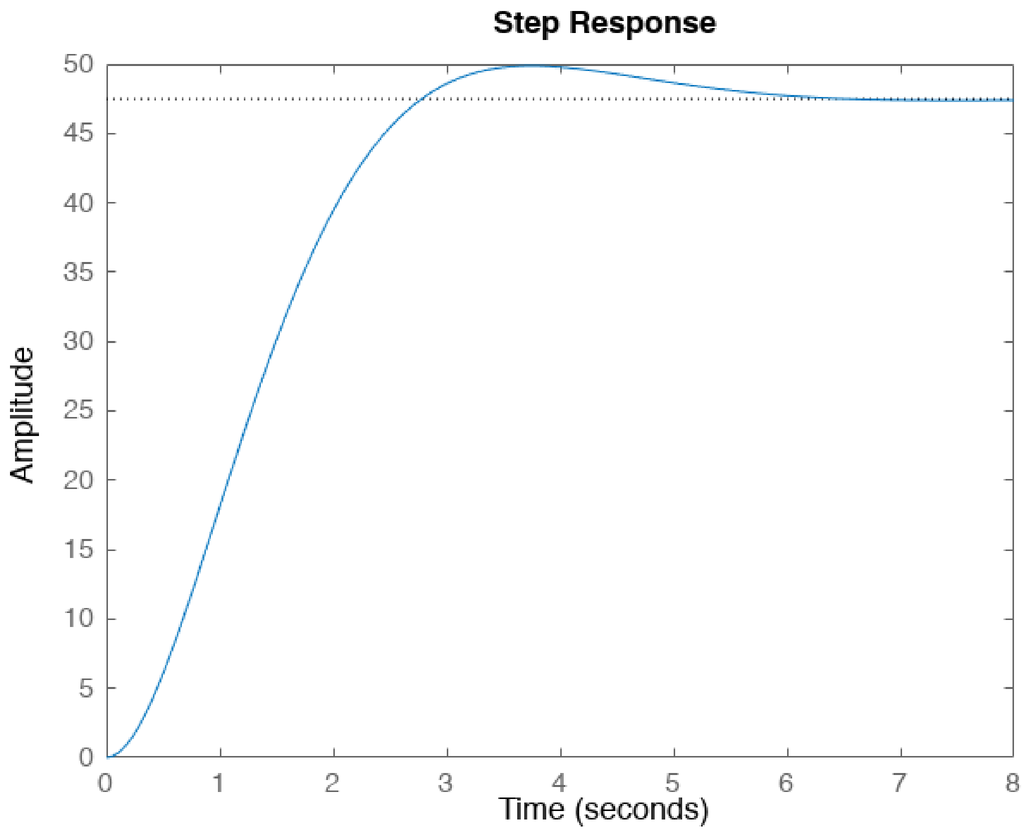
$$\text{Let } G_c = \frac{K_c\,(\tau\ s+1)}{s^2+\mathrm{xs}+y}$$

```
K_c=(1-Ess)*w_n^2/K_amp;
x=2*zeta*w_n;
y=w_n^2-K_amp*H*K_c;
G_c=K_c*(tau*s+1)/(s^2+x*s+y);
```

Continuous

Forwad Path Function : $G_{\mathrm{fp}} = G_c \cdot G_p$
Closed Loop Transfer Function : $G_{\mathrm{cl}} = \frac{G_c \cdot G_p}{1+G_c \cdot G_p \cdot H}$

```
G_fp=G_c*Gp;
G_c=feedback(G_fp,H);
Info_Continous=stepinfo(G_c);
step(G_c*50);       hold on;
```


Step Response
Amplitude
Time (seconds)
0
5
10
15
20
25
30
35
40
45
50
0
1
2
3
4
5
6
7
8

Optimum sampling time determination

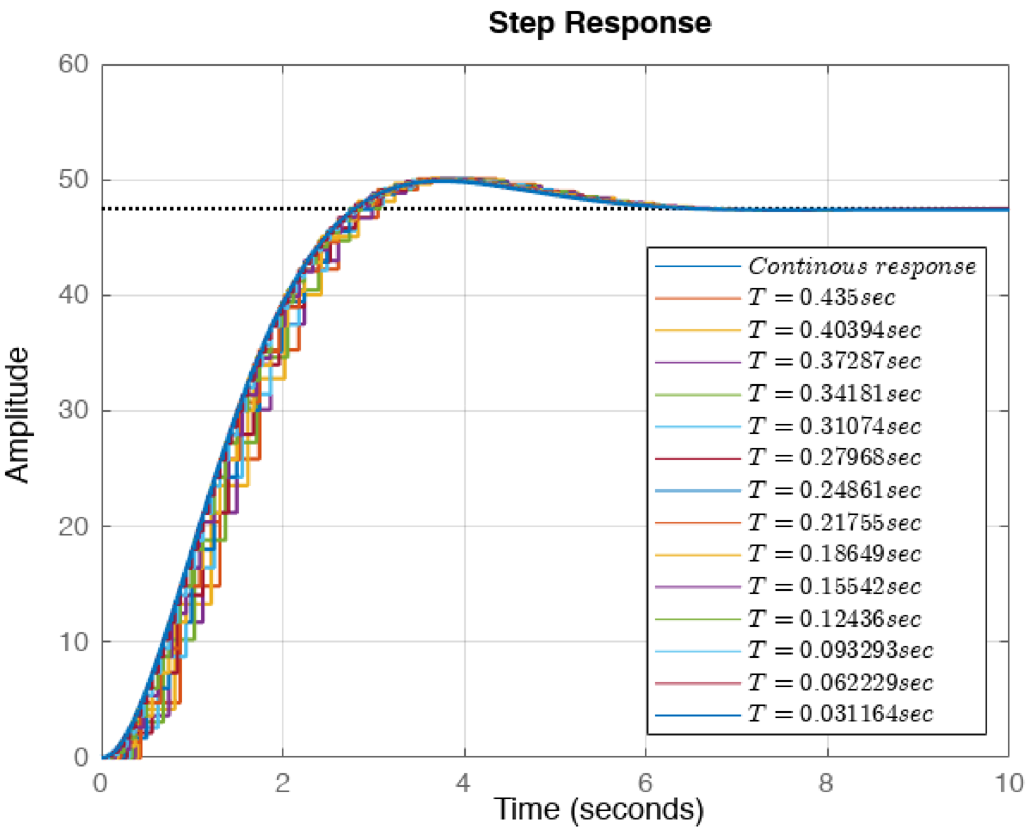
Typically for Arduinos (UNO, Nano, Mega) the minimums sampling time to read an analog input is 0.0001 seconds so we will take that as our minimum available sampling time and for our system we found out earlier that the maximum allowable sampling time can be obtained from $T_s|_{\max} \leq \frac{\tau}{10}$ so our maxium available value for the sampling time is $\frac{\tau}{10} = 0.\,435$ seconds.

The criteria we are trying to satisfy here is for the relative error between the continous and digitalized system to be less than $0.\,01$for the settling time and for the precentage overshoot.

```
T=linspace(0.1*tau,0.0001,15);
G_z=cell(length(T),1);   G_c=cell(length(T),1);   Sys_Info=cell(length(T),1);
Err=1e-2;       T_sampling=0;
for i=1:length(T)
    G_z{i}=c2d(G_fp,T(i));
    G_c{i}=feedback(G_z{i},H);
    Sys_Info{i}=stepinfo(G_c{i});
    if abs(Info_Continous.SettlingTime-Sys_Info{i}.SettlingTime)...
          /Info_Continous.SettlingTime<Err && abs(Info_Continous.Overshoot...
            -Sys_Info{i}.Overshoot)/Info_Continous.Overshoot<Err
        T_sampling=T(i);
        OS=Sys_Info{i}.Overshoot;
        T_Settle=Sys_Info{i}.SettlingTime;
        break
    end
end
```

Results

```
if T_sampling==0
    disp('No optimum sampling time found, try another range of T');
else
    index=find(T==T_sampling);
    legendstring=cell(1,index+1);
    legendstring{1}='$Continous\;response$';
    for i=1:index
    legendstring{i+1}=['$T= ', num2str(T(i)), 'sec$'];
    step(G_c{i}*50);
    end
    D_z=zpk(c2d(G_fp,T_sampling,'impulse'));
    hold off; grid on; box on;
    set(findall(gcf,'Type','line'),'LineWidth',1.3)
    legend(legendstring,'interpreter','latex','Location','SouthEast')
    display(T_sampling); display(OS);
    display(T_Settle);         display(D_z);
end
```




```
T_sampling = 0.0312
OS = 5.0359
T_Settle = 5.1733
D_z =

       0.0012093 z (z-0.9929)
  ---------------------------------
  (z-0.9929) (z^2 - 1.95z + 0.9514)

Sample time: 0.031164 seconds
Discrete-time zero/pole/gain model.
```

Conclusion

For the range we defined earlier $0.0001 \leq T_s \leq \frac{\tau}{10}$ the maximum minimum sampling time is $T_s = 0.031164$ sec