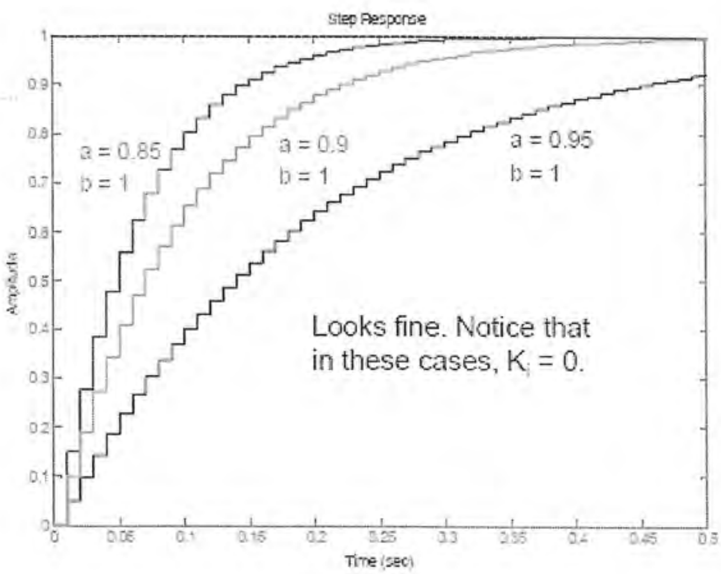
```
J = 0.001; Ka = 10;                    % Process parameters
T = 1/100;                             % Selected T
Gpc = tf(Ka,[J 0]);                    % DT process model
Gpd = c2d(Gpc,T,'zoh');                % Conversion
a = 0.85; b = 1;                       % Specified CL poles
Kp = J*(1-a*b)/(Ka*T);                 % Controller gains
Ki = J*(1-a)*(1-b)/(Ka*T*T);           → To know this T.F is
Gc = tf([(Kp+Ki*T) -Kp],[1 -1],T);
Gcl_d = feedback(Gc*Gpd,1);            % Closed-loop TF
step(Gcl_d);                           % Step response
[num,den] = tfdata(Gcl_d,'v');         % Check the roots
disp(roots(den));                      % Display them
```



Kp = 0.0015 , Ki=0 {for a=0.85, b=1} , Tr=Reading the time difference between (10%-90%)

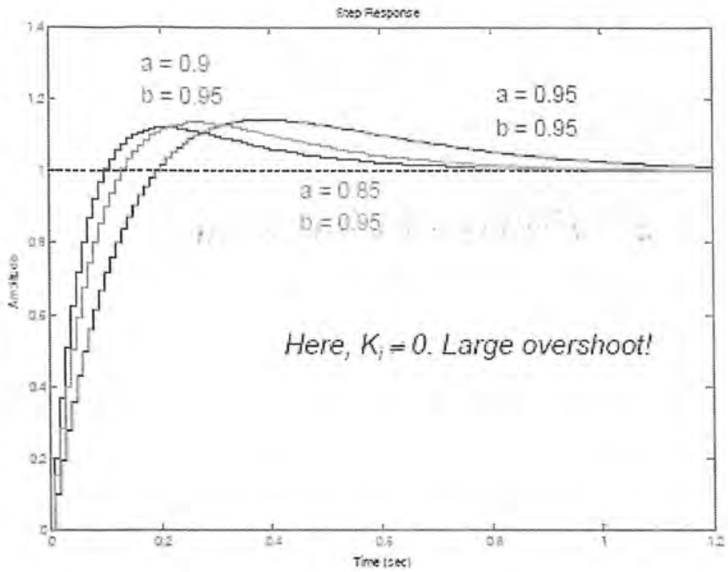
Gc(z)=(0.0015 z - 0.0015)/(z-1)

Note that:-

1- **In this design integral action is not necessary (because the system type 1).**

2- **When using integral action(b is not equal 1) the T.R behaves some overshot see fig below, while the design specifications no overshot:-**

→ P150



5.3 Emulation Design vs Direct Digital Control

- Emulation
  - Can use continuous time methods (well developed)
  - Few new tools needed
  - Works well if sampling fast
  - Mapping of control law from continuous time to discrete time is not exact
  - Ignore continuous system response between sampling times

- Direct digital control
  - Design of discrete time control law (and thus digital closed loop system) is exact for any sampling rate
  - Ignore continuous system response between sampling times

5.4 Minimal Prototype Design Method

The basic idea in this control design method is to achieve zero error at sample points, in the minimum number of sampling periods for step input. Where the controller is:-

$$D(z) = \frac{1}{G(z)} \frac{1}{(z-1)^{n-m}}$$

Where G(z) is the plant ,(n) order of Den. and (m) is order of Num.

Example

Let $G(s) = \dfrac{10}{(s+2)(s+5)}$

Design a minimum prototype controller with T=0.1 sec.

Sol

$$G(z) = (1 - z^{-1})\sum \frac{G(s)}{s}$$

$$G(z) = \frac{0.0398\ (z + 0.7919)}{(z - 0.8187)(z - 0.6065)}$$

$n = 2$

$m = 1$

$G(z)$ is stable

$$D(z) = \frac{25.12\,(z - 0.8187)(z - 0.6065)}{(z + 0.7919)(z - 1)}$$

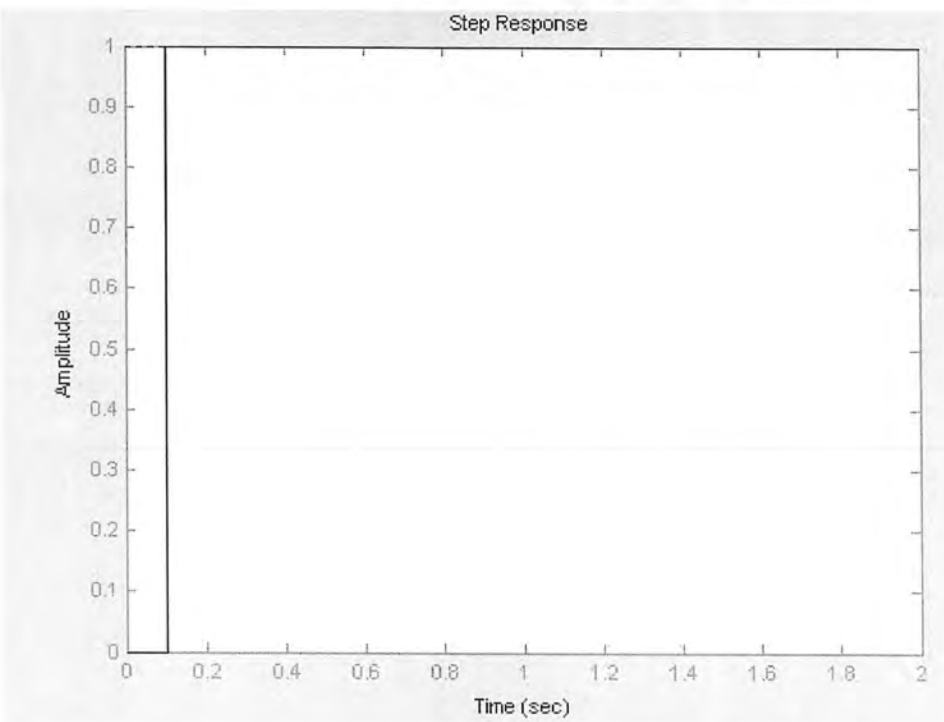
$$G(z)D(z) = \frac{1}{z - 1}$$

$$C.L.T.F = \frac{C(z)}{R(z)} = \frac{G(z)D(z)}{1 + G(z)D(z)} = \frac{1}{z}$$

$$C(z) = \frac{1}{z}R(z) = \frac{1}{z}\frac{z}{z-1} = \frac{1}{z-1}$$

$$C(kT) = z^{-1} + z^{-2} + z^{-3} + - - - - - - -$$

This is good response, because at the first sample the o/p reach steady-state without overshot.



5.5 Design of Deadbeat controller

In this method the response reaches the desired i/p in a minimum time(settling time) and zero Ess.

Design procedures:-

1- Take $G(z) = (1 - z^{-1}) \mathcal{Z}\left[\frac{G(s)}{s}\right] = \frac{Q(z^{-1})}{P(z^{-1})}$

2- **Let the controller D(z)=** $\frac{P(z^{-1})}{Q(1) - Q(z^{-1})}$

Where Q(1) is the value of Q(z) with z=1

Example1

Design deadbeat controller for:-

$$G(s) = \frac{2500}{s(s+25)}$$

$with:-$

$T = 0.01\sec$

sol

$$G(z) = \frac{0.1152z + 0.106}{(z-1)(z-0.7788)}$$

$$G(z^{-1}) = \frac{Q(z^{-1})}{P(z^{-1})} = \frac{0.1152z^{-1}(1+0.9217z^{-1})}{(1-z^{-1})(1-0.7788z^{-1})}$$

$$Q(1) = 0.22138$$

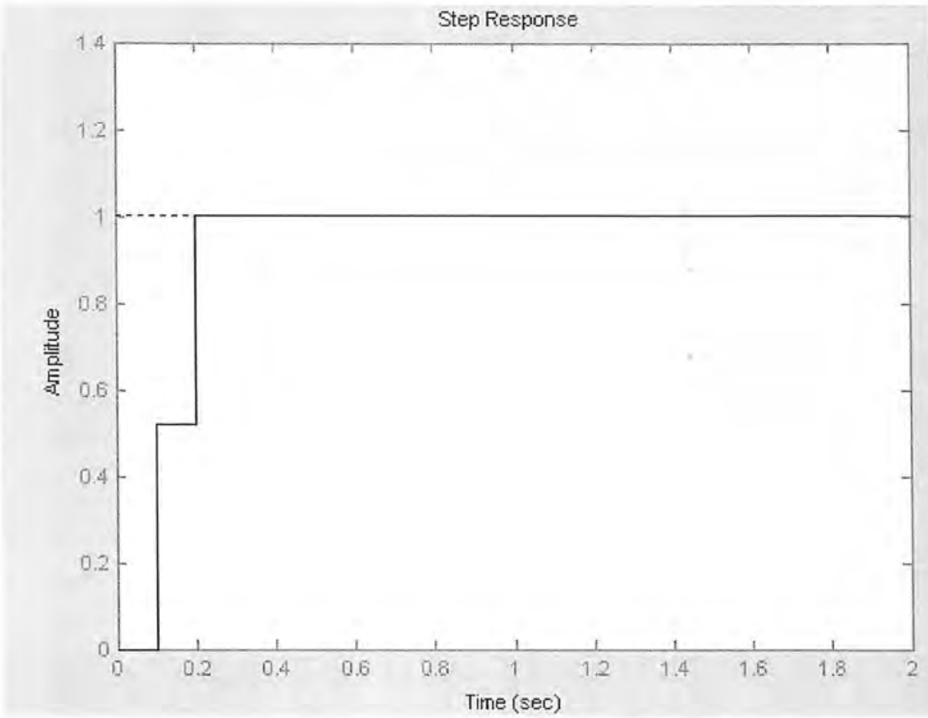
$$D(z) = \frac{(z-1)(z-0.7788)}{0.22138z^2 - 0.1152z - 0.106}$$

$$O.L.T.F\, G(z)D(z) = \frac{0.1152(z+0.9217)}{0.22138z^2 - 0.1152z - 0.106}$$

$$C.LT.F = \frac{C(z)}{R(z)} = \frac{G(z)D(z)}{1+G(z)D(z)} = \frac{0.5204(z+0.9217)}{z^2}$$

$$C(z) = \frac{0.5204(z+0.9217)}{z(z-1)}$$

$$C(kT) = 0.5204z^{-1} + z^{-2} + z^{-3} + -----$$



The response is good, because ,there is no overshot and Ess, with a minimum (Ts).

Problems of deadbeat controller

1- Reliability of controller
The Den. of D(z) must be more than or equal the Num. order.

2- Intersampling ripples
no overshot after reaching the settling time(after 2-samples).

How to check ripples

Intersampling ripples will be checked from fluctuations of control action M(z) {the o/p of controller}, where:-

$$M(z) = \frac{C(z)}{G(z)}$$

$$m(T) = a - bz^{-1} + 0 + 0 + ---$$

By **long division** , C(z) by G(z) , we get (a) and (b) values
For **ex.1**

$$M(z) = \frac{C(z)}{G(z)} = \frac{\dfrac{0.50204(z+0.9217)}{z(z-1)}}{\dfrac{(0.1152z+0.106)}{(z-1)(z-0.7788)}}$$

$$m(kT) = 4.5 - 3.5z^{-1} + 0 + 0 + 0 + - - -$$

There is no ripples , because m(kT) reaches the zero values after (2-sample)'

Example2

Design deadbeat controller for:

$$G(z) = \frac{0.368(z+0.72)}{(z-1)(z-0.368)}$$

And check the ripples.

Sol

Apply the same procedures for the design to get:-

$$D(z) = \frac{(z-1)(z-0.368)}{0.633z^2 - 0.368z - 0.265}$$

$$\frac{C(z)}{R(z)} = \frac{0.581(z+0.72)}{z^2}$$

$$C(kT) = 0.581z^{-1} + z^{-2} + z^{-3} + - - - - - -$$

To check the ripple

$$m(kT) = 1.582 - 0.582z^{-1} + 0 + 0 + 0 + - - - -$$

There is no ripples.

Example3

Design deadbeat controller and check the ripples. for:-

$$G(s) = \frac{1}{s^2}$$

$$if T = 1\sec$$

Sol

Apply the same procedures for the design to get:-

$$D(z) = \frac{2(z-1)(z-1)}{2z^2 - z - 1}$$

$$\frac{C(z)}{R(z)} = \frac{0.5(z+1)}{z^2}$$

$$C(z) = \frac{0.5(z+1)}{z(z-1)}$$

$$c(kT) = 0.5z^{-1} + z^{-2} + z^{-3} + z^{-4} + - - - -$$

To check ripples

$$m(kT) = 1 - z^{-1} + 0 + 0 + - - -$$

There is no ripples

Note that

In all these examples the input is assume step .for ramp input use:

$$R(z) = \frac{Tz}{(z-1)^2}$$