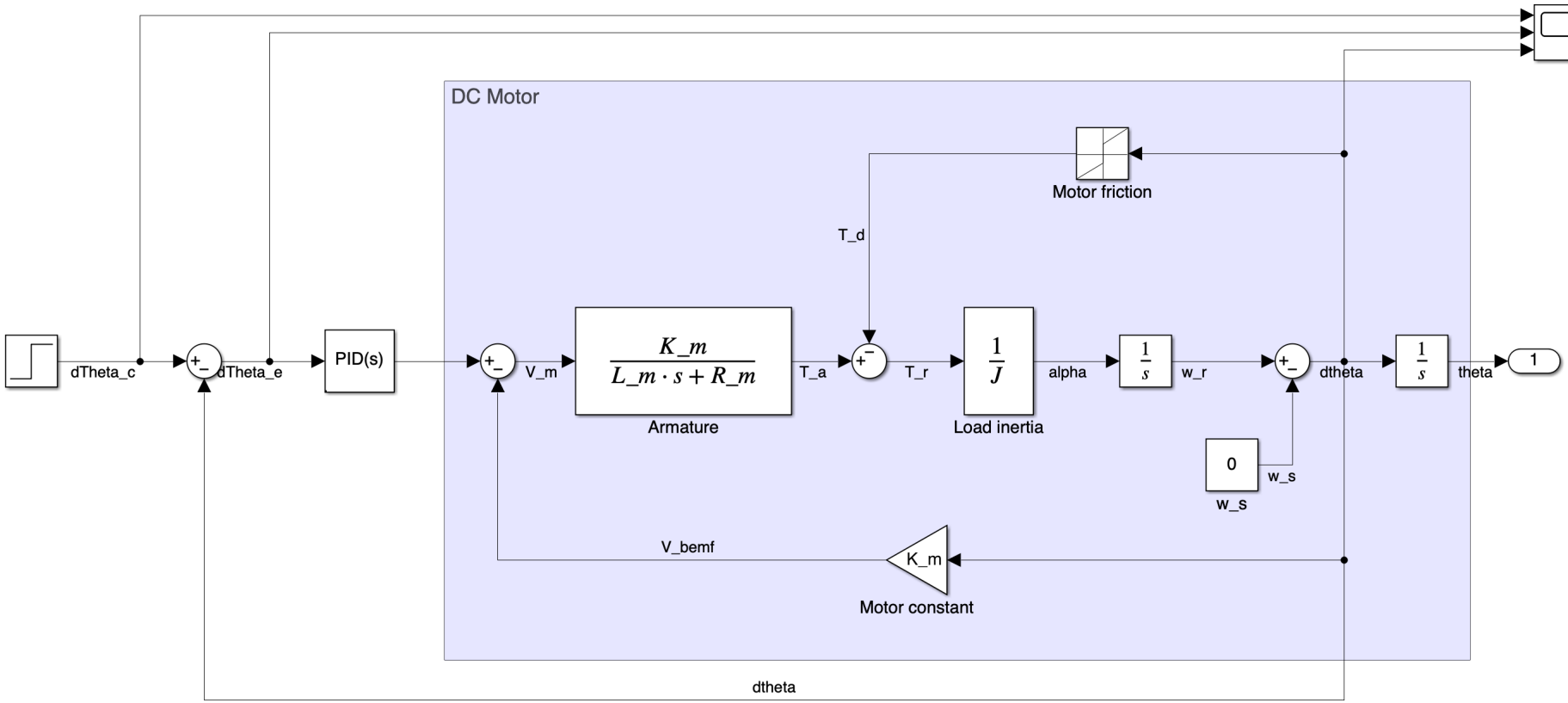
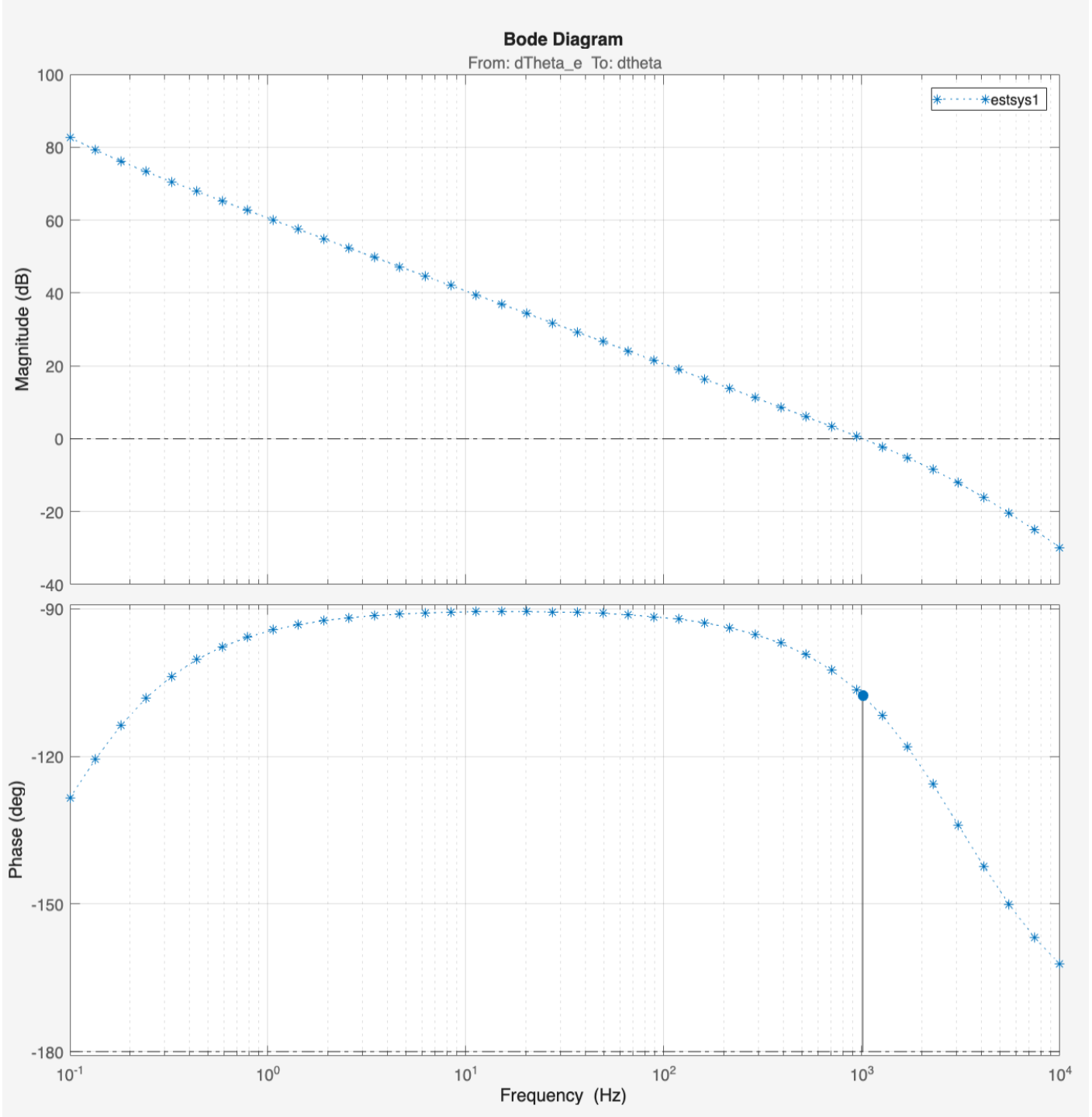
Embedded Control

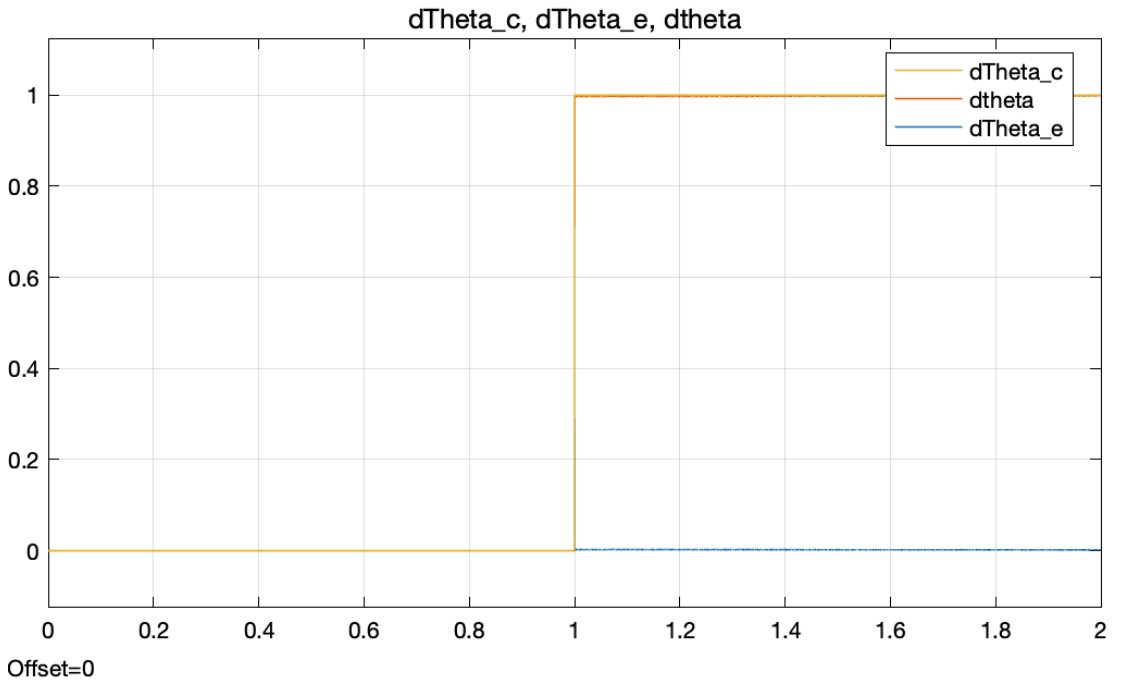


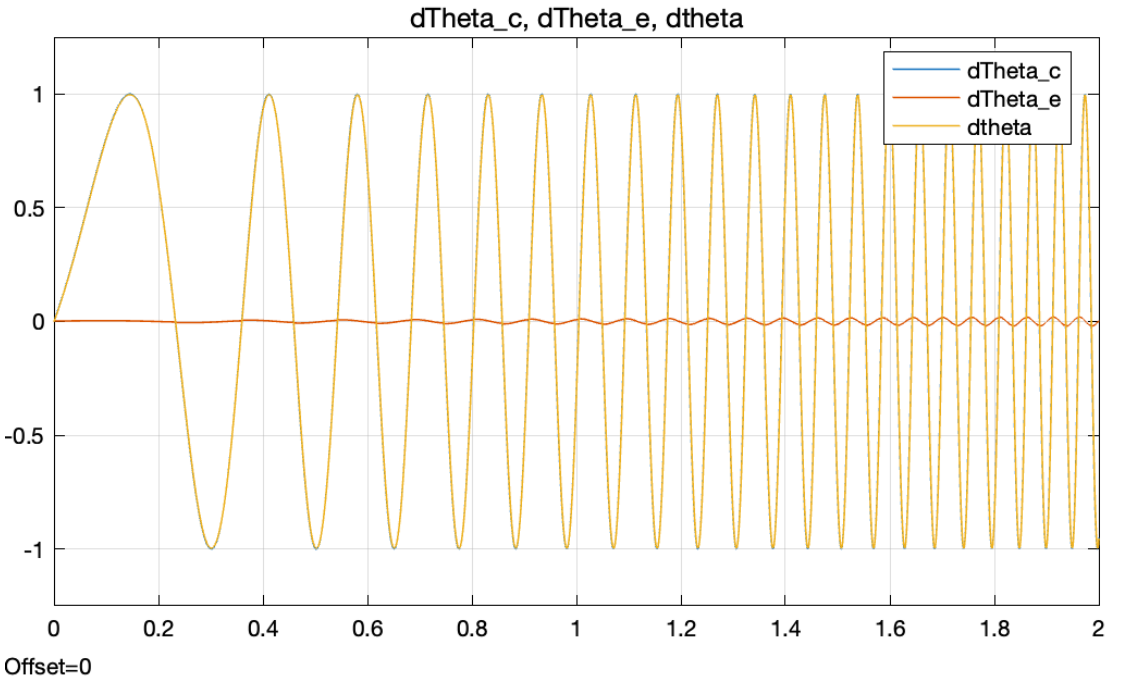
$$PID = P\left(1 + I\frac{1}{s} + D\frac{N}{1 + Ns^{-1}}\right)$$

$$PID = P\left(\frac{s + I}{s}\right)$$ as D = 0

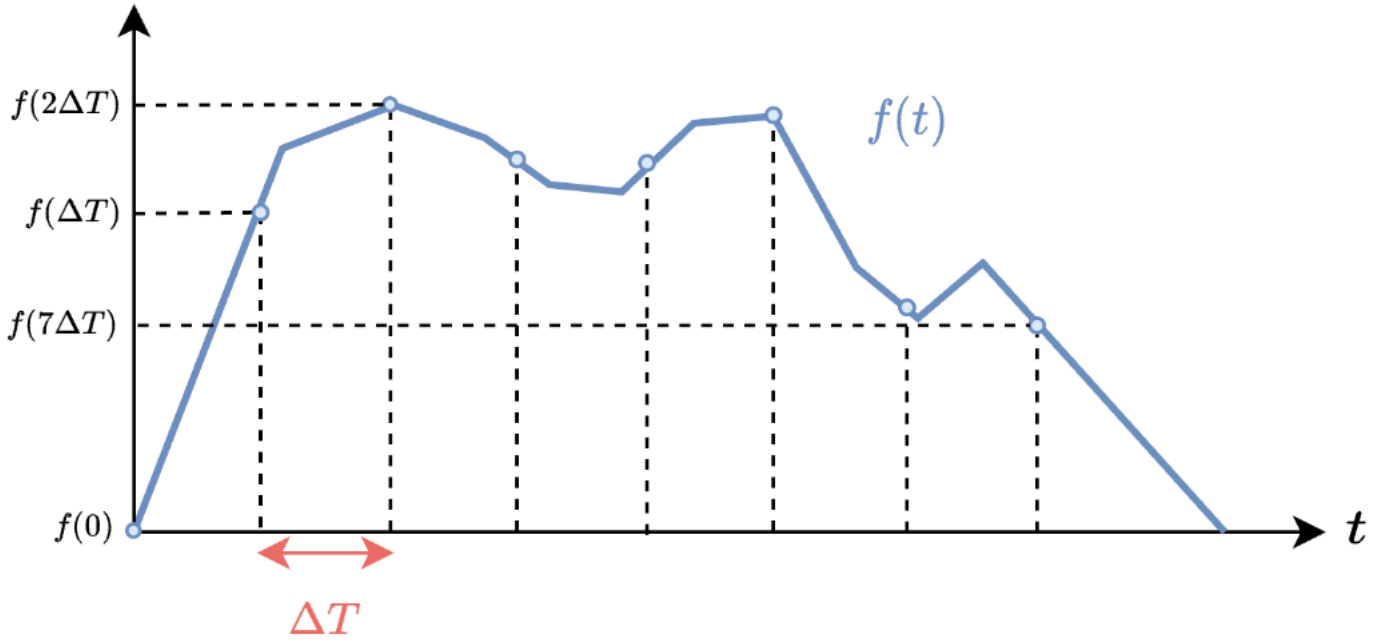
```
%% dc_motor_position controller parameters
% Controller parameters ====================
P = 5000;
I = 0.5;

% Motor parameters =========================
K_m = 40e-3;          %Nm/A
R_m = 6;              %Ohm
L_m = 300e-6;         %H
K_stic = 38e-3;       %Nm
K_fr = 60e-3;         %Nm/(rad/s)
J = 0.005;            %kgm^2
```


Bode Diagram
From: dTheta_e To: dtheta
estsys1
Magnitude (dB)
Phase (deg)
Frequency (Hz)


dTheta_c, dTheta_e, dtheta
dTheta_c
dtheta
dTheta_e
Offset=0


dTheta_c, dTheta_e, dtheta
dTheta_c
dTheta_e
dtheta
Offset=0

Analogue to Digital



- Plant operates on analogue signals.
- Digital controllers are are sampled incur a time delay.

- Analogue modelled in the **s** domain.
- Digital sections modelled in the **z** domain.

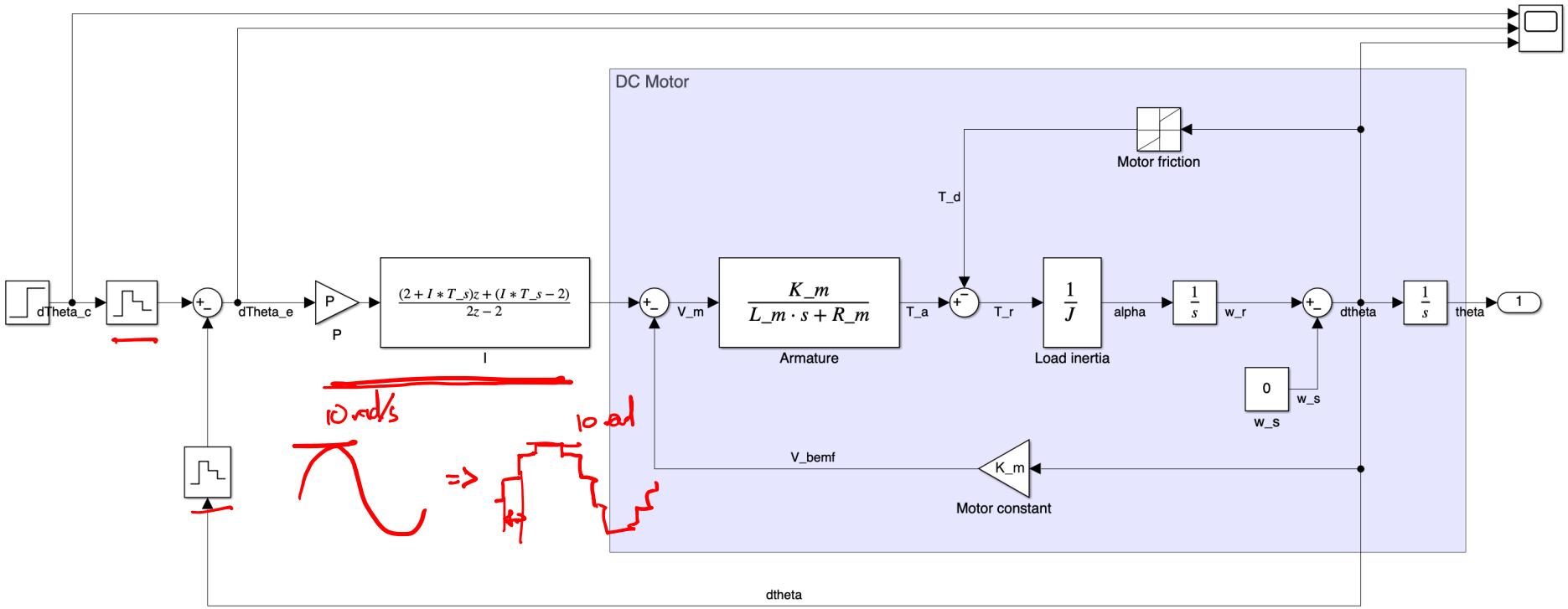
→ Tustin Transform →

$$s \approx \frac{2(z-1)}{\Delta T(z+1)}$$

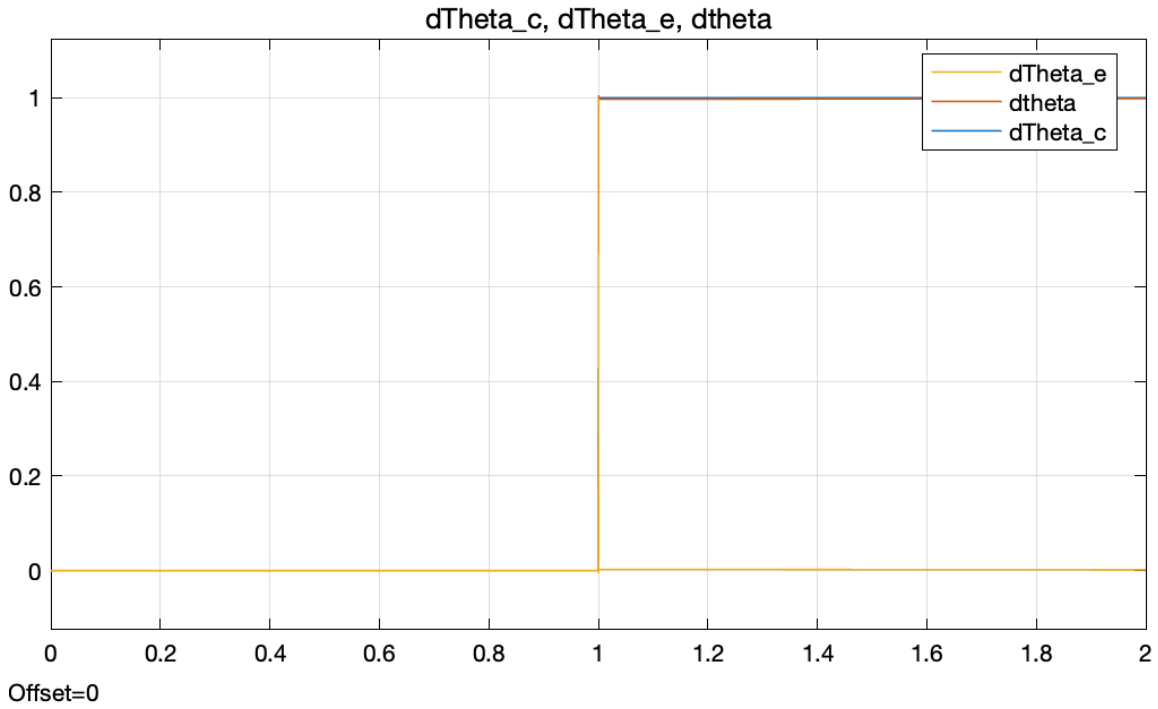
$$z \approx \frac{1+s\Delta T/2}{1-s\Delta T/2}$$

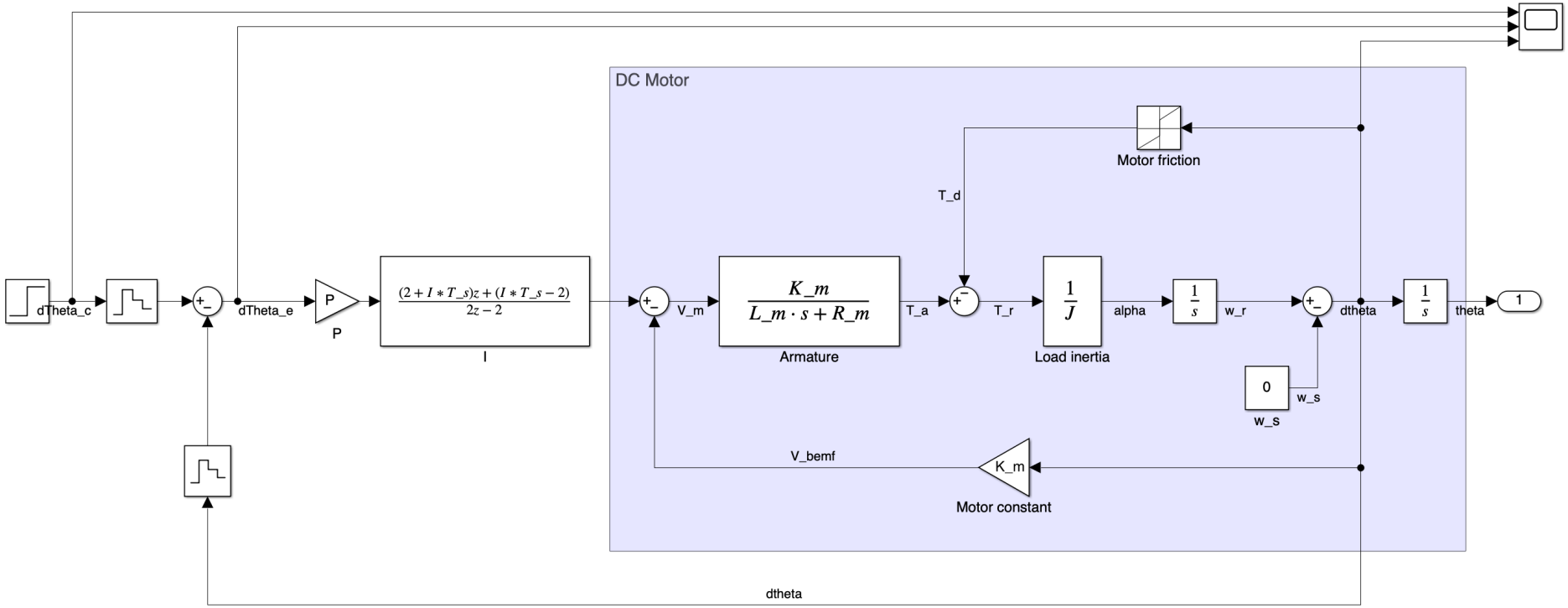
$$PID = P\left(\frac{s + I}{s}\right)$$

$$\text{PID} = \text{P} \times \left(\frac{(2 + IT_s)z + (IT_s - 2)}{2z - 2}\right)$$

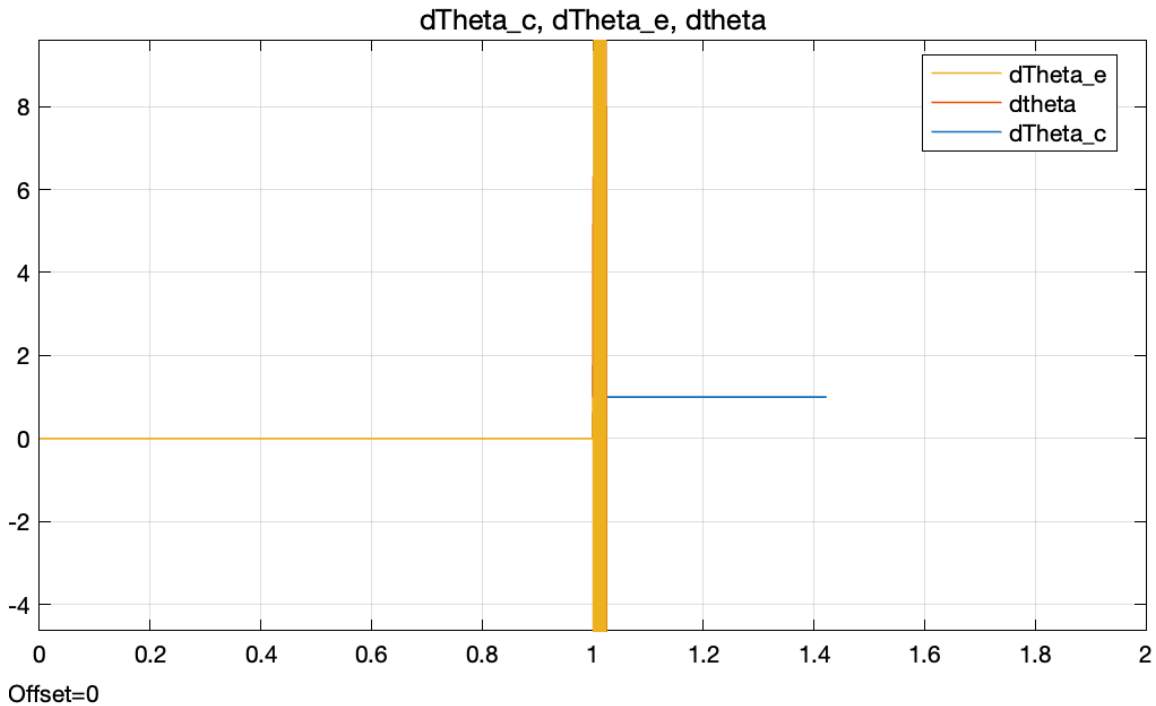


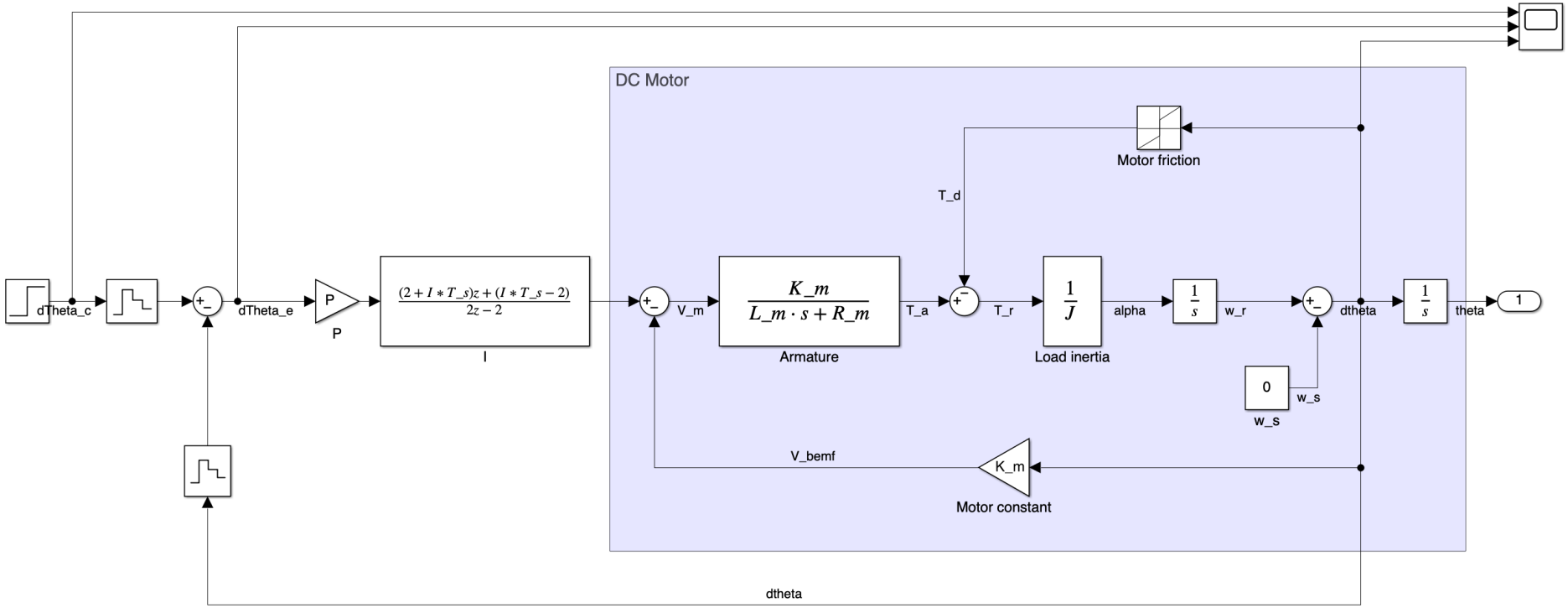

```
%% dc_motor rate controller parameters
% Controller parameters ====================
P = 5000;
I = 0.5;
T_s = 0.00001;          %s

% Motor parameters ==========================
K_m = 40e-3;            %Nm/A
R_m = 6;                %Ohm
L_m = 300e-6;           %H
K_stic = 38e-3;         %Nm
K_fr = 60e-3;           %Nm/(rad/s)
J = 0.005;              %kgm^2
```



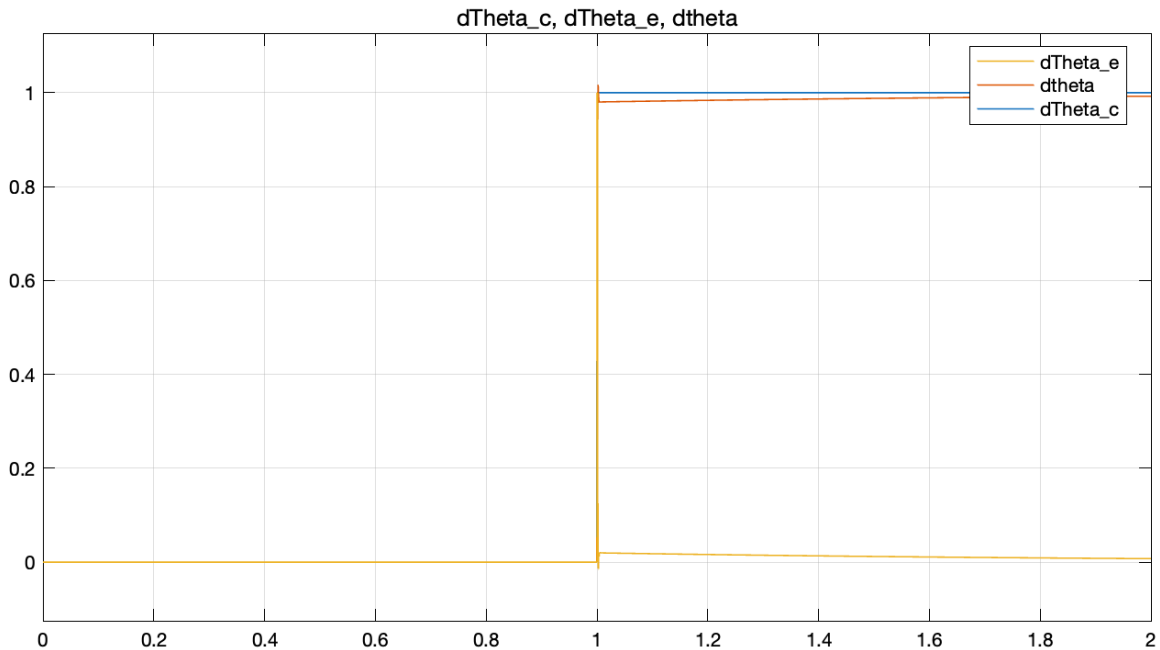


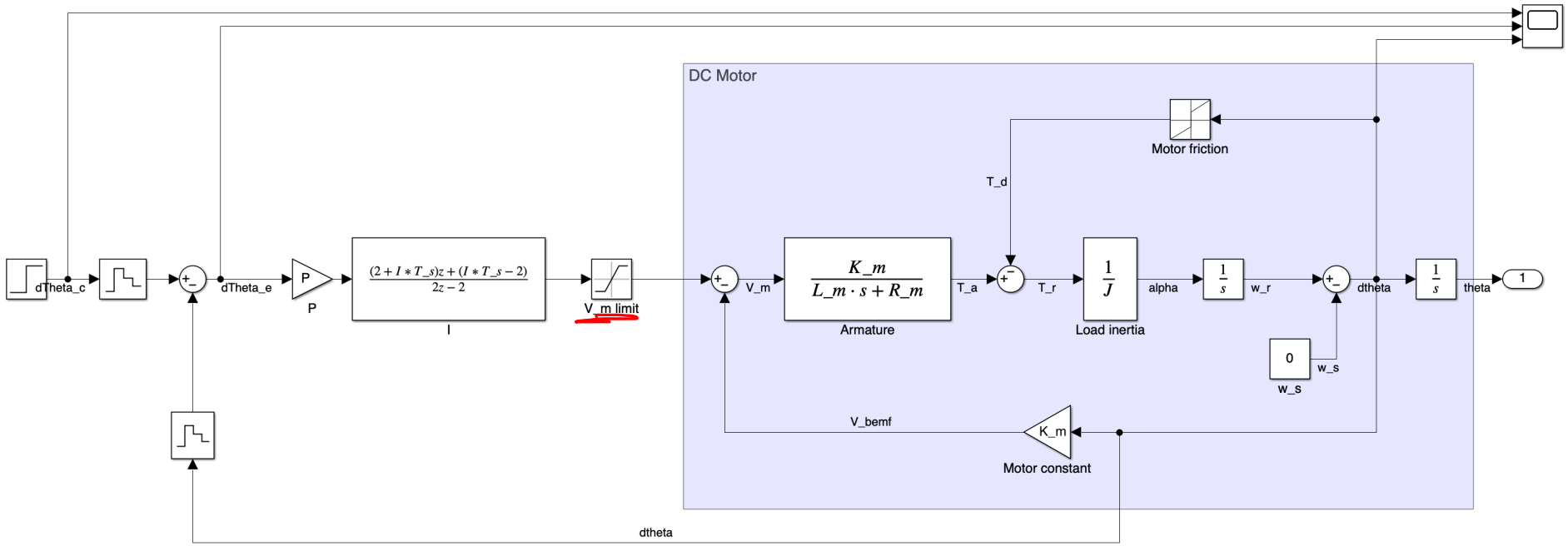

```
%% dc_motor rate controller parameters
% Controller parameters ========================
P = 5000;
I = 0.5;
T_s = 0.001;          %s

% Motor parameters ============================
K_m = 40e-3;          %Nm/A
V_m = 20;             %V
R_m = 6;              %Ohm
L_m = 300e-6;         %H
K_stic = 38e-3;       %Nm
K_fr = 60e-3;         %Nm/(rad/s)
J = 0.005;            %kgm^2
```



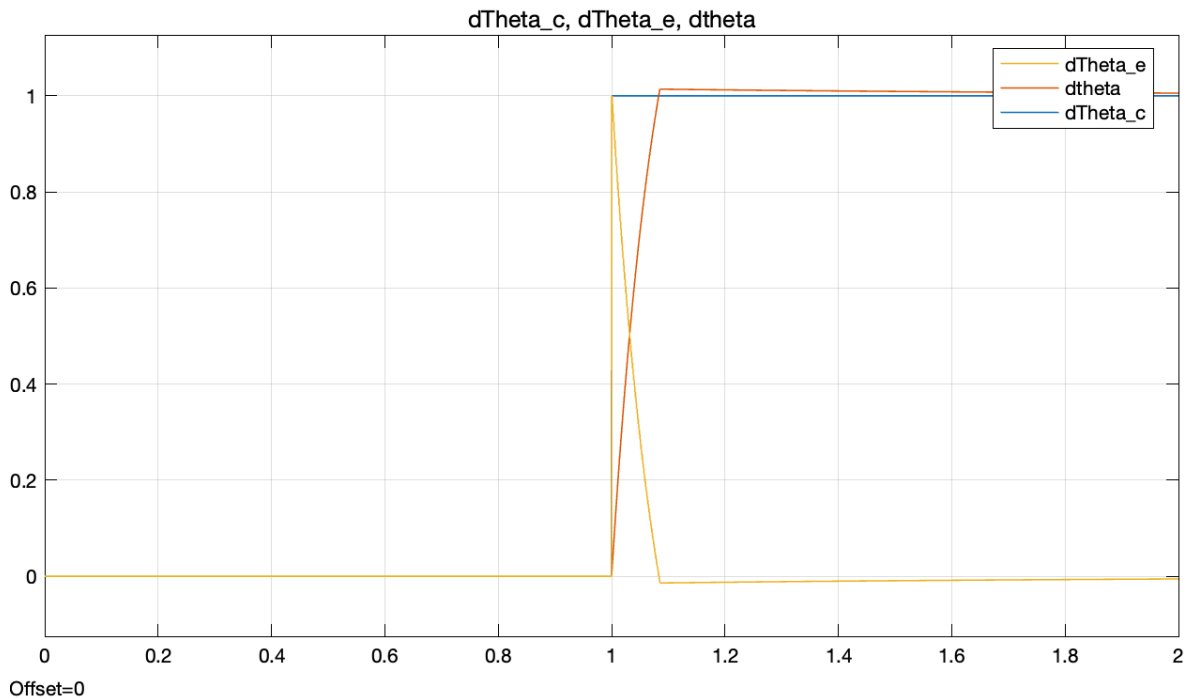


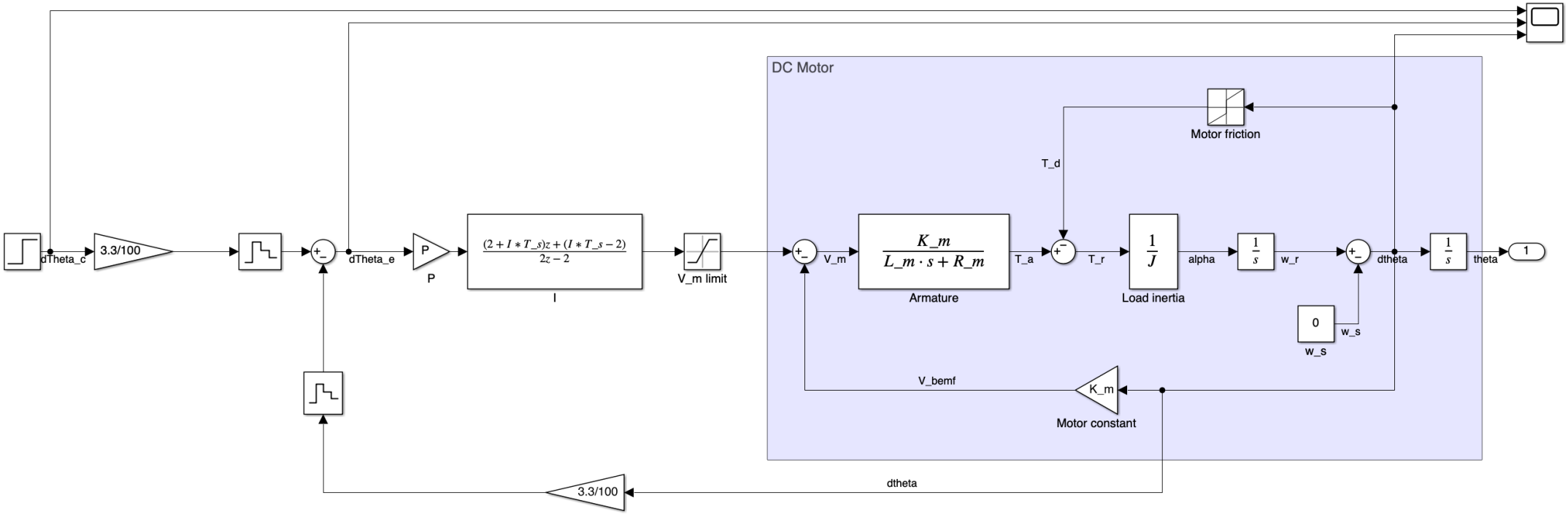

```
%% dc_motor rate controller parameters
% Controller parameters ====================
P = 700;
I = 1;
T_s = 0.001;          %s

% Motor parameters ==========================
K_m = 40e-3;          %Nm/A
R_m = 6;              %Ohm
L_m = 300e-6;         %H
K_stic = 38e-3;       %Nm
K_fr = 60e-3;         %Nm/(rad/s)
J = 0.005;            %kgm^2
```






```
%% dc_motor rate controller parameters
% Controller parameters ========================
P = 700;
I = 1;
T_s = 0.001;          %s

% Motor parameters =============================
K_m = 40e-3;          %Nm/A
V_m = 20;             %V
R_m = 6;              %Ohm
L_m = 300e-6;         %H
K_stic = 38e-3;       %Nm
K_fr = 60e-3;         %Nm/(rad/s)
J = 0.005;            %kgm^2
```

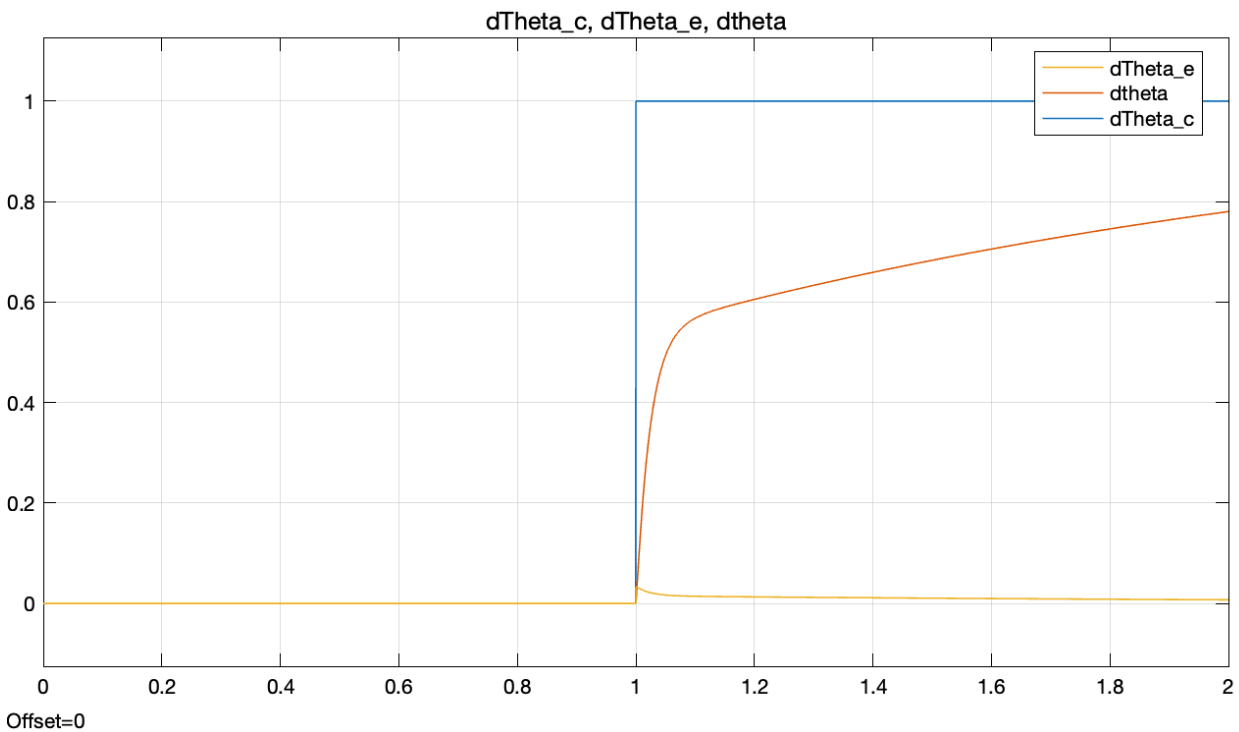


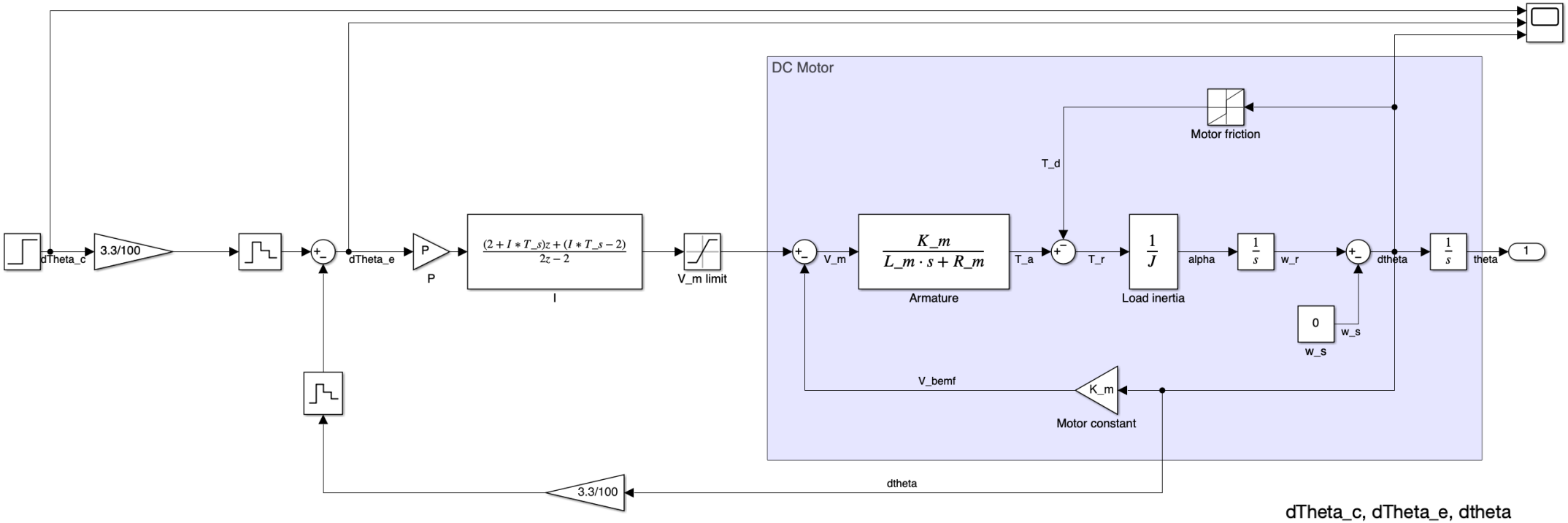


Add in model for sensors

- Analogue sensors giving V proportional to dTheta

V max = 3.3
dTheta max = 100 rad/s

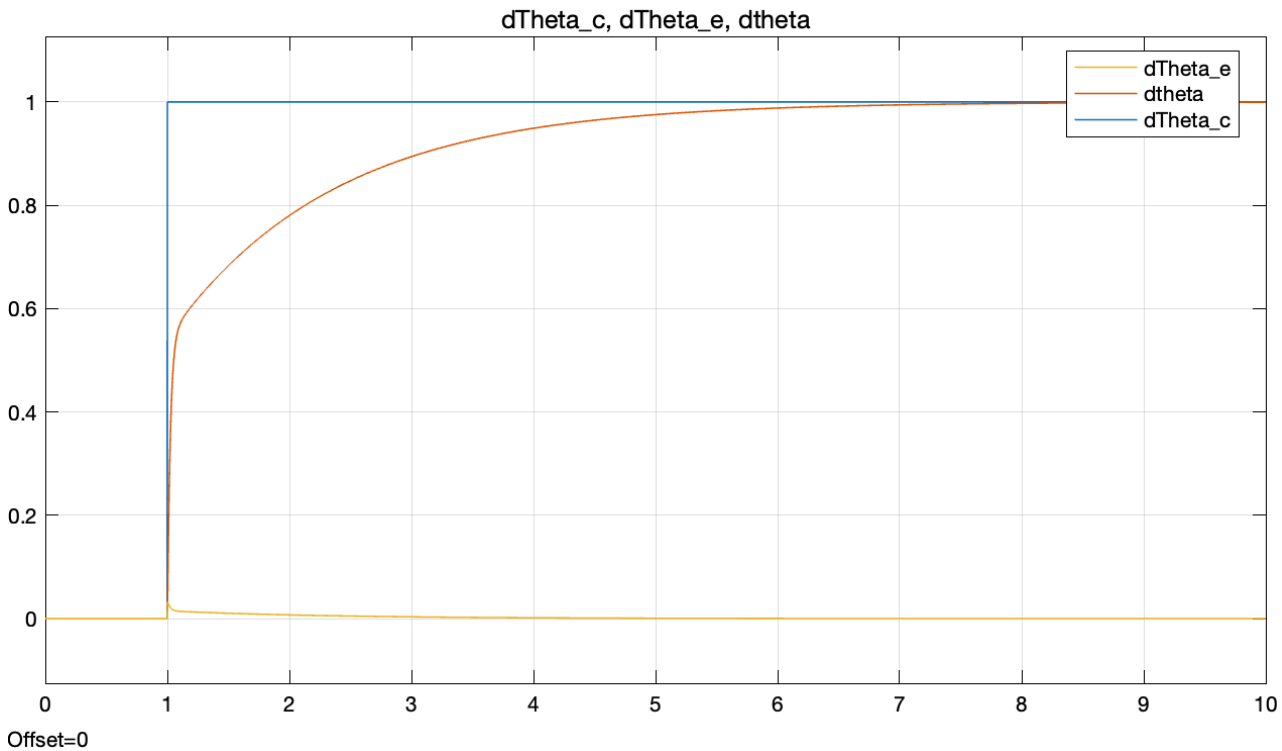


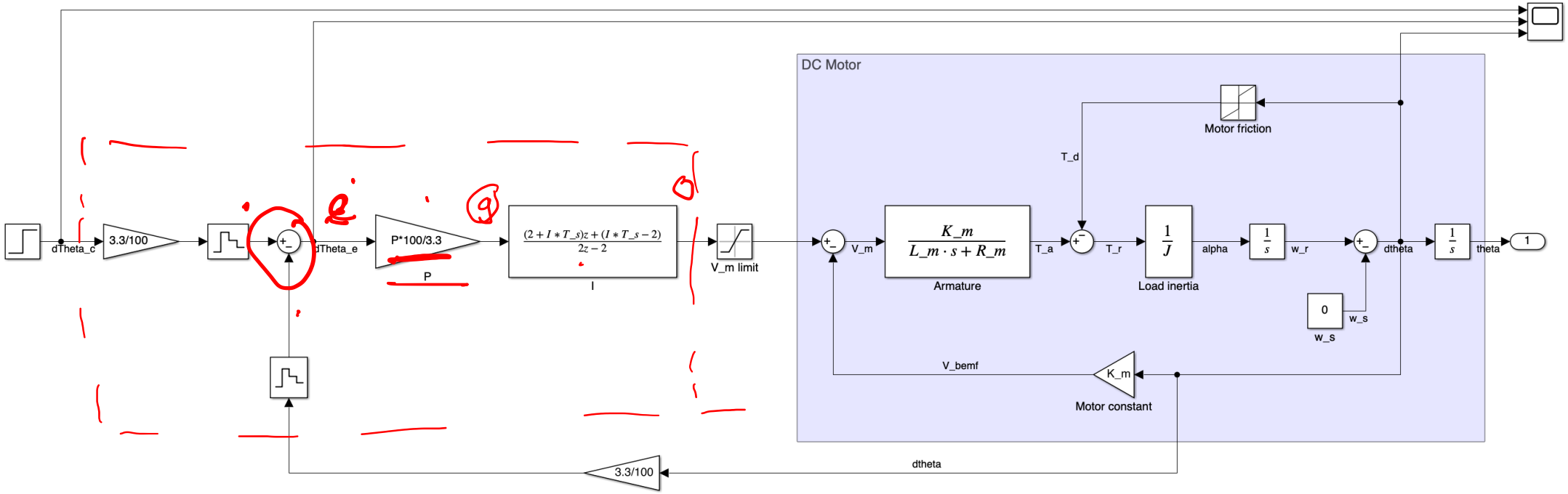


Add in model for sensors

- Analogue sensors giving V proportional to dTheta

V max = 3.3
dTheta max = 100 rad/s



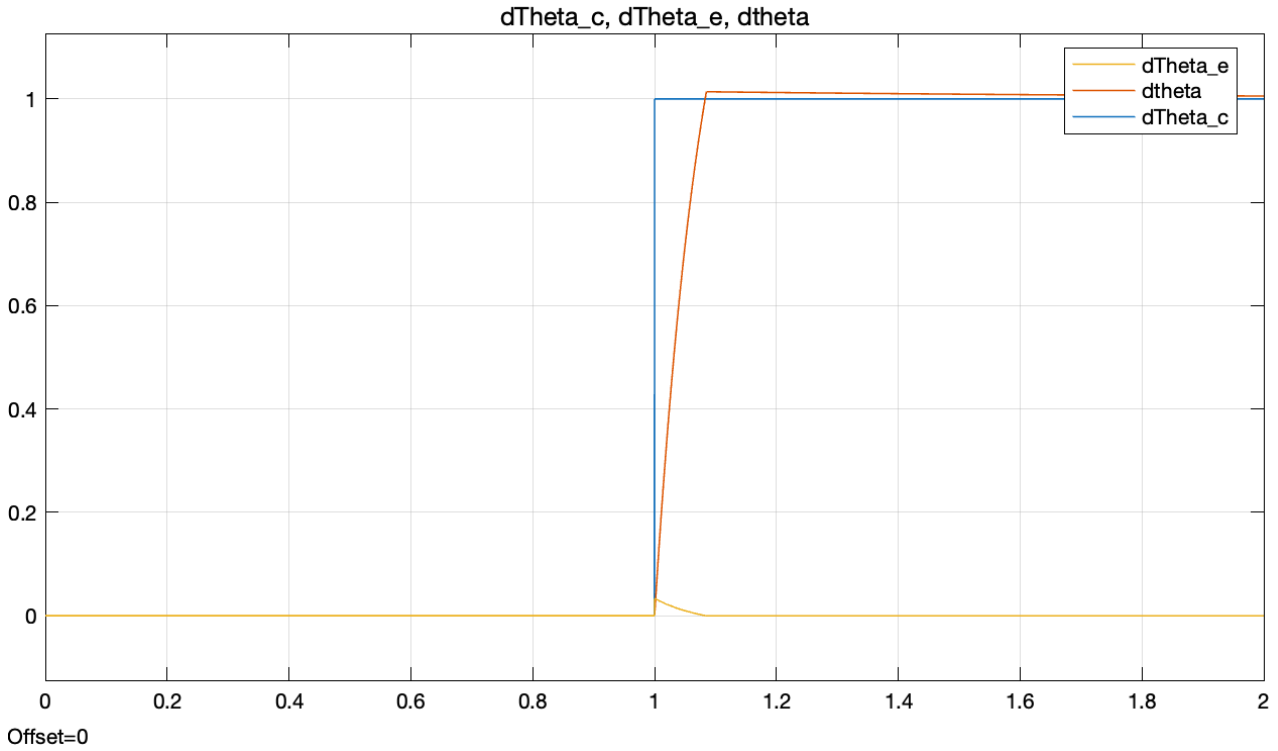


Add in model for sensors

- Analogue sensors giving V proportional to dTheta

V max = 3.3
dTheta max = 100 rad/s

-Account for change in **open loop gain.**



Difference Equations

$z^{-1} = T_s$

$$\frac{O(z)}{g(z)} = \frac{(2+IT_s)z + (IT_s - 2)}{2z - 2}$$

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

$$2O(z) - 2O(z)z^{-1} = (2+IT_s)\,g(z) + (IT_s - 2)\,g(z)\,z^{-1}$$

$$O(z) = \frac{(2+IT_s)\,g(z) + (IT_s - 2)z^{-1}g(z) + 2O(z)\cdot z^{-1}}{2}$$

$$O = \frac{(2+IT_s)g + (IT_s - 2)g_p + 2O_p}{2}$$