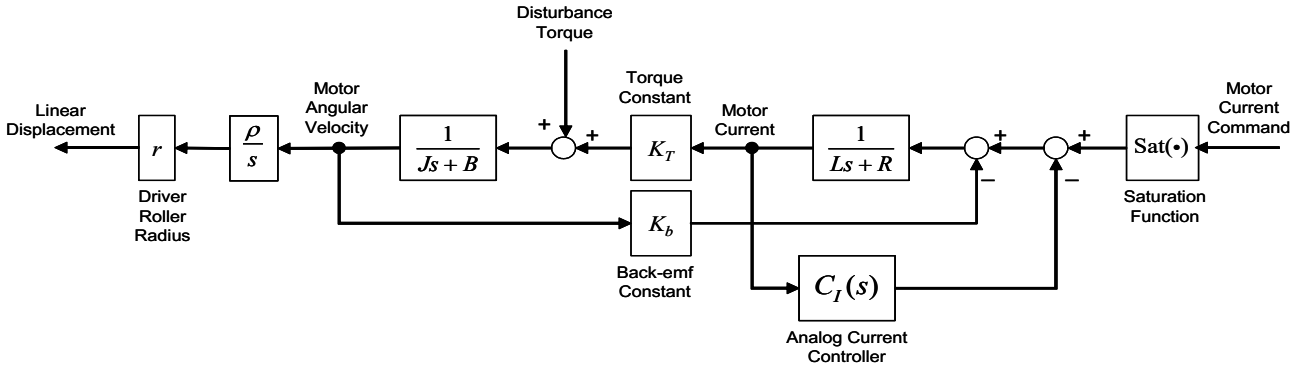
1. The experimental inkjet media advance system can be modeled by the following block diagram:



The parameters are:

K_T:	Motor torque constant	K_b:	Motor back-emf constant
L:	Motor armature inductance	R:	Motor armature resistance
J:	Effective rotational inertia	B:	Effective viscous friction coefficient
ρ:	Gear ratio	r:	Drive roller radius
Sat():	Current driver saturation function		

The analog current controller $C_I(s)$ is implemented in a current driver. For now, we will ignore the effect of the saturation function, Sat(), i.e. we will not exceed the saturation limit.

(A) If we assume that the current controller is well designed and that the current loop is sufficient fast that we can ignore its dynamics, draw the block diagram of the simplified system and calculate the resulting transfer function from the current command input to the linear displacement output. (This should be a second order system)

(B) Derive the ZOH equivalent discrete time transfer function for the continuous-time transfer function you obtained in (A).

(C) Write down the state-space realization of the continuous-time simplified plant you obtained in (A), use the driver roller angular displacement and angular velocity as the state variables.

(D) Derive the ZOH equivalent state space representation of the model you obtained in (C).

2. Consider a 3rd order discrete-time system described by

$$\mathbf{x}(k+1) = \mathbf{A}\cdot\mathbf{x}(k) + \mathbf{B}\cdot u(k)$$

where $u(k)$ is a scalar input. The initial condition is nonzero, i.e. $\mathbf{x}(0) = \mathbf{x}_0 \neq 0$.

(A) Find a control sequence, $u(0), u(1), u(2)$, if it exists, so that $\mathbf{x}(3) = 0$.(Hint: First express $\mathbf{x}(3)$ in terms of $\mathbf{x}_0$, $u(0)$, $u(1)$, and $u(2)$)

(B) While it may be obvious in your expression, state a condition so that the above control sequence exists for any nonzero initial state.

3. Given the following low-pass filter

$$G(s) = \frac{10}{s+10}$$

Design digital low-pass filters using (A) bilinear transformation and (B) bilinear transformation with pre-warping. Let the sample period to be 0.2 second and the frequency region of interest is between 0 and 10 rad/sec. Plot and compare the Bode diagram of the three filters. You should clearly describe your choice of the critical frequency used in (B). Please just add the code and files to your submitted PDF.