Objective: The objective of lab 2 is to: 1) complete our measurements of the MOTOMATIC internal parameters; 2) To obtain a state vaiable model of the MOTOMATIC.

Prelab (Counts as HW#9): (due Monday, October 3rd):

1. a) Using the transfer function Vout(s)/Vin(s) as found in Lab #1, find the SFG for the MOTOMATIC then find the state variable model in phase variable form.

 b) The actual variables (voltages) we can measure are Vout (the voltage from the potentiometer wiper arm) and Vg (the voltage from the generator/tachometer). Recall that $V_g = K_g\dot{\theta}_m = K_g N_a \dot{\theta}_{out} = K_g(9)\dot{\theta}_{out}$. Use a similarity transformation relating the state variables, [Vout Vg] to the state variables you found in part a). Then, find a new state variable model in terms of the state variables, [Vout and Vg]

 Hint: recall from class that we can use any similarity transform, x=Tz, to transform the given state coordinates (x) into a new state coordinate (z). The result we derived was $\begin{aligned}\dot{z} &= T^{-1}ATz + T^{-1}Bw \\ y &= CTz\end{aligned}$

 For this problem, x are the variables from your simulation diagram and z = $\begin{bmatrix} V_{out} \\ V_g \end{bmatrix}$. When you find the similarity transformation matrix T where x=Tz, T should be a diagonal matrix with the first element relating x_1 to V_{out} and the second diagonal element relating x_2 to V_g.

2. The schematic for the closed-loop unity feedback MOTOMATIC DC servo for which you found the step response is shown in **Figure 1.** Note how the output voltage, Vout, is fed-back to form an error (difference) signal with the system input, Vin.

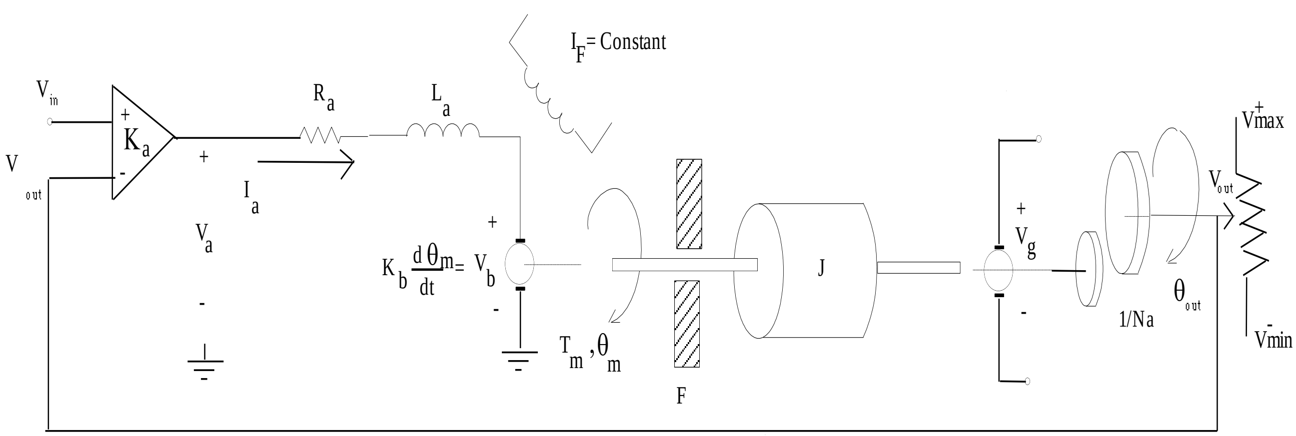

Figure 1. *Schematic of MOTOMATIC DC servo motor system.*

 a) Find the functional block diagram from the above schematic with outputs Vg and Vout.

 b) Find the closed-loop transfer function, Vout(s)/Vin(s), in terms of the parameters J, F, R, etc.

 c) Now let La = 0, and repeat part b. You should get a 2nd order system.

 d) Finally, find the open-loop transfer functions, Vg(s)/Vin(s) and Vout(s)/Vin(s) (remember how we do open-loop transfer functions)

e) Ra and La If we hold the motor shaft so that it cannot move, then the back emf voltage must be zero (i.e., Vb = 0). Find the transfer function, Ia(s)/Va(s), when Vb = 0. If we apply a sinusoidal voltage with amplitude A and frequency ω rad/sec at the armature terminals (i.e., $V_a = A\sin\omega t$), then Ia will also be a sinusoid in steady-state. Use your transfer function, $I_a(j\omega)/V_a(j\omega)$ to find two equations involving Ra and La if we assume sinusoidal steady-state (Hint: think magnitude and phase).

In Lab (Counts as HW#10) (due Wednesday, October 5th)

In the lab, you will measure Ra, La, J, F, and Ka.

1. a) Recall from EE415, that the value for the torque constant of a DC armature controlled motor is the same as the value for the back emf constant. Use your answer from Lab 1 for the back emf constant (Kb) to find the torque constant, K_T (make sure your units are consistent).

b) Apply a sinusoidal voltage at frequency ω to the motor while holding the motor shaft to insure that Vb=0. Take a plot of Va and Ia versus time and find the magnitude and phase of $I_a(j\omega)/V_a(j\omega)$. Use your answer to part 2e) of the Prelab to obtain values for Ra and La.

c) One of the reasons that our MOTOMATIC is not truly a linear second-order system is that the friction present in the motor contains Coulomb friction as well as viscous friction. Coulomb friction (also known as static friction or "stiction") is approximately a constant force always opposing the motion of the motor. If we call this Coulomb friction constant C, then we can write a new Newton's second law of motion for the Torques as seen at the motor:

$$T_m = K_T I_a = J\dot{\omega}_m + F\omega_m + C sgn(\omega_m) \qquad (1)$$

where sgn() is the signum funcion (i.e., sgn(x) = +1 if x > 0 or -1 if x <0).

One technique for measuring parameters is called a steady-state plot. This technique is performed by inputting a constant into the system, waiting fot the system to reach steady-state, then measure the system's output. By repeating this procedure for a variety of constant inputs, a plot of steady-state output values versus constant input values is obtained. For our particular system, we will input a constant Vin which will produce a constant motor speed (i.e., ω_m = constant). If we measure the generator output voltage, Vg = Kg ω_m, then we can write an equation for Ia in terms of Vg from equation (1). In fact, this equation will be the equation of a straight line (y = mx + b). Take a steady-state plot of Ia vs. Vg. Your plot should be fairly linear. Use the slope and the y-intercept of this plot to find the viscous friction coefficient, F, and the Coulomb constant, C.

2. a) J: If we ignore the nonlinear Coulomb friction (assume C=0), then equation (1) reduces to:

$$T_m = K_T I_a = J\dot{\omega}_m + F\omega_m = J\dot{V}_g / K_g + FV_g / K_g \qquad (2)$$

Run the motor at a constant speed, then set Ia = 0 by pulling out the lead of the armature circuit of the MOTOMATIC while the motor is turning. This is acomplished by pulling the red cap at the terminal labelled A (Please pull the cap not the red wire!). Measure the values of Vg and derivative of Vg at the point on the plot where you set Ia = 0. Then, use equation (2) to find the motor inertia, J.

b) Make a plot of Va vs. Vin. Find Ka, the gain of the amplifier, from this plot.

c) Substitute the values of Kb, K_T , Kp, Ra, La, F and J into your answers for Prelab problems 2b) and 2c). Compare your answers from Lab 1 for Vout(s)/Vin(s) as measured from the step reposne in experiment 1. Which modelling technique more accurately models how Vout responds to Vin, the step response method or internal parameter measurement? What are the advantages of each modelling technique?