1. (20%)

   (a) A commonly used op-amp circuit is shown in Fig. 1(a). Please find the $V_o(s)$ and $v_o(t)$.

   (b) Give any comments on the output voltage $v_o(t)$ found in part (a).

   (c) Find the transfer function $\frac{Y_1(s)}{F(s)}$, $\frac{Y_2(s)}{F(s)}$ of the system shown in Fig. 1(b).

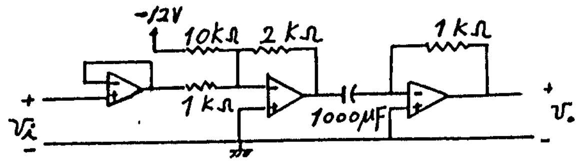

Fig 1(a)

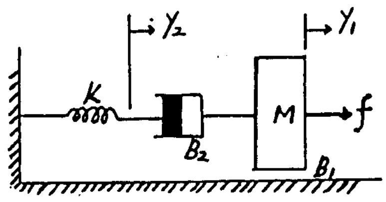

Fig 1(b).

2. (10%) The block diagram of a sampled-data control system is shown in Fig. 2.

   (a) Find the closed-loop transfer function $\frac{C(z)}{R(z)}$.

   (b) Find the unit-step response $c(kT)$.

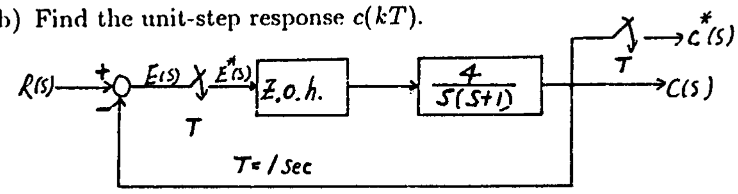

Fig 2.

3. (10%)

   (a) For the system of Fig. 3(a), determine if the system is controllable or observable ? Why !

   (b) For the system of Fig. 3(b), determine the controllability and observability.

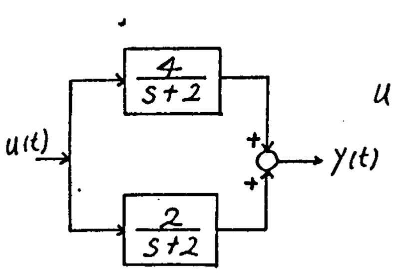

Fig 3 (a).

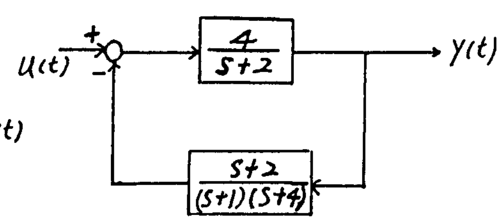

Fig 3 (b).

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4. (20%) A block diagram of a servo-control system for one of the axes of a plotter is shown in Fig. 4.
   (a) Let $K_d = K$ and $K_v = 0$, sketch the root-locus for the system.
   (b) If $K_d = 1$, find the range of K_v for which the system is stable.
   (c) If $K_v = 1$, find the range of K_d for which the system is stable.
   (d) Find the region of the $K_d - K_v$ plane on which the system is stable.

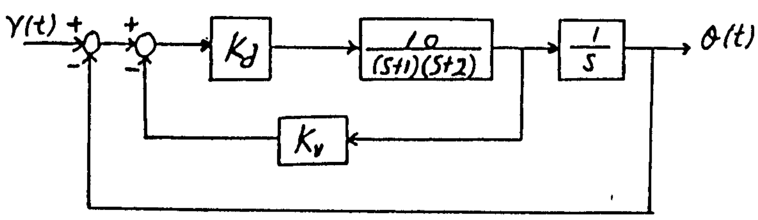

Fig. 4

5. (20%) For a closed-loop system of Fig. 5, the plant transfer function is given by

$$G_p(s) = \frac{5}{s+1}.$$

   (a) If $G_c(s) = 1$, find the steady-state error for a unit step input and $r(t) = 7 + 5cos(3t + 45°)$.
   (b) Design a **phase-lag** compensator $G_c(s)$ such that the pole of closed-loop system with $G_c(s) = 1$ does not move significently and the steady-state error is less than or equal to 0.1 for a unit step input.
   (c) Design a **PI** compensator $G_c(s)$ such that the steady-state error is less than or equal to 0.1 for a unit step input and the cloesd-loop system has a pole at $s = -5.9$.
   (d) Design a **PID** compensator $G_c(s)$ such that the closed-loop system has a pole at $s = -5.9$ and the steady-state error is less than or equal to 0.5 for a unit ramp input.

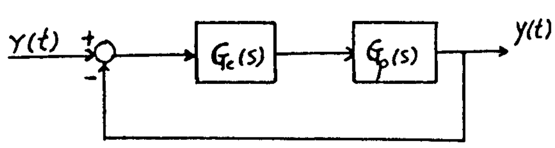

Fig. 5.

6. (20%) A system has an open-loop transfer function $G(s) = \frac{5}{(s+1)(s+2)}$.
   (a) Let $y = x_1$ and $\dot{x}_1 = x_2$, find the state equation by writing $\dot{x} = Ax + bu,\ y = cx$.
   (b) Find k_1 and k_2 so that $u = -k_1x_1 - k_2x_2$ moves the closed-loop system poles to $-1.5 \pm 1.5j$.
   (c) Find l_1 and l_2 of a state observer so that the state error equation has characteristic equation with $\omega_n = 15,\ \zeta = 0.5$.
   (d) Find k_1 and k_2 so that $u = -k_1x_1 - k_2x_2$ will minimize the following performance function

$$J = \int_0^\infty \{x_1^2(t) + x_2^2(t) + u^2(t)\}dt.$$