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**APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY**

SECOND SEMESTER M.TECH DEGREE EXAMINATION, MAY 2016

**Electrical & Electronics Engineering**

(Control Systems, Guidance and Navigational Control, Electrical Machines, Power System and Control)

**01EE6116: SLIDING MODE CONTROL**

**Time: 3 Hours** **Max Marks: 60**

***Answer any two FULL questions from each part***

**Part A (Modules I & II)**





1) a. Given a system described by $\dot{x} = Ax(t) + Bu(t)$ where there are n states, m inputs and p outputs. Its regular form with null space dynamics and range space dynamics after suitable transformation $z \rightarrow T_r x$ is given by

$$\dot{z}_1 = A_{11}z_1 + A_{12}z_2$$
$$\dot{z}_2 = A_{21}z_1 + A_{22}z_2 + B_2u$$

Show that if (A,B) is controllable, then ($A_{11}$,$A_{12}$) is also controllable. **(6)**

b. Briefly describe the following a) sliding phase b) reaching phase. **(3)**

2) a. An ideal sliding mode is the one where there exists a finite reaching time t= $t_r$ at which switching function σ(t) = 0. Derive an expression for $t_r$ in terms of σ(0). **(6)**

b. Briefly explain the phenomenon of chattering and how it can be eliminated . **(3)**

3) a. Show that the proportional rate reaching law obeys η-reachability condition. **(4)**

b. Briefly explain Filippov's continuation method. **(5)**

**Part B (Modules III & IV)**

4) a. State and explain Gao's reaching law for a discrete time system **(2)**

b. For an uncertain discrete time systems with matched uncertainity derive a robust sliding mode control using Gao's reaching law approach. **(7)**

5) a. What do you mean by a multirate output feedback system? (2)

b. For a multirate output feedback uncertain system with matched uncertainity derive a non switching based discrete time sliding mode control. (7)

6) a. Derive an expression for the time taken by the state trajectory to move from point at which it hits the sliding surface to the time it reaches the origin in case of a terminal sliding mode control when applied to a second order SISO system. (4)

b. For designing a discrete time sliding mode control using Bartoszewicz reaching law approach it is necessary to chose a known function ($s_d(k)$) which has to satisfy certain conditions in the sense of Bartoszewicz. Specify a function which satisfies all these conditions and mention how each of these conditions is getting satisfied by the chosen function. (5)





**Part C (Modules V& VI)**

7) a. Design an Utkin sliding mode observer for the following system so that the resulting observer dynamics is stable. (6)

$$\dot{x} = \begin{bmatrix} 0 & 1 \\ 0 & 0 \end{bmatrix} x;\ y(k) = [1\ 1]x(k)$$

b. Explain the design of super-twisting controllers. Also mention its advantage. (6)

8) a. Show that sliding mode based observation in an uncertain LTI system yields a reduced order motion during sliding mode independent of uncertainty. (6)

b. Differentiate between first order classical sliding mode controllers and a second order sliding mode controller. (3)

c. Write the relative degree w.r.t σ for the following case of sliding mode control

i. $\sigma, \dot{\sigma} = 0$ $and$ $\ddot{\sigma} = f(u)$ where u is the control input.

ii. $\sigma, \dot{\sigma}, \ddot{\sigma} = 0$ $and$ $\dddot{\sigma} = f(u)$ where u is the control input. (3)

9) a. Show that sliding mode based observation in a nominal LTI system yields a reduced order motion during sliding mode. (6)

b. Explain the design of twisting sliding mode controllers. (6)

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