國立臺北科技大學101學年度碩士班招生考試

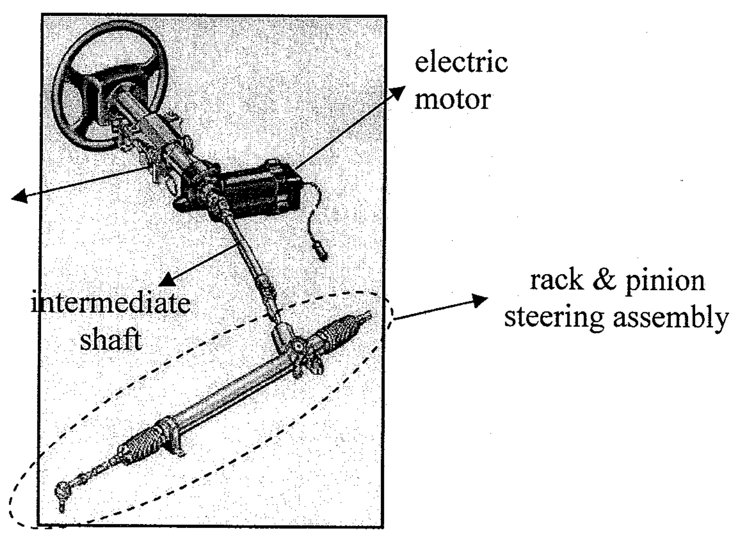
系所組別：1320 車輛工程系碩士班乙組

第一節　自動控制　試題

注意事項：

1. 本試題共四題，配分共100分。
2. 請標明大題、子題編號作答，不必抄題。
3. 全部答案均須在答案卷之答案欄內作答，否則不予計分。

一、Electric power steering (EPS) has several types. Column type EPS is often used for small passenger cars. The electric motor is mounted on the steering column with a gear ratio of G_m. G_m is used to amplify the motor output torque T_m to assist the driver to steer the front wheels. T_m is often designed as a function of the driver's torque and vehicle speed. An intermediate shaft with rotational stiffness k and damping coefficient b is used to connect the steering column and the rack & pinion steering assembly. The rotational inertia of the steering column is I_1. The rotational inertia of the rack & pinion steering assembly is I_2. The alignment torque T_a feedback from the tire/road interaction is not measurable but can also affect the rotational dynamics of the steering system. If you are asked to design a steering angle controller for automatic parking, how would you model the steering system for controller design? Please clearly define the state vector **x**, the control input u, the disturbance input w, and the output y. Then write the equation of motion in the **state-variable** form, i.e. $\dot{\mathbf{x}} = \mathbf{A}\mathbf{x} + \mathbf{B}u + \mathbf{G}w$ and $y = \mathbf{C}\mathbf{x} + \mathbf{D}u$. (20%) (Hint: (1) You don't need to consider the driver's torque for automatic parking. (2) Assume the rotational angle of I_1 is θ_1 and the rotational angle of I_2 is θ_2. Which rotational angle should be controlled for automatic parking?)

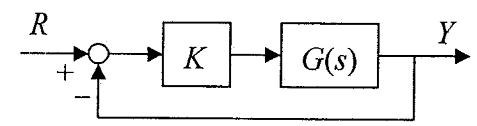


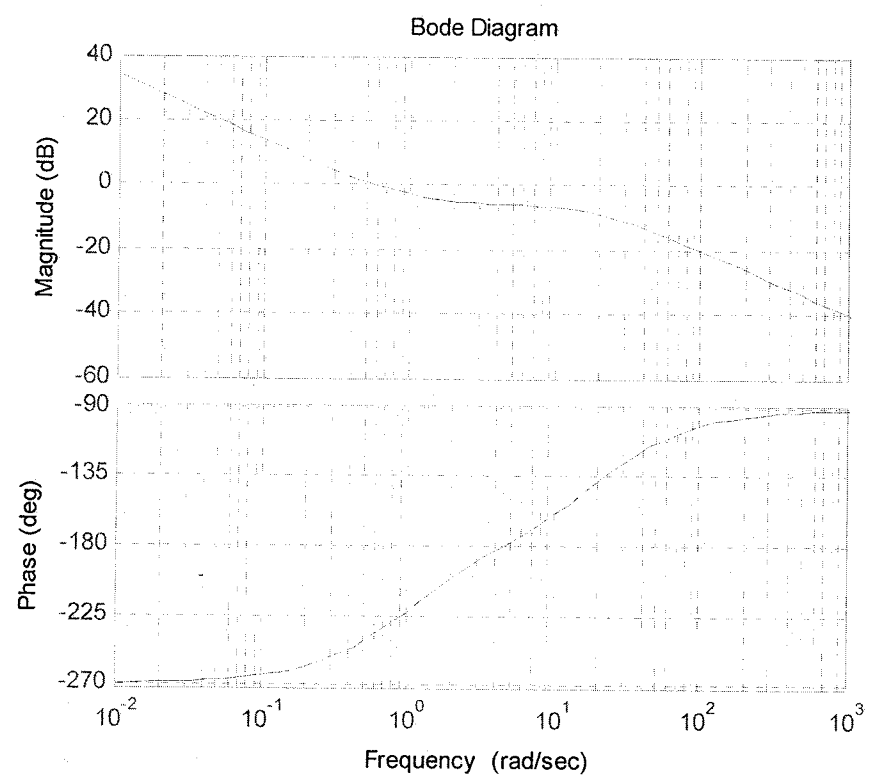
二、For the EPS system, torque control can be viewed as current control if the torque constant does not change for different operating conditions. The electric dynamics of the motor can be modeled as a first order system if the equivalent resistant R (0.5Ω) and inductance L (0.2mH) are known. MOSFETs are often used to control the motor terminal voltage via the PWM (pulse width modulation) technique. PWM can generate a fixed frequency (for example, 20kHz) voltage pulse whose on-time duration is controlled. Therefore, it is necessary to add a low-pass filter to reduce measurement noises and ripples of the current sensor. If cut-off frequency of the low-pass filter is selected to be 200rad/s, how would you design the lead-lag controller to satisfy the following performance requirement? (40%)

– bandwidth ≥ 1000rad/s
– good damping, i.e. PM = 90°
– steady-state error for a step reference input ≤ 1%

三、If the bode plot of the plant $G(s)$ are known,

1. Please show the possible transfer function (10%).
2. Obtain a rough sketch of the Nyquist plot with $K = 1$ (10%). You need to show the point where the Nyquist locus intersects with the real axis.
3. What is the range of K for a stable closed-loop system? (5%)





四、Please answer the following questions.

1. How could time delay affect the system stability? (5%)
2. What are the differences between adding a LHP zero and adding a RHP zero for a second-order system? (5%)
3. If you design a controller to place two poles at desired locations, does it guarantee that the close-loop system will behave like a standard second-order system? (5%)