

# Preface

From Prandtl's work at the beginning of last century, singular perturbation techniques (SPTs) have become the basic tool of fluid dynamics. Further the approach was extended to other fields of control theory and engineering including aircraft and rocket systems, power systems and nuclear reactor systems. The dynamics of singularly perturbed systems (SPSs) contain the interaction of the slow and fast phenomena so that the feedback design often suffers from high dimensionality and ill-posed problem. To alleviate the numerical stiffness, engineers usually use the singular perturbation approach to process the type of system. It lowers the model order by neglecting the fast dynamics and improves the approximation by reintroducing their effects as 'boundary layer' corrections in separate timescales. From the frequency domain perspective, poles farther to imaginary axis are associated with the natural signals that decay faster than those associated with poles closer to the imaginary axis on the left half  $s$ -plane. The fast modes dominate at the initial stage, and the slow modes are the primary contributors later. The fast/slow dynamics of the state trajectories correspond to the high/low-frequency parts of the system response.

In terms of perspectives of systems and control, Kokotovic and Sannuti had explored the optimal control problem of continuous-time SPSs. Two-point boundary value problem of open-loop systems had been analyzed and been converted controller design problem to solve the Riccati matrix equation of closed-loop systems. The methodology of singular perturbation methods and timescale (SPaTS) techniques, "gifted" with the remedial features of both dimensional reduction and stiffness relief, is considered as a "boon" to systems and control engineers. Thus, the goal of SPaTS techniques is to reduce and simplify the software and hardware implementation. Both the theory and the technique had now attained a maturity level for the continuous-time and discrete-time control systems described by ordinary differential and difference equations, respectively.

However, majority of researches are focused on the time domain state space analysis and synthesis about the SPSs. This book tries to pave a new way to fill the gap between frequency domain transfer function (TF) based results and time domain state space based results. We focus on topics such as  $H_\infty$  control, mixed

$H_2/H_\infty$  theory, positive real control, loop-shaping techniques, and quadratic stability, whose specifications are characterized by frequency domain inequalities described by transfer function matrices (TFMs). Due to the existence of the small parasitic parameters in the system model, such control problems usually suffer from high dimensionality and ill-posed problem. Advantage of our results is thereby taken as the unique frequency nature of SPSs to design a combined controller to deal with the original ill-posed problem. We adopt the classical slow-fast decomposition method or descriptor system approaches for SPSs, for convenience of development in the sequel, which is called singular method throughout this monograph, to design  $\varepsilon$ -independent or  $\varepsilon$ -dependent controllers for SPSs. It should be noted that our results can be extended to more complex systems with multi-timescale characteristics such as multiagent systems and stochastic systems.

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