Proposal for a New Academic Course

Name of Academic Unit : Department of Electrical Engineering

Preamble to the proposal (optional) : Mathematical models of dynamical systems are often of a very large order: whether the models are built from first principles or using data/system-identification techniques. Large order models are not amenable for analysis nor for simulation. In such a situation, it is essential to obtain a lower order approximation of the dynamical system and study of model order reduction techniques becomes central for analysis, controller-design, systems design, and systems simulation. This course aims to enable engineers to analyze which is the right technique for model order reduction depending on the application, and then obtain reduced order models using one or more of the relevant techniques.

Level : Postgraduate, though advanced undergraduates may be allowed in special cases with Instructor's approval

Programme : B.Tech./M.Sc./M.Tech./M.Phil/M.Mgt./M.Des./Ph.D./Other(Specify): **M. Tech/Ph.D.**

i	**Title** of the course	Model Order Reduction: Theory and Algorithms
ii	Credit Structure (**L-T-P-C**)	3-0-0-6
iii	**Type** of Course (Institute/ Departmental) + (Core/ Elective/ ...)	Departmental/Institute Elective
iv	Semester in which normally to be offered (**Autumn/Spring**)	Spring
v	Whether **Full or Half Semester** Course	Full Semester
vi	**Pre-requisite(s)**, if any (For the students) – *specify course number(s)*	1. EE302 or EE640 or an equivalent course in basic control theory 2. EE636 or equivalent course on Matrix Computation
vii	Course **Content** *	Module 1: Balanced truncation methods, Hankel singular values, Dual Riccati Equation balancing methods, Grammian (controllability/observability) based balancing methods. Module 2: Moment matching methods, POD and PCA based methods, Pade approximation of delay operators, error bounds on the approximation Module 3: Numerical methods for computing lower order models, Arnoldi algorithm, Riccati equation computation methods, complexity of the algorithm and practical implementation error aspects Module 4: One or more of the following topics (depending on the focus/instructor): a: Dissipativity preserving and passivity preserving methods, PRIMA (Passive Reduced-order Interconnect Macromodeling Algorithm) b: Singular perturbation methods and model order reduction techniques for systems with highly separate fast and slow t time-scale subsystems.

viii	**Texts/References** **	-- A. Antoulas, *Approximation of Large-scale Dynamical Systems,* SIAM Press, Philadelphia, 2004. -- P. Benner, V. Mehrmann and D.C. Sorensen, Dimension Reduction of Large-scale Systems, *Lecture Notes in Computational Science and Engineering,* volume 45, 2003. -- A. Odabasioglu, M. Celik, L.T. Pileggi, PRIMA: Passive Reduced-order Interconnect Macromodeling Algorithm, *IEEE Transactionson Computer-Aided Design of Integrated Circuits and Systems*, volume 17, no. 8, pages 645-654, 1988. -- H.L. Trentelman, H.B. Minh and P. Rapisarda, Dissipativity preserving model order reduction by retention of trajectories of minimal dissipation, *Mathematics of Control, Signals and Systems,* volume 21, pages 171-201, 2009. -- D.C. Sorensen, Passivity preserving model reduction via interpolation of spectral zeros, *Systems & Control Letters,* volume 54, pages 347-360, 2005. -- A. Antoulas, A new result on passivity-preserving model reduction, *Systems & Control Letters,* volume 54, pages 361-374, 2005. -- E.J. Davison, A method for simplifying linear dynamic systems, *IEEE Transactions on Automatic Control,* volume 11, no. 1, pages 93-101, 1966. – S. Marshall, An approximate method for reducing the order of a linear system, *Control Engineering,* volume 10, pages 642-648, 1966. – P. Kokotovic, H. K. Khali, and J. O'reilly, *Singular Perturbation Methods in Control: Analysis and Design,* SIAM, volume 25, 1999.
ix	Names of **Instructors**	Profs. Madhu N. Belur and Harish Pillai. Profs. Debraj Chakraborty, V.R. Sule and Debasattam Pal can teach this too.
x	Names of **other Departments/ Academic Units to whom** the course is **relevant**	Aerospace Engineering, Mechanical Engineering, Chemical Engineering, IDP in Systems & Control, Computer Science and Engineering
xi	Is/Are there any course(s) in the same/ other academic unit(s) which is/ are **equivalent** to this course? If so, please give details.	No equivalent course currently exists in IITB.
xii	**Justification/ Need** for introducing the course	Dynamical systems are getting larger and more complex. A standard example is VLSI, where very large interconnection of dynamical systems makes it hard for analysis and simulation. While one does have access to larger computers, it is essential to have smaller scalable models for large dynamical systems. Depending on the approximation criteria, there are several methods for obtaining a reduced order model: this course covers various criteria and the methods to reduce the model order. Algorithms for achieving this are central to the course and engineers dealing with analysis and synthesis of dynamical systems will benefit from this course.

* The course content must **clearly** specify the topics/ components/ material normally intended to be taught/ discussed in the course. It would help, also, to separate essential and optional content, if applicable.

Note to forward an Academic Course Proposal to the Institute Level Academic Bodies from the Academic Unit

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