UNIVERSITY OF WARWICK

Proposal Form for New or Revised Modules (MA1 - version 7 - April 2014)

Approval information	
Approval Type	☐ New module ☒ Revised module ☐ Discontinue module
Date of Introduction/Change	1 October 2018
If new, does this module replace another? If so, enter module code and title:	
If revised/discontinued, please outline the rationale for the changes:	Minor changes: 1) Added 20% of assessment based on 2 labs 2) Exam worth 60% instead of 80% 3) Increase of example classes (removal of seminars)
Confirmation that affected departments have been consulted:	Changes were made in consultations between the School of Engineering and WMG. Computer Science have been consulted via the CSE steering committee.

Module Summary	
1. Module Code (if known)	ES3C8
2. Module Title	Systems Modelling and Control
3a. Lead department:	School of Engineering
3b. Teaching Split (if known):	100% Engineering
4. Name of module leader	Dr Thomas Popham
5. Level	UG: ☐ Level 4 (Certificate) ☐ Level 5 (Intermediate) ☒ Level 6 (Honours) PG: ☐ Level 7 (Masters) ☐ Level 8 (Doctoral) See Guidance Notes for relationship to years of study
6. Credit value(s) (CATS)	15 credits
7. Principal Module Aims	Most disciplines of the engineering profession require a sound understanding of the techniques used in the modelling and control of dynamic, multi-domain physical, and other, systems. The aims of this module are: to build on techniques and computer tools for modelling, predicting and analysing the behaviour of dynamic

Module Summary	
	systems; and to build on concepts, principles and techniques employed in classical methods of single loop feedback control system design.
8. Principal Learning Outcomes	By the end of the module the student should be able to: 1. Develop mathematical models of physical systems (including non-linear) expressing with Ordinary Differential Equations, frequency domain and state-space techniques and representing in MATLAB/SIMULINK utilising engineering analogies to demonstrate commonality of behaviour. 2. Implement techniques of system identification (e.g. ARMAX, weiner-hopf filter, black box and grey box models) for data-driven dynamic models. 3. Utilise analytical, computational and numerical methods to analyse and predict dynamical (e.g. steady-state and transient response to a range of inputs) behaviour of physical systems including stability performance analysis for non-linear and discrete-time control systems. 4. Apply concepts and techniques to analyse the behaviour of open loop physical systems (including feasibility of end-user objectives), and to design feedback control systems (lead/lag, PID) using frequency domain and state-space techniques, and implement the solutions in MATLAB/SIMULINK and in the laboratory 5. Choose and evaluate theoretical and practical tools and methods for modelling, simulation, analysis and control of engineering systems
9. Timetabled Teaching Activities (summary)	28 x 1hr lectures 4 x 1hr example classes 2 x 1hr revision class 2 x 4hr laboratory sessions **TOTAL 42 Hours**
10. Departmental Web-link	http://www2.warwick.ac.uk/fac/sci/eng/eso/modules/year3
11. Other essential notes	Advice and feedback hours are available for answering questions on the module
12. Assessment methods (summary)	2 hour written examination (60%) Systems Modelling and System Identification Assignment (20%) Lab Assignment (20%)

For use by Strategic Planning and Analytics Office only - Do not fill in this section

Level	JACS3 Code	Teaching Split
		If not provided in 3b above

External Credit Level		Scheme	

Module Context

13. Please list all departments involved in the teaching of this module. If taught by more than one department, please indicate percentage split.

100% School of Engineering

14. Availability of module

Degree Code Pre 17-18 in	Title	Study Year	C/OC/ A/B/C	Credits
H106	BEng Engineering	3	O	15
New	BEng Engineering with Intercalated Year	4	O	
H107	MEng Engineering	3	O	
H109	MEng Engineering with Intercalated Year	3 or 4	O	
H110	MEng Engineering with a Year in Research	3 or 4	O	
H330	BEng Automotive Engineering	3	C	
H339	BEng Automotive Engineering with Intercalated Year	4	C	
H331	MEng Automotive Engineering	3	C	
H332	MEng Automotive Engineering with Intercalated Year	3 or 4	C	
H333	MEng Automotive Engineering with a Year in Research	3 or 4	C	
HH36	BEng Systems Engineering	3	C	
New	BEng Systems Engineering with Intercalated Year	4	C	
HH63	MEng Systems Engineering	3	C	
HH64	MEng Systems Engineering with Intercalated Year	3 or 4	C	
HH65	MEng Systems Engineering with a Year in Research	3 or 4	C	

Degree Code Post 17-18 in	Title	Study Year	C/OC/ A/B/C	Credits
H113	BEng Engineering	3	A	15
H111	BEng Engineering with Intercalated Year	4	A	15
H114	MEng Engineering	3	A	15
H115	MEng Engineering with Intercalated Year	3 or 4	A	15
H161	BEng Biomedical Systems Engineering	3	C	15
H163	BEng Biomedical Systems Engineering with Intercalated Year	4	C	15
H163	MEng Biomedical Systems Engineering	3	C	15
H164	MEng Biomedical Systems Engineering with Intercalated Year	3 or 4	C	15

Module Context

H335	BEng Automotive Engineering	3	C	15
H334	BEng Automotive Engineering with Intercalated Year	4	C	15
H336	MEng Automotive Engineering	3	C	15
H337	MEng Automotive Engineering with Intercalated Year	3 or 4	C	15
H605	BEng Electrical and Electronic Engineering	3	C	15
H608	BEng Electrical and Electronic Engineering with Intercalated Year	4	C	15
H606	MEng Electrical and Electronic Engineering	3	C	15
H607	MEng Electrical and Electronic Engineering with Intercalated Year	3 or 4	C	15
HH35	BEng Systems Engineering	3	C	15
HH34	BEng Systems Engineering with Intercalated Year	4	C	15
HH31	MEng Systems Engineering	3	C	15
HH33	MEng Systems Engineering with Intercalated Year	3 or 4	C	15
G406	BSc/BEng Computer Systems Engineering	3	A	15
G408	MEng Computer Systems Engineering	3	A	15

15. Minimum number of registered students required for module to run

1 (Core)

16. Pre- and Post-Requisite Modules

ES2A9 Engineering Mathematics and Technical Computing
Or ES2C7 Engineering Mathematics and Technical Computing.

Module Content and Teaching

17. Teaching and Learning Activities *(totals for module – please see guidance)*

Module duration (weeks)	**10**
Lectures	**28 x 1 hr**
Seminars	**0**
Tutorials	**0**
Project Supervision	0
Demonstration	0
Practical Class/Workshops	2 x 4 hr laboratory sessions

Module Content and Teaching		
Supervised time in studio/workshop	0	
Fieldwork	0	
External visits	0	
Work based learning	0	
Placement	**0**	
Year abroad	**0**	
Other activity *(please describe): e.g. distance-learning, intensive weekend teaching etc.*	**4 x 1 hr examples class** **2 x 1 hr revision class** **108 hrs guided independent learning**	
18. Assessment Method (Standard)		
Type of assessment	**Length**	**% weighting**
Written Examinations	2 Hours	**60**
Practical Examinations		
Assessed essays/coursework	Systems Modelling & Identification Assignment Lab Assignment	**20** **20**
18a. Final chronological assessment *(please see guidance)*	**Examination**	

19. Methods for providing feedback on assessment.
• Model solutions to past papers. • Support through advice and feedback hours. • Written feedback on assignment. • Cohort-level feedback on assignment. • Cohort-level feedback on final exam.
20. Outline Syllabus
Review of systems modelling (1st and 2nd order) linking behavior to physical parameters: block diagrams, signal-flow graphs, system classification, methodical and structured process; role of empirical data and model validation; Laplace transform, Fourier transform, and z-transform; system representation using transfer functions and block-diagram algebra. System representation: convolution in time domain and its interpretation in frequency domain; autocorrelation and cross correlation; power spectrum; sampled-data systems; converting a continuous-time system into its equivalent sampled data system using bilinear transformation; representations in time-domain, frequency domain, and state-space. System analysis (continuous-time): poles and zeros; stability and sensitivity; steady state response and transient response; type of the system; links between time-domain specifications and

frequency domain specifications; stability and performance analysis using Routh Hurwitz criterion, root locus, Nyquist plot, and Bode plots; robustness characterization using gain margin and phase margin; difficulties posed by time delays, uncertainties, disturbance, and noise.

Controller synthesis (continuous-time): reference tracking, disturbance rejection; series control vs feedback control; PID controllers, Smith predictor; lead/lag controller synthesis using root locus and Bode plots; controller synthesis using state-space methods – the notions of controllability and observability; linear quadratic regulator – cheap/expensive control.

Introduction to nonlinear systems: characterisation and review of principal sources of nonlinearity (saturation, hysteresis, dead zone, backlash, etc.); linearization and equilibrium points; describing functions; limit cycles; use of dither signals in mitigating limit cycles.

System identification: a brief overview - what it is and what it is used for; basics of matrix theory; model structure; parameter estimation using least squares estimation; Weiner-Hopf filter; black-box models and grey-box models; choice of the excitation input.

Computer tools for modelling, simulating and analysing dynamical systems: e.g. MATLAB/Simulink/Stateflow for controller design and system identification; laboratory experiments on controlling a rotary inverted pendulum.

Case-studies: e.g. DC drive control, disk-drive control, automotive cruise control, drug delivery, antenna control – a seminar is to be given on one of the 3 topics floated.

21. Illustrative Bibliography

1. Norman Nise, Control Systems Engineering (7th Edition). John Wiley & Sons, 2013.
2. Franklin, G.F., Powell, J.D. and Emami-Naeini, A., *Feedback Control of Dynamic Systems (6th Edition)*, Pearson Academic Computing, 2012.

22. Learning outcomes

Successful completion of the module leads to the learning outcomes. The learning outcomes identify the knowledge, skills and attributes developed by the module.

Learning Outcomes should be presented in the format "By the end of the module students should be able to..." using the table at the end of the module approval form:

Resources

23. List any additional requirements and indicate the outcome of any discussions about these.

Approval	
24. Module leader's signature	Dr Thomas Popham
25. Date of approval	20 March 2018
26. Name of Approving Committee (include minute reference if applicable)	School of Engineering and WMG Course and Module Approval Committee Minute 158-17/18
27. Chair of Committee's signature	Professor Gillian Cooke
28. Head of Department(s) signature	Professor David Towers

Examination Information		
A1. Name of examiner (if different from module leader)		
A2. Indicate all available methods of assessment in the table below		
% Examined	**% Assessed by other methods**	**Length of examination paper**
60	**40**	**2 hours**
A3. Will this module be examined together with any other module (sectioned paper)? If so, please give details below.		
A4. How many papers will the module be examined by?	☒ 1 paper	☐ 2 papers
A5. When would you wish the exam take place (e.g. Jan, April, Summer)?	**Summer**	
A6. Is reading time required?	☐ Yes	☒ No
A7. Please specify any special exam timetable arrangements.		
A8. Stationery requirements		
No. of Answer books?	**1**	
Graph paper?	**Y**	
Calculator?	**Y**	
Any other special stationery requirements (e.g. Data books, tables etc)?	**Engineering Data Book**	
A9. Type of examination paper		
Seen?	☐ Yes	☒ No
Open Book?	☐ Yes	☒ No
Restricted?	☐ Yes	☒ No
If restricted, please provide a list of permitted texts:		

LEARNING OUTCOMES		
(By the end of the module the student should be able to....)	**Which teaching and learning methods enable students to achieve this learning outcome? (reference activities in section 17)**	**Which summative assessment method(s) will measure the achievement of this learning outcome? (reference activities in section 18)**
Develop mathematical models of physical systems (including non-linear) expressing with Ordinary Differential Equations, frequency domain and state-space techniques and representing in MATLAB/SIMULINK utilising engineering analogies to demonstrate commonality of behaviour.	Lectures, examples sheets, examples classes and laboratories	Examination and Assignments
Implement techniques of system identification (e.g. ARMAX, weiner-hopf filter, black box and grey box models) for data-driven dynamic models.	Lectures, examples sheets, examples classes and laboratories	Examination and Assignments
Utilise analytical, computational and numerical methods to analyse and predict dynamical (e.g. steady-state and transient response to a range of inputs) behaviour of physical systems including stability performance analysis for non-linear and discrete-time control systems.	Lectures, examples sheets, examples classes and laboratories	Examination and Assignments
Apply concepts and techniques to analyse the behaviour of open loop physical systems (including feasibility of end-user objectives), and to design feedback control systems (lead/lag, PID) using frequency domain and state-space techniques, and implement the solutions in MATLAB/SIMULINK and in the laboratory	Lectures, examples sheets, examples classes and laboratories	Examination and Assignments
Choose and evaluate theoretical and practical tools and methods for modelling, simulation, analysis and control of engineering systems	Lectures, examples sheets, examples classes and laboratories	Assignments

Note: The students will be tested on the above via theoretical questions in exam and via software implementations in the MATLAB coding assignment and in the lab project.