# Course Content

<table>
<thead>
<tr>
<th>Academic Year</th>
<th>AY2018/2019 S2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Course Coordinator</td>
<td>Cai Wenjian</td>
</tr>
<tr>
<td>Course Code</td>
<td>EE4265</td>
</tr>
<tr>
<td>Course Title</td>
<td>Process Control Systems</td>
</tr>
<tr>
<td>Pre-requisites</td>
<td>EE3011 Modelling and Control</td>
</tr>
<tr>
<td>No of AUs</td>
<td>3</td>
</tr>
<tr>
<td>Contact Hours</td>
<td>2-hour lecture and 1-hour tutorial session per week. In total, 26 lecture hours and 13 tutorial hours per semester.</td>
</tr>
<tr>
<td>Proposal Date</td>
<td>14 Jan 2019</td>
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## Course Aims

Process control system is a widely applied technology in the continuous and batch processes in the manufacturing field. The purpose of the subject is to serve as an introduction to the analysis and design of such control systems. Specifically, the subject aims to equip the students with

1. a basic understanding of the practical issues related to the control of industrial processes
2. the modeling, analysis and design techniques applicable to these control systems and
3. an awareness of the advanced control techniques that could be applied to such processes

## Intended Learning Outcomes (ILO)

By the end of the course, you will be able to:

1. Explain the use of process control in industry processes.
2. Explain the concepts of process control including modelling, analyse and control.
3. Explain the basics of single loop, multi-loop, nonlinear, enhanced and complex control systems.
4. Apply process control technologies to solve engineering control problems
5. Apply the fundamental theory and concepts of process control

## Course Content

1. Introduction to process control
2. Process Modelling
3. Feedback Control Systems
4. Model based PID control system design
5. Enhanced Control Structures
6. Feedback Controller Design for non-linear systems
7. Multivariable control systems
8. Complex Control Structures
9. Process Control Applications
### Course Outline

<table>
<thead>
<tr>
<th>S/N</th>
<th>Topic</th>
<th>Online Lecture Hours</th>
<th>Tutorial Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Introduction to process control</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>Process Modelling</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>3</td>
<td>Feedback Control Systems</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>4</td>
<td>Model based PID control system design</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>5</td>
<td>Enhanced Control Structures</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>6</td>
<td>Feedback Controller Design for non-linear systems</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>7</td>
<td>Multivariable control systems</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>8</td>
<td>Complex Control Structures</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>9</td>
<td>Process Control Applications</td>
<td>2</td>
<td>1</td>
</tr>
</tbody>
</table>

**Total hours**

<p>| | |</p>
<table>
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<tr>
<th></th>
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<tbody>
<tr>
<td></td>
<td>26</td>
</tr>
<tr>
<td></td>
<td>12</td>
</tr>
</tbody>
</table>

### Assessment (includes both continuous and summative assessment)

<table>
<thead>
<tr>
<th>Component</th>
<th>Course LO Tested</th>
<th>Related Programme LO or Graduate Attributes</th>
<th>Weighting</th>
<th>Team/Individual</th>
<th>Assessment rubrics</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Two in-class quizzes (conducted during tutorials)</td>
<td>1-5</td>
<td>EAB SLO*(a)</td>
<td>20%</td>
<td>Individual</td>
<td></td>
</tr>
<tr>
<td>2. Two take-home assignments</td>
<td>1-5</td>
<td>EAB SLO* (a), (c)</td>
<td>10%</td>
<td>Individual</td>
<td></td>
</tr>
<tr>
<td>3. Class participation</td>
<td>1-5</td>
<td>EAB SLO* (a)</td>
<td>10%</td>
<td>Individual</td>
<td></td>
</tr>
<tr>
<td>4. Final exam</td>
<td>1-5</td>
<td>EAB SLO* (a), (c)</td>
<td>60%</td>
<td>Individual</td>
<td></td>
</tr>
</tbody>
</table>

**Total 100%**

### Mapping of Course SLOs to EAB Graduate Attributes

<table>
<thead>
<tr>
<th>Course Student Learning Outcomes</th>
<th>Cat</th>
<th>EAB’s 12 Graduate Attributes* (indicate full/partial/weak moon/blank for the whole course for SLO a-I)</th>
</tr>
</thead>
<tbody>
<tr>
<td>EE4265 Process Control</td>
<td>PE</td>
<td>(a) ● (b) ● (c) ● (d) ● (e) ○ (f) ● (g) ● (h) ● (i) ○ (j) ○ (k) ○ (l) ○</td>
</tr>
</tbody>
</table>

1. Explain the use of process control in industry processes.  
   EAB SLO* (a), (c)

2. Demonstrate the concepts of process control including modelling, analysis and control.  
   EAB SLO* (a), (b), (d)
3. Explain the basics of single loop, multi-loop, nonlinear, enhanced and complex control systems. EAB SLO* (a), (d), (g)

4. Apply process control technologies to solve engineering control problems EAB SLO* (c), (g), (i)

5. Apply the fundamental theory and concepts of process control EAB SLO* (a), (c), (d)

Legend:  ●  Fully consistent (contributes to more than 75% of Student Learning Outcomes)
         ◼  Partially consistent (contributes to about 50% of Student Learning Outcomes)
         ○  Weakly consistent (contributes to about 25% of Student Learning Outcomes)
         Blank  Not related to Student Learning Outcomes

Formative feedback
- After each quiz and assignment, correct methods to solve relevant problems will be discussed during tutorials, and the correct answers will be uploaded to the course webpage.
- During each tutorial class, key knowledge in the lecture videos will be repeated so that students will have chances to raise their questions and expose their comprehension difficulties.
- For students who have more learning challenges, individual office hours may be arranged for them to meet lecturers directly.
- Students can directly upload their questions on the course webpage or send them to the lecturers’ email accounts, and discuss with lecturers.

Learning and Teaching approach

<table>
<thead>
<tr>
<th>Approach</th>
<th>How does this approach support students in achieving the learning outcomes?</th>
</tr>
</thead>
<tbody>
<tr>
<td>LECTURE</td>
<td>Previously, students had difficulty in visualising complex schematic diagrams and relating them to block diagrams, and also had difficulty in understanding the complex concepts due to the practical nature of the subject. The online lecture videos will use vivid animation technologies to help students understand those concepts and easily grasp the key ideas on modelling and control. It will help you to achieve all 1-7 LOs.</td>
</tr>
<tr>
<td>TUTORIAL</td>
<td>Each week there will be a 1-hour tutorial session, during which those key concepts and potential difficulty points in the lecture videos will be repeated so that students will have chances to better understand them. Exercises will be provided during the tutorial sessions on all subjects covered in lectures. Students will also be able to directly interact face-to-face with lecturers to raise your questions and concerns so that you get feedbacks directly. It will help students to achieve all 1-8 LOs.</td>
</tr>
</tbody>
</table>

Reading and References
Textbook

References:

Course Policies and Student Responsibilities
- To pass the course, students need to obtain an overall course grade above F.
- For tutorials falling on holidays, makeup sessions will be arranged.
- For those students who can't attend quizzes, owing to legitimate excuse, makeup quizzes will be arranged.
- Home assignment submissions must be in time. Any late submissions will not be considered, unless a strong justification is submitted and approved by lecturers.
- Discussions among students for home assignments are allowed. But students need to use his/her own language to describe solutions.

You are expected to take the following responsibilities:
- To attend the lecture and watch lecture videos in time.
- To complete all assignments individually and timely.
- To attend both quizzes.
- To attend the final exam.
- To engage discussions with lecturers during tutorials and online interactions.

Academic Integrity
All students shall be treated equally and fairly in the grading of their home assignments, quizzes, class participations and final exams. There will be zero tolerance of cheating in home assignments, quizzes and final exams. Any violation of this kind shall result in a zero mark, and possibly a failure grade of this course. It is the lecturers` responsibility to ensure course materials to be accessible and comprehensible, and proper feedback to students shall be provided in a timely manner.

Course Instructors

<table>
<thead>
<tr>
<th>Instructor</th>
<th>Office Location</th>
<th>Phone</th>
<th>Email</th>
</tr>
</thead>
<tbody>
<tr>
<td>A/P Cai Wenjian</td>
<td>S2-B2a-08</td>
<td>67906862</td>
<td><a href="mailto:ewjcai@ntu.edu.sg">ewjcai@ntu.edu.sg</a></td>
</tr>
</tbody>
</table>

Planned Weekly Schedule
<table>
<thead>
<tr>
<th>Wk</th>
<th>Topic</th>
<th>Learning Outcomes</th>
<th>Source Materials</th>
<th>Learning Approach / Learning Activity</th>
</tr>
</thead>
</table>
| 1  | Introduction to process control | ILO 1 and 2. Role of Process control in the industries with application examples  
- Distillation Column  
| 2  | Process Models | ILO 2-4  
Modelling of industrial processes and derivation of transfer function.  
- Mass and energy balance.  
- Time delay systems  
Tutorial |
| 3  | Process Models | ILO 2-4  
Empirical modelling  
- Classical methods from Step testing  
- Least from Step testing  
Tutorial |
| 4  | Feedback Control Systems | ILO 2 and 4  
Tutorial |
| 5  | Feedback Control Systems  
Model based PID control system design | ILO 2 - 4  
Tutorial |
| 6  | Model based PID control system design | ILO 2 - 4  
Tutorial |
| 7  | Enhanced Control Structures | ILO 2 - 4  
Tutorial |

Recess Week

Neural Networks & their Applications

8  Feedback | ILO 2 – 4 | Seborg Dale E, | Lecture |
<table>
<thead>
<tr>
<th>Week</th>
<th>Module</th>
<th>Topics</th>
<th>Reading Material</th>
<th>Time</th>
</tr>
</thead>
</table>
| 9    | Feedback Controller Design for nonlinear systems | ILO 2 - 4 Control system design for Nonlinear system  
- Local Linearization technique  
- Gain scheduling technique  
| 10   | Multivariable control systems | ILO 2 - 4  
Fundamental concepts  
- pole and zeros  
- stability  
- Loop pairing, decentralized control, decoupling control | | Lectures 19-20 Tutorial |
| 11   | Multivariable control systems | ILO 2 - 4  
Control system design  
- decentralized control  
- decoupling control | | Lectures 21-22 Tutorial |
| 12   | Complex Control Structures | ILO 5 -7  
Control system design for safety and special industrial process  
- ratio control  
- Override control  
- Auctioneering control  
- Split-range control  
- Coordinate control | | Lectures 23-24 Tutorial |
| 13   | Process Control Applications | ILO 5 -7  
Process control system design issues from schematic diagram  
- Information collection  
- Sensor and actuator location  
- Controller design and tuning  
- Performance evaluation | | Lectures 25-26 Tutorial |
Appendix 2: The EAB (Engineering Accreditation Board) Accreditation SLOs (Student Learning Outcomes)

a) **Engineering knowledge**: Apply the knowledge of mathematics, natural science, engineering fundamentals, and an engineering specialisation to the solution of complex engineering problems

b) **Problem Analysis**: Identify, formulate, research literature, and analyse complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.

c) **Design/development of Solutions**: Design solutions for complex engineering problems and design system components or processes that meet the specified needs with appropriate consideration for public health and safety, cultural, societal, and environmental considerations.

d) **Investigation**: Conduct investigations of complex problems using research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.

e) **Modern Tool Usage**: Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modelling to complex engineering activities with an understanding of the limitations

f) **The engineer and Society**: Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal, and cultural issues and the consequent responsibilities relevant to the professional engineering practice.

g) **Environment and Sustainability**: Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for the sustainable development.

h) **Ethics**: Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.

i) **Individual and Team Work**: Function effectively as an individual, and as a member or leader in diverse teams and in multidisciplinary settings.

j) **Communication**: Communicate effectively on complex engineering activities with the engineering community and with society at large, such as, being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions.

k) **Project Management and Finance**: Demonstrate knowledge and understanding of the engineering and management principles and economic decision-making, and apply these to one’s own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.

l) **Life-long Learning**: Recognise the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.