Unit 4085: Mechatronic Systems in Manufacturing

Unit code	**K/617/3945**
Unit level	**4**
Credit value	**15**

Introduction

Mechatronic systems are a fusion of different engineering disciplines including electrical, electronic and mechanical engineering, and control and computer systems engineering. This integration of technologies enables greater automation in manufacturing, leading to time saving, increased output and cost savings. Examples of mechatronic systems include integrated automated production lines; measuring, testing and calibration systems for quality control; and closed-loop control systems for process optimisation.

Topics within this unit include the evolution, design and characteristics of mechatronic systems; sensors, transducers and actuators; closed-loop feedback systems; programmable control devices; interfacing; system integration design; and functional safety requirements.

On successful completion of this unit students will be able to explain the design and operational characteristics of a mechatronic system, identify and apply a range of sensors, transducers and actuators, evaluate programmable control devices and design an integrated mechatronic system for a manufacturing specification.

Learning Outcomes

By the end of this unit students will be able to:

LO1 Explain the design and operational characteristics of a manufacturing mechatronic system

LO2 Investigate a range of mechatronic system components and technologies

LO3 Review the operation, selection and interfacing of programmable control devices within a manufacturing mechatronic system

LO4 Design a mechatronic system for a manufacturing application.

Essential Content

LO1 Explain the design and operational characteristics of a manufacturing mechatronic system

Origins, evolution and applications:

History and early development; evolution from purely mechanical to integrated mechatronic systems

Industrial robots and alternative applications, e.g. vehicle driver assistance systems, medical applications, domestic goods, space exploration, sports and leisure systems.

Elements of a mechatronic system:

Physical system modelling; sensors and actuators; control and feedback signals; data acquisition and processing; computerised control; overview of open and closed-loop control systems.

Mechatronic system integration:

Conventional systems versus mechatronic systems for manufacturing and inspection stages; high-performance versus lower cost; interpreting system requirements; understanding system constraints; selection and placement of sensors; interface matching; reliability and safety.

LO2 Investigate a range of mechatronic system components and technologies

Analogue and digital signals:

Continuous versus discrete signals; voltage (0-10 v) versus current (4-20 mA)

Amplification and attenuation, sources of noise, filtering, Analog-to-Digital Converter (ADC) resolution, pulse width modulation.

Sensors and transducers:

Temperature, light level, force, pressure, speed, position, proximity, sound, flow, humidity, vibration, voltage, current

Interpreting data sheets; selection criteria; calibration and testing.

Actuators:

Types: linear, rotary, hydraulic, chain, pneumatics

Applications: valves, motors, servomechanism (servo), micro-positioning motors

Interpreting data sheets; selection criteria; mounting, force, torque, enclosure protection

National Electrical Manufacturers Association (NEMA) and International Electrotechnical Commission (IEC).

LO3 **Review the operation, selection and interfacing of programmable control devices within a manufacturing mechatronic system**

Microcomputer system architecture:

CPU, memory, data, program, input/output (I/O), data and address bus.

Programmable logic controllers (PLCs):

Selection criteria: size, functionality, flexibility, performance, connectivity, security, manufacturers

Programming: IEC 61131-3 Languages, software tools

Advantages and disadvantages of PLCs

Interfacing to a mechatronic system.

Microcontrollers:

Selection criteria: processor, speed, memory, power, range of I/O

Programming languages: C, C++, assembly and alternative third-party and open-source software

Software tools: debuggers, emulators, simulators

Advantages and disadvantages of microcontrollers

Interfacing to a mechatronic system.

Alternative programmable control devices:

Programmable automation controller (PAC), industrial PC based robot controllers, remote telemetry units (RTU), field programmable gate array (FPGA).

Functional Safety:

International Engineering Consortium (IEC) standard IEC61508

Hazard and risk assessment (HARA)

Safety integrity levels (SILs) of programmable devices.

LO4 **Design a mechatronic system for a manufacturing application.**

Design methodologies:

Identification of skill sets required by team members for a mechatronic system project

Interpreting requirements to develop concept design and specification

VDI 2206 (guideline for the design of mechatronic systems): general cycle of problem solving on the micro level; the V-shaped model on the macro level

Process modules for repeating design steps; advanced design modelling and simulating system behaviour.

Functional Safety:

International safety standards: ISO 13849-1, IEC 61061,2006/42/EC, IEC 618005-2

European Machinery Directive 2006/42/EC for safety-related parts of a control system (SRP/CS), integrating safety into the design process

Hazard and risk assessment: hazard and operability study (HAZOP), failure modes and effects analysis (FMEA), fault tree analysis (FTA)

Use of multi-function safety relays.

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Explain the design and operational characteristics of a manufacturing mechatronic system		
P1 Describe the key elements of a mechatronic system. **P2** Explain the origins, evolution and benefits of mechatronic systems in manufacturing.	**M1** Analyse how system integration has transformed conventional manufacturing mechatronic systems.	**D1** Evaluate the operation of a mechatronic system within a manufacturing environment characterizing the different technologies and interfaces.
LO2 Investigate a range of mechatronic system components and technologies		
P3 Identify the types of sensors and transducers used within a manufacturing mechatronic system. **P4** Identify the types of actuators used within a manufacturing mechatronic system.	**M2** Justify a range of instrumentation devices for a given mechatronic system design specification.	**D2** Evaluate types of signals used in instrumentation devices and a range of signal processing techniques used when integrating mechatronic systems.

Pass	Merit	Distinction
LO3 Review the operation, selection and interfacing of programmable control devices within a manufacturing mechatronic system		
P5 Describe the characteristics of programmable logic controllers and applications within manufacturing mechatronic systems. **P6** Describe the characteristics of embedded microcontrollers and applications within manufacturing mechatronic systems.	**M3** Analyse the operation and interfacing of a range of programmable control devices used in manufacturing mechatronic systems. **M4** Analyse the range of programming languages and software tools available for programmable control devices used within manufacturing mechatronic systems.	**D3** Evaluate a programmable control device for a given mechatronic system application with consideration to Functional Safety.
LO4 Design a mechatronic system for a manufacturing application.		
P7 Interpret a set of requirements to a specification for a manufacturing mechatronic system. **P8** Produce a block diagram to illustrate the design of a manufacturing mechatronic system, documenting appropriate design methodology. **P9** Design a mechatronic system based on a given specification and block diagram.	**M5** Assess compliance, safety and risk management issues present in the design solution.	**D4** Justify the selection of components and technologies for the development of a manufacturing mechatronic system.

Recommended Resources

Note: See HN Global for guidance on additional resources.

Print Resources

Alciatore D. (2018*) Introduction to Mechatronics and Measurement Systems*. 5th Ed. McGraw Hill.

Bolton, W. (2015) *Mechatronics.* 6th Ed: *Electronic Control Systems in Mechanical and Electrical Engineering*. Harlow: Pearson Education.

Clarence, W. de S. (2010) *Mechatronics: A Foundation Course*. Boca Raton, Florida: CRC Press.

Tacchini M. (2023) *Functional Safety of Machinery: How to Apply ISO 13849-1 and IEC 62061*. Wiley.

Websites

http://www.inderscience.com	Inderscience Publishers
	International Journal of Mechatronics and Manufacturing Systems
	International Journal of Automation and Control
	International Journal of Mechatronics and Automation
http://www.controleng.com	Control Engineering
	Integrating safety into engineering into mechatronic design
	Top-down strategies for innovation in mechatronic machine engineering
	When to use multi-function safety relays
	(General reference)
http://www.howtomechatronics.com	How to Mechatronics
	'How it works'
	(Briefings)

http://www.vdi.eu	Association of German Engineers VDI-Standard VDI 2206: Design Methodology for Mechatronic Systems (General reference)

Links

This unit links to the following related units:

Unit 4033: Programmable Logic Controllers (PLCs)

Unit 4068: Industrial Robots

Unit 4080: Material Handling Systems.